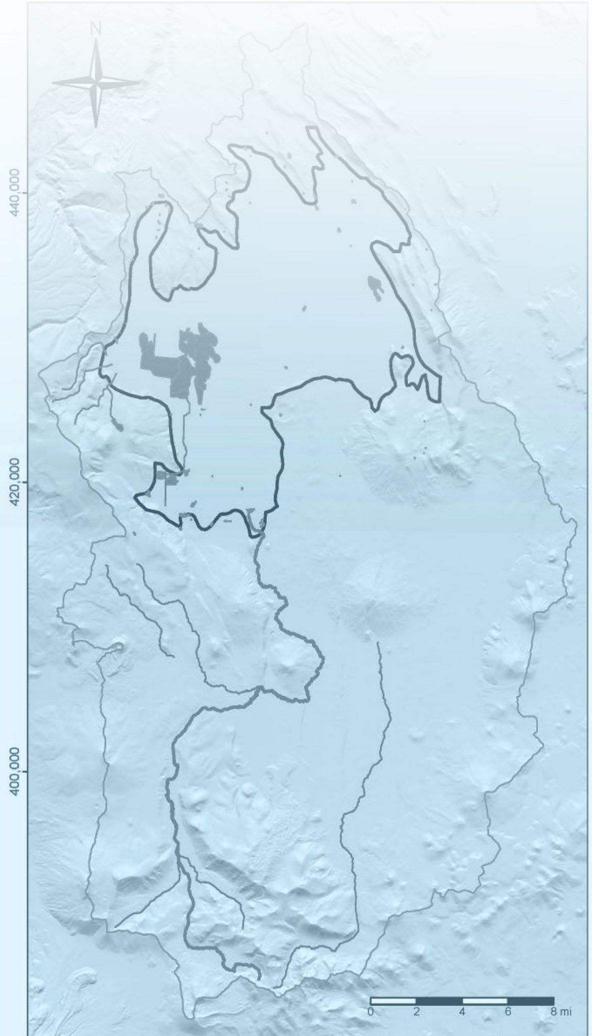
REVISED JULY 2024

SISKIYOU COUNTY FLOOD CONTROL & WATER CONSERVATION DISTRICT

Butte Valley Groundwater Sustainability Plan



SISKIYOU COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT GROUNDWATER SUSTAINABILITY AGENCY BUTTE VALLEY GROUNDWATER SUSTAINABILITY PLAN

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Butte Valley Basin Groundwater Sustainability Plan
Siskiyou County Flood Control and Water Conservation District

This report was prepared by the staff and subconsultants of Larry Walker Associates and of the University of California Davis. The findings, recommendations, specifications, or professional opinions are presented within the limits described by the client, in accordance with generally accepted professional engineering and geologic practice. The Butte Valley basin setting was prepared under the direction of a professional geologist or engineer licensed in the state of California as required per California Code of Regulations, Title 23 Section 354.12 consistent with professional standards of practice. No warranty is expressed or implied.

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Table of Contents

Table of Figures

Table of Tables

List of Appendices

List of Acronyms

Abbreviation	Explanation
ug/L	Micrograms per liter
AF	Acre-feet
AFY	Acre-feet per year
amsl	above mean sea level
ASAR	Adjusted sodium absorption ratio
bgs	Below ground surface
BVID	Butte Valley Irrigation District
BVWA	Butte Valley Wildlife Area
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Public Health
cfs	Cubic feet per second
CIWQS	California Integrated Water Quality System Project
CNRA	California Natural Resources Agency
CSEHD	County of Siskiyou Environmental Health Division
DAC	Disadvantaged community
DOI	U.S. Department of the Interior
DWR	California Department of Water Resources
ft	Foot/feet
FZ	Fault zone, an interconnected network of closely space earthquake faults.
gal	Gallon(s)
gpm	Gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HCM	Hydrogeologic conceptual model
Holocene	A geologic time scale term, marking the time period between 11,500 years ago to the Present.
in	Inch/inches
km	Kilometer/kilometers
l/min	Liters per minute
m	Meter/meters
m3	Cubic meters
3/yr	Cubic meters per year
Ma	Million years ago
MCL	Maximum contaminant level
mg/L	Milligrams per liter
MHI	Median household income

mi	Mile/miles
ML	Local magnitude (Richter magnitude)
MW	Monitoring well
NCRWQCB	California North Coast Regional Water Quality Control Board
NOAA	United States National Oceanic and Atmospheric Administration
OSWCR	Online Systems for Well Completion Reports
Pleistocene	A geologic time scale term, marking the time period between 1.8 Ma and 11,500 years ago.
Pliocene	A geologic time scale term, marking the time period between 5.3 Ma and 1.8 Ma years ago.
PLSS	Public Land Survey System
ppb	Parts per billion
ppm	Parts per million
Quaternary	A geologic time scale term, marking the time period between 1.8 Ma to the Present.
SDAC	Severely disadvantaged community
sq	Square
SWRCB	California State Water Resources Control Board
TDS	Total dissolved solids
Tertiary	A geologic time scale term, marking the time period between 65.5 Ma to 1.8 Ma.
U.S.	United States
UL	Upper level
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFS	United States Forest Service

Glossary

Term	Explanation
Adjudicated Areas	Where disputes over legal rights to groundwater have resulted in a court-issued ruling (known as an adjudication). Adjudications can cover an entire basin, a portion of a basin, or a group of basins.
Alluvial Fan	A gently sloping mass of sediment deposited by a stream that looks like an open fan when viewed from above. They often occur in arid or semiarid regions where a stream issues from a narrow canyon onto a plain or valley floor.
Alluvium	Clay, silt, sand, gravel, or other particulate material that have been deposited by a body of running water in a streambed, flood plain, delta, or at the base of a mountain.
Andesite	A fine-grained dark-colored ignous rock that has been erupted on the Earth’s surface, and is more viscous or ”sticky” compared to basalt. Cooled andesite lava flows typically consist of large, smooth-sided blocks up to several meters (~10 feet) in size. The edges of lava flow edges are steep and can be more than 100 m (300 ft) thick, consisting of piles of large angular blocks balancing precariously on one another.
Basalt	A dark-colored, fine-grained igneous rock that has been erupted on the Earth’s surface, that typically form thin, extensive lava sheets that can travel long distances. Basalt is the least viscous or most ”fluid” of the main lava types. It is considered the most primitive type of lava, with minimal alteration from the source mantle material beneath the tectonic plates.
Basin Prioritization	Classification of California’s 515 groundwater basins and subbasins into priorities based primarily on the importance of groundwater to the area. The priority of basins and subbasins determines the schedule for completing GSPs and whether SGMA provisions apply in a given basin. Critical, High, and medium, priority basins must comply with SGMA.
Best Management Practices (BMPs)	Practices designed to help achieve sustainable groundwater management. BMPs are intended to be effective, practical, and based on best available science.
Block Faulting	A type of normal faulting where large normal faults break the Earth’s crust into blocks as the region is pulled apart under extensional stress. Typically forms valleys, such as Death Valley in California.
Breccia	A coarse-grained rock of angular rock fragments that has been consolidated with mineral cement or fine-grained matrix.
Bulletin 118	A California Department of Water Resources (DWR) document outlining the locations and characteristics of groundwater basins in California.
Confined Aquifer	A water bearing formation that is completely filled with groundwater and under pressure from overlying material that restricts movement of water.

Consolidated / Unconsolidated	Consolidation is any process where loose material becomes firm and coherent, such as cementation of sand into sandstone. Unconsolidated material is loose earth material such as volcanic ash or sand.
Critically Overdrafted	Basins and subbasins identified by DWR to be subject to conditions of critical overdraft. GSPs are due in 2020.
Dacite	A fine-grained light-colored ignous rock that has been erupted on the Earth's surface, with a mineral composition that makes dacite lava flows sluggish and thick. Typically, dacite lava flows are so viscous and thick that they form a dome over the eruption center at the end of an explosive eruption cycle. Eruptions of dacite magmas can be explosive.
Dune Sand	Sand piled up by the wind into a sand dune.
Eocene	An epoch within the Tertiary period that began 55.8 million years ago (Ma) and ended 33.8 Ma.
Glaciation	The formation of glaciers, a large mass of ice formed on land that can cause extensive erosion of surrounding rock. When glaciers melt, they can leave behind moraines or mounds of rock debris (glacial till). The last major period of glaciation in the western US was 18,000 years ago.
Graben	An elongate portion of the crust bound by faults on the long sides and displaced downward, such as rift valleys. They form in conditions where the Earth's crust is being pulled apart under extensional stress.
Groundwater Sustainability Agency (GSA)	One or more local agencies that implement the provisions of SGMA.
Groundwater Sustainability Plan (GSP)	A local plan proposed by a GSA and approved by the state.
Holocene	An epoch within the Quaternary that began 0.012 million years ago (Ma) and continues to the present.
Igneous	A rock that solidified from molten material such as lava or magma. One of the three major rock classes (igneous, sedimentary, metamorphic).
Measurable Objectives	Conditions linked to the sustainability goals of the GSP, to be achieved in the basin within 20 years.
Metamorphic	A metamorphic rock formed from mineralogical, chemical, or structural changes of a pre-existing rock in response to changes in temperature, pressure or stress. This generally occurs if the rock has been moved deep into the Earth's crust, such as through long-term deposition of materials on top of the rock or faulting. One of the three major rock classes (igneous, sedimentary, metamorphic).
Miocene	An epoch within the Tertiary period that began 23 million years ago (Ma) and ended 5.3 Ma.

Normal Fault	A fracture in the Earth crust that forms when a region is under extensional stress (the region is being pulled apart). The fault dip is usually 45 to 90 degrees. Typically, one block or side of the fault is moving down relative to the other side.
Phytogenic Dune	Phytogenic dunes are common in modern day playas and form when wind-deposited silt and fine sand are trapped by scrub plants.
Playa	A playa is a dry, vegetation-free, flat area at the lowest part of an undrained desert basin.
Pleistocene	An epoch within the Quaternary that began 1.8 million years ago (Ma) and ended 0.012 Ma.
Pliocene	An epoch within the Tertiary period that began 5.3 million years ago (Ma) and ended 1.8 Ma.
Potentiometric Surface	The total head of groundwater, defined as the level at which groundwater would rise in a well. The water table is a type of potentiometric surface.
Pyroclastic Deposit/Rock	Pyroclastic rocks are composed of rock fragments from an explosive volcanic eruption or aerial expulsion from a volcanic vent, and may include ash, lapilli, bombs, blocks, and shattered country rock.
Quaternary	A period that starts after the end of the Tertiary that began 1.8 millions years ago (Ma) and continues in the present. Epochs or sub-periods within the Quaternary, from the oldest to most recent, includes the Pleistocene and Holocene.
Rhyolite (Tuff)	A light-colored ignous rock that has been erupted on the Earth’s surface, with a mineral composition that typically erupts explosively and fragments into small pieces (pyroclasts). Consolidated rhyolite pyroclasts is called a rhyolite tuff. Rhyolite is typically pale colored and often light grey, tan, or pink.
Sedimentary	A sedimentary rock formed from the consolidation of sediment, such as sand (sandstone) or organic material (coal). One of the three major rock classes (igneous, sedimentary, metamorphic).
Sustainability Goals	Metrics established in the GSP planning process to ensure that a basin is operated within its sustainable yield.
Sustainable Yield	The amount of water that can be extracted from a basin without causing problems to the groundwater basin.
Talus	A heap or mass of rock fragments lying at the base of a cliff or very steep, rocky slope, and formed by gravitational falling, rolling, or sliding.
Tertiary	A period in the geologic time scale that began 65.5 million years ago (Ma) and ended 1.8 Ma. The Tertiary includes several sub-periods or epochs, from the oldest to most recent: Paleocene, Eocene, Oligocene, Miocene, and Pliocene. The next period after the end of the Tertiary is the Quaternary.
Tuff	A rock of consolidated pyroclastic (fragmented rock erupted explosively) material.

Unconfined Aquifer	A water bearing formation partially filled with groundwater where the upper groundwater surface is free to fluctuate under atmospheric pressure.
Unconformity	A break in the geologic record, typically by erosion. Commonly recognized by a sudden jump or large gap in rock ages between deep older rocks and shallow young rocks.
Undesirable Results	The problems that SGMA strives to solve or prevent.
Volcanic Ash	Fine pyroclastic material (material ejected from a volcanic eruption) smaller than 2 mm in diameter. The term usually refers to unconsolidated material. Consolidated volcanic ash is called a tuff.
Water Budget	An estimated accounting of all the water (surface and groundwater) that flows into and out of a basin.

Glossary references include King (1994); USGS (2009b); USGS (2009a); USGS (n.d.d); USGS (n.d.a); USGS (n.d.c); USGS (n.d.b); Bates and Jackson (1984); Francis and Oppenheimer (2004); USGS (2007); USGS (n.d.e).

EXECUTIVE SUMMARY

ES-1: Introduction (Chapter 1)

Background (Section 1.1)

Section 1 describes the 2014 Sustainable Groundwater Management Act (SGMA) and the purpose of the Groundwater Sustainability Plan (GSP). Section 1 also introduces the management structure of the agencies developing and implementing the GSP.

SGMA was established to provide local and regional agencies the authority to sustainably manage groundwater resources through the development and implementation of GSPs for high and medium priority subbasins (e.g., Butte Valley). In accordance with SGMA, this GSP was developed and will be implemented by the groundwater sustainability agency (GSA) representing the Butte Valley groundwater basin (Basin): the Siskiyou County Flood Control and Water Conservation District.

The California Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) provide primary oversight for implementation of SGMA. DWR adopted regulations that specify the components and evaluation criteria for groundwater sustainability plans, alternatives to GSPs, and coordination agreements to implement such plans. To satisfy the requirements of SGMA, local agencies must do the following:

Locally controlled and governed GSAs must be formed for all high- and medium-priority groundwater basins in California.

- GSAs must develop and implement GSPs or Alternatives to GSPs that define a roadmap for how groundwater basins will reach long-term sustainability.
- The GSPs must consider six sustainability indicators defined as: groundwater level decline, groundwater storage reduction, seawater intrusion, water quality degradation, land subsidence, and surface-water depletion.
- GSAs must submit annual reports to DWR each April 1 following adoption of a GSP.
- Groundwater basins should reach sustainability within 20 years of implementing their GSPs.

This GSP was prepared to meet the regulatory requirements established by DWR. The completed GSP Elements Guide is organized according to the GSP Emergency Regulations sections of the California Code of Regulations and is provided in Appendix 1-D.

On January 18, 2024, the GSA received a letter from DWR with the determination that the Butte Valley GSP was determined to be incomplete. The letter documents DWR's review of the GSP, including outlining deficiencies and corrective actions. The GSA has the opportunity to implement these corrective actions in a 180-day period, ending on July 16, 2024. The determination letter from DWR is included as Appendix 3-D.

The two deficiencies were identified as:

Deficiency 1: The GSP does not include a reasonable assessment of overdraft conditions and reasonable means to mitigate overdraft.

Deficiency 2: The GSP does not establish sustainable management criteria for chronic lowering of groundwater levels in a manner substantially compliant with the GSP regulations.

To address deficiency 1 the Hydrologic Conceptual Model was expanded to better and more explicitly describe current hydrogeologic understanding of groundwater in the Basin and its relationship to the larger groundwater system of the Upper Klamath Basin that it is part of. This provides the context for understanding the key components of the water budget of the Basin and their drivers: groundwater inflow, recharge and pumping within the Basin, and groundwater outflow.

The GSP was revised to include details of long-term water level dynamics across the Basin, which had been increasing or were stable prior to 1980 and have been in chronic decline over much of the period since 2000. An extensive analysis of groundwater storage changes since 1990 and the chronic lowering of groundwater storage since 2000 have been added to the GSP to quantify, based on water level measurements and estimates of specific yield, average annual groundwater storage declines for various periods and to compare them to estimated groundwater extraction in the Basin. Additional hydrologic information was provided corroborating numerical model estimates of potential recharge in the uplands that feed groundwater inflow to the Basin.

Clarification has been added to identify four creeks, Meiss Lake, and Butte Creek as interconnected surface waters that potentially recharge groundwater when and where flowing.

Additional analysis also provides an improved explanation of groundwater outflows and their relationship to Basin water levels. Two analytical and a revised modeling analysis were employed in the revised GSP to derive and justify a sustainable yield of the Basin. The sustainable yield is estimated to be 65,000 acre-feet per year. The sustainable yield is 10% to 15% lower than groundwater extraction in the Basin over the most recent periods and is expected to stabilize water levels in the basin. The revised sustainable yield is a best available estimate of groundwater extraction that balances subsurface inflows and Basin recharge with Basin groundwater extraction and the minimum Basin subsurface outflows necessary to maintain groundwater levels in the Basin at a long-term dynamic steady-state such that water levels in the Basin meet the MO and do not violate the MT.

To address the mitigation portion of this deficiency, the GSA added four projects and management actions to Chapter 4 that mitigate the effects of declining groundwater levels in the Basin and stop chronic lowering of water levels: a) City of Dorris Well Deepening and Pipeline Replacement Project (already in progress), b) Well Inventory and Well Mitigation Program, c) Preliminary Groundwater Allocation Program and, d) Groundwater Demand Management. The projects are scheduled for implementation within the current five-year period. These PMAs are added to avoid further groundwater level declines beginning in 2025 and ensure the Basin fully operates within its sustainable yield by the beginning of the 2027-2032 implementation period. (Groundwater Demand Management Program and Groundwater Allocation Program) and simultaneously address negative impacts to beneficial uses and users due to groundwater level declines (City of Dorris project, Well Mitigation Program).

To address the second deficiency, the sustainable management criteria for the chronic lowering of groundwater levels sustainability indicator were revised. The quantitative undesirable result definition was modified to consider this updated Well Failure analysis and the impact to domestic, municipal, and agricultural well users under undesirable result conditions. Minimum thresholds were raised by 15 ft, and the updated Well Failure Analysis was used to evaluate depletion of supply, and dewatering of wells at these levels. Discussion of these thresholds, and consideration for beneficial uses and users, is included in the revised discussion of the chronic lowering of the water level sustainability indicator in Chapter 3.

A sustainable management criterion for interconnected surface water (ISW) and groundwater-dependent ecosystems (GDEs) was added to the plan. The GDE impact discussion was updated with the monitoring of GDEs and ISWs added since GSP submittal, and the planned work and timelines to further understand and evaluate ISWs and GDEs in the Basin.

A completely updated Well Failure Analysis (Appendix 3-C) was performed and used to evaluate wells that may be dewatered under undesirable results. The Well Failure Analysis in Appendix 3-C was updated to reflect the correct number of known wells in the Basin and additional methods were employed to corroborate the estimates of wells at risk for well failure. The updated well infrastructure discussion, maps of wells, methods description, and number and location of wells that may be negatively affected when minimum thresholds are reached can be found in Appendix 3-C. A well mitigation program is detailed as part of the "Well Inventory and Well Mitigation Program" PMA, included in Chapter 4.

Specific updates to chapters are discussed in the corresponding sections below.

Purpose of the Groundwater Sustainability Plan

The Butte Valley GSP outlines a 20-year plan to direct sustainable groundwater management activities that consider the needs of all users in the Basin and ensure a viable groundwater resource for beneficial use by agricultural, residential, industrial, municipal and ecological users. The initial GSP is a starting point towards the achievement of the sustainability goal for the Basin. Although available information and monitoring data have been evaluated throughout the GSP to set sustainable management criteria and define projects and management actions, there are gaps in knowledge and additional monitoring requirements. Information gained in the first five years of plan implementation, and through the planned monitoring network expansions, will be used to further refine the strategy outlined in this draft of the GSP. The GSA will work towards implementation of the GSP to meet all provisions of the SGMA using available local, state, and federal resources. It is anticipated that coordination with other agencies that conduct monitoring and/or management activities will occur throughout GSP implementation to fund and conduct this important work. Fees or other means may be required to support progress toward compliance with SGMA.

ES-2: PLAN AREA AND BASIN SETTING (CHAPTER 2)

Chapter 2 provides an overview of the Basin area. This includes descriptions of plan area, relevant agencies and programs, groundwater conditions, water quality, interconnected surface waters (ISWs), and groundwater dependent ecosystems (GDEs). These details inform the hydrogeologic conceptual model and water budget developed for the Basin which will be used to frame the discussion for sustainable management criteria (SMCs; Chapter 3) and projects and management actions (PMAs; Chapter 4).

Description of Plan Area (Section 2.1)

Summary of Jurisdictional Areas and Other Features (Section 2.1.1)

The Basin is a medium priority basin located in Northern California. The Basin is surrounded by several mountain ranges: the Cascade Mountains in the north, south and west, the Mahogany Mountain ridge in the east and Sheep Mountain and Red Rock Valley in the southeast. The major water features in the basin are Meiss Lake and several streams including Butte Creek. The primary communities in Butte Valley are the City of Dorris (population 962) and the smaller communities of Macdoel (population 155) and Mount Hebron (population 81) (DWR 2016b). All three of these populations are classified as severely disadvantaged communities (SDACs), based on annual median household income. The most significant land use in the Basin is for agriculture, accounting for 35% of the land in the Basin according to the 2010 County land use survey (DWR 2010) with primary crops of alfalfa, grain and hay, pasture, and strawberry.

Water Resources Monitoring and Management Programs (Section 2.1.2)

Section 2.1.2 documents monitoring and management of surface water and groundwater resources in the Basin and their relation to GSP implementation. These include federal, state, and local agencies and their associated activities in Butte Valley.

Land Use Elements or Topic Categories of Applicable General Plans (Section 2.1.3)

Applicable land use and community plans in the Basin are outlined in Section 2.1.3, including the County of Siskiyou General Plan and City of Dorris General Plan.

Additional GSP Elements (Section 2.1.4)

Well policies, groundwater use regulations and the role of land use planning agencies and federal regulatory agencies in GSP implementation are outlined in Section 2.1.4.

BASIN SETTING (SECTION 2.2)

Section 2.2 includes descriptions of geologic formations and structures, aquifers, and properties of geology related to groundwater, among other related characteristics of the Basin.

Hydrogeologic Conceptual Model (Section 2.2.1)

The hydrogeologic conceptual model encompasses the Basin setting including its geographical location, climate, geology, soils, land use and water management history, and hydrology (Sections 2.2.1.1 through 2.2.1.9).

Current and Historical Groundwater Conditions (Section 2.2.2)

General Groundwater Flow Conditions of Butte Valley - Overview (Section 2.2.2.1)

This section was added as part of the July 2024 revision to address the deficiencies and corrective actions identified by DWR. Discussion in this section includes the Butte Valley groundwater Basin's position and interactions in the larger groundwater flow system and interactions with neighboring subbasins within this groundwater flow system. Additions were made to provide additional context on the Basin's hydrogeological setting within the broader Upper Klamath Basin and to provide greater detail on groundwater recharge and discharge dynamics within the Basin.

Development of Groundwater Resources (2.2.2.2)

Groundwater as a source of irrigation was vital for the Basin's settlement and development. Lack of major surface water was a major impediment to agricultural development until the first irrigation well was drilled by BVID, in 1929. Major expansion of irrigated agriculture and groundwater development occurred mostly during the 1950s to 1970s.

Groundwater Elevation (2.2.2.3)

Groundwater levels in the Basin fluctuate on a short-term scale with a seasonal high in the spring and seasonal low in the fall, and over the long term based on precipitation levels and changes in the amount of total groundwater extraction. Groundwater recharge in the Basin depends on precipitation, which has been in decline since the 1980s. Groundwater levels have decreased around 30 feet from the spring of 1979 to the spring of 2015; the decline in groundwater levels in five wells is shown in Figure 1. This section was updated in July 2024 to include discussion of groundwater levels where long-term (about 70-year) records are available, through early 2024. Specific wells are used to illustrate groundwater level trends observed in wells in different areas of the Basin. Water levels were stable or increased in the 1950s – 1970s following drought conditions in the late 1940s. Chronic lowering of water levels is observed across the basin since 2000 and, in some wells, since 1980.

Estimate of Groundwater Storage and Groundwater Storage Changes (2.2.2.4)

Groundwater storage and specific yield are difficult to estimate due to the interconnectivity of all confined and unconfined units, and critical data gaps in the main water bearing and recharge unit, the High Cascade Volcanics. For the unconfined units, Lake Deposits, pyroclastic rocks, and Butte Valley Basalt, the weighted average specific yield is calculated to be 9.5% and total groundwater storage capacity is 2,560,000 acre-feet. The High Cascade Volcanics has unknown depth and extent, and a total estimate of storage is based on the Butte Valley Integrated Hydrologic Model (BVIHM; see Section 2.2.3). This section was updated in July 2024 to include a description of the revised method to calculate groundwater storage changes, which uses groundwater elevation change at each well and extrapolated to a Thiessen polygon (Voronoi polygon). This is a change from the method used in previous annual reports (WY2021 and 2022), which used Thin Plate Spline interpolation and looked at year-over-year fall water level changes to evaluate annual change in storage. Comparison of the results of both methods are provided. The estimated average decline in groundwater storage in the 80,000 acre Basin, between spring 2000 and spring 2024, was 6,300 acre-feet per year.

Groundwater Quality (Section 2.2.2.4)

Based on an evaluation of Basin groundwater quality using available monitoring data (see Appendix 2-B), a list of constituents of interest was generated for the Basin. This list includes

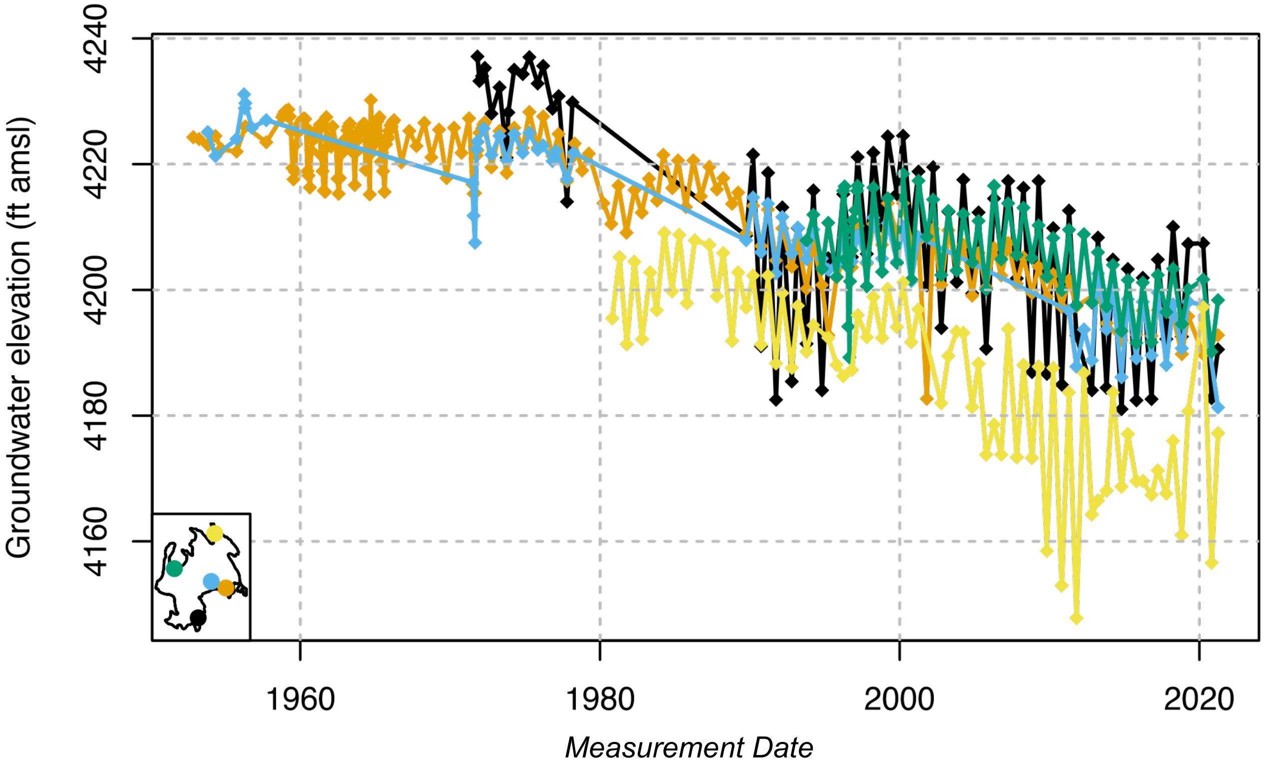

Figure 1: Groundwater elevation measurements over time in five wells, one located in each hydrogeologic zone.

1,2 Dibromoethane, arsenic, benzene, boron, nitrate, and specific conductivity. The known contaminated sites in the Basin include a PCE plume near Dorris, Calzona Tankways, and a former petroleum fueling facility.

Seawater Intrusion (Section 2.2.2.5)

The Basin is located well over 100 miles east of the Pacific Ocean with lowest observed water levels thousands of feet above mean sea level. Seawater intrusion is therefore not an issue of concern.

Land Subsidence Conditions (Section 2.2.2.6)

Land subsidence is lowering of the ground surface elevation and is not known to be currently or historically significant in the Basin. The maximum observed subsidence is approximately 0.15 ft (46 millimeters [mm]) between June 2015 to September 2019 in an area west of the City of Dorris. The change in land elevation was likely the result of localized land leveling. Land subsidence will continue to be periodically re-evaluated.

Identification of Interconnected Surface Water Systems (Section 2.2.2.7)

ISWs are defined as surface water which is connected to groundwater through a continuous saturated zone. SGMA mandates an assessment of the location, timing, and magnitude of ISW depletions, and to demonstrate that projected ISW depletions will not lead to significant and undesirable results for beneficial uses and users of groundwater.

The Basin is a hydrologically closed basin. No surface water leaves the Basin and the Basin has no major drainage. Surface waters in Butte Valley are limited to Meiss Lake (hydrologically a terminal lake) and five creeks: Butte, Prather, Ikes, Harris, and Musgrave. Many of these waterbodies go dry in the summer and fall. Groundwater elevations near the creeks have been identified as data gaps. Interpolated (i.e., estimated) groundwater levels near the creeks are generally more than 30 feet below these creeks, suggesting losing stream conditions. Lack of streamflow data are also known data gaps. Additional information is required to determine in more detail the interconnections between the surface water bodies in Butte Valley with groundwater and the magnitude and direction of flow exchange. For the purposes of this plan, these surface waters are considered interconnected to groundwater.

Identification of Groundwater Dependent Ecosystems (Section 2.2.2.8)

SGMA refers to GDEs as “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.”

The habitat ranges of freshwater species in the Basin with special designations (i.e., endangered, threatened, species of special concern, or on a watch list) were mapped. Riparian vegetation is prioritized for management in the Basin: managing for riparian vegetation addresses the needs of other special-status species in the Basin. These prioritized species are considered throughout the GSP, particularly in setting the sustainability indicators defined in Chapter 3 and identifying projects and management actions identified in Chapter 4. Vegetative GDE identification and classification was conducted through:

- The mapping of potential GDEs.
- Assigning rooting depths based on predominant assumed vegetation type.
- Establishing representations of depth to groundwater.
- Identifying potential areas where depth to groundwater, rooting depth, and presence of potential GDES confirm likely groundwater-dependence.

Potential mapped GDEs were grouped into two categories: potential GDE (where the grid-based analysis showed that the area is likely to be connected to groundwater) or potentially not a GDE (where the grid-based analysis showed that the area is disconnected from groundwater). Based on this analysis, around 10% of the mapped potential GDE area is likely connected to groundwater and assumed to be a GDE (shown in Figure 2, below). The current list of potential GDEs is considered tentative, a data gap, and dependent on collection of additional groundwater level data. An update was made to this section in July 2024, the addition of Figure 2.32, which shows rain, stream gage, and groundwater level monitoring added to fill data gaps in areas near potential GDEs and ISWs.

Water Budget (Section 2.2.3)

This section was updated in July 2024 to present the model BVIHM area and the Basin area to clarify and replace erroneous data in the original GSP. The model is currently under further refinement and calibration and will continue to be updated throughout GSP implementation. The historical water budget for the Basin was estimated for the period October 1989 through September 2018, using the Butte Valley Integrated Hydrologic Model (BVIHM). This 29-year model period includes water years ranging from very dry (e.g., 2014) to very wet (e.g., 1999). On an interannual scale, it includes a multi-year wet period in the late 1990s and a multi-year dry period in the late 2000s and mid-2010s.

The water budget is presented as flows into and out of two subsystems of the integrated watershed: the soil zone (land/soil model subsystem) and the groundwater subsystem. The water budget for the entire watershed is also included in this section.

In the historical water budget, Basin inflows include precipitation on the valley floor (to land) and subsurface inflow or mountain front recharge from the surrounding quaternary volcanics underlying the upper watershed (to groundwater). Precipitation input is variable with a median of 39 thousand acre-feet (TAF) per year. At 157 TAF per year, median subsurface inflows to the Basin are estimated be four times larger than Basin precipitation. Basin outflows consist of evapotranspiration (from land) and subsurface outflow (from groundwater) with median values of 71 and 120 TAF per year, respectively. Fluxes between the two subsystems include recharge (from land to groundwater) and groundwater pumping for applied water (from groundwater to land). Median recharge to groundwater is 26 TAF per year, 40 TAF lower than the median groundwater pumping value. This difference between pumping and recharge is made up for though lateral inflows into the Basin.

While soil zone storage shows minimal interannual change, aquifer storage varies, with a long-term trend indicating 5.2 TAF per year simulated groundwater depletion, on average, between 1990 and 2018.

Fifty-year future projected water budgets were developed using historical hydroclimate data (for water years 1991 to 2011) and four climate change scenarios were applied to explore potential effects of global warming on the Butte Valley watershed.

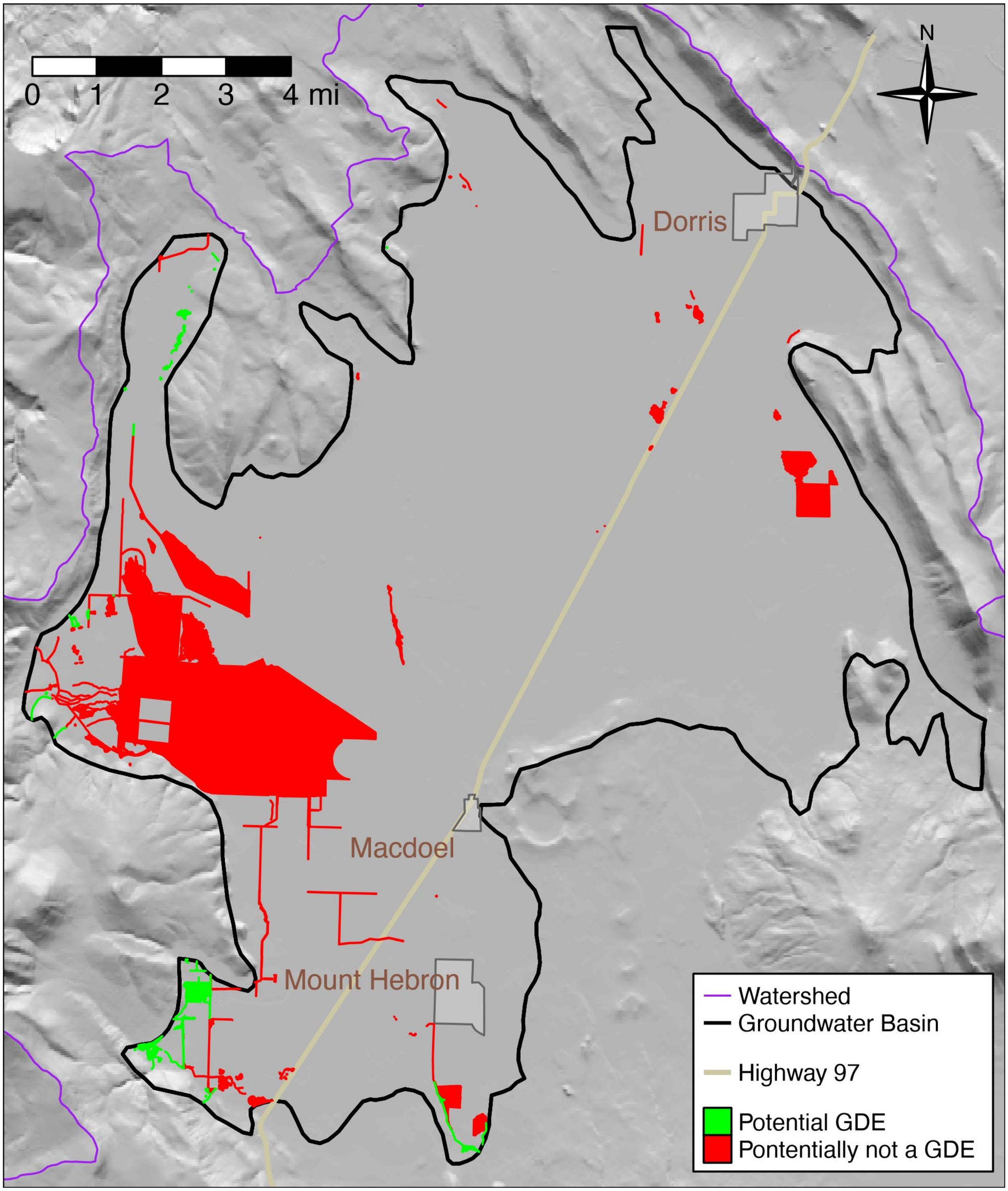

Figure 2: Categorized GDEs (including ISWs) for the Basin.

Future Water Budget (Section 2.2.4)

The future projected water budget uses the observed weather parameters from water years 1991 to 2011 to create a hypothetical future period in which climate conditions are the same as this "base case" period from 1991 to 2011. Climate-influenced variables are modified to create four climate change scenarios: a near-future, far-future, far-future with Wet with Moderate Warming, far-future with Dry with Extreme monitoring climates. BVIHM was run for the base case and all four of the climate change projected scenarios are run for 2022 to 2071. (These estimates have not been updated in the July 2024 revision).

Sustainable Yield (Section 2.2.5)

This section was revised in July 2024 to add relevant information on the conceptual basis for estimating sustainable yield and improve understanding of how subsurface outflow from the basin is a critical factor in average groundwater levels within the Basin. The sustainable yield was estimated to be 65 TAF/ yr using a combination of basic analytical models and modeling analyses. The sustainable yield is 10% - 15% below recent groundwater pumping requiring implementation of PMAs that reduce future groundwater pumping to the sustainable yield. Efforts to achieve sustainable yield in the Basin will begin immediately to ensure that the Basin is fully operating under its sustainable yield by 2027.

ES-3: SUSTAINABLE MANAGEMENT CRITERIA (CHAPTER 3)

Chapter 3 builds on the information presented in the previous chapters and details the key sustainability criteria developed for the GSP and associated monitoring networks.

Chapter 3 was revised in July 2024 to address the deficiencies and corrective actions identified by DWR. The primary changes include:

1. Both text and maps in Section 3.3 were updated in July 2024 to show the current monitoring network and record the progress in the work to fill data gaps since GSP submittal.
2. Section 3.3.2 was amended to include a summary of the updated method to calculate groundwater storage change.
3. The groundwater level sustainable management criteria were revised. Specifically, a quantitative definition of the undesirable result was added (Section 3.4.1.1) and the minimum thresholds were revised to demonstrably avoid undesirable results (Section 3.4.1.2). The GSA has committed to mitigating up to 20% of domestic wells. The revised Minimum Threshold ensures that the likely number of wells at risk of falling dry, if water levels across the Basin were at the minimum threshold, about 12% of domestic wells (28 wells) can be mitigated by the GSA. Minimum thresholds for groundwater levels were raised by at least 15 feet to what was the original GSP called the "soft-landing trigger". In wells shallower than the original "soft-landing trigger, the minimum threshold is set at least 5 ft above the total well depth.
4. A sustainability management criterion for interconnected surface water and groundwater dependent ecosystem was added to chapter 3 to more clearly define the GSA's efforts to protect environmental uses and users of groundwater and interconnected surface water. Significant monitoring and assessment of GDEs is ongoing to further evaluate potential undesirable results at the minimum threshold.
5. A revised well failure analysis was performed (Appendix 3C), ensuring consistent use of DWR OSWCR well log data, adding additional methodology to reduce estimation uncertainty, and clarifying the presentation of results. Maps are included, showing the number of expected well outages between 2015 and 2023, by section, based on the presented methodology (up to 6% of domestic wells, i.e., up to 14 domestic wells), and showing the expected number of well outages,

by section, if water levels decline further to the minimum threshold (an additional 6% or 14 domestic wells). A decline in water levels from 2015 to the minimum thresholds is estimated to put 28 domestic wells, 10 agricultural wells, and no public supply wells at risk of falling dry.

Sustainability Goal and Sustainability Indicators (Section 3.1)

The Sustainability Goal of the Basin is to maintain groundwater resources in ways that best support the continued and long-term health of the people, the environment, and the economy in Butte Valley for generations to come.

The GSP details six sustainability indicators with a goal of preventing undesirable results to any one of the following sustainability indicators:

1. Chronic Lowering of Groundwater Levels
2. Reduction of Groundwater Storage
3. Degraded Water Quality
4. Depletions of Interconnected Surface Water
5. Seawater Intrusion
6. Land Subsidence

Table 3 defines undesirable results for each sustainability indicator. Quantifiable minimum thresholds (MT), measurable objectives (MO), and interim milestones were also developed as checkpoints that evaluate success in maintaining the sustainability goal and are quantified in Chapter 3 of the GSP. Monitoring wells throughout the basin will be used to assess conditions relevant to each sustainability indicator. Monitoring wells were selected based on well location, monitoring history, well information, and well access.

Table 3: Butte Valley GSP Sustainability Indicator undesirable results defined.

Sustainability Indicator	Undesirable Result Defined
Chronic Lowering of Groundwater Levels	The fall low water level observation in 25% (4/13 wells) representative monitoring sites in the Basin fall below the respective minimum threshold for 2 consecutive years.
Reduction of Groundwater Storage	Same as ”Chronic Lowering of Groundwater Levels.”
Degraded Water Quality	More than 25% of groundwater quality wells exceed the respective maximum threshold for concentration and/or concentrations in over 25% of groundwater quality wells increase by more than 15% per year, on average over ten years.
Depletions of Interconnected Surface Water	SMCs not developed for this sustainability indicator due to lack of information on interconnectedness of surface water and groundwater in the Basin. Depending on funding and the filling of data gaps, SMCs may be set in a future GSP update.
Seawater Intrusion	Not applicable for the Basin.
Land Subsidence	Groundwater pumping induced subsidence is greater than the minimum threshold of 0.1 ft (0.03 m) in any single year.

Appendix 3-C was revised in July 2024 to address the deficiencies and corrective actions identified by DWR. Changes have been made to both the hydrographs and the well failure analysis sections. The primary change to hydrographs is the update on the SMCs for each RMP. The well failure analysis has been updated and reorganized with primary changes as below:

- Audited well records in OSWCR regarding the best information available for well locations, well construction information, and planned use.
- Replaced the result of fall 2017 in the original well failure analysis with the analysis of fall 2023 to reflect the most recent fall conditions. And added the analysis of well outages risk at minimum threshold across the basin to validate the feasibility of well mitigation at MT
- Clarified and expanded the approaches for well outage risk analysis (direct comparison and wet depth trend analysis) with more in-depth discussion and details.

ES-4: PROJECTS AND MANAGEMENT ACTIONS TO ACHIEVE SUSTAINABILITY (CHAPTER 4)

Chapter 4 describes past, current, and future projects management actions (PMAs) used to achieve the Butte Valley sustainability goal.

Chapter 4 was revised in July 2024 to address the deficiencies and corrective actions identified by DWR. The primary changes include addition of three PMAs: a well inventory and mitigation program, a preliminary groundwater allocation program, and a groundwater demand management PMA. Additionally, updates were made to include current work with the addition of the City of Dorris Well Deepening and Pipeline Replacement PMA.

To achieve the sustainability goals for Butte Valley by 2042, and to avoid undesirable results over the remainder of a 50-year planning horizon, as required by SGMA regulations, multiple PMAs have been identified and considered in this GSP. PMAs are categorized into three different tiers, as follows:

Tier I: Existing PMAs that are currently being implemented and are anticipated to continue to be implemented.

Projects or management actions in the Tier I category include:

- Abandonment of Sam’s Neck Flood Control Facility
- City of Dorris Water Conservation
- Well Drilling Permits and County of Siskiyou Groundwater Use Restrictions
- Kegg Meadow Enhancement and Butte Creek Channel Restoration
- Permit required for groundwater extraction for use outside the basin from which it was extracted (Siskiyou County Code of Ordinances)
- Upland Management
- Watermaster Butte Creek Flow Management

Tier II: PMAs with initiation and implementation from 2022 through 2027 by individual member agencies.

Tier II PMAs include:

- Well Inventory and Mitigation Program
- Preliminary Groundwater Allocation Program
- Groundwater Demand Management
- City of Dorris Well Deepening and Pipeline Replacement
- High Priority PMAs - Data Gaps and Data Collection
    - Butte Valley Integrated Hydrologic Model (BVIHM) Update (High Priority)
    - Drought Year Analysis (High Priority)

  - Expand Monitoring Networks (High Priority)
  - General Data Gaps (High Priority)
  - Groundwater Dependent Ecosystem Data Gaps (High Priority)
  - Interconnected Surface Water Data Gaps (High Priority)

- Avoiding Increase of Total Net Groundwater Use Above Sustainable Yield
- Management of Groundwater Use and Recharge
- Conservation Easements
- Dorris Water Meter Installation Project
- Irrigation Efficiency Improvements
- Public Outreach
- Voluntary Managed Land Repurposing (not including Conservation Easements)

Tier III: Additional PMAs that may be implemented in the future, as necessary (initiation and/or implementation 2027 to 2042).

Tier III PMAs, identified as potential future options, include:

- Alternative, Lower ET Crops
- Butte Creek Diversion Relocation
- Butte Valley National Grassland Groundwater Recharge Project
- Strategic Groundwater Pumping Restriction

Additionally, other management actions are outlined that may be explored during GSP implementation.

ES-5: PLAN IMPLEMENTATION, BUDGET AND SCHEDULE (CHAPTER 5)

Section 5 details key GSP implementation steps and timelines. Cost estimates and elements of a plan for funding GSP implementation are also presented in this section.

Implementation of the GSP will focus on the following several key elements:

1. GSA management, administration, legal and day-to-day operations.
2. Implementation of the GSP monitoring program activities.
3. Technical support, including BVIHM model updates, SMC tracking, and other technical analysis.
4. Reporting, including preparation of annual reports and five-year evaluations and updates.
5. Implementation of PMAs.
6. Ongoing outreach activities to stakeholders.

Annual implementation of the GSP over the 20-year planning horizon is projected to cost between $65,000 and $260,000. The GSA may pursue funding from state and federal sources for GSP implementation. As the GSP implementation proceeds, the GSA will further evaluate funding mechanisms and fee criteria and may perform a cost-benefit analysis of fee collection to support consideration of potential refinements.

Chapter 1

INTRODUCTION

1.1 BACKGROUND AND PURPOSE

In September 2014, Governor Jerry Brown signed into law the Sustainable Groundwater Management Act (SGMA), a three-bill legislative package composed of Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley) and SB 1319 (Pavley), which is codified in Section 10720 et seq. of the California Water Code. The legislation provides a framework for long-term sustainable groundwater management across California. The intent of SGMA is to provide local and regional agencies the authority to sustainably manage groundwater resources to help preserve water supplies for existing and potential beneficial uses and to protect communities, farms, and the environment against prolonged dry periods and climate change.

The California Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) provide primary oversight for the implementation of SGMA. DWR adopted regulations that specify the components and evaluation criteria for groundwater sustainability plans, alternatives to Groundwater Sustainability Plans (GSPs), and coordination agreements to implement such plans. To satisfy the requirements of SGMA, local agencies must do the following:

- Locally controlled and governed Groundwater Sustainability Agencies (GSAs) must be formed for all high- and medium-priority groundwater basins in California.
- GSAs must develop and implement GSPs or Alternatives to GSPs that define a roadmap for how groundwater basins will reach long-term sustainability.
- The GSPs must consider six sustainability indicators defined as: groundwater level decline, groundwater storage reduction, seawater intrusion, water quality degradation, land subsidence, and surface-water depletion.
- GSAs must submit annual reports to DWR each April 1 following adoption of a GSP with the first report due April 2022.
- Groundwater basins should reach sustainability within 20 years of implementing their GSPs.

The Butte Valley Groundwater Basin (Basin) is a medium-priority basin in Siskiyou County in Northern California. A description of the Basin, including a summary of the jurisdictional areas, water resources monitoring, and management, land use, and groundwater conditions are presented in Chapter 2.

In accordance with SGMA, this GSP was developed and will be implemented by the GSA representing the Basin, the Siskiyou County Flood Control and Water Conservation District.

Per SGMA requirements, the GSA is responsible for developing and submitting a GSP by January 31, 2022. The GSA feels the GSP will provide long-term sustainability for all beneficial uses and users of water. The GSA also anticipates these plans will be a tool used for the overarching watershed goal of improving water management in the watershed, bringing multiple interests to the table to resolve water conflicts in the Basin.

1.2. SUSTAINABILITY GOAL

The overall sustainability goal of groundwater management in the Basin is to maintain groundwater resources in ways that best support the continued and long-term health of the people, the environment, and the economy in the Basin, for generations to come. Further description of the sustainability goal, as it relates to the sustainability indicators, is included in Chapter 3.

1.3. AGENCY INFORMATION AND MANAGEMENT STRUCTURE

1.3.1. Agency Information

Siskiyou County Flood Control and Water Conservation District

190 Greenhorn Road Yreka, CA 96097

1.3.2. Organization and Management Structure

The Siskiyou County Flood Control and Water Conservation District is the sole GSA for the Basin. The Siskiyou County Flood Control and Water Conservation District Act (Cal Uncod. Water Deer, Act 1240 §§ 1-38) was adopted by the State Legislature in 1959. This Act established a special district of the same name, and of limited powers that could provide flood protection, water conservation, recreation and aesthetic enhancement within its boundaries. At the time of its creation, the jurisdictional boundaries of the Flood District were smaller than those of the County. In 1983, following the County of Siskiyou Local Agency Formation Commission (LAFCO) action, the balance of the County was annexed into the District, making its jurisdictional boundaries coincide with the County. The District is governed by a Board of Directors that is composed of the Board of Supervisors;; however, the District is a separate legal entity from the County, with independent rights and limited powers set forth in its originating Act. The District's purpose is to conserve and control storms, floods, and other waters and ensure their beneficial use.

1.3.3. Legal Authority of the GSA

Approved by the District Board on April 4, 2017, the Siskiyou County Resolution FLD17-01 authorized the District to act as the GSA for the Butte, Scott and Shasta Valley groundwater basins.

1.3.4. Contact Information for Plan Manager

The Siskiyou County Natural Resources Department is designated as the Plan Manager, and can be reached at:

1312 Fairlane Rd

Yreka, CA 96097

Phone: 530-842-8005

SGMA@co.siskiyou.ca.us

1.3.5. Estimated Cost of Implementing GSP and GSA's Approach to Meet Costs

The GSA will pursue all available grant funding opportunities to assist in covering the yearly costs. The GSA utilized a consultant to conduct a fee study, in case the GSA feels funds need to be raised publicly to pay for yearly management of the plans. It is expected that the GSA will manage implementation and reporting of the GSP, with support from other entities as needed.

1.4. NOTICE AND COMMUNICATION

1.4.1. Notice

GSP information, GSA Board and Advisory Committee meeting schedules, and useful links can be found at the County of Siskiyou Website.[1]

The GSA holds publicly noticed public Board and Advisory Committee meetings to allow stakeholders to engage and provide input throughout the process, as well as meetings with specific working groups in the Basin to address specific technical topics or questions. As the GSP is developed and implemented, the website will be updated accordingly with new information for public comment. Notices of public hearings are communicated through multiple methods including local newspapers and postings on the County of Siskiyou website. An SGMA email outreach list exists to inform the public on meeting information, subjects, and how to provide comments.

1.4.2. Decision Making Process

The Siskiyou County Flood Control and Water Conservation District is governed by the Siskiyou County Board of Supervisors and covers the entire boundaries of the three medium-priority basins. The District was enacted in 1957 to provide for the control and conservation of flood and storm waters and the protection of watercourses, watersheds, public highways, life and property from damage or destruction from such waters; to provide for the acquisition, retention, and reclaiming of drainage, storm, flood, and other waters and to save, conserve, and distribute such waters for beneficial use within the District boundaries, and to replenish and augment the supply of water in natural underground reservoirs. The District's Board of Directors is composed of the Siskiyou County Board of Supervisors, which are elected by the citizens of Siskiyou County. The District operates under the authority of the Board of Directors and Siskiyou County Natural Resources staff manages the GSP development and implementation.

Decisions of the District are completed pursuant to a majority vote. Actions of the Board are informed with input from the Butte Valley Advisory Committee, a community-based organization whose members are appointed by Board members. Meetings of the Advisory Committee are publicly noticed and are consistent with the Brown Act. The public, stakeholder working groups, non-profit organizations and other users and uses of groundwater are encouraged to participate in GSP implementation at publicly noticed Board and Advisory Committee meetings.

1.4.3. Public Outreach

1.4.3.1. Communication and Engagement Plan

The Siskiyou County Groundwater Sustainability Agency developed a Butte Valley Basin Stakeholder Communication and Engagement Plan (C&E Plan) to educate interested parties about local SGMA implementation, describe the phases of GSP development, encourage public participation in the process, and address noticing and communication requirements in the law (Appendix 1-A).

The C&E Plan describes how the local GSA was formed in Siskiyou County, the support role played by technical and facilitation consultants, and the process by which the GSA board of directors (GSA Board) — with support from a stakeholder advisory committee — gathers, considers, and responds to needs and interests of constituents throughout the community.

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[1] {https://www.co.siskiyou.ca.us/naturalresources/page/sustainable-groundwater-management-act-sgma}

Consensus building is a foundational principle of all committee discussions, and membership is intended to reflect the diversity of beneficial groundwater uses and users in the Basin.

The GSA maintains a government-to-government relationship with any Native American Tribe in Siskiyou County or the larger Klamath River watershed, that expresses interest in SGMA. Tribal representatives have been appointed to the advisory committees in the Scott Valley, Shasta Valley and Butte Valley groundwater basins. Moreover, Siskiyou County and the Karuk Tribe formalized good faith communication protocols around SGMA through an established memorandum of understanding.

The Butte Valley C&E Plan includes the following overarching public outreach goals:

- Provide the GSA, Advisory Committee, community leaders and other beneficial users a roadmap to ensure a broad understanding and consistent messaging of SGMA requirements.
- Foster information sharing, communication and collaboration, and opportunities for stakeholders to have meaningful input on the GSA decision-making process.
- Provide reasonable opportunities for interested stakeholders to receive and understand the technical groundwater information developed as part of the GSP process.
- Ensure a collaborative GSP development and implementation process that is widely seen in the community as fair and respectful to the range of interested or affected stakeholders.
- Assist the GSA in meeting all SGMA communication and engagement requirements.

Specific objectives which help the GSA achieve these overarching goals include the following:

- Educate stakeholders on:
  - Important SGMA requirements, events and milestones.
  - The role, authorities and responsibilities of the local GSA in Siskiyou County.
  - The advisory committee's role and how the public can stay informed or involved.
  - The benefits of having a technically robust and broadly supported GSP.
  - Potential changes to groundwater monitoring and management under SGMA.
  - How the interests of beneficial uses and users will be considered under SGMA.
- Develop strategies and communication mechanisms for obtaining broad stakeholder input and feedback that informs GSP development.
- Coordinate outreach and engagement activities that foster information sharing, raise awareness, and encourage public engagement in SGMA.
- Ensure the needs, interests, and perspectives of all beneficial uses and users are identified, documented and considered by the GSA Board.
- Support local beneficial users to identify, preempt or otherwise proactively address and resolve different perspectives or conflicts over groundwater use and management.
- Track all input received by beneficial users during the GSP development process and document GSA Board responses as input is considered.
- Develop strategies and communication mechanisms for long-term GSP implementation.

A comprehensive list of identified stakeholder groups in the Basin is included in the C&E Plan. Initially developed by GSA staff, the list was reviewed and expanded by the local SGMA advisory committee. The list may be improved and updated at any time during the GSP development or implementation process. Stakeholder groups included in the list represent a priority target audience for SGMA-related communication and engagement.

The final section of the C&E Plan describes outreach strategies which the local GSA employs to effectively advance SGMA implementation. Specific tools and forums include the following:

- Advisory committee meetings
- Constituent briefings with local organizations
- Tribal engagement
- Public meetings and workshops
- GSA Board meetings
- Coordination with local resource conservation districts
- Coordination with state and federal agencies
- Integration of relevant studies and materials
- Interested parties list
- Informational materials
- County SGMA website
- Local media and public service announcements

The local GSA will evaluate the effectiveness and efficacy of its C&E Plans for each SGMA groundwater basin in Siskiyou County. Evaluations will likely occur at or near key milestones, such as the completion of a major phase of work or shortly before or after submission of the GSP for evaluation by DWR. As needed, the C&E Plan will be updated to best serve Siskiyou County, its constituents, and all its collaborative partners in the SGMA implementation process.

1.4.3.2. Butte Valley Basin Beneficial Uses and Users

Groundwater in the Basin serves the needs of communities, farms, and businesses and provides high-quality drinking water to urban and rural residents, in addition to helping to sustain vital ecosystems. Beneficial uses of groundwater include water for irrigation, agriculture, domestic use, municipal use, and water for the protection and enhancement of fish and wildlife. Beneficial uses and users of the Basin have been identified as the following:

- Agricultural users (farmers, ranchers, dairy professionals).
- Rural, Agricultural, and Domestic well owners.
- Municipal well operators.
- Public water systems.
- Local land use planning agencies.
- Environmental uses and users of groundwater, including but not limited to habitat that supports fish, birds, animals and insects; endangered species protection; protection of beneficial habitat for recreation and other societal benefits.
- Surface water users.
- Tribal Governments.
- Disadvantaged communities (the entire Basin is a DAC or SDAC, see map in Chapter 2 - Section 2.1.1).

1.4.3.3. Public Engagement Opportunities

The GSA is committed to encouraging the active involvement of diverse social, cultural, and economic elements of the population within the Basin. The County of Siskiyou website provides information regarding GSA Board Meeting frequency, background information, documents, status updates, and contact information. GSP updates will be included as noticed per GSA respective meeting agendas that are published in advance. Meetings providing updates on GSP development are scheduled regularly, typically once a month, to inform the public and Interested Parties and provide opportunities to ask questions and make suggestions. These meetings are posted on the County of Siskiyou website and announced via email. A full list of public meetings where the GSP was discussed or considered is included in Appendix 1-B.

In addition, GSP Staff will be available throughout the GSP development process to communicate and engage with Interested Parties and the public. Interested Parties can be involved in GSP development by providing input throughout the process.

Other avenues for public engagement included or will include:

- **GSA Board meetings**: During the Public comment period of any Siskiyou County Board of Supervisors or Siskiyou County Flood Control & Water Conservation District (GSA) Board meetings
- **Working Groups**: Working groups may be formed during GSP implementation to provide specific input from Interested Parties or on specific topics.
- **Comments**: An opportunity for the public or interested parties to comment on draft GSP sections or chapters is provided. Comments received through this process and the responses provided are included in Appendix 1-C.

1.4.4. Coordination

GSA and Siskiyou County staff, and at times technical team, held coordination meetings or phone calls to provide additional input into the GSP with various state agencies, Tribes, non-governmental organizations (NGOs), or members of the public. GSA staff and, at times, the technical team also attended non-SGMA-focused workshops to provide updates or information regarding SGMA and the GSP development. Some highlights of those efforts are below:

- California Department of Fish and Wildlife (CDFW)
  - GSA staff has monthly coordination meetings with CDFW staff to discuss numerous topics, which include SGMA updates and key items and issues related to groundwater management.
- Shasta Indian Nation
- Klamath Coalition of the Willing
  - This is a large group of NGOs, Tribes, and irrigators brought together to develop solutions related to the Klamath Basin conflicts. County staff and the technical team have interacted with the group and developed project ideas that are either being implemented or in initial design phases, including managed aquifer recharge, storage development and improving upland lake management. These projects are further described in Chapter 4.
- Butte/Tulelake

- GSA staff and the technical team has met with Lower Klamath Wildlife Refuge manager to discuss findings of possible existing connections between the groundwater basins. The Lower Klamath is a low priority basin and therefore is not required to develop a GSP.
- GSA and the Butte Valley technical team met with the technical consultant team for Tule Lake to share results and expected GSP outcomes.

1.5. GSP ORGANIZATION

The GSP is organized in accordance with the GSP Emergency Regulations and statutory provisions of SGMA. The format of the GSP is similar to the outline provided by DWR's Sustainable Groundwater Management program. A brief summary of each GSP section is provided below.

Executive Summary. Provides a summary of what is included in the GSP.

Chapter 1 – Introduction. The Introduction includes the purpose and administration of the GSP, sustainability goal, agency information, and GSP organization.

Chapter 2 – Plan Area and Basin Setting. Plan Area describes the geographic setting, existing water resources planning and programs, and additional GSP components. The Basin Setting includes a detailed discussion of the hydrogeologic conceptual model used to prepare the GSP; current and historical groundwater conditions; future groundwater conditions after allowances for growth, land use changes, and climate change; and a discussion of the area's current and future groundwater budget.

Chapter 3 – Sustainable Management Criteria. Includes the sustainability goal, addresses the mandated six sustainability indicators (SI) that monitor undesirable results; defines the minimum thresholds (MT) for each undesirable result; and sets measurable objectives (MO) for the GSP complete implementation, including interim milestones for intermediate plan years. This Chapter also describes the network of monitoring wells and other information to measure the GSP outcome; assesses the need for improvements to the network to provide fully representative data; and address monitoring protocols and data analysis techniques.

Chapter 4 – Projects and Management Actions to Achieve Sustainability. Describes potential projects and management actions (PMAs) that may be implemented in pursuit of sustainability. Where available, project details include measurable objectives that are expected to benefit from the PMA, required permits, anticipated benefits, estimated costs, and how the PMA will be accomplished.

Chapter 5 – Plan Implementation. Describes the GSP implementation process, including estimated costs, sources of funding, a preliminary schedule through full implementation, description of the required data management system, methodology for annual reporting, and how progress evaluations will be conducted over time.

Appendices – References and Technical Studies. Contains the references and sources used to prepare this GSP.

> **DWR GSP Elements Guide**– This GSP was prepared to meet the regulatory requirements established by DWR, as shown in the completed GSP Elements Guide, provided in Appendix 1-D, which is organized according to the California Code of Regulation Sections of the GSP Emergency Regulations.

Chapter 2

PLAN AREA AND BASIN SETTING

2.1 DESCRIPTION OF THE PLAN AREA

2.1.1 Summary of Jurisdictional Areas and Other Features

The Butte Valley groundwater basin (Basin) is a 79,700 acre (125 square miles [sq mi]; 326 square kilometers [sq km]) subbasin within the upper Klamath Groundwater Basin that extends between California and Oregon (Wood 1960; Gannett, Wagner, and Lite Jr. 2012). The Butte Valley watershed (Watershed) is roughly three times larger than the Basin and contains two other Department of Water Resources (DWR) recognized groundwater basins. The Watershed is the drainage area that recharges surface water in the Basin, as shown in Figure 2.1. The Watershed is located immediately northeast of Mount Shasta, whose flank can be seen in the bottom left corner of Figure 2.1.

The predominately agricultural Basin is in northern Siskiyou County, California, just south of the Oregon border (see Figure 2.1). Under the 2019 basin prioritization conducted by DWR, the Basin (DWR Basin 1-003) is designated as medium priority (DWR 2019d). The Basin sits on the western edge of the Modoc Plateau, a broad and rugged volcanic upland with land surface elevations generally between 4,500 to 5,000 feet (ft; 1371 to 1524 meters [m]) above mean sea level (amsl) (Gannett, Wagner, and Lite Jr. 2012). The Basin itself is located at an elevation of about 4,230 ft – 4,270 ft (1290 m – 1300 m) amsl. The basin is topographically closed and bounded by topographic highs in all directions: the Cascade Mountains in the north, south and west, the Mahogany Mountain ridge in the east and Sheep Mountain and Red Rock Valley in the southeast (DOI 1980; DWR 2004). The Basin contains Meiss Lake, the remnant of a prehistoric lake that once filled Butte Valley, and several streams that all flow into the Basin from the surrounding Watershed, as shown in Figure 2.1 (King 1994). Butte Creek is the largest stream flowing into Butte Valley, albeit over less than 1.3-mile distance into the Basin's southern boundary where much of the existing flow typically percolates into the subsurface.

2.1.1.1 Jurisdictional Areas and Land Use

The Siskiyou County Flood and Water Conservation District serves as the Groundwater Sustainability Agency (GSA) for the Basin. The Basin has three notable population centers: the City of Dorris (Population: 962), Macdoel (Population: 155), and Mount Hebron (Population: 81) (DWR 2016b). Due to their small populations, Macdoel and Mount Hebron are described as census-designated places by the United States (U.S.) Census Bureau. U.S. Highway 97 crosses the Basin from the southwest to northeast, passing through Dorris and Macdoel. The Union Pacific Railroad passes through Butte Valley from north to south, passing through all three cities. The railroad generally follows U.S. Highway 97 between Macdoel and Dorris and leaves the Valley north of Dorris via a train tunnel through the Mahogany Mountain ridge. South of Mount Hebron, the railroad generally follows the path of Butte Creek (Figure 2.1). The Basin and Watershed do not contain any tribal lands or tribal interests.

Disadvantaged Communities

There are three severely disadvantaged communities (SDACs) in the Basin that suffer from a combination of economic, health, and environmental burdens (Figure 2.3). By definition, disadvantaged communities (DACs) have a median household income (MHI) less than 80% of the statewide MHI while SDACs are below 60%. All three of the communities in the Basin are categorized as SDACs: Dorris has a MHI of $28,963, Macdoel has a MHI of $35,294, and Mount Hebron has a MHI of $28,170 (DWR 2016b). All SDAC communities rely on groundwater as their sole source of drinking water, using a combination of municipal water districts, small water suppliers, and domestic wells.

Water Suppliers

The Basin has no adjudicated areas and contains one irrigation district, one water district, and four small water suppliers (**Figure 2.2**). The Butte Valley Irrigation District (BVID) is a private water supplier that manages irrigation water for roughly 5,000 acres (20 square kilometers [sq mi]) of land northwest of Mount Hebron. It manages the largest groundwater distribution and management network in the Basin and distributes water throughout the service area through a network of pipes. Farms serviced by the irrigation district are allocated two acre-feet per acre per year (AFY; 0.6 meters per year [m/yr]). BVID supplies water from approximately 20 wells out of its 25 well network. The City of Dorris has a small municipal water district serving approximately 938 residents (McKay 2019). It has two wells in its supply network. However, one well is only used as an emergency supply (McKay 2019). Groundwater supplies 100% of the district water supply (McKay 2019).

In the region surrounding Macdoel and Mount Hebron, four small water suppliers report to the California Department of Public Health (CDPH) (SWRCB 2019a). Macdoel Waterworks operates in the middle of Macdoel and serves a population of 20 with two monitoring wells (SWRCB 2019a). Juniper Village Farm Labor Housing is located southeast of Macdoel and has one groundwater well serving a population of 200 (SWRCB 2019a; SWRCB 2019c). The Mt. Hebron Work Center is operated by the U.S. Forest Service (USFS) and operates in the middle of Mount Hebron with one groundwater well serving a population of 30 (SWRCB 2019a; SWRCB 2019c). The USFS Goosenest District Office operates west of Mount Hebron alongside U.S. Highway 97. It has one groundwater well serving a population of 30 (SWRCB 2019a; SWRCB 2019c).

Federal Managed Lands

Over 40% of the Basin is covered by federal and state-managed lands, as shown in Figure 2.2. Federally managed land consists of the Klamath National Forest, including the Butte Valley National Grassland and small sections of the National Forest along the Basin border. The Butte Valley National Grassland is primarily north of U.S. Highway 97, covering 18,400 acres (74 sq km) or 23% of the total Basin surface area. Butte Valley Grassland became the nation’s 20th National Grassland in 1991 after strong support from the local Congressional delegation, California Cattlemen’s Association, California Department of Fish and Wildlife (CDFW; formerly California Department of Fish and Game), and the local public.

After serving as a military practice bombing range in the 1940s, the federal government and Natural Resources Conservation Service (formerly Soil Conservation Service) re-stabilized the soil by planting over 4,000 acres (16 sq km) of crested wheatgrass. They worked with local ranchers to set up grazing associations and developed local conservation practices, which continue to the present day. Today, the National Grassland is shrub-steppe, with sagebrush, rabbitbrush, bitterbrush, basin wild rye, intermediate wheatgrass, and other arid grasses and flowers with scattered western juniper trees. Grazing cattle reside within the National Grassland alongside local wildlife including mule deer, Roosevelt elk, pronghorn, coyote, marmot, weasel, porcupine and bobcat. Resident bird species include Swainson’s Hawk, golden eagle, bald eagle, merlin, sandhill crane, great horned owls, short-eared owls, and long-eared owls, with winter visitors including red-tailed hawk, Ferruginous Hawk, rough-legged hawk, northern harrier, American Kestrel, and prairie falcon (USFS 2020).

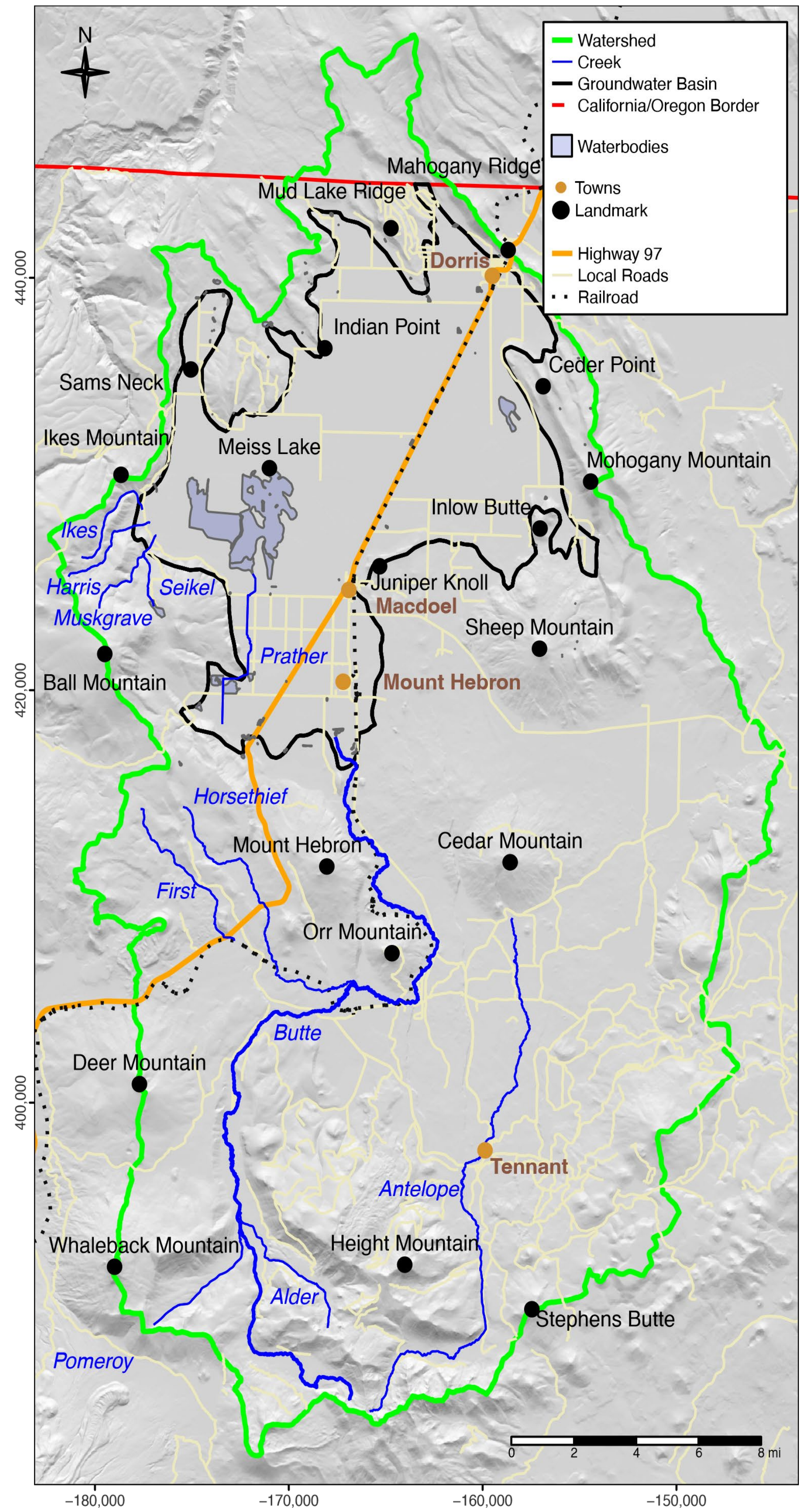


Figure 2.1: Butte Valley Watershed and Groundwater Basin Boundary.

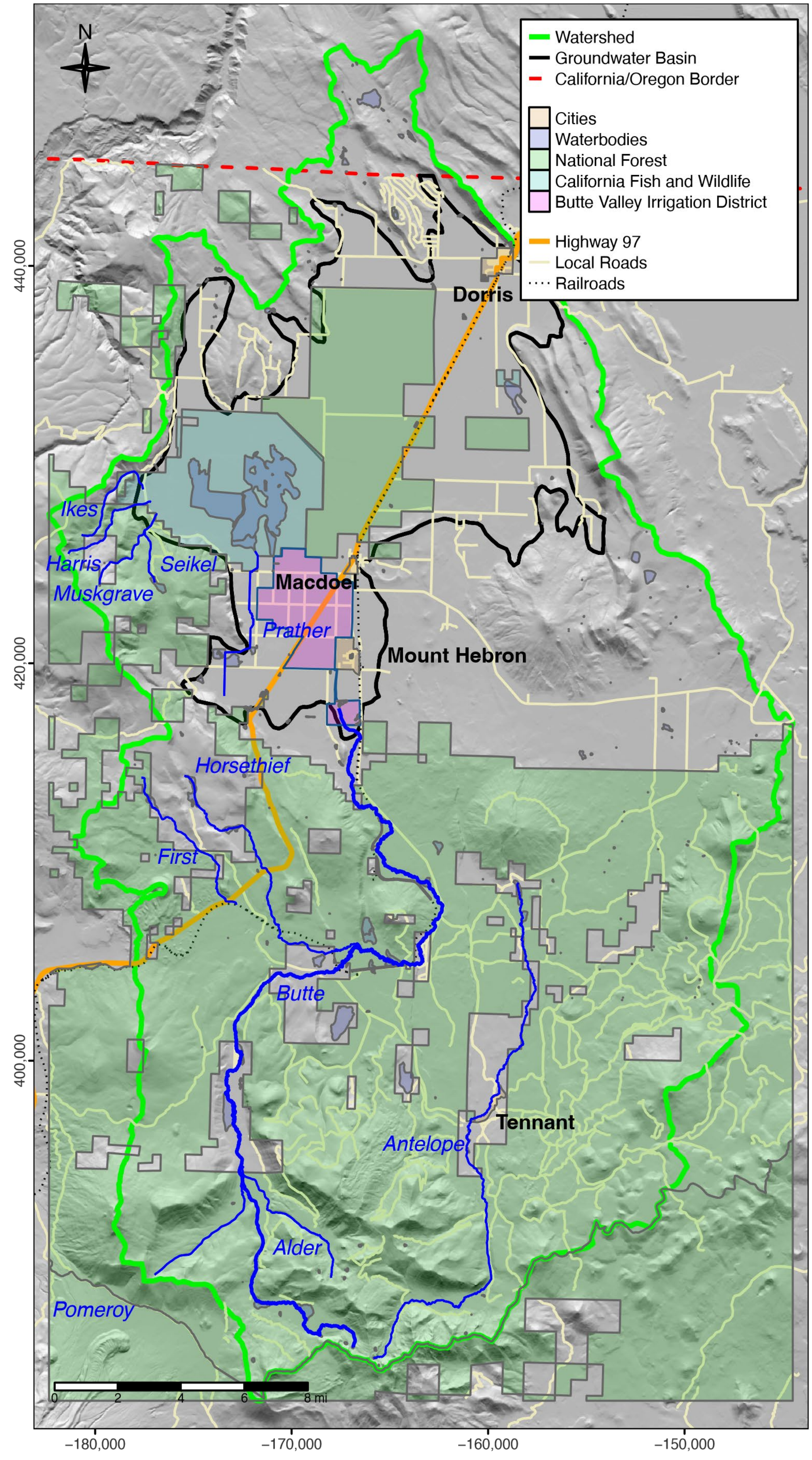


Figure 2.2: Butte Valley Watershed Jurisdictional Authorities.

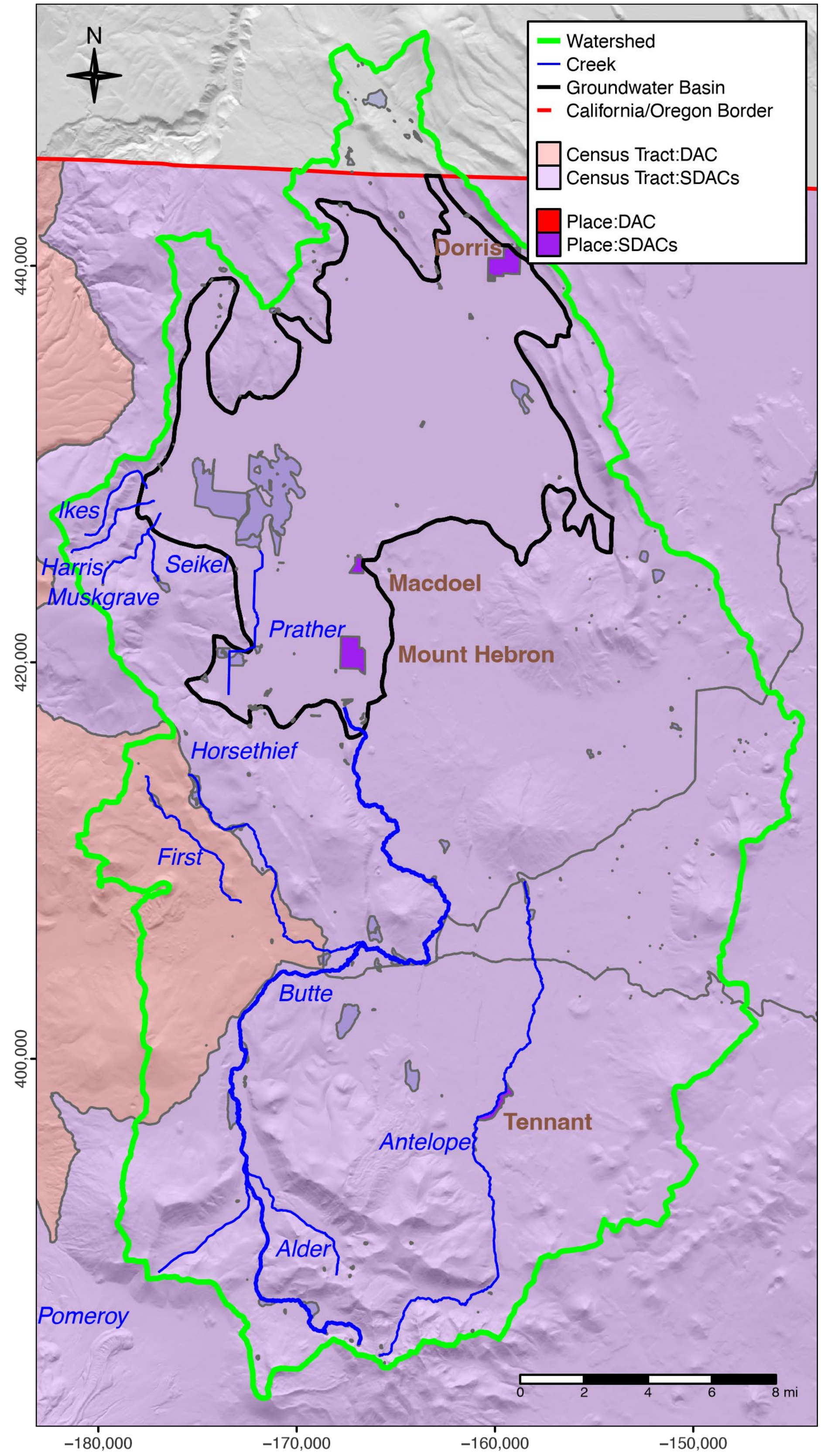


Figure 2.3: Based on the 2016 U.S. Census, place and tract boundaries of Disadvantaged Communities (DACs: $42,737 <= MHI < $56,982) and Severely Disadvantaged Communities (SDACs: MHI < $42,737) in the Butte Valley watershed, using data from the DWR DAC Mapping Tool (DWR 2016b).

During World War II the US Navy used 7,040 acres (28 sq km) of land to develop the Siskiyou Rocket and Bombing Range, an aerial gunnery range used in winter when other stations were inhibited by poor weather conditions. By May 1945, the U.S. Navy gained use of the area for air-to-ground firing, high- and low-level bombing and strafing. Sub-Caliber Aerial Rockets were used at the site. The area covered parts of the Butte Valley National Grassland and Butte Valley Wildlife Area. The U.S. Department of Defense (DOD) has conducted a site inspection and monitored the site for discarded military munitions and explosives, including unexploded ordinance. In 1984, a wildlife survey discovered a rocket that was removed by the DOD, though only inert practice rockets were used at the site. Qualitative site reconnaissance and soil sampling found that metal pollution does not exceed human health screening values. The Department of Toxic Substances Control is the oversight and cleanup agency for the site, but no further action is planned as of September 2013. The cleanup site floods in the winter and is populated with grazing cattle the rest of the year (DTSC 2020).

State Managed Lands

The state owns 13,500 (55 sq km) acres within the Basin, or 17% of the total Basin surface area, which includes the Butte Valley Wildlife Area (BVWA) and a small property at Mud Lake, as shown in Figure 2.2. BVWA is 13,200 acres (53.4 sq km) with 4,400 acres (17.8 sq km) of intensively managed wetlands, 4,000 acres (16.2 sq km) of Meiss Lake, and 4,800 acres (19.4 sq km) of upland habitat (NCRWQCB 2008). It is bordered by the federal Klamath National Forest on the east and southwest. The Fish and Game Commission designated the site as a wildlife area in 1981 and it is currently managed by CDFW. Over 200 species of birds can be spotted in the Wildlife Area. Recreational activities include camping, hiking, wildlife viewing, and hunting. Hunting options include waterfowl, coots, moorhens, snipe, and doves. Four-grain fields lie on the west and south side of the Wildlife Area. The small property at Mud Lake is owned but not managed by the state.

Land Use

Historical land use maps for Butte Valley are not available before 1996. Even without detailed historical land use surveys, there are enough historical records to form an image of changing land use over time. Irrigated agricultural land in Butte Valley has increased from approximately 4,700 acres (1,900 hectares) in 1928 to nearly 28,000 acres (11,300 hectares) in the 1970s and has been relatively stable since, as shown in Figure 2.5 (Adams 1929; Appendix 2-E). The DWR land use surveys for 2000 and 2010 (DWR 2000, 2010) and for 2014 (Davids Engineering, Appendix 2-E) include additional information on irrigation-equipped idle land acreage and managed wetlands acreage. Earlier records for Butte Valley likely do not include irrigation-equipped idle land or managed wetlands acreages.

Butte Valley's economy is dominated by agriculture. For the revision of this GSP, land use of the Butte Valley groundwater basin from the 2010 County land use survey was audited. Land use parcels included in the original GSP were re-evaluated or clipped to exclude any area outside of the Bulletin 118 boundary. The 2010 County land use survey assessed 48.5% of the Basin area and identified the following land use percent coverage: agriculture (35.2%), idle land (4.1%), Riparian Vegetation (including managed wetlands, 5.7%), urban (2.3%) and miscellaneous land use (1.2%). As of 2010, the major crops in Butte Valley were alfalfa, hay, and nursery strawberry, which occupied approximately 14,800 acres, 7,400 acres, and 3,200 acres (5,990 hectares, 3,000 hectares, 1,300 hectares) respectively (DWR 2010). Butte Valley National Grassland is not included in the land use survey, but a number of local ranchers have permits to graze cattle (USFS 2020). Acreages associated with various land uses surveyed by DWR are shown spatially for 2010 in Figure 2.4 (DWR 2010), and numerically for 2000 and 2010 in Table 2.1 (DWR 2000, 2010).

Nursery strawberry is a significant economic commodity in Butte Valley. Recent market prices are $50,000 per acre of nursery strawberries compared to $1,040 per acre of alfalfa (in 2016) and $822 per acre of hay (in 2016) (Smith 2016). Butte Valley nurseries produce approximately 500 million strawberry plants annually (Nelson 2021). Strawberries in California grow on approximately 39,000 acres (USDA 2020a) and approximately 3,000 of those acres are from nursery production in Butte Valley.

Table 2.1: Acreage and percent of total Basin area covered by all identified land uses in the 2000 and 2010 DWR land use survey

Land Use Description	Acres		Percent of Basin Area	
	2000	2010	2000	2010
Alfalfa pasture	14,160	14,844	17.8	18.6
Grain and Hay	7,785	7,449	9.8	9.3
Urban Vacant	354	835	0.4	1.0
Riparian Vegetation (including managed wetland)	6,112	4,530	7.7	5.7
Idle	1,210	3,241	1.5	4.1
Truck and Nursery and Berry Crops	2,322	3,541	2.9	4.4
Pasture	2,486	2,234	3.1	2.8
Urban Residential	369	645	0.5	0.8
Semiagricultural and Incidental to Agriculture	252	610	0.3	0.8
Water Surface	3,223	385	4.0	0.5
Urban Industrial	140	275	0.2	0.3
Urban Commercial	44	44	0.1	0.1
Barren and Wasteland	15	1	0.0	0.0
Urban Landscape	0	17	0.0	0.0

Butte Valley crops have several different growing cycles. Alfalfa is grown for four to six years before ripping soil and reseeding. In contrast, nursery strawberries rotate in a three-year rotation with one year each of nursery strawberries, idle/fallow and hay (Nelson et al. 2019). In 2010, approximately 9,900 acres (4,000 hectares) were part of that rotation. Strawberries are only grown from March to September and receive irrigation throughout (Nelson et al. 2019). A small amount of garlic, occupying less than 400 acres, is also grown from September to August with irrigation throughout the winter if precipitation is insufficient.

Strawberry is grown and harvested in Butte Valley for daughter plant production. Mother plants are started under protective coverings where they are grown for approximately twelve weeks under 22-inch tall micro-tunnels of flat fabric slightly above crops (Nelson et al. 2019). After twelve weeks, the micro-tunnels are removed and the plants are allowed to produce stolons, commonly called runners, which produce daughter plants (Nelson et al. 2019). Eventually, the daughter plants produce roots and form independent cloned plants from the mother plant. The harvested products grown in Butte Valley are live plants for transplant. Daughter plants are then transplanted to other regions where they produce fruit. In mid to late September, the field is harvested for strawberry plants, which are later transported to other parts of the United States for eventual berry production (Nelson et al. 2019).

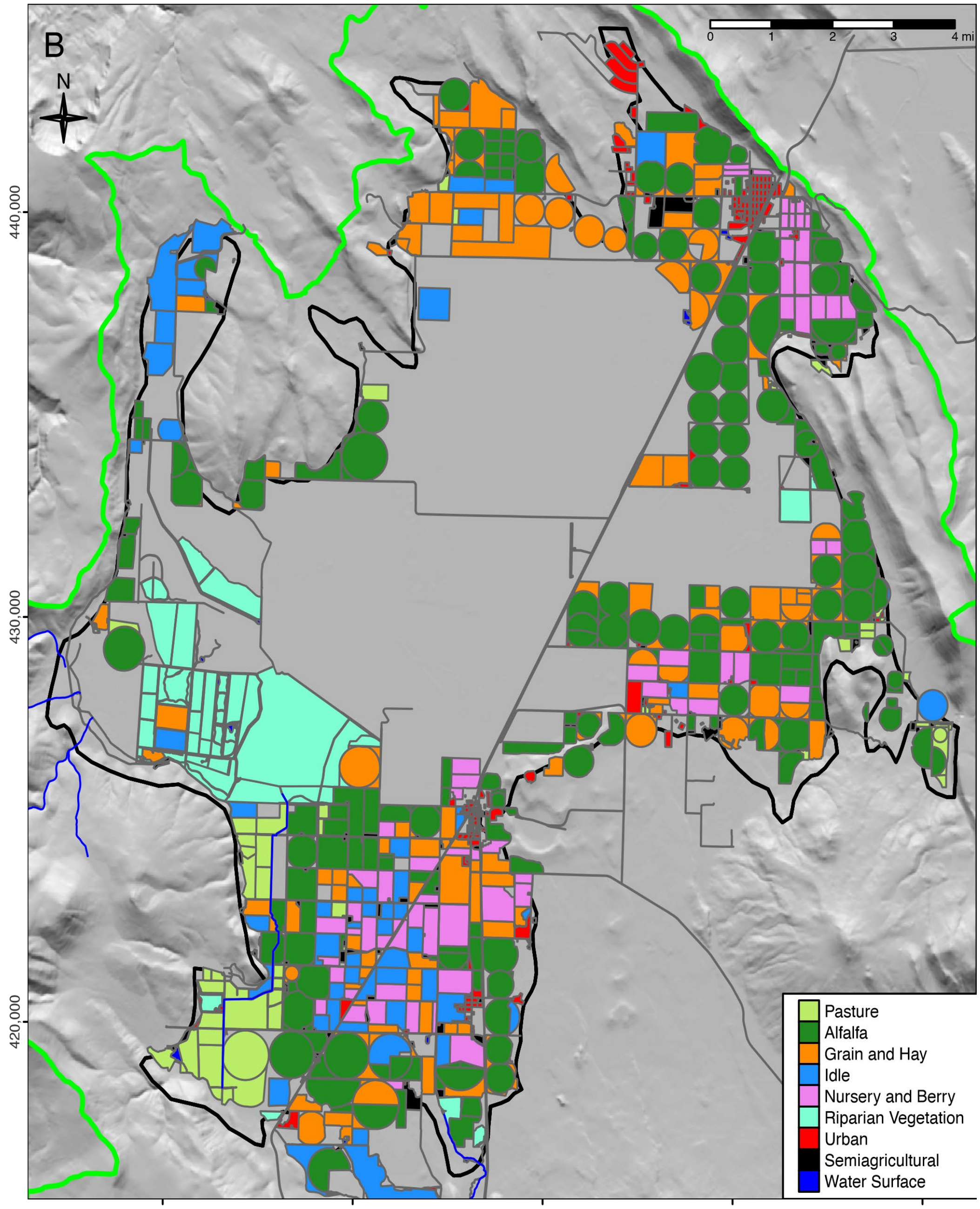
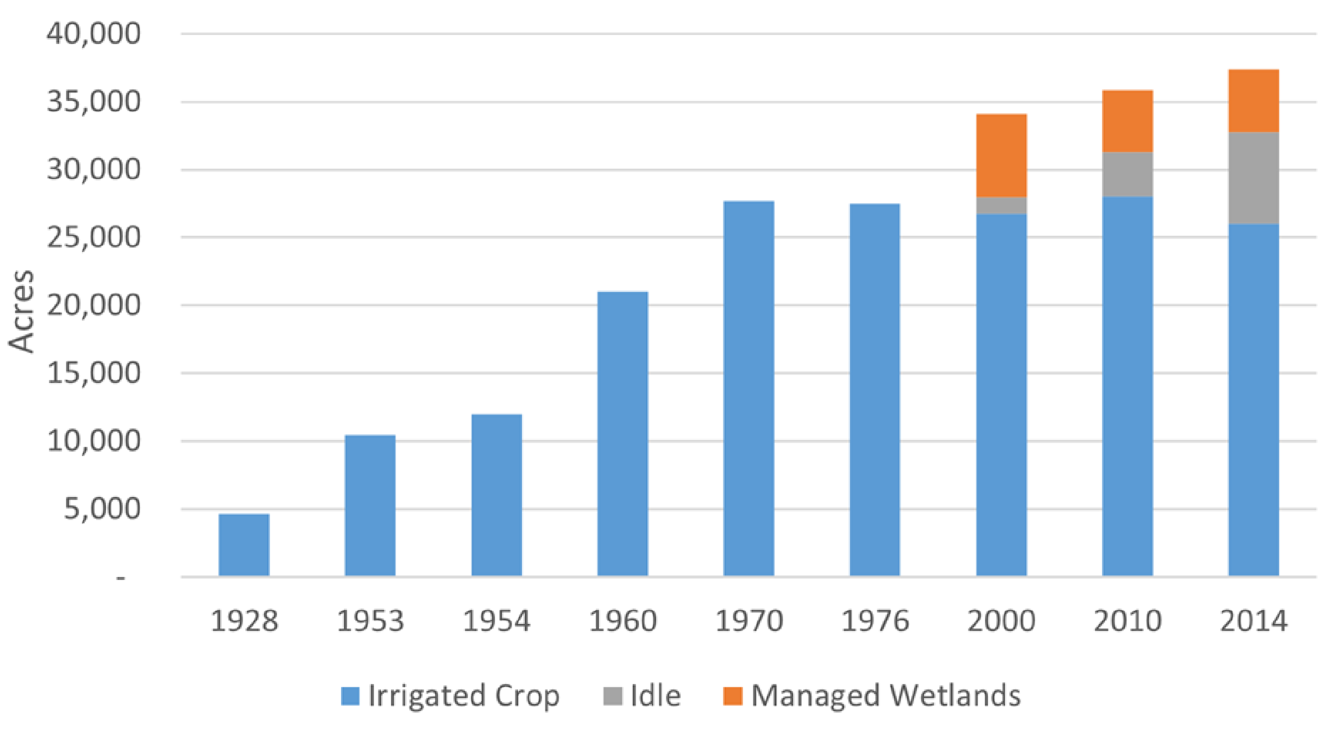


Figure 2.4: Land use within the Butte Valley Groundwater Basin boundary taken from the DWR 2010 Land Use Survey



Note on BVWA irrigation demand: DWR (1998) reports an average groundwater use within the Butte Valley Wildlife Area to be 3,000 ac ft/year, on average, or 1.1 ac ft/ac per year, indicating 2,700 acres of irrigated lands within BVWA. Davids Engineering reports (Appendix 2-F) that BVWA includes 4,300 acres of managed wetlands and 4,400 acres of upland vegetation, of which 1,000 acres are irrigated (700 acres of managed wetlands and 300 acres of irrigated grains). Nursery strawberries (about 3,500 acres in any given year), require second-year fallowing. Within Butte Valley Irrigation District, grower's current groundwater allocation of 2 ac ft/ac per year is applied as 4 ac ft/ac on nursery strawberry acreage, 0 ac ft/ac on fallow land, and 2ac ft/ac on grain.

Figure 2.5: Acreages of irrigated crops, irrigation-equipped idle land (when reported), and managed wetlands (when reported) in Butte Valley, Siskiyou County, California (Adams 1929; Horn et al. 1954; Denton et al. 1976; Phillips 1980; DWR 2000; DWR 2010; Appendix 2-E; County of Siskiyou 1996)

2.1.1.2 Well Records

Public data regarding wells are limited in Butte Valley. Using data from the DWR Online System for Well Completion Reports (OSWCR; see DWR 2019a), it is possible to visualize the approximate distribution (i.e., well density) of domestic, agricultural, and public water wells in the Basin, aggregated to each Public Land Survey System (PLSS) section (Figure 2.6). Because OSWCR represents an index of Well Completion Report records dating back many decades, this dataset may include abandoned or destroyed wells, or quality control issues such as inaccurate, missing, or duplicate records, but is nevertheless a valuable resource for planning efforts. BVID is the source of additional well records. For the revision of this GSP, the location of well records was audited. Well records included in the original GSP were excluded if reported locations fell outside the Basin (if reported section locations were entirely outside the Basin).

The primary uses of the wells reviewed were:

- Domestic Wells: 163
- Agricultural Production Wells: 148
- Public/Municipal Wells: 6

For 78 wells, no planned use was specified. Potentially, a large fraction of these wells serve domestic well water use. Other uses included industrial (2 wells), monitoring (22 wells), stock water (10 wells), and testing (14 wells). Of these 443 wells, all were assessed to be in or near Butte Valley, and all wells were geolocated with the specificity necessary to include them in the Butte Valley geologic model. A database of these wells was created to facilitate model development.

The density of groundwater wells is highest in the south and east sections of the Basin, especially near the cities of Dorris, Macdoel, and Mount Hebron, following the extent of agricultural land use, as shown in Figure 2.6 and discussed further in Section 2.1.3.3. The density of wells per square mile is shown in Figure 2.6.

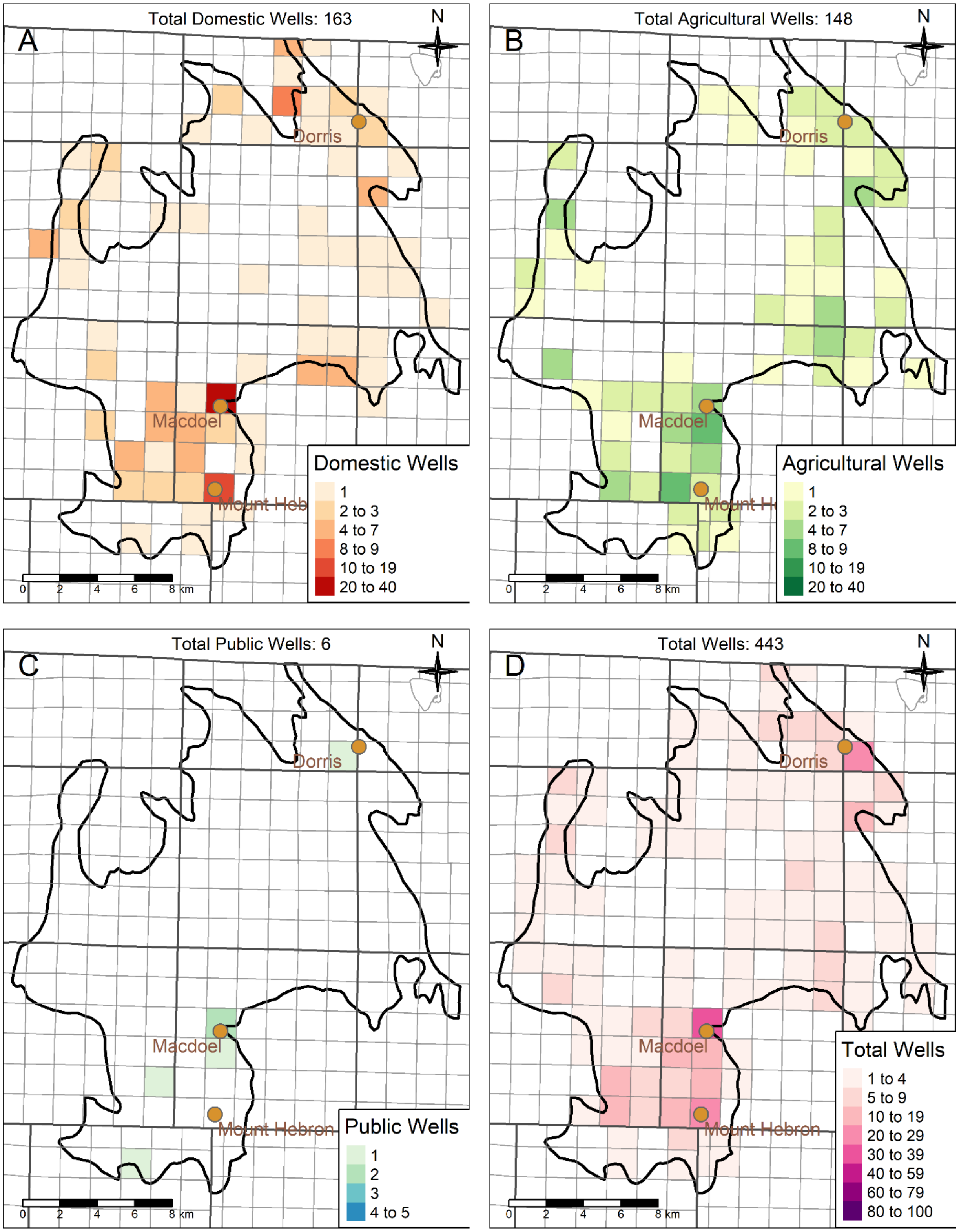


Figure 2.6: Choropleth maps indicating number of domestic (panel A), agricultural production (panel B), and public (panel C) Well Completion Reports present in each Public Land Survey System (PLSS) section, based on data from the DWR Online System for Well Completion Reports (OSWCR). Panel D shows the sum of panels A-C. PLSS sections delineated on maps are nominally one square mile

2.1.2 Water Resources Monitoring and Management Programs

There is historical and ongoing work in the Basin related to monitoring and the management of surface water and groundwater resources. The following section describes each monitoring and/or management program and outlines the current understanding of (a) how these programs will be incorporated into the groundwater sustainability plan (GSP) implementation and (b) how they may limit operational flexibility in GSP implementation. At this time Butte Valley does not have established conjunctive use programs for surface and groundwater allocation. The programs described include:

- Water Quality Control Plan for the North Coast Region (Basin Plan)
- California Statewide Groundwater Elevation Monitoring Program (CASGEM)
- Butte Valley Irrigation District (BVID)
- City of Dorris Municipal Water District
- United States National Forest Service (USFS)
- California Department to Fish and Wildlife (CDFW)
- United States Bureau of Reclamation (USBR)
- Butte Valley Sustainability Agency (GSA)
- Endangered Species Conservation Laws
- Federal Endangered Species Act (ESA)
- California Endangered Species Act (CESA)

2.1.2.1 Water Quality Control Plan for the North Coast Region

Groundwater within Butte Valley is regulated by the North Coast Regional Water Quality Control Board's (NCRWQCB) *Water Quality Control Plan for the North Coast Region* (Basin Plan; see NCRWQCB 2018). Groundwater is defined in the Basin Plan as:

> *Groundwater is defined as subsurface water in soils and geologic formations that are fully saturated all or part of the year. Groundwater is any subsurface body of water which is beneficially used or usable; and includes perched water if such water is used or usable or is hydraulically continuous with used or usable water.*

The Basin Plan includes water quality objectives for groundwater based on the assigned beneficial uses (NCRWQCB 2018). Table 2-1 in the Basin Plan designates all groundwaters with the following beneficial uses:

- Municipal and Domestic Supply (MUN)
- Agricultural Supply (AGR)
- Industrial Service Supply (IND) • Native American Culture (CUL).

Potential beneficial uses designated for groundwater include: Industrial Process Supply (PRO) and Aquaculture (AQUA; see NCRWQCB 2018). The MUN beneficial use designation is used to protect sources of human drinking water and has the most stringent water quality objectives. The MUN beneficial use applies to all groundwater in Butte Valley.

Section 3.4 and Table 3-1 of the Basin Plan outlines the water quality objectives for all groundwaters in the North Coast Region and those specific to the Butte Valley Hydrologic Area (NCRWQCB 2018). The Basin Plan refers to the California Code of Regulations for Domestic Water Quality and Monitoring Regulations (Title 22) for nearly all numeric limits (NCRWQCB 2018; State of California 2019). The Basin Plan water quality objectives and numerical limits are used in Section 2.2.2 of the GSP regarding water quality characterization and issues of concern. They also guide Chapter 3 of the GSP regarding groundwater sustainability criteria related to degraded water quality. The Basin Plan provides some limitations to operational flexibility in GSP implementation because the GSP must align with Basin Plan components such as water quality standards.

2.1.2.2 California Statewide Groundwater Elevation Monitoring Program

The California Statewide Groundwater Elevation Monitoring (CASGEM) Program collects and centralizes groundwater elevation data across the state, and makes them available to the public. The CASGEM Program was established in response to the passage of California State Senate Bill X7-6 in 2009. Currently, all CASGEM data are made available to the public through the interactive mapping tool on the CASGEM Public Portal website (DWR 2019b). Additionally, the full dataset can be retrieved from the California Natural Resources Agency (CNRA) Open Data website (CNRA 2019).

In Butte Valley, as of September 2019, there were 6 CASGEM wells and 40 wells designated as “voluntary” mapped within the Basin boundary, and an additional 18 voluntary wells immediately adjacent to the Basin (DWR 2019b). “Voluntary” status indicates that the well owner has contributed water level measurements to the CASGEM database, but the well is not enrolled in the CASGEM monitoring program.

Well monitoring under the CASGEM Program is ongoing. CASGEM water level data are used in the GSP to characterize historical Basin conditions and water resources (see Section 2.2.2) and will inform future management decisions. No limitations to operational flexibility in GSP implementation are expected in the Basin due to implementation of the CASGEM Program.

2.1.2.3 Butte Valley Irrigation District

Butte Valley Irrigation District (BVID) manages the largest groundwater distribution and management network in the Basin serving approximately 5,000 acres (20 sq km) of farmland. BVID distributes water throughout the service area through a network of pipes. BVID only services agriculture customers and no domestic customers. Farms serviced by the irrigation district are allocated two acre-feet per acre per year (0.6 m/yr). BVID supplies water from approximately 20 wells within its 25-well network. BVID and BVWA have an agreement where both entities can divert water from Meiss Lake to farmland, however BVID has not exercised the agreement due to pumping costs and the poor quality of the lake water (Kit Novick 1996).

BVID surface water and groundwater operations are important to all aspects of the GSP, from historical water quality data to land use to groundwater recharge. BVID will be a key partner for GSP implementation. BVID operations and management will likely affect operational flexibility in GSP implementation in the Basin. The GSA will collaborate with BVID to balance flexibility of operations and management with GSP implementation in the Basin.

2.1.2.4 City of Dorris Municipal Water District

The City of Dorris has a small municipal water district serving approximately 938 residents (McKay 2019). Groundwater has supplied 100 percent of the district water supply since the town was founded in 1908. The municipal water supply is pumped from a single well, Well #6, which was drilled in 1971 to a depth of 1,236 ft (377 m). A back-up well, Well #4 (“Old Sandy”), is used for emergencies (Bray & Associates 2015; McKay 2019). “Old Sandy” was discontinued from use due to the production of an excessive amount of sand and elevated arsenic concentrations. Well #6 is metered and approximately 142 million gallons (gal) of water was pumped in 2014. Groundwater is treated with chlorine at the well site (Bray & Associates 2015).

The City of Dorris is designated as a severely disadvantaged community (SDAC) and has struggled to obtain funding to maintain its water distribution lines (Bray & Associates 2015; DWR 2016b). Many of the water distribution lines in Dorris are the original lines installed over 100 years ago, and some sections of pipe installed in 1912 are still in use (Bray & Associates 2015). The City is applying for grants and looking to increase assessment fees under Proposition 218 to fund extensive replacement of and upgrades to the City’s water distribution system (Bray & Associates

2015; McKay 2019). In the early 1980s, a federal grant funded the construction of a 750,000-gal (2,840 m^3) welded steel water reservoir, which remains in use today. Bray & Associates proposed a Capital Improvement Plan of several million dollars and recommended installation of water meters to encourage water conservation, a move that was estimated to reduce water consumption by 30% if implemented (Bray & Associates 2015). The City successfully received grants from the Department of Public Health Safe Drinking Water State Revolving Fund and State Revolving Fund to begin the Dorris Water Meter Installation Project in 2021. The project will install water meters, replace old pipelines, and locate missing services.

The Municipal Code of the City of Dorris includes a water conservation program (Title 13, Chapter 5). The City may order the appropriate stage of water conservation based on projected supply and customer demand. The three water stages with mandatory compliance apply restrictions to a variety of water-dependent activities such as landscape watering and car washing. The most severe water conservation stage applies water usage cuts for agricultural or commercial nursery purposes and commercial, manufacturing, and processing processes.

City reports and data are used in the GSP to characterize historical Basin conditions and the City is expected to be a key partner for GSP implementation. City operations and management will likely affect operational flexibility in GSP implementation in the Basin. The GSA will collaborate with the City to balance flexibility of operations and management with GSP implementation in the Basin.

2.1.2.5 United States Forest Service

USFS manages the Klamath National Forest, of which the Butte Valley National Grassland is included. USFS manages the Mt. Hebron Work Center in the city of Mount Hebron and the Goosenest District Office, both of which have groundwater wells that report data to CDPH and SWRCB (SWRCB 2019a; SWRCB 2019c). The USFS also owns and manages Juanita Lake, with water rights to divert water from Seikel Creek (a tributary of Muskgrave Creek) to the lake. From April 30 to November 1, 0.56 cfs can be diverted directly from Seikel Creek and 340 acre-feet (AF) of water can be stored from November 1 to April 30 (Kit Novick 1996).

USFS will be a key partner for GSP implementation. USFS land covers roughly 23% of the Basin surface area and coordination with the GSA will be important for GSP implementation. Butte Valley National Grassland operations and management will likely affect operational flexibility in the Basin. The GSA will collaborate with the USFS to align operations with GSP implementation in the Basin.

2.1.2.6 California Department of Fish and Wildlife

The Butte Valley Wildlife Area (BVWA) is managed by the California Department of Fish and Wildlife (CDFW). In 1979, the California Legislature adopted Senate Concurrent Resolution No. 28 (SCR28) to maintain existing wetlands and increase wetland acreage by 50 percent by the year 2000. The purchase of BVWA preserved its existing wetlands. CDFW is working on expanding BVWA wetlands by restoring former wetlands to functioning wetlands for wildlife habitat (Kit Novick 1996). The BVWA management area is shown in Figure 2.7. CDFW manages 13,400 acres (54 sq km) of land that includes Meiss Lake and its surrounding land (DWR 1998). CDFW directly owns 13,200 acres and cooperatively manages lands owned by the United States Bureau of Land Management (BLM) and USFS. In the northwest corner of BVWA, BLM owns 80 acres managed for wildlife (field 11A). Adjacent to the southwest BVWA boundary, USFS owns 150 acres managed for wildlife (Kit Novick 1996). Water resources in BVWA are used for irrigation and wetland maintenance (Kit Novick 1996). Wetland expansion and management of Meiss Lake floodwaters have improved wildlife habitat, increased groundwater recharge for agricultural wells, improved forage for livestock in the National Grasslands, and reduced Siskiyou County pumping costs for flood protection (Kit Novick 2009).

BVWA is managed as a waterfowl habitat for the Pacific Flyway and provides foraging, resting and sanctuary areas for migratory birds. Resident waterfowl such as the Canada Goose and several duck species use BVWA for nesting, brood-rearing and molting. Three threatened or endangered species, including the bald eagle (state endangered status under review), sandhill crane, and Swainson's hawk use BVWA for hunting, nesting and foraging (Kit Novick 1996; CDFW 2021c). Bald eagles are year-round residents of BVWA with dozens of eagles during the winter.

Within BVWA is 4,000 acre (16 sq km) Meiss Lake, managed wetlands and crop lands, meadows, creeks, native grasslands, brush fields and pine-oak forests (Kit Novick 1996). The 8,400 acres of wetlands are maintained by 40 miles of dikes and levees, 31 miles of canals and channels, 325 nesting islands and over 150 water control structures (NCRWQCB 2008). Macdoel Ditch is a 0.8 mi long drainage canal leading from the east shore of Meiss Lake to the adjacent USFS Butte Valley National Grasslands that can transport lake water to the grasslands (Kit Novick 1996; County of Siskiyou 1996). BVWA also includes riparian corridors along Ikes, Harris, Muskgrave and Prather Creeks, tributaries to Meiss Lake. Cereal grain crops are grown for waterfowl food and include wheat, barley, oats, and rye (Kit Novick 1996). Perennial crops are grown to provide nesting cover for ground nesting birds and include wheatgrass, alfalfa and native meadow hay. During the summer and fall, parts of the BVWA are flooded to provide brood habitat and habitat for migratory waterfowl, respectively (DWR 1998).

Water used to flood the BVWA ponds is generally provided by surface water supplies but is augmented or replaced with groundwater during surface water deficient periods (DWR 1998). Surface water supplies are typically sufficient for wetland flooding in the spring but insufficient in the summer and fall. BVWA surface water comes from four creeks and one canal that flow toward Meiss Lake. From the west, spring-fed Ikes, Harris, and Muskgrave Creeks flow into the Perimeter Canal, which flows to Meiss Lake. From the south, spring-fed Prather Creek flows directly into Meiss Lake. Estimated creek inflows are 15,000 to 20,000 acre-feet annually but are low or nonexistent in the summer and fall. The Irrigated District Canal delivers excess irrigation water to Meiss Lake from wells and summer runoff, though flows are normally very low. Meiss Lake is a managed reservoir with a depth no greater than 6 feet. Lake depths greater than 6 feet cause flooding for adjacent private farmland. Lake water increases in alkalinity in the summer and fall and is not suitable to flood wetlands or irrigate crops when surface water supplies are low (Kit Novick 1996).

BVWA uses groundwater to meet its water demand when surface water supplies are insufficient, particularly in the summer and fall (Kit Novick 1996; DWR 1998). BVWA has five deep irrigation wells, though only four are currently used for production: Wells 1, 2, 3, and 5A. Wells 1, 2, and 3 tap into the High Cascade Volcanics water bearing formation. Groundwater from the three wells is used to irrigate food and nesting cover crops and maintain water levels in the BVWA wetlands for summer brood water for resident birds (500 to 600 acres of wetland) and fall migrating birds (increase to 1,000 to 1,200 acres of wetland). The four wells are operated intermittently from June to August and continuously from September to the end of October, though the pumps will run longer in drought years. In the southwest portion of BVWA, Wells 1, 2, and 3 are relatively shallow with depths of 90 to 284 feet. The wells once had artesian flows of 15 to 500 gpm. The artesian flows of Wells 1, 2, and 3, and several smaller domestic wells near BVWA headquarters stopped during the droughts of 1977, 1980 to 83, and from 1987 to Present. Wells 1, 2, and 3 have water yields of 2,588, 1,377, and 1,460 gpm, respectively. Well 7A is on the north side of BVWA with water yields of 2,500 gpm. Groundwater pumping from the four wells has no to minimal impact on offsite irrigation wells. Groundwater in the High Cascade water bearing formation near BVWA headquarters flows northerly then northeasterly (Kit Novick 1996).

Well 5A is located southeast of Meiss Lake and taps into the Butte Valley Basalt water bearing formation. Groundwater from the well is only used to sprinkler-irrigate cereal grain crops in BVWA due to the seasonal depletion of the aquifer. It is 278 feet deep with water yields of 3,000 gpm. In the years 1981, 1991, 1992, and 1994, the well has gone dry near the end of the irrigation season when the Butte Valley Basalt water bearing formation was depleted (Kit Novick 1996).

In 1998 the BVWA total annual water demand was 13,200 AF. From the 1980s to 1998, the annual BVWA groundwater extraction amount has varied from 2,000 AF to 5,300 AF, with an average annual amount of approximately 3,000 AF. The average groundwater demand was expected to increase to 3,500 AF due to a proposed 500 AF increase in groundwater development. However the actual long-term average use (1987 to 2008) has actually decreased to 2,746 AF (K. Novick 2009). As of 1998, the BVWA applied groundwater demand was about 1.1 AF per acre (DWR 1998).

In 1998, DWR investigated DFG Well 7A (27C01M), located north of Meiss Lake, for an unacceptable level of interference with neighboring wells and springs. Well 7A taps into the highly transmissive High Cascade Volcanics water bearing formation and was confirmed to cause interference with adjacent wells but had minimal impact on nearby springs located on Holzhauser Ranch in Sam's Neck. Additionally, the 1998 DWR well interference study found that groundwater flow around Well 7A is noticeably influenced by nearby faults, which can act as both a flow barrier and a very transmissive conduit for flow (DWR 1998). CDFW altered use of Well 7A in a desire to be a good neighbor and minimize possible effects on the wells of private neighbors (K. Novick 2009). Actions included reduction of volume pumped from Well 7A from 2,800 gpm to 1,500 gpm and overall operation is coordinated with adjacent private landowners to minimize any impacts on their irrigation wells (K. Novick 2009).

CDFW will be a key partner for GSP implementation. CDFW land covers roughly 17% of the Basin surface area and coordination with the GSA will be important for GSP implementation. CDFW reports and data are used to characterize the Basin in Section 2.2 of the GSP. CDFW operations and management will likely affect operational flexibility in GSP implementation in the Basin. CDFW groundwater extraction may potentially impact neighboring wells and the resulting cone of depression may be asymmetrical due to local faults (DWR 1998). The GSA will collaborate with the CDFW to align operations with GSP implementation in the Basin.

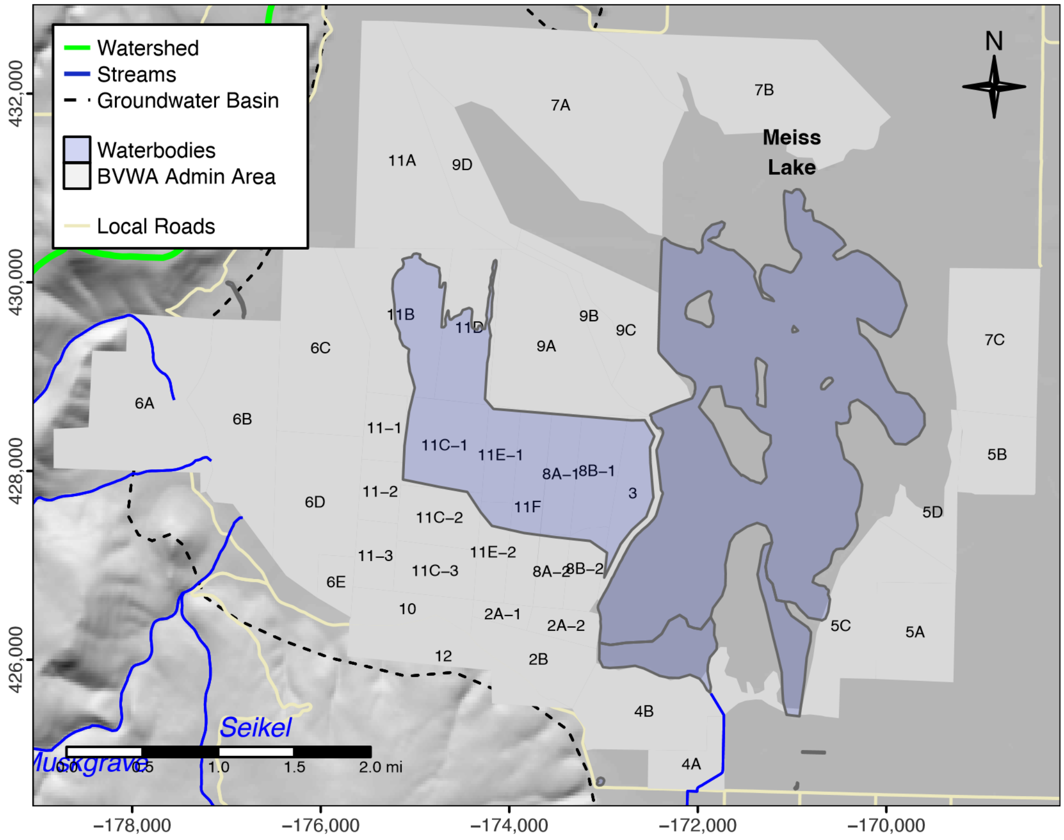


Figure 2.7: Map of the Butte Valley Wildlife Area adapted from the 1996 draft management plan for the wildlife area (Novick 1996)

2.1.2.7 United States Bureau of Reclamation

Through its WaterSMART program, the United States Bureau of Reclamation (USBR) is granting funds to the GSA to install 10 co-located, continuous groundwater level and soil moisture sensors that will be incorporated into the Basin's GSP development and implementation. The GSA will collaborate with the USBR to align operations with GSP implementation in the Basin.

2.1.2.8 Endangered Species Conservation Laws

Federal Endangered Species Act

The Federal Endangered Species Act (ESA) outlines a structure for protecting and recovering imperiled species and their habitats. Under the ESA, species are classified as "endangered," referring to species in danger of extinction throughout a significant portion of its range, or "threatened," referring to species likely to become endangered in the foreseeable future. The ESA is administered by two federal agencies, the Interior Department's U.S. Fish and Wildlife Service (FWS), primarily responsible for terrestrial and freshwater species, and the Commerce Department's National Marine Fisheries Service (NMFS) which primarily handles marine wildlife and anadromous fish.

California Endangered Species Act

The California Endangered Species Act (CESA) was first enacted in 1970 with the purpose of conserving plant and animal species at risk of extinction. Similar to the ESA, CESA includes the designations "endangered" and "threatened," used to classify species. Definitions for these designations are similar to those under the ESA and apply to native species or subspecies of bird, mammal, fish, amphibian, reptile, or plant. An additional category "candidate species" exists under

CESA that includes species or subspecies that have been formally noticed as under review for listing by CDFW. Additional detail on species in Butte Valley listed under CESA can be found in Section 2.2.1.7 as part of the discussion on groundwater dependent ecosystems (GDEs).

Both the ESA and CESA are used in the GSP to guide the identification of key species for consideration as part of GDEs. Listed species will continue to be considered throughout GSP implementation, as part of any project and management actions (PMAs), and to help inform future management decisions. These endangered species conservation laws may limit operational flexibility in GSP implementation. The GSA will incorporate this legislation into its decision-making and may seek to coordinate with the relevant state and federal lead agencies, as necessary.

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans

2.1.3.1 General Plans

The overarching framework for land use and development in the County of Siskiyou (County) is the Siskiyou County General Plan (General Plan). A community-specific General Plan was also developed in Butte Valley for the City of Dorris. Elements of the general plans outline goals for land use and development, and mechanisms for achieving those goals that include policies and zoning regulations. The GSP will be developed to conform with the general plans as much as possible.

County of Siskiyou General Plan

The County's General Plan (County of Siskiyou 2019b) serves as a guide for land use decisions within the County, ensuring alignment with community objectives and policies. While the General Plan does not prescribe land uses to parcels of land, it does identify areas that are not suitable for specific uses. The components of the General Plan with the most relevance to the GSP include the Conservation Element and Open Space Element. Many of the objectives and policies within the General Plan align with the aims of the GSP and significant changes to water supply assumptions within these plans are not anticipated.

The Conservation Element of the General Plan recognizes the importance of water resources in the County and outlines objectives for the conservation and protection of these resources to ensure continued protection of beneficial uses for people and wildlife. Methods for achieving these objectives include local legislation such as flood plain zoning and mandatory setbacks, subdivision regulations, grading ordinances, and publicly managed lands to ensure preservation of open spaces for recreational use. The importance of water resources is clearly noted in this element: “Groundwater resources, water quality, and flood control remain the most important land use determinants within the county” (County of Siskiyou 1973). Specific topics addressed include preventing pollution from industrial and agricultural waste, maintaining water supply and planning for future expansion, reclaiming and recycling wastewater, and protecting watershed and recharge lands from development. These objectives in the Conservation Element mirror the objectives of the GSP, namely ensuring a sustainable water supply, the protection and preservation of watershed and water recharge lands, and prevention of degradation of water quality.

The Open Space Element of the General Plan includes in its definition of open space any area of land that serves as open space, watershed and groundwater recharge land, among other uses. The importance of protecting these lands is recognized for maintaining water quality and quantity. Mechanisms to preserve these spaces include maintaining or creating scenic easement agreements, preserves, open space agreements, and the designation of lands for recreational or open space purposes. A policy for open space requirements is included with minimum thresholds of 15% of proposed developments as open space. Protection of open space for habitat, water quality, and water quantity align with the objectives of the GSP.

Siskiyou County Zoning Plan

The County of Siskiyou Zoning Plan (Zoning Plan) is codified in Title 10, Chapter 6 commencing with Article 37 (County of Siskiyou 2019a). The County of Siskiyou Zoning Ordinance outlines the permitted types of land use within each zoning district. Zoning categories include residential, commercial, industrial, agricultural, forestry, open space, and flood plains. Many of the purposes and policies of the Zoning Plan align with the objectives of the GSP. In particular, the “wise use, conservation, development and protection” of the County’s natural resources, protection of wildlife, and prevention of pollution support the objectives of the GSP. Mechanisms to achieve these goals include permitted and restricted uses for land parcels, and requirements and stipulations for land use and development.

2.1.3.2 Community Plans

Dorris General Plan

The City of Dorris General Plan (DGP) outlines objectives and programs to guide decision-making as it relates to land use and development to ensure the physical, economic, and social wellbeing of the community. The DGP is applicable through Year 2025 (updated in 2007) and incorporates all elements, as required by Section 65402 of the California Government Code: land use, circulation, housing, conservation, open space, noise, and safety (City of Dorris 2007).

2.1.3.3 Williamson Act Land

Contracts under the California Land Conservation Act of 1965, commonly known as the Williamson Act, are used to preserve open space and agricultural lands. Local governments and private landowners enter into voluntary agreements to restrict land for use in agriculture or as open space. Private landowners that enter into a Williamson Act contract benefit from lower property taxes. Lands that are eligible to be enrolled under these contracts must be a minimum of 100 acres and can be enrolled as either Prime or Non-Prime Williamson Act Farmland, based on the productivity specifications outlined in Government Code § 512021. In the County of Siskiyou, as of 2014, 96,993 acres (393 sq km) were enrolled as Prime Land and 324,300 acres (1,312 sq km) were enrolled as Non-Prime Land (DOC 2016).

2.1.3.4 Neighboring Groundwater Basins

The Butte Valley groundwater basin has several neighbors that may affect the ability of the GSA to achieve sustainable groundwater management: Tule Lake, Lower Klamath, Red Rock Valley, and groundwater basins to the northeast in adjacent Oregon are, with Butte Valley, part of the larger, mostly volcanic groundwater system of the Upper Klamath Basin (see Section 2.2). Shasta Valley groundwater basin is separated from Butte Valley through a groundwater divide in variably permeable volcanic uplands. DWR lists Tule Lake and Shasta Valley groundwater basins as medium priority basins, while the Lower Klamath and Red Rock Valley groundwater basins are low priority (DWR 2009).

2.1.4 Additional GSP Elements

2.1.4.1 Policies Governing Wellhead Protection and Well Construction, Destruction and Abandonment

In the Basin, wellhead protection and well construction, destruction and abandonment are conducted according to relevant state guidelines.

Well standards are codified in Title 5, Chapter 8 of the Siskiyou County Code. These well standards define minimum requirements, including those for monitoring wells, well construction, deconstruction, and repair, with the objective of preventing groundwater pollution or contamination (County of Siskiyou 2020). Processes and requirements for well permitting, inspections, and reporting are included under this chapter of the County Code of Ordinances.

The County of Siskiyou Environmental Health Division (CSEHD) is the local enforcing agency with the authority to issue well permits in the County. Well permit applications require information from the applicant and an authorized well contractor, along with a fee.

The County has worked on obtaining hydrological data/modeling to help inform individual well permitting decisions beginning with the Scott Valley; and public discussion and decision making related to the impacts of the public trust doctrine on groundwater management is on-going. The GSA will look for opportunities to coordinate with the County on providing collected hydrologic information that may assist the County.

2.1.4.2 Groundwater Extraction and Illegal Cannabis

On August 4, 2020, Ordinance 20-13 amended Chapter 13 of Title 3 of the County Siskiyou Code of Ordinances to add Article 7. Article 7 defines finds extracting and discharging use of groundwater for illegal cultivation of cannabis to be a public nuisance and a waste and/or unreasonable use of groundwater and prohibits extraction and discharge of groundwater underlying the County for this activity. Ordinance 20-13 was replaced by Ordinance 20-15 in the fall of 2020; however, the substantive provisions of the ordinance remain the same.

Groundwater extraction for the cultivation of illegal cannabis has expanded over the past five to seven years. This current land use practice is not accounted for in either the historical or future water budget analysis.

Siskiyou County has adopted multiple ordinances relating to the regulation of cannabis. Chapter 15 of Title 10 of the Siskiyou County Code prohibits all commercial cannabis activities, and Chapter 14 limits personal cannabis cultivation to the indoor growth of a maximum of 12 plants on premises with a legal water source and an occupied, legally established residence connected to an approved sewer or septic system. Personal cultivators are also prohibited from engaging in unlawful or unpermitted surface drawing of water and/or permitting illegal discharges of water from the premises. Despite these ordinances, illegal cannabis cultivators continue to operate within and near the Basin.

Illegal cannabis growers rely on groundwater from production and residential well owners and utilize water trucks to haul groundwater off the parcel from which it is extracted for use at other locations. The proliferation and increase of illegal cannabis cultivation taking place in the Basin is a significant community concern; however, obtaining an accurate estimate of overall consumptive groundwater use for this illegal activity has been a challenge for the GSA due to it occurring on private and secluded parcels and the increasing use of covered greenhouses for illegal cannabis cultivation. Future model scenarios may use an estimated number of cannabis plants from the Siskiyou County Sheriff Department and a consumptive use of four to ten gallons of water per plant per day to consider the potential impacts to groundwater resources from this activity under current and future conditions.

In addition to community concern about estimated consumptive use of groundwater in the Basin for illegal cannabis cultivation, there is also concern about water quality impacts from the potential use of illegal and harmful chemicals at illegal grow sites, which may leach into the groundwater (see Chapter 2, Water Quality), and the non-permitted human waste discharge methods that have been found to occur at some of these sites. Data on baseline water quality conditions at illegal cannabis cultivation sites within the Basin or at nearby wells have not been collected; however, the GSA intends to include available wells within close proximity to these sites in its future monitoring network for the purpose of measuring water quality.

The GSA considers groundwater used for illegal cannabis cultivation to be a “waste and unreasonable use of water,” but acknowledges that there is not substantial enough data to include groundwater the use estimates from illegal cannabis production in the overall and future water budgets. The GSA will coordinate with local enforcement agencies regarding providing collected hydrologic information and will also use the emphasis on collecting data during the first five years of plan implementation to better understand the impacts of groundwater use for illegal cannabis on overall Basin-wide use estimates and the relation to nearby groundwater aquifers.

2.1.4.3 Groundwater Export

Groundwater export is regulated in the County under Title 3, Chapter 13 of the Siskiyou County Code. Since 1998, Chapter 13 has regulated the extraction of groundwater from Bulletin 118 basins underlying the County for use outside of the basin from which it was extracted. Exceptions include 1) groundwater extractions by a district purveyor of water for agricultural, domestic, or municipal use where the district is located partially within the County and partially in another county, so long as extracted quantities are comparable to historical values; and 2) extractions to boost heads for portions of these same water purveyor facilities, consistent with historical practices of the district. Groundwater extractions for use outside the County that do not fall within the exceptions are required to obtain a permit for groundwater extraction. Permit application processes, timelines, and specifications are described in this ordinance.

In May of 2021, Title 3, Chapter 13, was amended to add Article 3.5, which regulates, through ministerial permitting, the extraction of groundwater for use off the parcel from which it was extracted. This provision requires extracted groundwater be for uses and activities allowed by the underlying zoning designation of the parcel(s) receiving the water and does not apply to the extraction of water for the purposes of supplying irrigation districts, emergency services, well replenishment for permitted wells, a “public water system,” a “community water system,” a “noncommunity water system,” or “small community water system” as defined by the Health and Safety Code, serving residents of the County of Siskiyou.

2.1.4.4 Policies for Dealing with Contaminated Groundwater

Migration of contaminated groundwater from point sources, such as leaking fuel tanks, is managed through coordination with NCRWQCB. Open and historic (“closed”) cleanup sites are discussed in Section 2.2.2.5, subsection “Contaminated Sites.” Non-point sources of contaminated groundwater, such as pesticides, are described in Section 2.2.2.5.

2.1.4.5 Replenishment of Groundwater Extractions and Conjunctive Use

There are no artificial groundwater replenishment or conjunctive use projects in Butte Valley. Proposed projects and management actions are described in Chapter 4.

2.1.4.6 Coordination with Land Use Planning Agencies

The GSA will manage land use plans and coordinate land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity.

2.1.4.7 Relationships with State and Federal Regulatory Agencies

The GSA has relationships with multiple state and federal agencies, as described in the Section 2.1.2. These state and federal agencies include CDFW, NCRWQB, USFS, DWR, and USBR. The GSA will continue to coordinate and collaborate with these agencies throughout GSP development and implementation.

2.2 BASIN SETTING

2.2.1 Hydrogeologic Conceptual Model

Overview

Butte Valley is a topographically closed internally drained basin at the boundary between the western Modoc Plateau and eastern Cascade Range geomorphic provinces, near the western and northwestern border of the Medicine Lake Highlands. Butte Valley experiences east-west directed extensional tectonics and north-trending normal faults expressed as block faulting (Bryant 1990). This chapter reviews the background of the hydrogeologic conceptual model. A hydrogeologic conceptual model (HCM; see DWR 2016a) fulfills the following:

1. Provides an understanding of the general physical characteristics related to regional hydrology, land use, geology and geologic structure, water quality, principal aquifers, and principal aquitards of the Butte Valley groundwater basin (Basin) setting;
2. Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks; and,
3. Provides a tool for stakeholder outreach and communication.

The following is a graphical and narrative description of the physical components of the Basin. The following elements are required by DWR (DWR 2016c):

- Scaled cross-sections.
- Topographic information.
- Surficial geology.
- Soil characteristics.
- Delineation of existing recharge areas that substantially contribute to the replenishment of the Basin, potential recharge areas, and discharge areas.
- Surface water bodies.
- Source and point of delivery for local and imported water supplies.

2.2.1.1 Topography

Butte Valley is a structurally controlled closed drainage basin and the valley floor is a practically flat surface, with elevations ranging over an exceedingly narrow range from 4,226 to about 4,270 ft (1,288 to 1,300 m) amsl, shown in Figure 2.8 (Bryant 1990; County of Siskiyou 1996). Elevations near the basin margin may reach 4,400 ft (1340 m) amsl along the slopes of surrounding ranges. The Watershed is roughly three times larger than the Basin. As shown in Figure 2.13, the flat-floored structural depression is surrounded by youthful fault scarps and merges into fields of broken Quaternary basalts to the south (DOI 1980). The mountainous topography that bounds the Basin ranges from 5,000 to 8,000 ft (1,524 to 2,438 m) amsl (DWR 1968). The Basin is bounded in the north, south and west by the Cascade Mountains and on the southeast by Sheep Mountain and Red Rock Valley (Wood 1960; DWR 2004). Topography to the north is marked by block-faulted volcanic plateaus and several flat-floored grabens, including Sam’s Neck and Pleasant Valley, that project beyond the Basin (DOI 1980; Bryant 1990). The eastern boundary has a prominent northwestward trending fault block (the Mahogany Mountain ridge or Mahogany Ridge), which isolates the Basin from the Lower Klamath Lake marshland in the northeast (DWR 2004). The Mahogany Ridge is 20 mi (32 km) long, 1 to 3 mi (1.6 to 4.8 km) wide and bordered by steep, slightly dissected, talus-covered fault scarps. The north end of the ridge is broken by several en-echelon faults while the south end is characterized by a gently southward sloping plateau (DOI 1980).

The Watershed is immediately northeast of Mount Shasta, seen in the bottom left corner of Figure 2.8. The northern Watershed border crosses the state border into Oregon, with the northernmost extent bounded between Chicken Hills and Hamaker Mountain. In Oregon, Grenada Butte and Randolph Flats are within the Watershed. In addition to Butte Valley, the Watershed includes Red Rock Valley (northeast of Cedar Mountain), Round Valley (between Cedar Mountain and Orr Mountain), the Bray Town Area (south of Orr Mountain), plus other unnamed valleys.

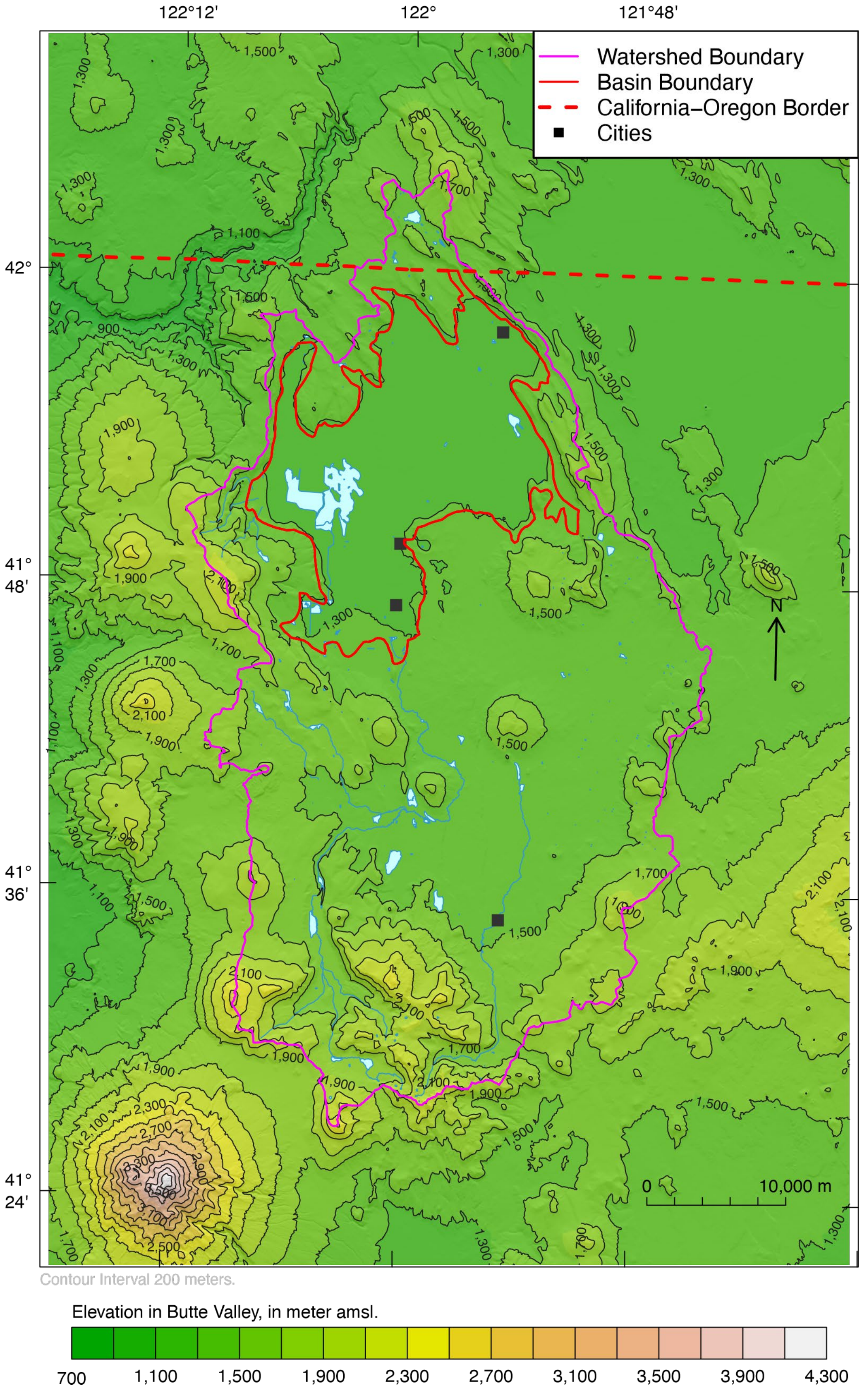


Figure 2.8: Topography of the Butte Valley Groundwater Basin and surrounding Watershed. City names from north to south are: Dorris, Macdoel, Mount Hebron and Tennant

2.2.1.2 Climate

Butte Valley has a semiarid climate characterized by warm, dry summers and cool, wet winters. The Cascade Range on the west side of the Basin casts a rain shadow across the Basin, where precipitation is highest on the west side of the valley and decreases eastward (Kit Novick 1996). Annual precipitation also increases northward (DWR 2004). In 1996, the mountains and foothills on the west side of the Butte Valley Wildlife Area received an average of 20 to 28 inches of rainfall a year, the crop lands on the west side of Meiss Lake received 15 to 22 inches, BVWA headquarters received 18 inches, and the east side of Meiss Lake received 10 to 12 inches. Snow can occur during any month of the year but normally falls between November and March (Kit Novick 1996). July through September are historically the driest months [DOI (1980); see Figure 2.9]. Long term climate records are available from National Oceanic and Atmospheric Administration (NOAA) weather stations in the Butte Valley watershed; relevant stations are listed in Table 2.2.

The Basin has experienced decreasing precipitation during much of the period between 1970 to 2020. From the 1940s to 2020, the NOAA station in Mount Hebron has an average annual precipitation of 9.3 inches (Figure 2.9). Between 1942 and 1979, the 10-year trailing rolling average precipitation ranged from 9.5 to 12.4 in (24.1 to 31.5 cm; water years 1953 and 1971, respectively); since 1980, it has ranged between 5.7 and 10.8 in (14.5 to 27.4 cm; water years 2018 and 1980, respectively; see Figure 2.9). Much of the expansion in agricultural land in Butte Valley occurred before 1976, with irrigated land expanding to 27,500 acres (11,130 hectares), during a period when average rainfall was relatively stable and significantly greater.

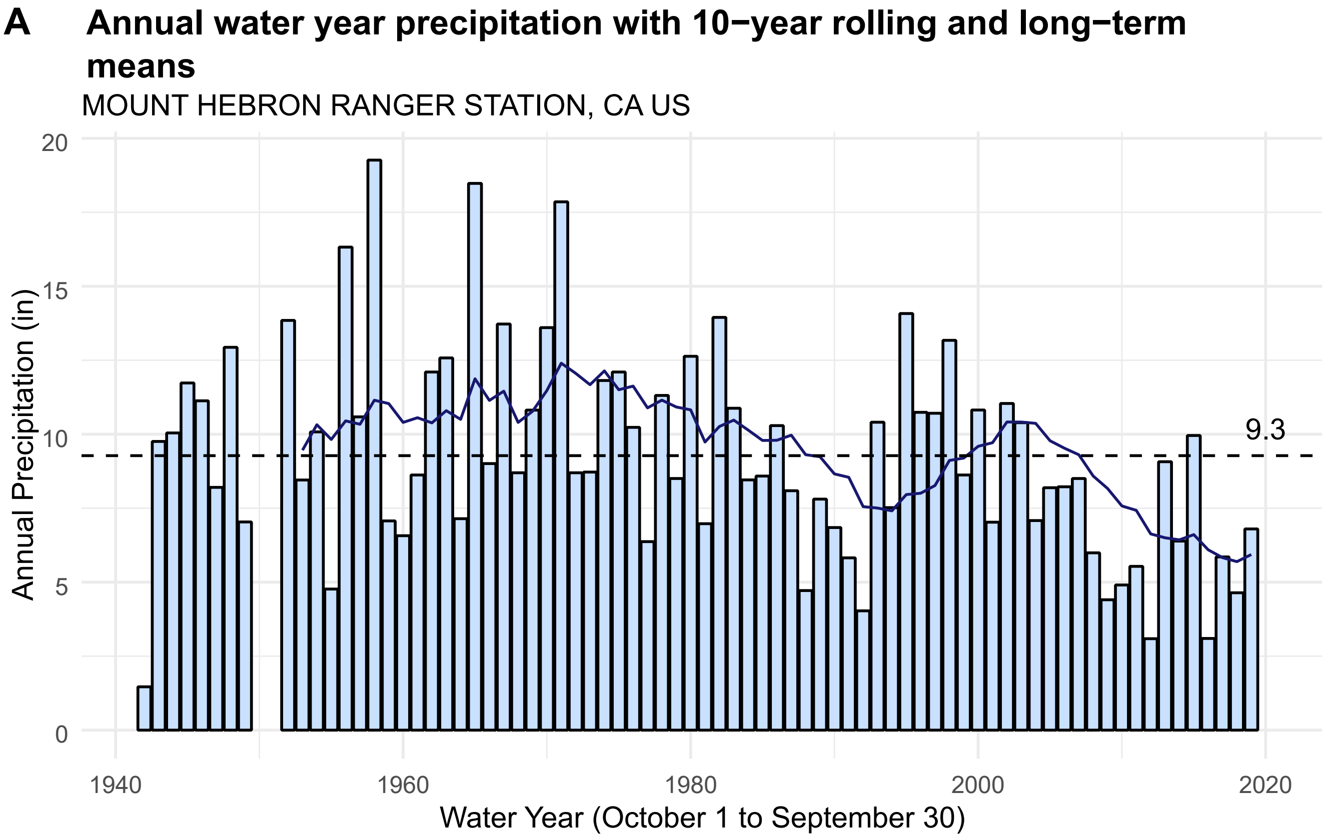
Mean daily low and high temperatures for January and July are -8 to 7°Celsius (C; 17 to 44°Farenheit [F]) and 5 to 29°C (41 to 84°F), respectively (Figure 2.10). Temperature extremes range from over 38°C (100°F) in the summer to below -18°C (0°F) in the winter (DOI 1980). Reference evapotranspiration (ET) ranges from 0.002 to 0.33 in/day (0.005 to 0.84 cm/day; Figure 2.10). Pan evaporation in Butte Valley is estimated to be 48 inches a year, with wind mainly responsible (Kit Novick 1996). Figure 2.11 illustrates the recent climate shift by comparing the average temperature in the past 15 years to historical records. In the past 15 years, the average maximum and minimum air temperature increased roughly 1° to 5°F (Figure 2.11).

Historically, killing frosts could occur at any time of the year and the growing season in Butte Valley was limited by the last and first killing frosts (<28°F). The growing season generally extended from May to October, but frequent killing frosts in May and June usually shortened the usable growing season. The average growing season was roughly 100 days but varied greatly. In 1952, only one day was frost-free. A short growing season and frost danger limited the type and amount of agricultural crops grown within Butte Valley (DOI 1980; Kit Novick 1996). Crops in BVWA were limited to hardy cereal grains and quickly maturing plants, which have marginal commercial value due to frost damage (Kit Novick 1996).

Over the past few decades, the frost danger in Butte Valley has decreased (Figure 2.12). The yearly average of days with temperatures less than 32 F has sharply declined since the 1980s. In recent years, strawberry crops have become increasingly important in Butte Valley.

Snow measurements in the Butte Valley watershed is a climate data gap. The nearest California

Data Exchange Center (CDEC) weather stations are outside the watershed boundary. None of the NOAA weather stations in the Watershed are situated in the west or south mountains, which are important to surface and groundwater recharge.



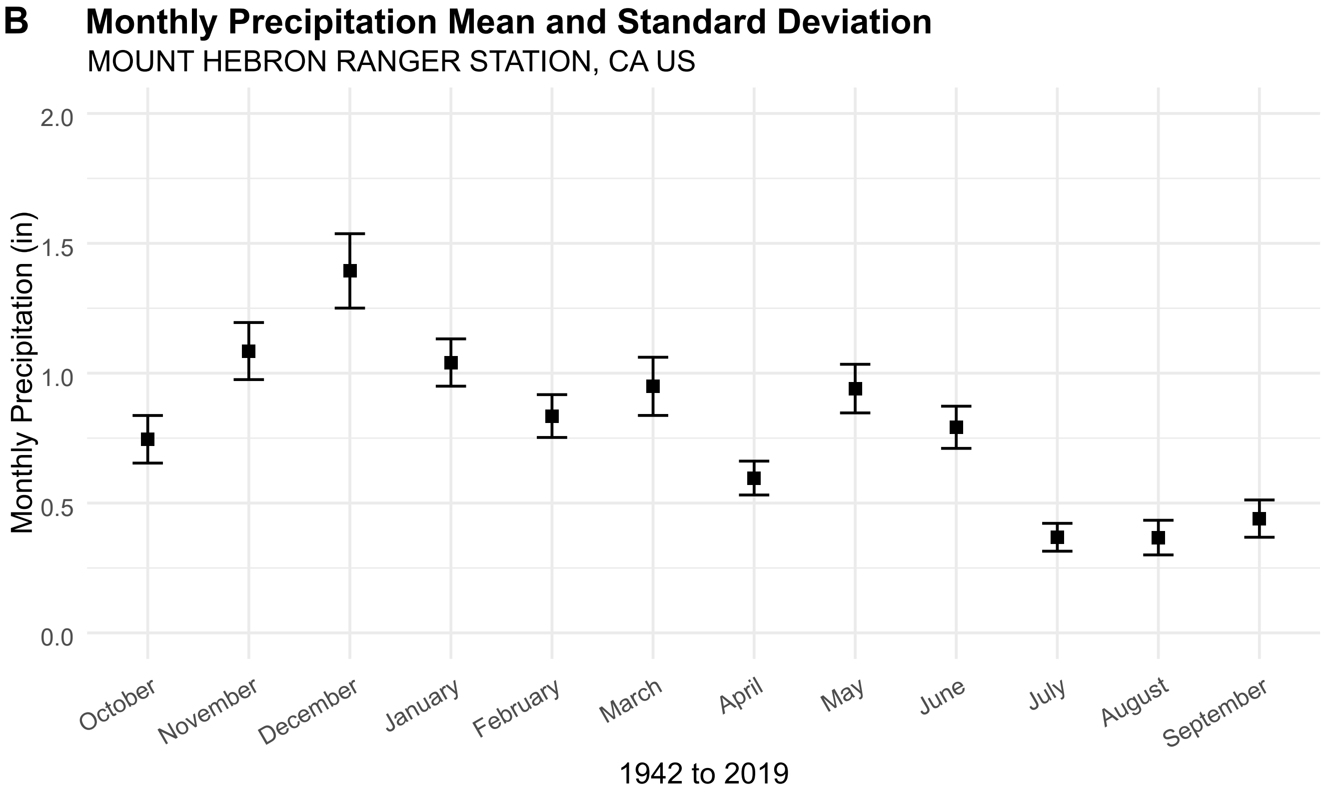
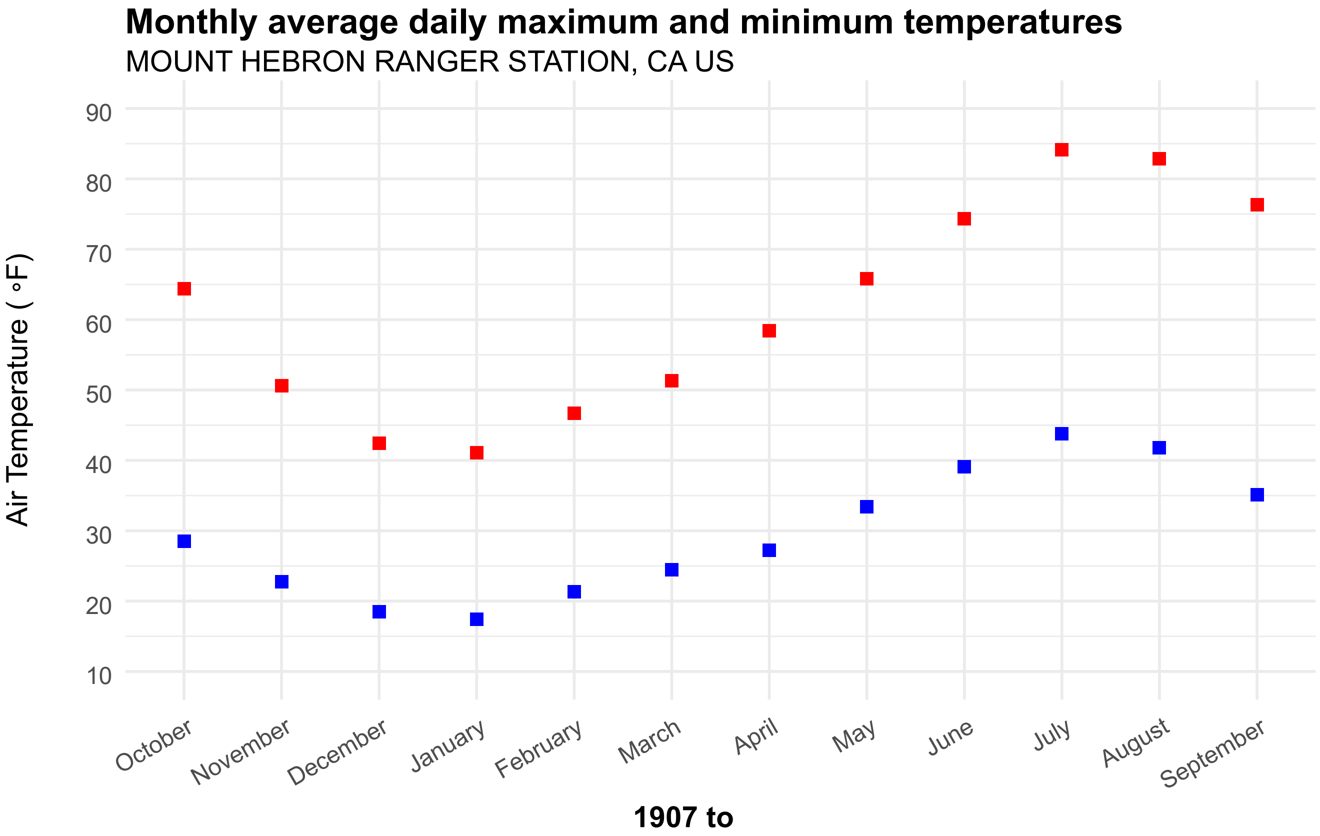


Figure 2.9: Annual (Panel A) and monthly precipitation (Panel B) over the 1942 to 2019 record as measured at the Mount Hebron Ranger weather station (USC00045941). In Panel A, the 10-year rolling average is shown as the average over the entire period of record. Each bar represents one

water year, the total precipitation during the period between October 1 and September 30. Only the years 1950 and 1951 had significant data gaps and were removed.



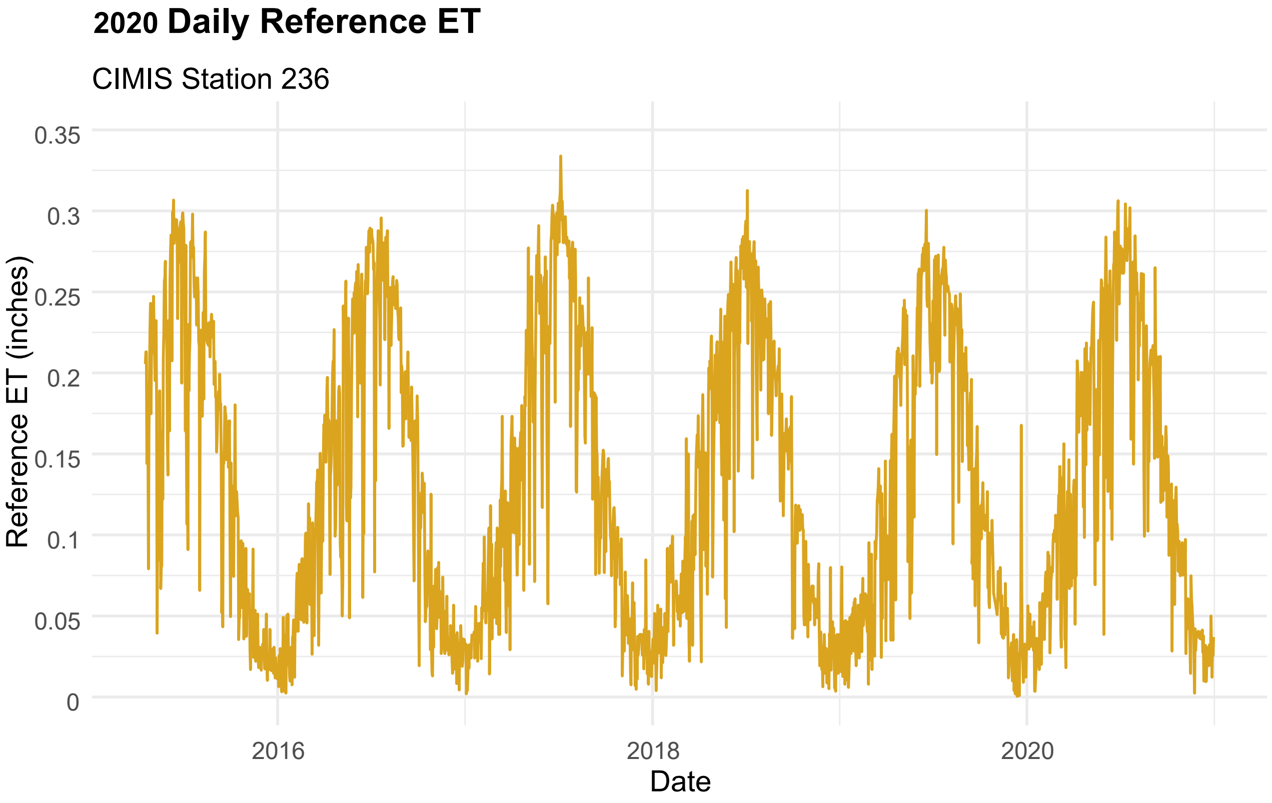
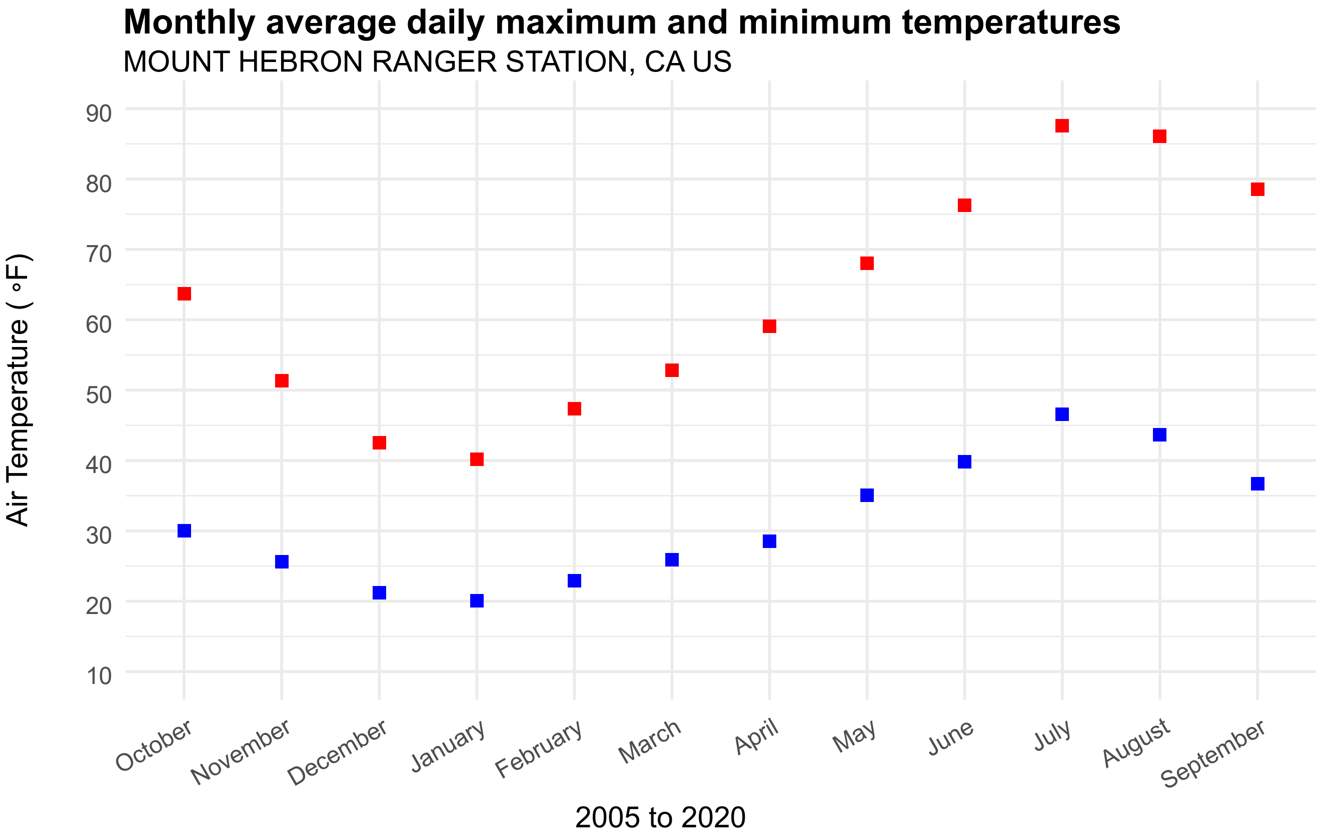


Figure 2.10: Monthly averages of daily maximum and minimum air temperature (top panel) over the 1942 to 2020 record at the Mount Hebron Ranger Station (USC00045941), and reference

evapotranspiration (ET) from 2015 to 2020 calculated at CIMIS Station 236 between Macdoel and Mount Hebron.



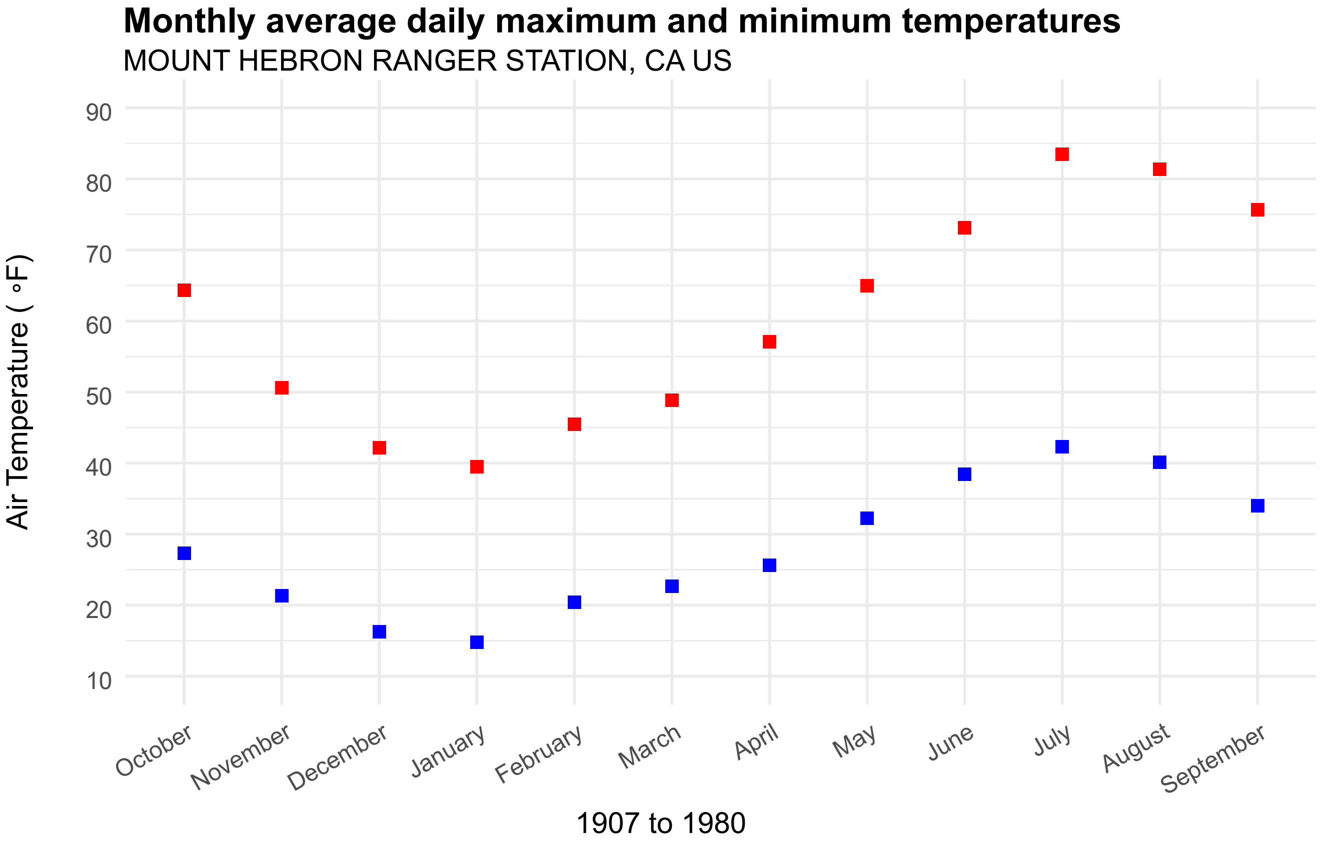


Figure 2.11: Monthly averages of daily maximum and minimum air temperature (top panel) over the 1942 to 1980 and 2005 to 2020 record at the Mount Hebron Ranger Station (USC00045941), which shows the recent warming of the Valley.

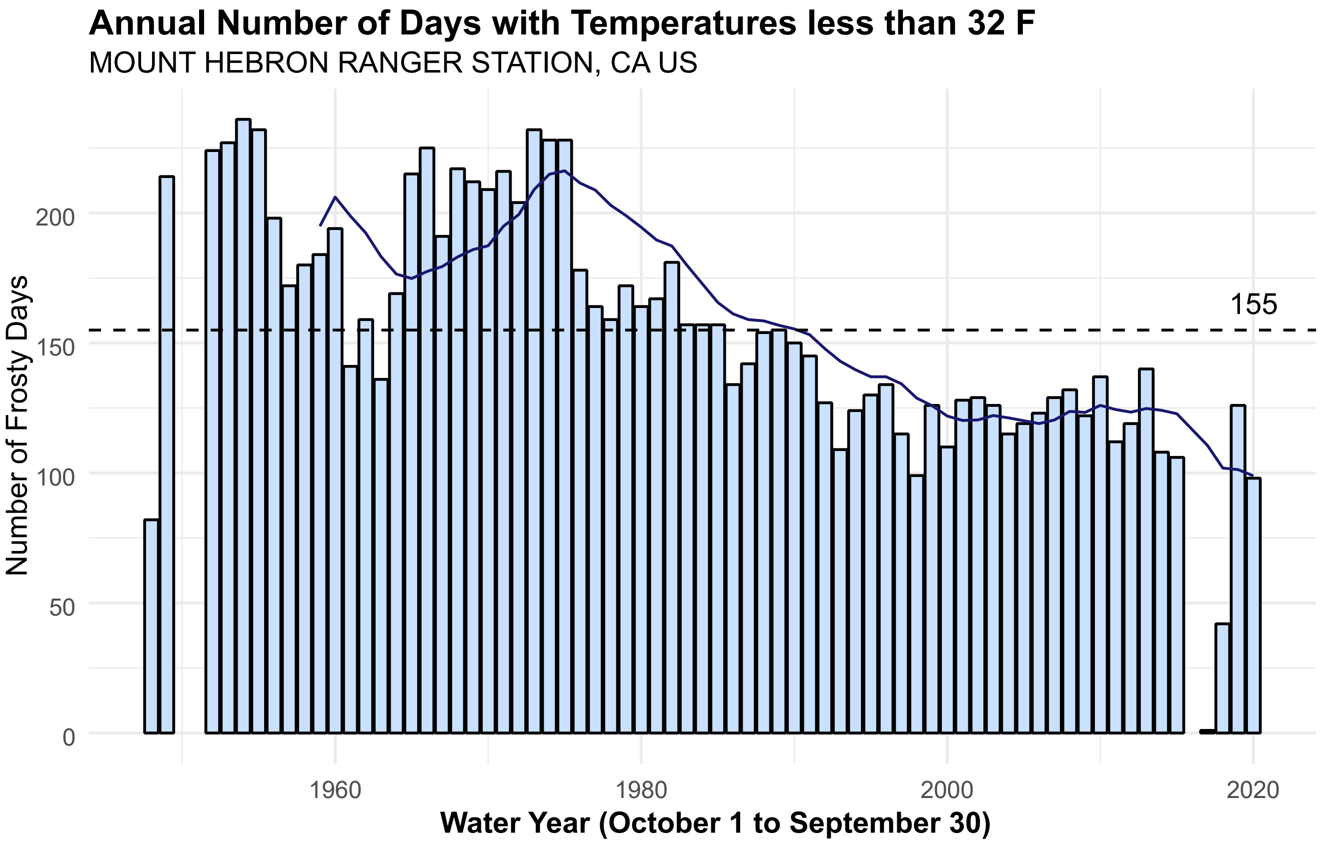


Figure 2.12: Total number of days with temperature minimums less than 32 F, representing frost potential. Totals are occasionally impacted by station equipment outages.

Table 2.2: Station details and record length for NOAA weather stations in the Butte Valley watershed.

Station ID	Station Name	Elevation (ft amsl)	Start Date	End Date	Record Length (Years)	No. Missing Days
US1CASK0010	DORRIS 0.2 SW, CA, US	4249	1998-06-17	2021-06-27	23.0	1
USC00045940	MOUNT HEBRON 11 ESE, CA US	4383	1952-05-01	1960-12-31	8.7	7
USC00045941	MOUNT HEBRON RANGER STATION, CA,US	4250	1907-01-01	2020-04-01	113.2	1956
USC00048860	TENNANT, CA, US	4754	1952-05-01	1957-08-31	5.3	3
USR0000CJUA	JUANITA LAKE CALIFORNIA, CA, US	5400	1988-12-30	2021-06-27	32.5	11102
USR0000CVAN	VAN BREMMER CALIFORNIA, CA, US	4928	1993-06-01	2021-06-27	28.1	9921

2.2.1.3 Geologic History

The oldest rocks near Butte Valley were formed between the Eocene to Miocene (56 to 5.3 million years ago [Ma]) during the formation of the Western Cascades. The predominantly andesite volcanic rocks consist of interbedded basalts, dacites, rhyolite tuffs, and breccias. At the end of the Miocene (~5.3 Ma), the original Western Cascade landscape and parent cones were destroyed by uplift and erosion. During the same period, the regional uplift created the ancestral Cascade Range and a series of northwest-trending faults that cut through the Western Cascades. From the late Pliocene to the Pleistocene (3.6 to 0.012 Ma), volcanism reactivated in the region, forming a north-trending series of broad shield volcanoes along the crest of the ancestral Cascades. These volcanoes erupted the highly fluid basalts and andesites found in the High Cascade volcanic rocks in Butte Valley. The present Cascade Range was formed later in the Pleistocene (2.6 to 0.012 Ma) through the eruptions of andesites, dacites, and rhyolites. Sometime in the Pleistocene (2.6 to 0.012 Ma), faulting began to form the structural depression that would become Butte Valley (DOI 1980).

The Basin became a closed drainage basin as Butte Valley dropped and adjacent fault block mountains uplifted (County of Siskiyou 1996). At the same time Meiss Lake occupied Butte Valley, depositing the Lake Deposits on the valley floor (DOI 1980). During the Quaternary (2.6 Ma to Present), glaciation occurred in the high mountains that form the headwaters of Butte Creek, the largest creek in the Valley. Glaciation created glacial moraines and cirque valleys at the Butte Creek headwaters (King 1994). From the end of the Pleistocene to Present (0.012 Ma to Present), renewed volcanic activity erupted large amounts of fluid basalts from fissures in the High Cascades, including the Butte Valley Basalt (DOI 1980). This recent volcanic activity has shrunk the Butte Valley watershed by cutting off small drainages such as the Grass Lake area (King 1994). Today, the Cascade Range continues to be volcanically active. Butte Valley also remains seismically active (DOI 1980).

2.2.1.4 Geologic Units

The surface geology of Butte Valley and adjacent regions are primarily volcanic with lake deposits, alluvial fan deposits, and alluvium with some deposits of dune sand and talus (Wood 1960). A generalized geologic map of the Butte Valley watershed is shown in **Figure 2.13** and described in Table 2.3 (Wood 1960; Jennings et al. 2013). Cross-sections A-A' through C-C' are shown in **Figure 2.14, Figure 2.15, Figure 2.16**. A 1,573 ft (479 m) deep test well drilled in 1978 by the U.S. Department of the Interior (DOI) in the south side of the Valley offers an example of Butte Valley stratigraphy (DOI 1980): from 0–47 ft (24–137 m) depth is alluvium deposits, from 47–78 ft (14–24 m) depth is Butte Valley Basalt, from 78–1,317 ft (24–401 m) is Lake Deposits (where 78–450 ft (24–137 m) is sands and gravels with thin clay interbeds, and 450–1,279 ft (137–390 m) is predominantly clay), and 1,279 to greater than 1,573 ft (390–479 m) is High Cascade Volcanics. Similar stratigraphy appears in Cross-section A-A' between 400 to 12,000 m distance (Figure 2.14). In other parts of the valley, the Butte Valley Basalt disappears and the stratigraphy is limited to lake sediments and High Cascade Volcanics, shown in **Figure 2.14, Figure 2.15**, and **Figure 2.16**. The following outlines the geologic units from oldest to youngest, separating the volcanic and sedimentary deposits.

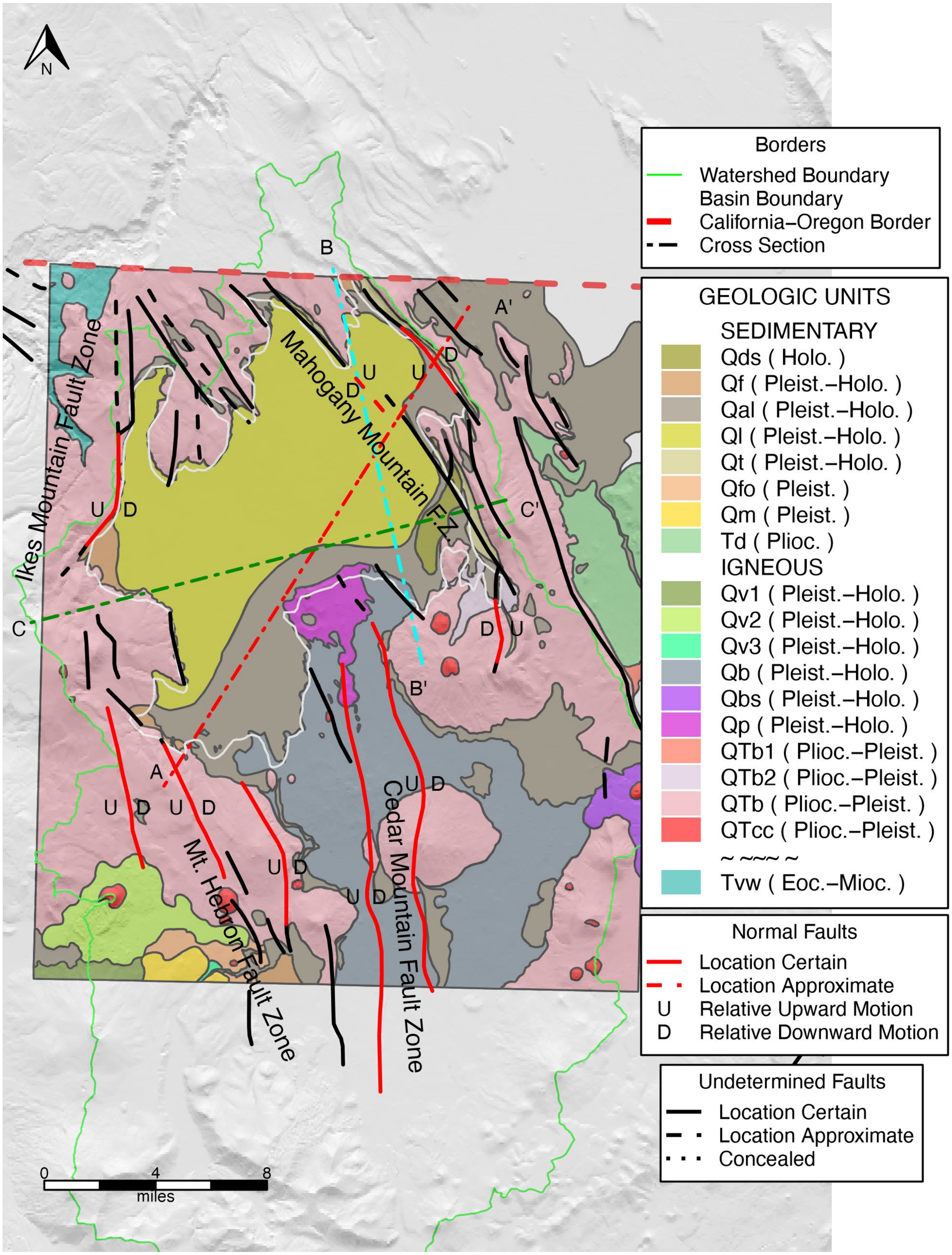


Figure 2.13: Geology of the Butte Valley Groundwater Basin and surrounding watershed. Fault zones are plotted with their major faults (minor faults not plotted). Legend abbreviations include the time periods Holocene (H.), Pleistocene (Pleist.), Pliocene (Plioc.), Miocene (Mioc.) and, Eocene (Eoc.). Geology layer from Wood, 1960.

Table 2.3: Geology Map Unit Descriptions (Wood 1960).

Unit Name	General Lithology	Age	Description
Qds	Dune Sand	Holocene	Unconsolidated sand, in part actively drifting.
Qf	Alluvial-fan deposits	Pleistocen Holocene	e-Unconsolidated deposits consisting of poorly sorted boulders, gravel, sand, and silt beneath alluvial fans. Also includes remnants of older alluvial-fan deposits. Generally poorly permeable but transmits water to underlying formations.
Qal	Alluvium	Pleistocen Holocene	e-Includes sand, gravel, and clay in the eastern and southern parts of Butte Valley; poorly sorted alluvial deposits collected in relatively shallow basins or depressions; local playa deposits; and gravel and sand in major stream channels. Moderately permeable.
Ql	Lake deposits	Pleistocen Holocene	e-Semiconsolidated clay, volcanic ash, diatomite, and sand with local stringers of gravelly sand. Locally interfingers with and is overlain by talus, alluvium, and alluvial-fan deposits. In general poorly permeable but moderately permeable along the east side of Butte Valley.
Qt	Talus	Pleistocen Holocene	e-Wedge-shaped deposits of blocky debris at the base of steep fault scarps. Highly permeable. May contribute to groundwater recharge. May act as groundwater storage reservoir or drain.
Qfo	Fluvioglacial deposits	Pleistocene	Poorly sorted rounded to angular rock fragments, boulders, sand, clay, and silt.
Qm	Glacial moraines	Pleistocene	Unstratified bouldery deposits in a clayey matrix.
Td	Diatomite	Pliocene	Massive-appearing gray to white diatomite. Locally contains interbedded sand, cindery tuff-breccia, and volcanic ash.
Qv1	Younger volcanic rocks of the ”High Cascades”	Pleistocen Holocene	e-Highly permeable and important as recharge media. Hypershene-rich andesitic flos of Deer Mountain.
Qv2	Younger volcanic rocks of the ”High Cascades”	Pleistocen Holocene	e-Highly permeable and important as recharge media. Black vesicular olivine-augite basalt flows from Little Deer Mountain.
Qv3	Younger volcanic rocks of the ”High Cascades”	Pleistocen Holocene	e-Highly permeable and important as recharge media. Black vesicular olivine basalt in Butte Creek Canyon.
Qb	Butte Valley basalt	Pleistocen Holocene	e-Grey vesicular olivine basalt that is highly permeable.

Table 2.3: Geology Map Unit Descriptions (Wood 1960). ***(continued)***

Unit Name	General Lithology	Age	Description
Qbs	Basaltic flows near Sharp Mountain	Pleistocen Holocene	e-Dark-colored olivine basalt that is highly permeable.
Qp	Pyroclastic rocks	Pleistocen Holocene	e-Well-consolidated massive to thin-bedded lapilli tuff, and tuff-breccia. It is moderately permeable.
QTb1	Basaltic lava flows	Pliocene-Pleistocene	Generally very permeable and important for groundwater recharge. Grey vesicular olivine basalt flows on Big and Little Tablelands and extensive basalt flows south of Klamath Lake.
QTb2	Basaltic lava flows	Pliocene-Pleistocene	Generally very permeable and important for groundwater recharge. Coarsely vesicular black aphantic basalt near Sheep Mountain.
QTb	Older volcanic rocks of the ”High Cascades”	Pliocene-Pleistocene	Pale-grey olivine basalt and basaltic andesite and discontinous layers of yellowish tuff and tuff-breccia. Very permeable and an important groundwater storage reservoir.
QTcc	Cinder-cone deposits	Pliocene-Pleistocene	Red, brown, and black scoria mounds and cinder cones composed chiefly of andesitic and basaltic ejecta of Pliocene age and younger. Very permeable and largely unsaturated.
~~	Erosional or non-depositional surface	Miocene-Pliocene	Major Unconformity
Tvw	Volcanic rocks of the ”Western Cascades”	Eocene-Miocene	Chiefly andesitic lava flows and lesser amounts of andesitic tuff-breccia and lapilli tuff.

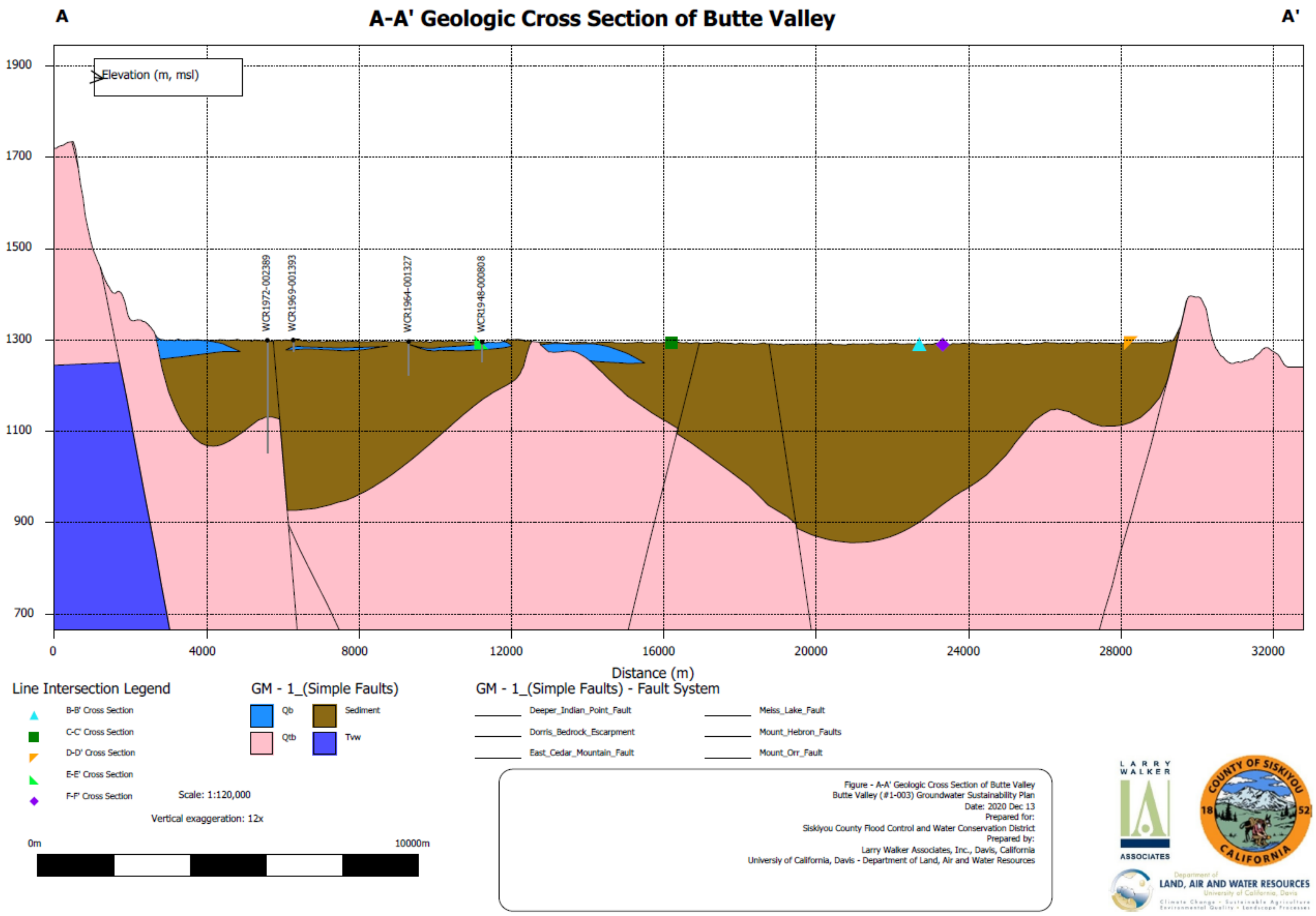


Figure 2.14: Cross Section A-A’ crosses Butte Valley from the southwest to the northeast corner, shown in the geology map.

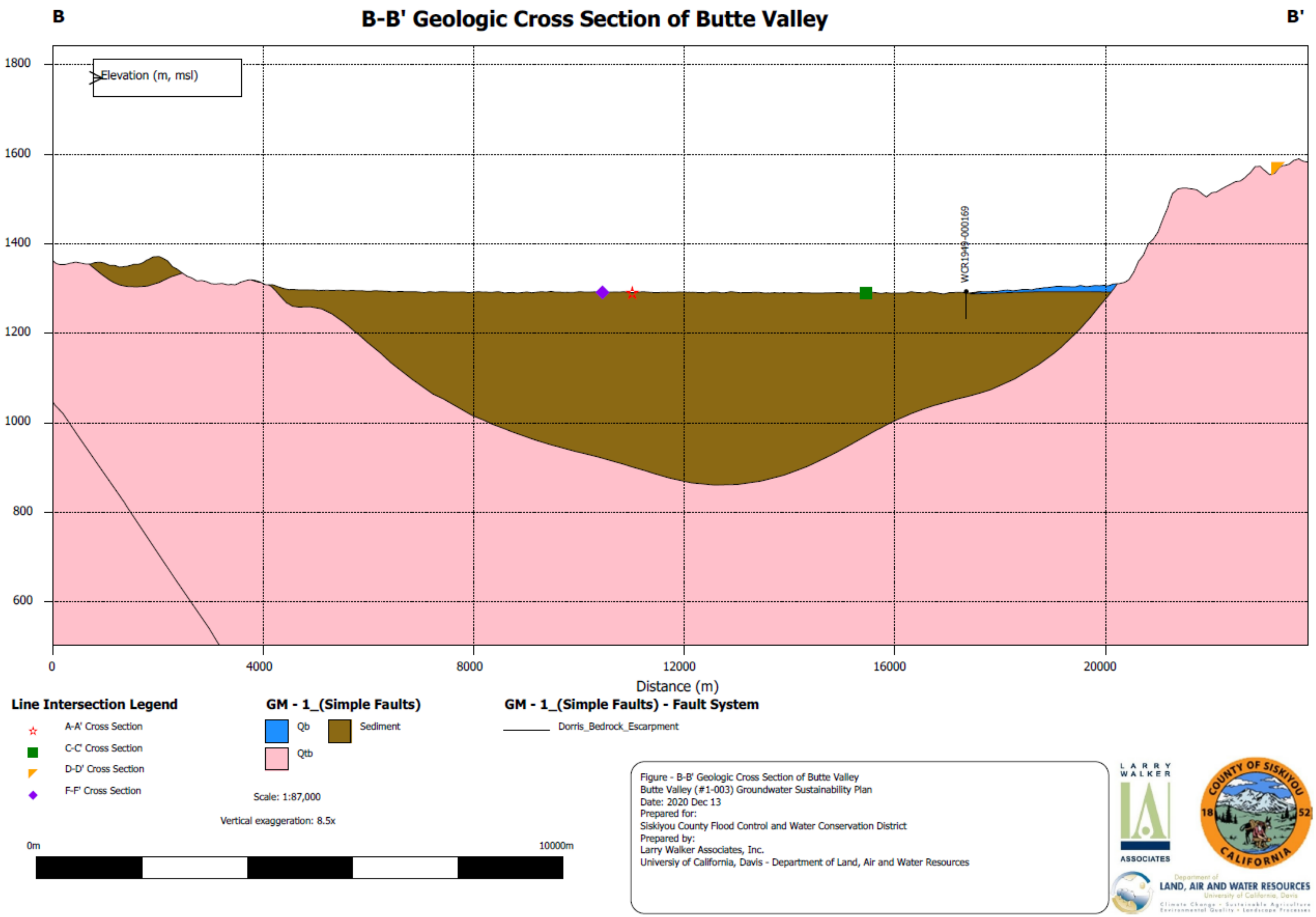


Figure - B-B' Geologic Cross Section of Butte Valley
Butte Valley (#1-003) Groundwater Sustainability Plan
Date: 2020 Dec 13
Prepared for:
Siskiyou County Flood Control and Water Conservation District
Prepared by:
Larry Walker Associates, Inc.
University of California, Davis - Department of Land, Air and Water Resources

Figure 2.15: Cross Section B-B' crosses Butte Valley from north to south near Dorris, shown in the geology map.

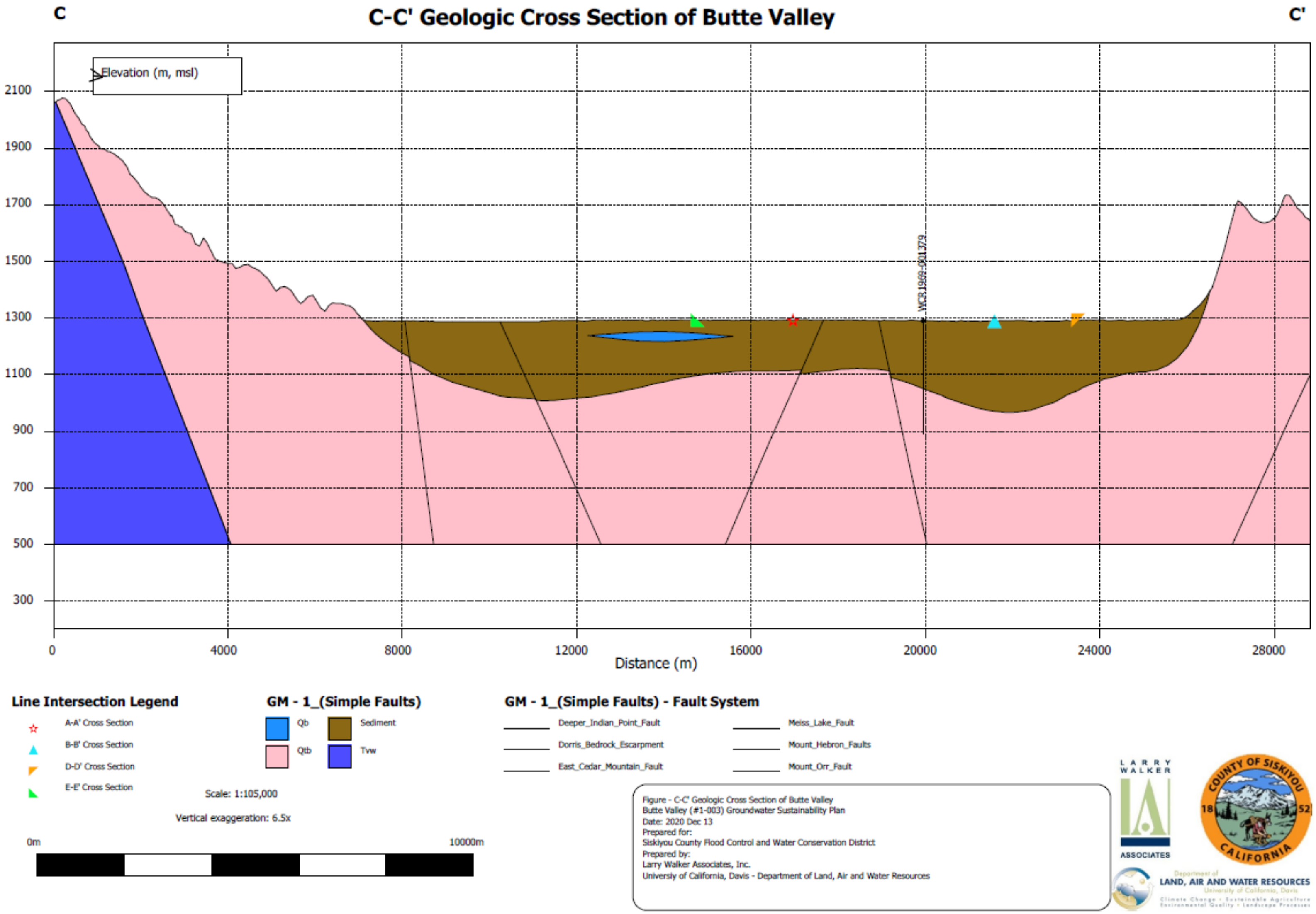


Figure - C-C' Geologic Cross Section of Butte Valley
Butte Valley (#1-003) Groundwater Sustainability Plan
Date: 2020 Dec 13
Prepared for:
Siskiyou County Flood Control and Water Conservation District
Prepared by:
Larry Walker Associates, Inc.
Universiy of California, Davis - Department of Land, Air and Water Resources

Figure 2.16: Cross Section C-C' crosses Butte Valley from the west to east, shown in the geology map.

Western Cascades Subprovince

The upper Klamath Basin has been volcanically active for at least 35 million years with two subprovinces directly underlying Butte Valley: the Western Cascades subprovince and High Cascade subprovince (Gannett, Wagner, and Lite Jr. 2012). In Butte Valley, the oldest geologic unit with surface exposure is the volcanic rocks of the Western Cascades (Tv and Tvp in Figure 2.13). Western Cascades rocks are 20 to 33 million years old and can be up to 20,000 ft (6,096 m) thick with primarily early to middle Tertiary lava flows, andesitic mudflows, tuffaceous sedimentary rocks, and vent deposits (Gannett, Wagner, and Lite Jr. 2012). Near Butte Valley the unit is primarily andesite and andesitic tuff breccias (DOI 1980). In general, Western Cascade deposits have low permeability due to devitrified (changed to clays and other minerals) tuffaceous materials and weathered lava flows with abundant secondary minerals. Low permeability limits the flow of groundwater through the Western Cascade unit and acts as a barrier to regional groundwater flow. The unit dips to the east and defines the lower boundary of the regional groundwater flow where present (Gannett, Wagner, and Lite Jr. 2012). This formation has not been penetrated by Butte Valley wells (DOI 1980). The unknown depth to the Western Cascades Subprovince precludes its appearance in the cross-sections.

High Cascade Subprovince

The High Cascade subprovince unconformably overlies the Western Cascade unit, with ages from the late Miocene to late Pleistocene (5.3 to 0.012 Ma). Deposits within the upper Klamath Basin are constructional features such as volcanic vents and lava flows with relatively minor interbedded volcaniclastic and sedimentary deposits (Gannett, Wagner, and Lite Jr. 2012). High Cascade deposits in Butte Valley include Pliocene volcanic rocks and Pliocene cinder cone deposits (Wood 1960). Within the Valley, the depth to the High Cascade Volcanics confined water bearing formation varies from 47 to 1,317 feet bgs (Kit Novick 1996).

A 1977 seismic refraction survey attempted to find the depth and structural configuration of the High Cascade Volcanics water bearing formation. The survey may have detected the contact between the High Cascade Volcanics and underlying Western Cascade Volcanics or a transition to a more massive part of the High Cascades Series. The survey found that faulting through the High Cascades Volcanics has made the top of the unit very irregular and the depth to the unit can locally vary hundreds of feet between nearby wells. The surface of the High Cascade unit generally dips to the east, likely related to the fault system uplifting Mahogany Mountain (DOI 1980). Cross-sections A-A’ and C-C’ show that the top of the High Cascade Subprovince (Unit Qtb) is irregular and generally deepens toward the east (Figure 2.14 and Figure 2.16).

Butte Valley Basalt and Other Small Basalt Flows

All surface exposures of basaltic flows in Butte Valley and south of the Basin are important for groundwater recharge. Deposited in the late Pleistocene or Holocene, Butte Valley Basalt is a highly permeable uniform sheet of vesicular basalt that overlies and interfingers with lakebed deposits (DWR 2004). Surface exposures are in the southern part of the Basin and likely extend into the subsurface under the valley floor lake deposits through Macdoel and Meiss Lake, the southern valley floor and west of Inlow Butte (Wood 1960). The extent of the Butte Valley Basalt is shown in Figure B.2 in Appendix 2-A.

The depth of the Butte Valley Basalt varies from 0 to 110 feet bgs (Kit Novick 1996). The basalt ranges in thickness to 80 ft (24 m), averaging approximately 40 ft (12 m) (Figure 2.14 and Figure 2.15). The subsurface extent is estimated to be 27 sq mi (70 sq km). The fractured basalt is commonly rough, broken, cavernous, and scoriaceous at contacts between relatively thin flow units. The basalt is predominantly located in the southern and southeastern region of the Valley at depths of less than 150 ft (46 m) (DWR 2004). Other small basalt flows in Butte Valley include the very permeable Pleistocene lava flows near Sheep Mountain (Wood 1960).

Pyroclastic Rocks

Pyroclastic rocks in Butte Valley are typically well consolidated, massive to thin-bedded lapilli tuffs and cindery tuff breccias that are generally cross-bedded and include abundant fragments of basalt and scoria. The deposits underlie a region located east and southeast of Macdoel ranging up to 400 ft (122 m) in thickness near Juniper Knoll. These deposits rest upon lake deposits and are partially overlapped by Butte Valley basalt (Wood 1960; County of Siskiyou 1996).

Lake Deposits

During 1.8 million years of the Quaternary Period, times of decreased temperature and increased precipitation created lakes in many hydrologically-closed drainage basins in the Western United States, such as Lakes Bonneville and Lahontan in the Great Basin. The maximum size of the Quaternary paleolake in Butte Valley was 73 sq mi (189 sq km) with a maximum depth of 46 ft (14 m). This maximum extent created a shoreline terrace at 4,268 ft (1,301 m) amsl elevation around the valley rim. The 4,268 ft (1,301 m) amsl terrace is the best developed shoreline terrace in Butte Valley and is at its widest on the north and east valley rims, particularly near Picard Cemetery on Mud Lake Ridge and just east of Dorris. Compared to other Quaternary paleolakes, the Butte Valley 4,268 ft (1,301 m) amsl terrace is underdeveloped, suggesting that the paleolake maximum was short-lived. While at this maximum extent, the paleolake overflowed into Rock Creek, a tributary of the Klamath River, through Sam's Neck. This overflow may have been brief due to the lack of a distinct overflow channel connecting the Sam's Neck notch at 4,265 to 4,268 ft (1,300 to 1,301 m) amsl to the Rock Creek channel. However hard bedrock at the channel site may have resisted erosion of a deeply-cut overflow channel and therefore, lake overflow may have lasted over a longer period. Concurrently, Butte Creek may have deposited deltaic sediments at the 4,268 ft (1,301 m) amsl shoreline (King 1994).

The lack of well-developed shorelines at the Butte Valley rim suggests that the paleolake was mostly confined to the valley floor. However, shoreline terraces in Butte Valley have been highly disturbed by human activity, including disturbances from the construction of houses, buildings, and roads on top of existing terraces. Other weak paleolake shorelines occur at 4,262 ft (1299 m) and 4,255 ft (1297 m) amsl. An example of the 4,262 ft (1299 m) amsl terrace is located at the end of Indian Point, where it is 33 ft (10 m) wide and consists of coarse beach sand with scattered angular talus boulders. An example of the 4,255 ft (1297 m) amsl terrace is located on the west side of Cedar Point. Below 4,255 ft (1297 m) amsl is the shallow sloping valley floor, where any further paleolake shorelines may have been destroyed by agricultural activity or never formed due to a rapid reduction in lake size to modern levels (King 1994).

Based on core samples, where lake deposits can exceed 900 feet (300 meters) in thickness, Butte Valley has been the site of a lake for between one and three million years (Carter 1994; Mathias 2014) (Figure 2.14, Figure 2.15, and Figure 2.16). Based on sediment accumulation rates, shallow sediments appear to accumulate at a rate of 8.3 cm per thousand years to a depth of approximately 78 meters. Below 78 meters below ground surface, corresponding with approximately 930,000 years in age, sediment accumulation rates decrease to 0.9 cm per thousand years (Roberts et al. 1996). Quaternary pyroclastic deposits in older lake deposits show evidence of being laid down in lake water. At the end of the Pleistocene, the Butte Valley paleolake may have experienced rapid desiccation after the end of the last glacial cycle, reducing the lake size to the current Meiss Lake. Quaternary paleolakes in the Great Basin also have evidence of a rapid desiccation after the end of the last glacial cycle, about 10-12,000 years ago. A rapid desiccation reducing lake size could explain the gap in lake shorelines from 4,255 ft (1297 m) amsl elevation to 4,236 ft (1291 m) amsl (King 1994).

The rapid desiccation of the Butte Valley paleolake created an environment of playas and phytogenic dunes. Much of the original valley floor has been disturbed by human activity, particularly by the leveling of fields. A large remnant east of Meiss Lake has never been cultivated and highly resembles a playa surface. In the 1950s, the USGS mapped two small playas on the southeastern side of the Valley before the area was converted to agricultural fields. In some locations between Meiss Lake and Dorris, phytogenic dune ridges trend northwest/southeast in parallel with area faulting. These phytogenic dunes likely formed through increased scrub vegetation along fault fissures in the lakebed, where increased moisture can occur (King 1994).

Alluvial Fan Deposits

Isolated remnants of alluvial fan deposits are located on the west side of Butte Valley (DWR 2004). Alluvial fan deposits in Butte Valley are saturated, but poorly permeable with groundwater yields suitable for stock or domestic wells (DOI 1980).

In Butte Valley, these deposits were deposited during the Pleistocene to the Present and are composed of poorly-sorted volcanic rock debris, rounded cobbles of volcanic origin, gravel, sand, and clay from the Cascade Range (DOI 1980; DWR 2004). The deposits are coarse near the mountain fronts and grade into fine materials in the lower part of the fans. The fans interfinger with lake deposits at depth. The deposits have low permeability except where well-sorted gravel lenses are encountered and generally yield small quantities of water to wells. Thickness of the deposits range up to 350 ft (107 m) (DWR 2004).

Alluvium

In Butte Valley, alluvium deposits were deposited from the Pleistocene to Recent and are moderately permeable but generally above the water table. Within the Basin alluvium deposits include several different types (Wood 1960):

- Sand, gravel, and clay in the eastern and southern parts of Butte Valley.
- Poorly-sorted alluvial deposits in relatively shallow basins or depressions.
- Local playa deposits.
- Gravel and sand in major stream channels.

Alluvium in the northern Butte Valley was deposited by sheetfloods, slope wash, and other agents of erosion. Deposits on the eastern border are mainly fine to coarse-grained sand of volcanic origin, with perhaps lakeshore or beach deposits. They were deposited by sheetfloods, slope wash, rill wash, and other colluvial processes. Some alluvium has been redeposited as windblown or dune sand mantling parts of the steep fault scarps (Wood 1960).

In the south, sand and gravel alluvium deposits unconformably overlie the Butte Valley basalt and overlie and locally interfinger with the lake deposits (Wood 1960; DOI 1980). They are characterized by lenticular deposits of clay, silt and sand. The deposits are generally poorly permeable and can yield water for stock or domestic wells (DOI 1980). Along the valley margin, the alluvial deposits range from 0-60 ft (0-18 m) in thickness. Volcanic sand and gravel alluvium in the southwest of Butte Valley was likely deposited by Butte Creek flood waters and may represent a delta built by the creek during the high stages of the lake that formerly filled the Valley. Dune sand near Macdoel is wind reworked volcanic sand that is currently being leveled and cultivated (Wood 1960).

Playa deposits are common in the Butte Valley region, with clay, silt, and minor amounts of sand. They occur in the topographically lowest areas of small enclosed basins and merge laterally into alluvial slope deposits. They have low permeability and likely have highly saline water (Wood 1960).

Other alluvium deposits are poorly sorted and unconsolidated gravel, sand, and silt. They stem from the decomposition and erosion of volcanic material in adjacent mountainous areas and were deposited in basins and depressions by streams, sheetfloods, slope wash, and other erosional processes (Wood 1960).

Talus

Talus in Butte Valley are highly permeably wedge-shaped deposits of blocky debris at the base of steep fault scarps on the north and east sides of the Valley (Wood 1960). Talus deposits generally act as groundwater conduits and drains and may act as groundwater storage reservoirs where interfingered with saturated sediments. Water bearing properties are unknown and the few wells that penetrate talus deposits likely draw groundwater from both the talus sediments and other interconnected aquifer subunits (DOI 1980).

The deposits are unsorted, uncemented, angular blocks, boulders, and fragments of volcanic rocks of a few inches to greater than 6 ft (1.8 m). In some areas, the gaps between coarse materials have been filled by sand. In Butte Valley, large talus deposits primarily occur on the east margin, near the City of Dorris down to Sheep Mountain. In some areas the talus deposits are concealed underneath and likely interfinger alluvial and land-bed deposits. On westward-facing scarps, talus deposits are covered by windblown sand. The thickness and lateral extent of the talus deposits is not well defined, though two wells near Dorris encountered 143 and 360 ft (44 and 110 m) of talus (Wood 1960).

Dune Sand

A very young deposit generally above the water table, a large dune sand deposit sits on the eastern border of Butte Valley, west and north of Inlow Butte and south of Cedar Point (Wood 1960; King 1994). Dune sand deposits too small to plot on a geologic map exist elsewhere in Butte Valley. Dune sand covers High Cascade rock outcrops in westward-facing escarpments along the Butte Valley border (Wood 1960).

The deposit is unconsolidated, fine-to-coarse, massive, loosely compacted, crossbedded quartz sand that is in part actively drifting and up to 20 ft thick. The dune sand was reworked from lake and alluvial deposits which have migrated eastward and northward from old abandoned lake shorelines. Dunes have largely been stabilized by a sparse cover of vegetation, but some sections have dunes actively advancing upon older dunes, talus and High Cascades rock outcrops (Wood 1960). The majority of the extensive aeolian dune deposits south of Cedar Point were likely produced by wave action on the eastern shorelines of the Quaternary Butte Valley paleolake (King 1994).

2.2.1.5 Faults

Beginning in the Pleistocene (2.6 to 0.012 Ma), faulting began to form Butte Valley and remain active today (DOI 1980). Butte Valley is bordered on all sides by the Cedar Mountain fault system, a complex group of generally north- to north-northwest-striking normal faults along the boundary between the Cascade Ranges and the Modoc Plateau (Bryant 2000). Fault displacement is nearly vertical and ranges from a few feet to possibly more than several thousand feet along major faults (DOI 1980). The fault system has offset the latest Pleistocene and Holocene volcanic rocks, glacial, and alluvial deposits (Wood 1960; Bryant 1990, 2000). Historic surface fault rupture is associated with the local magnitude (ML; Richter magnitude) 4.6 Stephens Pass earthquake of August 1, 1978 (Bryant 2000). An earthquake in late June of 1966 shook the Dorris area and ruptured the clay lining of a waste effluent evaporative treatment pond about 0.5 mi (0.8 m) southwest of Dorris (DWR 1968; DOI 1980). The faults near Dorris exhibit evidence of continuing into the bedrock below the valley floor (DWR 1968).

Five sections of the Cedar Mountain fault system exist within Butte Valley: Cedar Mountain, Mahogany Mountain, Mount Hebron, Meiss Lake, and Ikes Mountain Faults. The Cedar Mountain Fault Zone begins at the northern border of the Basin through the middle to the southern border (see Figure 2.13). Within Butte Valley the fault zone is 6.8 mi (11 km) wide, with numerous short, northwest-trending faults in the Valley floor and through the Butte Valley Basalt. Offset features within the Valley indicate that the fault zone has been active during the Holocene (Bryant 2000). The northwest Basin border is characterized by the Ikes Mountain Fault, a north-trending normal fault. It was active in the late Quaternary with little evidence for more recent activity. The Meiss Lake Fault passes through the middle of Meiss Lake and is a north-trending fault with Holocene activity. Some geomorphic evidence suggests a component of right-lateral strike slip. The Valley border in the southwest is defined by the Mount Hebron Fault Zone, a 4.3 mi (7 km) wide series of north to northwest-trending normal faults. Geomorphic evidence limits fault activity to the Quaternary and late Quaternary. The Mahogany Mountain Fault Zone marks the northwest border of the Basin, a northwest-trending zone of normal faults with vertical displacement to the southwest. Geomorphic evidence suggests that the fault has been active in the Holocene (Bryant 1990, 2000).

A 1998 DWR Well Interference Investigation in the northwestern portion of the Basin indicates that local faults can act as both a flow barrier and very transmissive conduit for groundwater flow. The study's conclusions suggest that other faults in the area likely influence groundwater flow in a similar fashion. The aquifer performance test of the BVWA Well 7A shows structural continuities, including (DWR 1998):

- A strong north-south hydraulic continuity along a fault trace adjacent to two monitoring wells.
- Areas on either side of a fault adjacent to Well 7A are somewhat isolated from each other, with improved hydraulic continuity within a common fault-bounded area.
- There is a hydraulic connection in talus deposits along a fault trace.
- Well 7A has an asymmetrical cone of depression, attenuated on the east side of the fault trace.

Faults in the Basin support the formation of springs, where numerous Basin springs align with faults. Faults can impede groundwater flow and cause a buildup of groundwater, which can emerge at the surface in the form of a spring. Local agriculture in the Basin can be supported by springs, such as Holzhauser Ranch in Sam's Neck, where water from two springs are collected into ponds for irrigation (DWR 1998).

2.2.1.6 Water Bearing Formations

Water bearing formations within the Basin aquifer are described in the following discussion, where the principal water bearing formations are Lake Deposits, Butte Valley Basalt, and High Cascade Volcanics, and minor formations are Alluvial Fan Deposits and Pyroclastic Rocks (DWR 1998; DWR 2004). Unconfined formations include the Lake Deposits, Pyroclastic Rocks, and the Butte Valley Basalt (DOI 1980). Within the Basin the Lake Deposits cover the High Cascade Volcanics and Butte Valley Basalt, confining the two formations in most areas (DWR 1998). The Butte Valley Basalt can also be locally confined when overlain by fine-grained alluvium with low permeability (DOI 1980). Comparatively, the High Cascade Volcanics and Butte Valley Basalt have high yields and the Lake Deposits have relatively low yields (DWR 1998).

Groundwater flow and distribution in the Basin is controlled by localized faulting, aquifer material variability, and the interconnection of formation units, which can enhance, diminish, or block flow. Faults and fractures can act as either groundwater conduits or barriers to flow (DWR 1998). Faults in Butte Valley may act as vertical paths of high permeability locally connecting the Lake Deposits and High Cascade Volcanics water bearing formations (DWR 1968). Faults can also offset formations and juxtapose more permeable formations against less permeable units (DWR 1998). There is limited vertical hydraulic continuity between the low, variably permeable Lake Deposits and high isotropic permeable High Cascade Volcanics due to the contrasting permeability (DWR 1968; DWR 1998). The High Cascade Volcanics water bearing formation is confined and separate from the Lake Deposits near Dorris (DWR 1968), and Meiss Lake (DWR 1998).

High Cascade Volcanics Water Bearing Formation

The High Cascade Volcanics water bearing formation is highly fractured, very permeable, highly transmissive, and an important regional groundwater source (DWR 1998; DWR 2004). The High Cascade Volcanics is divided into a series of "compartments" by fine-grained feeder dikes radiating out from parent cones and by a series of northwest-trending faults (Kit Novick 1996). Wells are routinely developed into this geologic unit and water yields range from 700 to 5,000 gallons per minute (gpm), but often produce over 3,000 gpm. Groundwater within the unit is usually confined by Lake Deposits and some irrigation wells have artesian flows (Kit Novick 1996; DWR 2004). Most wells in Butte Valley encounter the formation at depths between 240 to 600 ft, with some wells intercepting the formation at shallow depths of 47 ft or deep depths of 1,317 ft. Springs stemming from the High Cascade Volcanics supply the perennial flows for Prather, Muskgrave, Harris, and Ikes Creeks. By the 1990s, this water bearing formation had not experienced overdraft (Kit Novick 1996).

Beyond being a major element of the Basin's groundwater storage reservoir, the High Cascade Volcanics is also very important for groundwater recharge. It has a large areal extent beyond the Basin margin and acts as an intake media for groundwater recharge into the Basin (DWR 2004). It defines the Basin boundaries in the west, north, and east and underlies the lake bed deposits (Wood 1960; DWR 2004).

The High Cascade Volcanics consist of successive sheets of basalt, basaltic andesite, discontinuous layers of massive basaltic tuff and tuff breccia, and some isolated lapilli tuff, and cinder-cone deposits. The individual flow units range in thickness from 10- to 50-ft (3 to 15 m) and intermittently up to 100 ft (30 m) (DWR 2004). Individual well yields are highly dependent on the flow thickness and number of flow contacts intercepted, as well as vertical fracturing (DOI 1980; DWR 2004). Tuffaceous deposits are essentially non-water-bearing except for fracture zones and intercalated basaltic flows (DWR 2004).

Butte Valley Basalt Water Bearing Formation

Historically the Butte Valley Basalt has been the primary groundwater-producing water bearing formation in the southern part of the Basin (DWR 1998). The unit is also the most productive formation in the region, with water yields of 1,000 to 4,000 gpm and an average of 2,000 gpm (Kit Novick 1996). Highly productive wells from this formation are common in the Macdoel-Mount Hebron area and can generate up to 4,000 gpm (DWR 1998; DWR 2004). Specific capacities of 100 gpm per foot of drawdown are common and values up to 1,100 gpm per foot of drawdown have been documented (DWR 2004). A temporary seasonal overdraft occurs during the latter part of the irrigation season evidenced by well interference from overutilization (DWR 2004). This formation has been developed to its maximum productivity and in some years seasonal pumpage exceeds storage capacity (Kit Novick 1996; DWR 2004). Toward the end of the irrigation season, some shallow BVID and BVWA wells go dry but recover by the following season after groundwater recharge. The formation recharges annually with no year-over-year decline in average to above average precipitation years (Kit Novick 1996).

The Butte Valley Basalt consists of a highly permeable, fractured, uniform sheet of vesicular basalt with an average thickness of 40 ft (12 m) and a range from 6 ft (1.8 m) to hundreds of feet thick (DOI 1980; DWR 1998; DWR 2004). A system of nearly vertical joints or shrinkage cracks through the unit facilitates the vertical migration of groundwater (DWR 1998). Internally, the formation consists of comparatively thin lava flows where contacts between flows are commonly rough, broken, cavernous, and scoriaceous (DWR 1998; DWR 2004). The combination of vertical and horizontal flow paths makes the Butte Valley Basalt a productive water bearing formation (DOI 1980). The basalt is predominantly located in the southern and southeastern region of the Basin at depths of less than 150 ft (46 m), overlies and interfingers with Lake Deposits, and has an estimated subsurface extent of 27 sq mi (70 sq km) (DWR 2004). The unit extends northward as far as the east side of Meiss Lake (Kit Novick 1996). The rough broken surface exposures provide areas of recharge (DWR 2004). Butte Creek is diverted to several locations to recharge the Butte Valley Basalt (Kit Novick 1996).

Lake Deposits Water Bearing Formation

The Lake Deposits is the most important water bearing formation on the east side of the Valley but yields less water than the Butte Valley Basalt and High Cascade Volcanics water bearing formations. The water bearing formation is locally both unconfined and confined. Lake Deposits can occur both above and below the Butte Valley Basalt but always above the High Cascade Volcanics. The formation depth ranges from 0 to 125 ft bgs. Water yields from the best wells range from 1,500 to 2,600 gpm (Kit Novick 1996).

Lake Deposits vary widely in their ability to transmit water, but are generally more permeable and coarser grained on the east and south sides of the Valley and more permeable along the Basin margin compared to mid-basin (DOI 1980; DWR 1998; DWR 2004). Mid-basin Lake Deposits generally represent fine-grained lake deposits while the valley margins generally contain coarser, sandier near-shore deposits from the paleolake that once filled Butte Valley. Along the Basin margins, Lake Deposits interlayer with volcanic rocks and can yield moderate to high groundwater yields (DWR 1998). Coarser Lake Deposits in the western and northwestern part of the basin generally yield sufficient water for stock wells, while the more sandy eastern valley margin can have yields up to 2,500 gpm (DWR 2004). At the southern Basin margin deposits are interfingered with the recharging Butte Valley Basalt and well yields can exceed 4,100 gpm (DWR 1998; DWR 2004). Lake Deposits are generally lenticular (DWR 1968).

The Lake Deposits consist of semi-consolidated deposits of relatively impermeable sand, silt, clay, ash, lenses of diatomaceous clay, and local stringers of gravelly sand (DWR 1998; DWR 2004). Unit thickness is variable from 350 to 1,300 ft (107 to 396 m), but generally thickens to the west and unconformably overlies the older volcanic rocks of the High Cascades (DOI 1980; DWR 2004). In the central Basin, a calcium carbonate cemented clay hardpan soil is usually present from six inches to several feet beneath most soils and is particularly close to the surface around Meiss Lake (County of Siskiyou 1996; DWR 2004). The hardpan impedes vertical groundwater recharge into the Lake Deposits water bearing formation (DWR 1998).

Sand deposits in the Lake Deposits exhibit a general grain size and thickness gradation from south to north, suggesting the presence of a major stream entering the paleolake from the south, with coarser material dropping out of suspension first in the south and the finer material being carried and deposited north and west. In the south, coarse-grained lake deposits are interfingered with and underlie the Butte Valley Basalt (DOI 1980).

West of U.S. Highway 97, Lake Deposits on the west and northwest valley sides are generally fine-grained silts and clays of very low permeability that commonly serve as confining layers (DOI 1980; DWR 2004). Though saturated with groundwater these fine-grained lake deposits yield only small quantities of water to stock wells (DOI 1980).

East of U.S. Highway 97, Lake Deposits are loose, fine to medium-grained bedded sands interbedded with clay (DWR 2004). East of U.S. Highway 97, northeast of Juniper Knoll and in the southern part of the Valley, lenses and beds of sands and gravels over 300 ft (91 m) thick are interbedded with and overlie finer-grained clays and silts. East of U.S Highway 97, northeast of Juniper Knoll and the east side of the Basin, the lake deposits are loose, fine to medium-grained, current-bedded sands interbedded with clay. To the north, the thickness and number of sand lenses generally diminish and the grain size decreases. Near Dorris are discontinuous lenses of fine to medium sand that yield water to mainly domestic or low-yielding irrigation wells (DOI 1980). In the eastern half of the Basin, specific capacities range from 9 to 62 gpm per foot of drawdown. Locally, and along the eastside Basin margin, specifically sandy lake deposits can interfinger with highly permeable deposits of beach sand and talus debris (DWR 2004).

South of Macdoel, the sand layers thicken and the grain size increases. The coarse-grained lake deposits in the south are moderately to highly permeable with loose sands and gravels that yield water freely but cause problems with well drilling and completion. Wells in these lake deposits often report “sanding up” problems and can have issues with caving (DOI 1980).

Alluvial Fan Deposits Water Bearing Formation

Isolated remnants of alluvial fan deposits are located on the west side of Butte Valley. These deposits are composed of poorly-sorted volcanic rock debris, cobbles, gravel, sand, and clay from the Cascade Range. The deposits are coarse near the mountain fronts and grade into fine materials in the lower part of the fans. The fans interfinger with Lake Deposits at depth. The deposits have low permeability except where well-sorted gravel lenses are encountered and generally yield small quantities of water to wells. Thickness of the deposits range up to 350 ft (107 m) (DWR 2004).

Pyroclastic Rocks Water Bearing Formation

The deposits underlie a region located east and southeast of Macdoel ranging up to 400 ft (122 m) in thickness near Juniper Knoll (Wood 1960; DWR 2004). Deposits are exposed on the surface over a large area east of Macdoel. The unit is moderately to highly permeable and will yield water freely to wells where it is saturated (DOI 1980). Most of the outcrop lies above the saturated zone, where it acts as an intake area for groundwater recharge (Wood 1960; DOI 1980). These rocks have largely been developed for stock wells (DWR 2004).

The Pyroclastic Rocks unit is characterized by well-consolidated, massive to thin-bedded lapilli tuffs and cindery tuff breccias that are generally cross-bedded and include abundant fragments of basalt and scoria (DWR 2004). Deposits were created via at least two widely separated eruptive events (DOI 1980). The deposit overlies the lake deposits. The Butte Valley Basalt was deposited between the two main pyroclastic events and locally overlaps and is interbedded with the pyroclastic deposit (DOI 1980; DWR 2004).

2.2.1.7 Groundwater Recharge

Natural recharge occurs primarily from the infiltration of precipitation, underflow from the Basin adjacent volcanic rocks (on the north, west, and south margins) and streamflow losses (DWR 2004). Surface exposures of Butte Valley Basalt, High Cascade Volcanics, and Pyroclastic Rocks within the watershed are sources of recharge from rain and snow (Kit Novick 1996; DWR 2004). The High Cascade Volcanics recharges via snow pack in the north, west, and south sides of the Watershed (Kit Novick 1996). Lake Deposits also contain sources of groundwater recharge where volcanic talus deposits occur along fault scarps that cut into deeper water bearing formations (DWR 1998). Groundwater recharge via streamflow losses are provided by Butte, Antelope, Prather, Ikes, Harris, and Muskgrave Creeks (Kit Novick 1996). In the southern part of the Basin, seepage losses from unlined canals along the western fringe and deep percolation from irrigation also contribute to recharge (DWR 2004). The wetlands and canals in BVWA also recharge the groundwater (Kit Novick 1996).

2.2.1.8 Soil Characteristics

Soils in Butte Valley have developed in the valleys, basins, foothills, and mountain slopes, with distinct characteristics in each location. The following discussion references map units, named for major soil components, in the U.S. Department of Agriculture (USDA) 1994 Soil Survey of Butte Valley-Tule Lake Area (USDA 1994). A map of soil orders in the watershed is shown in Figure 2.17. The general soil units discussed below are shown in Figure 2.18. The infiltration and runoff potential as defined in hydrologic soil groups is shown in Figure 2.19. In Butte Valley, areas of poor soil permeability have an accumulation of salt and alkali, and tend to occur in areas with a hardpan (1996 Siskiyou County). Soils in the center of the Basin and bench lands along the northern valley rim have a prominent heavy calcareous hardpan (DOI 1980). In adjacent cropland, fields are leached through deep canals to decrease salts and alkali, and the hardpan is ripped periodically to improve rooting depth and drainage (Kit Novick 1996).

Most soils in Butte Valley are derived from lacustrine deposits, from the paleolake that used to fill the Valley. The center of the Basin, from the lowest elevation at Meiss Lake to the eastern valley side, is slightly lower than the north and south valley areas. The center of the Basin has historically acted as an evaporation basin for the spring runoff (DOI 1980).

Valley Floor Soils

The Butte Valley floor contains several soil orders: Ultisols in the middle of the Valley, Mollisols at the Valley edges, and Inceptisols and Vertisols west of Meiss Lake. The valley floor is further divided into several general soil units, which are broad areas that have a distinctive pattern of soils, relief, and drainage. While each soil subunit is a unique natural landscape, the general soil units can be used for general land uses and broad interpretive purposes (USDA 1994).

The Inlow-Ocho soil unit is centered in the Butte Valley National Grasslands and extends southwest to Meiss Lake and crosses U.S. Highway 97 towards Inlow Butte. It is a silt to very fine sandy loam that forms on lake terraces. The unit formed from lacustrine sediment and alluvium derived from volcanic ash and extrusive igneous rock. It is moderately deep to shallow, moderately well drained to somewhat poorly drained, with slopes of 0-2%. Below the subsoil is a hardpan at about 18-33 in (0.46–0.84 m) below the surface. Below the hardpan is loamy sand. Minor components of this soil include well-drained loamy Modoc soils, with a subsoil of loam and sandy clay loam, and shallow, poorly-drained Ocho Variant soils, with a subsoil of clay. The soil unit is mainly used as rangeland. Hazards of the Inlow soils include soil blowing and sodicity, while the Ocho soils have issues with sodicity, a shallow effective rooting depth, surface crusting, and ponding. Soil hazards limit the production of forage and make seeding unfeasible. The moderate hazard of soil blowing requires onsite investigation prior to mechanical treatment. The sodicity hazard is deemed unfeasible to overcome (USDA 1994).

The agricultural land in Butte Valley is predominantly underlaid by Mollisols. Mollisols on the north half of Butte Valley are characterized by the Modoc-Rojo soil unit. The soil unit forms on lake terraces and was created in alluvium and lacustrine sediment derived from extrusive igneous rock and material weathered from tuff and volcanic ash. The loamy soil is moderately deep, with slopes from nearly level to moderately sloping (0-9% slope). The surface layer is loam to sandy loam and the subsoil is loam, sandy clay loam or sandy loam. A hardpan or duripan lies roughly 28-34 in (0.71-0.86 m) below the surface. Below the hardpan is sand, weathered tuff, and volcanic ash. The soil unit also has minor components of the well-drained Dehill, Dotta, Mudco, and Truax soils and the moderately well-drained Medord, Doel, and Rangee Variant soils. Dehill, Dotta, Medford, and Traux soils are deep soils at higher elevations with no duripan. Mudco and Rangee Variant soils have a duripan within 20 in (0.51 m) of the surface. Doel soils have a surface layer underlain by sand. The Mullisol Modoc-Rojo soil unit is used for cultivated crops, hay and pasture, and rangeland. Hazards include soil blowing, hardpan depth, low available water capacity, and frost potential. The depth to volcanic tuff in the Rojo soils discourages ripping. A temporary water table above the hardpan can be prevented with good irrigation management (USDA 1994).

Agricultural activity in the southern half of Butte Valley is predominantly underlain by the soil unit Poman-Fordney, whose subunits are classified as either an Ultisol or Mollisol. This unit also surrounds Dorris. The sandy soils lie on alluvial plains and terraces and were formed from volcanic tuff and other kinds of extrusive igneous rock. It is moderately deep to very deep and nearly level to strongly sloping (0-15% slope). The surface layer is loamy sand. The substratum of the very deep, excessively drained Fordney soils is loamy sand. The moderately deep and somewhat excessively drained Poman soils have a subsoil of loamy sand above a duripan at about 29 in (0.74 m) below the surface. Underlying the duripan is sand. Minor components of the soil unit are the well-drained Dehill soils, the moderately well-drained Doel soils and the somewhat poorly-drained Podus and Poe soils. Dehill soils are sandy loams at higher elevations. Podus soils have a duripan at 10-20 in

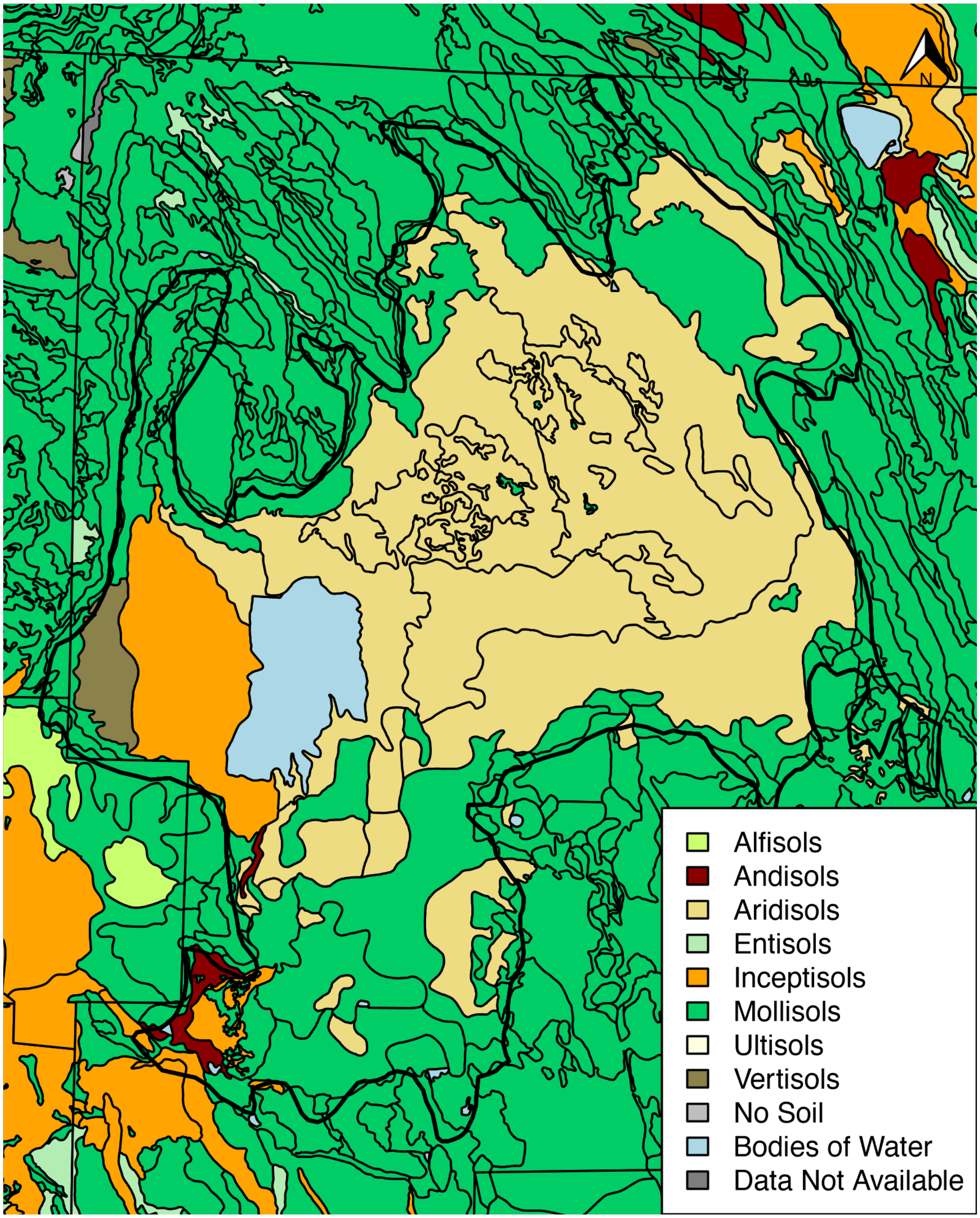


Figure 2.17: Soil classifications in Butte Valley.

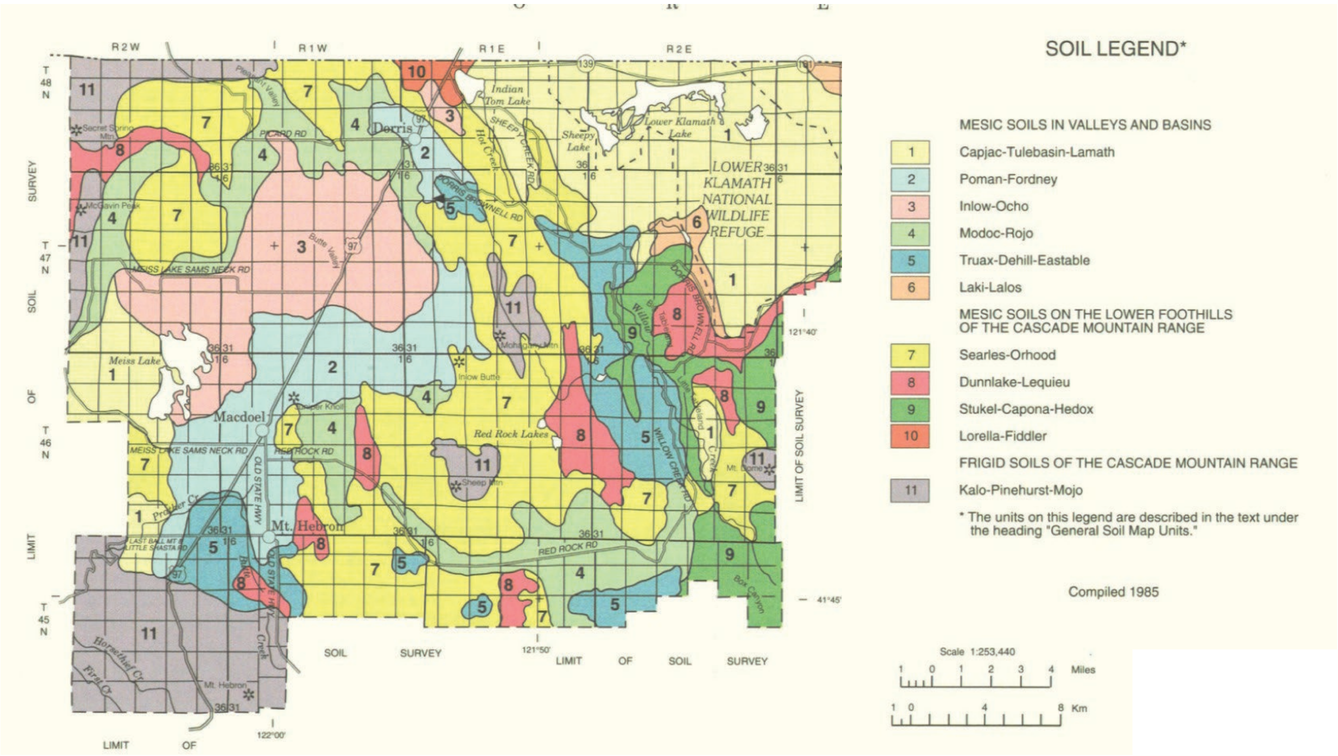


Figure 2.18: General Soil Map of Butte Valley from the 1994 USDA Soil Survey of the Butte Valley-Tule Lake Area. Modified from the original 1994 USDA General Soil Map, included in Appendix 2-A.

(0.25-0.51 m) below the surface and have a high water table. Similarly, Poe soils, too, have a high water table, but with a duripan at 20-40 in (0.51-1.0 m) below the surface. The Poman-Fordney soil unit is used for cultivated crops, hay and pasture, rangeland, and home development. Issues include a rapid rate of water intake and low available water capacity. Hazards include soil blowing and a risk for frost (USDA 1994).

The Capjac-Tulebasin-Lamath soil unit has subunits that can be classified as an Inceptisol, Vertisol or Andisol. This loamy soil occurs in lake basins and forms from lacustrine sediment derived dominantly from diatomite, volcanic ash, and extrusive volcanic rock. The soil is very deep, nearly level (0 to 2% slope) and very poorly drained to poorly drained. The subunits in Butte Valley share further characteristics, where they are all very deep, artificially drained soil in lake basins, protected by dikes and levees, and have a water table controlled by pumping to deep lateral drains (USDA 1994).

The Vertisol subunit is a Pit silty clay, formed in poorly drained alluvium derived from extrusive igneous rock. Dikes and levees protect this soil from brief flooding from January through May (USDA 1994). The water table is maintained at a depth of 5-6 ft (1.5–1.8 m). It is a silty clay at 0-26 in depth, silty clay loam or clay loam at 26-31 in and silt loam at 26-31 in (0.66–0.79 m) (USDA 2020b). Permeability is low and available water capacity is high. The unit is used for cultivated crops such as wheat and barley, and rangeland. Soil issues include a high shrink-swell potential and a susceptibility to compaction (USDA 1994).

There are two pockets of Inceptisols on the eastern side of the Valley. The subunit west of Meiss Lake is a Teeters silt loam and the subunit south of Meiss Lake along Prather Creek is a Lamath silt loam. Both formed from poorly drained silty or lacustrine sediment derived from diatomite, volcanic ash, and extrusive igneous rock. Dikes and levees protect the soil from brief flooding from March through May (USDA 1994). The water table is maintained at a depth of 1.5-4 ft (0.46-1.2 m). The soil is saline. The Teeters silt loam soil unit is silt loam, with some silt at 10-60 in (0.25-1.5 m) depth. The Lamath silt loam soil unit is silt loam at 0-21 in (0-0.53 m) depth, sand and loamy sand at 21-53 in (0.53-1.3 m) depth, and stratified sand to silt loam at 21-53 in (0.53–

1.3 m) depth (USDA 2020b). The diatomite and volcanic ash origin of the soil creates a very high water capacity. Soil blowing is a moderate hazard when the surface layer is dry under high wind conditions. The soil is used for cultivated crops, hay and pasture and wildlife habitat (USDA 1994).

The Andisols are Capjac silt loam, formed in poorly drained lacustrine sediment derived from diatomite and volcanic ash. Dikes and levees protect this soil from rare flooding from October through May. The water table is maintained at a depth of 1.5-3.0 ft (0.46–0.91 m). The surface layer down to about 26 in (0.66 m) depth is silt loam and the substratum down to 60 in (1.5 m) or more is slightly saline silt loam. Permeability is moderate and frost is a hazard. The diatomite and volcanic ash origin of the soil creates a very high water capacity. Soil blowing is a moderate hazard when the surface layer is dry under high wind conditions. This soil is used for wildlife habitat, cultivated crops, and irrigated hay and pasture (USDA 1994).

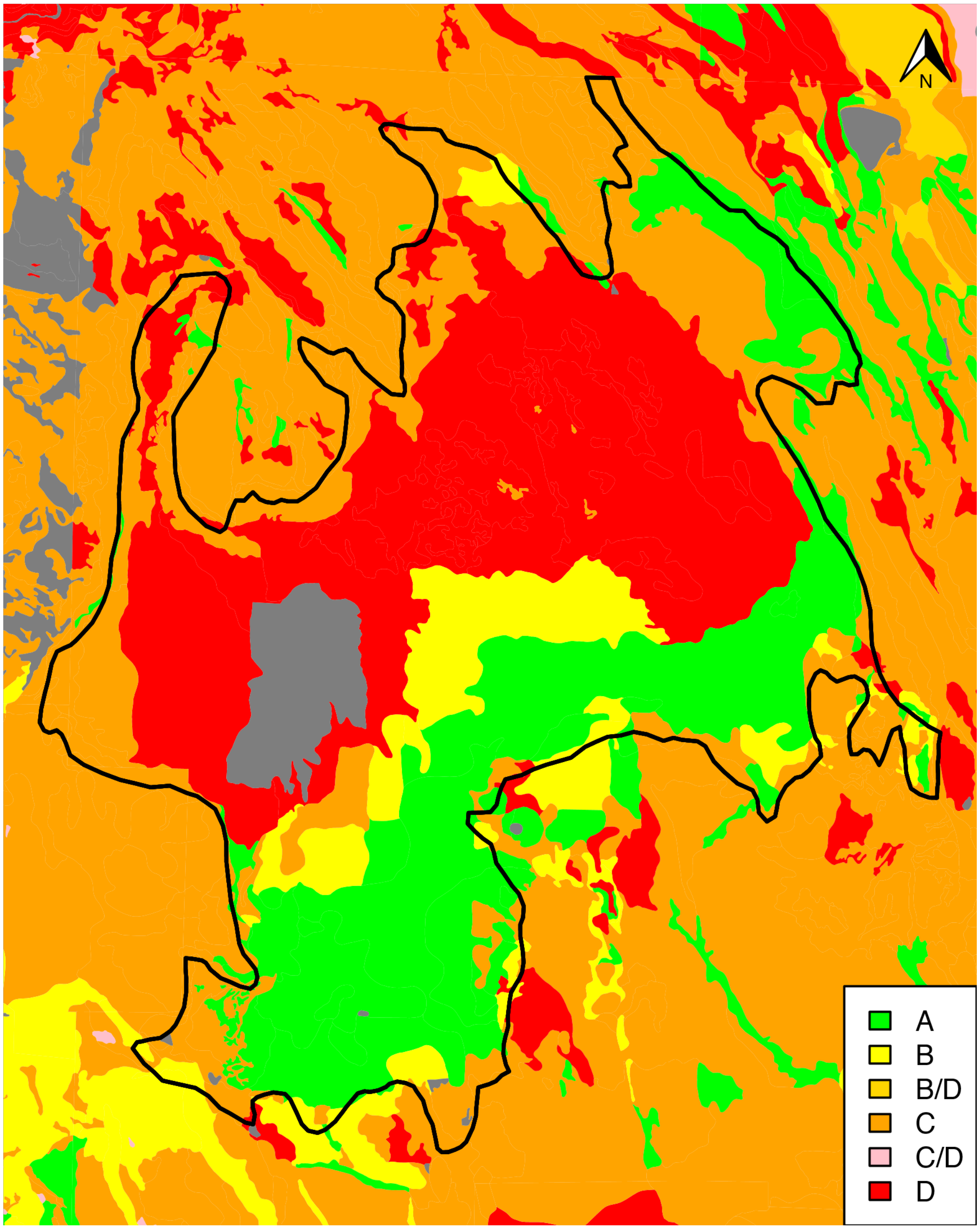


Figure 2.19: Hydrologic soil groups in Butte Valley, where Group A are soils with a high infiltration rate and low runoff potential to Group D with very slow infiltration rate and high runoff potential.Soils have two Groups if a portion is artificially drained and the rest undrained.

Alluvial Fan Soils

From U.S. Highway 97 west of Mount Hebron to the southern valley rim below the highway and Mount Hebron is the Traux-Dehill-Eastable soil unit. It is a well drained, very deep, loamy soil that forms on alluvial fans, formed dominantly in alluvium derived from volcanic tuff and extrusive igneous rock. It is nearly level to strongly sloping, with slopes of 0-15%. Traux soils are predominantly sandy loam, with sandy clay loam subsoil. Dehill soils are fine sandy loam. Eastable soils are loams with a clay loam subsoil. Minor soil units are the well drained Dotta, Hedox, and Munnell soils and the moderately well-drained Leavers soil. The general sand unit is used for cultivated crops, irrigated hay and pasture, and rangeland. Soil hazards include soil blowing and frost (USDA 1994).

Soils of the Lower Foothills of the Cascade Mountain Range

The foothills bordering Butte Valley are dominated by the Mollisol Searles-Orhood soil unit. The well-drained soil forms on hills and mountains and formed in material weathered from extrusive igneous rock. The very stony or very cobbly loamy soil is moderately deep and shallow, and gently sloping to very steep (2-50% slope). The surface layer is a very stony or very cobbly loam. The upper part of the subsoil is very cobbly loam and the lower part is very cobbly clay loam and very cobbly loam. Extrusive ignous bedrock is about 16 or 28 in (0.41-0.71 m) deep. The soil unit has various minor components with variations on the main soils, such as a clayey subsoil, soils deeper than 60 in (1.5 m) deep or less than 10 in (0.25 m) deep. The soil unit also has instance of rock outcrops, with no soil cover, and areas of rubble, where 90% or more of the surface is covered by stones and boulders. The soil unit is used for rangeland and growth of western juniper. High surface slopes and general stoniness limits seeding, livestock access, and woodcutting (USDA 1994).

The Dunnlake-Lequieu soil unit occurs sparsely at the valley borders. The very stony loamy soils are shallow to very shallow, with slopes from 0-50%. The soil occurs on plateaus and mountain side slopes and formed from material weathered from extrusive igneous rock. Both Dunnlake and Lequieu soils have a very stony loam surface layer. Dunnlake soils have a clay loam upper subsoil and gravelly clay lower subsoil, with hard, extrusive igneous bedrock at about 16 in (0.41 m) depth. Lequieu soils have a 5 in (0.13 m) substratum of very cobbly loam and andesite bedrock at 8 in (0.20 m) depth. Due to the surface stoniness and depth to bedrock, the soil unit is used as rangeland (USDA 1994).

Soils of the Cascade Mountain Range

The edges of the Basin contain parts of the Kalo-Pinehurst-Mojo general unit. The stony to very stony loamy soil occurs on mountains and formed in material weathered from extrusive igneous rock. The soil is moderately deep to deep with slopes that are moderately sloping to steep (5-50% slope). The surface layer is very stony sandy loam, stony sandy loam or stony loam. The subsoil is very cobbly loam, very cobbly clay loam, gravelly loam, very stony loam, or clay loam. Extrusive igneous bedrock occurs between 27-55 in (0.69-1.4 m) depth. The soil unit is used as woodland, with some livestock grazing.

2.2.1.9 Surface Water Bodies

Surface water bodies in the Basin include Meiss Lake and spring-fed intermittent streams. Butte Creek is the largest stream in the Watershed. Spring-fed perennial streams include Ikes, Prather, Muskgrave, and Harris, which drain into Meiss Lake (DOI 1980). Seikel Creek is a tributary of Muskgrave Creek and its water is partially diverted to Juanita Lake by the USFS (Kit Novick 1996). Major surface water features are shown on Figure 2.1.

Historically, Mud Lake was a perennial lake residing southeast of Macdoel, with the aptly named Lakeview Cemetery on the east shore, but has recently become a small intermittent pond. Mud Lake was about 40 acres (0.16 sq km) in 1909, and was too alkaline for domestic or irrigation uses, but was used by cattle. A water body south of Cedar Point has historically been called Alkali or Soda Lake and occupied 600 to 700 acres (2.4 to 2.8 sq km) in 1909, but was deemed far too alkaline for domestic or irrigation use. The 1909 USDA Soil Survey observed a slight rise in the valley floor north of Macdoel towards Dorris, which separated Meiss Lake and Soda Lake (USDA 1909).

Outside the Basin, the Butte Valley Watershed includes three additional named streams and numerous small lakes and ponds. Antelope Creek was once a tributary of Butte Creek up until the eruption of the Butte Valley Basalt (King 1994). Spring-fed First and Horsethief Creeks are south of Ball Mountain. Intermittent surface water bodies in the high mountains of the southern watershed include: Duck Lake southwest of Haight Mountain, Surprise Lake on Ash Creek Butte; Antelope Creek Lakes and Hemlock Lake near Rainbow Mountain; and Frog Lake on the valley floor northeast of Rainbow Mountain. Intermittent surface water bodies on the valley floor of the middle Watershed include: Antelope Sink north of Cedar Mountain; Orr Lake at the base of Orr Mountain; the unnamed pond west of Cedar Mountain formed by the Butte Creek spillway, Russell Lake in Red Rock Valley; and a large unnamed lake between Tennant and Butte Creek at 41.615389 north latitude, -122.008856 west longitude. Intermittent surface water bodies in the high elevations northwest of Mount Hebron include: Mud Lake where U.S. Highway 97 leaves the Butte Valley floor; and Pumpkinseed Lake northwest of Mount Hebron. Perennial surface water bodies include Mud Lake on Mud Lake Ridge, Juanita Lake near Ball Mountain, Red Rock Lakes east of Sheep Mountain, and Deyarmie Lake in Red Rock Valley.

Meiss Lake

Meiss Lake is a shallow, alkaline water body that lies on the west side of the Valley and is managed by CDFW in BVWA. BVWA and Meiss Lake are important for the Pacific Flyway and are a major migration and staging area for waterfowl, sandhill cranes, and other water birds (NCRWQCB 2008). Meiss Lake is a 4,000 acre (16.2 sq km) managed reservoir, with a maximum depth of six feet (Kit Novick 1996). Before the mid-1940s, Meiss Lake and adjacent wetlands covered about 10,000 acres (40.5 sq km) (NCRWQCB 2008). In 1909, the considerably deeper western half of Meiss Lake was 6 ft (1.8 m) deep, while the rest of the lake was only 2-3 ft (0.61-0.91 m) deep or less (USDA 1909). From the mid-1940s to 1981, Meiss Lake and adjacent wetlands were systematically diked, channeled, drained and converted to agricultural uses (NCRWQCB 2008). In the 1940s, a North-South dike was constructed to divide the lake in half and convert the western half into farmland. The eastern half of the lake was used as a reservoir to manage inflowing and outflowing water. In the winter, water from Muskgrave, Harris, and Ikes Creeks were diverted onto the fields to built soil moisture, then pumped into Meiss Lake in the spring for planting. As noted above, the lake bed on the eastern half is four feet higher than the former lake bed in the west. The farmland on the former lake bed has been periodically reflooded by Meiss Lake (Kit Novick 1996). By 1981, Meiss Lake, its adjacent wetlands and tributaries had been substantially altered, lost or degraded from their pre-1940s state (NCRWQCB 2008). After BVWA was purchased by the State in 1981, the wetlands and tributaries are being managed and restored (Kit Novick 1996).

Meiss Lake is a closed basin and receives surface water from four spring-fed creeks and one canal. From the west flow Ikes, Harris, and Muskgrave Creeks and from the south flows Prather Creek. Estimated creek inflows are 15,000 to 20,000 acre-feet annually but are low or nonexistent in the summer and fall. The Irrigated District Canal delivers excess irrigation water to Meiss Lake from wells and summer runoff, though flows are normally very low. Seikel Creek, a tributary of Muskgrave Creek, is partially diverted by the USFS to Juanita Lake from April 30 to November 1. In the 1940s, dams were built at Juanita Lake to provide irrigation water to Meiss Ranch, the precursor of BVWA (Kit Novick 1996).

Historically, the size of Meiss Lake has varied. Commonly the lake nearly dries up by early fall (Kit Novick 1996). Meiss Lake typically goes completely dry every 15-20 years and was dry in 1955, 1965, 1981, 1987, 1988, 1990, 1991 and 1992 (County of Siskiyou 1996). Precipitation patterns have continued to fluctuate, with a wet period between 1993 to 1999 and dry cycle from 2000 to 2008 (2006 was very wet) [2009 BVWA Plan Addendum]. Meiss Lake went dry in 2000, 2001, 2002, 2003, 2004, 2005, 2007, and 2008 (K. Novick 2009). The hardpan and soil type at Meiss Lake create a large shallow impermeable basin subject to high evaporation rates (County of Siskiyou 1996). The pan evaporation rate for Butte Valley is estimated to be 48 in (1.2 m) per year, primarily driven by wind (Kit Novick 1996; County of Siskiyou 1996).

The water quality of Meiss Lake is heavily dependent on the season, where the quality is good during and shortly after the winter-spring runoff period then declines during the summer and fall as inflows cease and evaporation increases. During the summer and fall, electrical conductivity, pH, TDS, and alkalinity increase in value. For example, pH is roughly 7.4 in the spring and 10.1 in the fall. In general, the lake water has high turbidity due to the relatively shallow water (less than 6 ft) and is high in sodium bicarbonate. The high turbidity and alkalinity compared to the Klamath River restricts pumping of Meiss Lake water into the Klamath River after April 30. After July 1, BVWA does not use Meiss Lake water for crop irrigation or wetlands maintenance because alkalinity, pH, and electrical conductivity exceed safe levels for plant growth (Kit Novick 1996).

Evidenced by the hundreds of feet of lake sediment on the Butte Valley floor, paleolakes have occupied the Basin for at least hundreds of thousands of years. The flatness of the valley floor means small changes in Meiss Lake levels cause large changes in lateral lake size. Two Holocene (0.012 Ma to Present) shorelines can be distinguished via aerial photography interpretation of soil and vegetation and archaeological evidence. The prehistoric Meiss Lake at its maximum had its shoreline at the 4,236 ft (1,291 m) amsl elevation contour, covering an area of 11.6 sq mi (30 sq km) at a depth of 10 ft (3 m). The historic high level for Meiss Lake is 4,232 ft (1,290 m) amsl, which is marked by a change in vegetation. The current Meiss Lake shoreline is at 4229 ft (1,289 m) amsl. Above the prehistoric 4,236 ft (1,291 m) amsl shoreline, vegetation is marked by scrub vegetation similar to that growing on Quaternary lake deposits on the valley floor. Between the historic 4,232 ft (1,290 m) amsl shoreline and prehistoric 4,236 ft (1,291 m) amsl shoreline, the vegetation is marked by grasses and scattered scrub. Between the current lake shoreline and the historic 4,232 ft (1,290 m) amsl shoreline, the area is covered with grasses (King 1994).

Meiss Lake was likely below the 4,232 ft (1,290 m) amsl shoreline for most of the Holocene due to the well-defined soil profile between 4,232 ft (1290 m) and 4,239 ft (1292 m) amsl called the Pit Series, which suggests that the area has not been underwater for an extended time. Soils in the historically drained Meiss Lake bed are classified as the Teeters Series and are less developed then the Pit Series. Additionally, the Teeters Series soil is only 24 in (0.61 m) deep compared to the 40 in (1 m) deep Pit Series (King 1994).

Along the old Meiss Lake shorelines there is evidence of prehistoric human habitation. Prehistoric habitations on the eastern shore are dated from 6,640 to 565 years before present along both the 4,236 ft (1,291 m) and 4,232 ft (1,290 m) amsl shorelines. Additional prehistoric habitations along the west shore range from 9,000 to 1,400 years before present between 4229 ft (1,289 m) and 4,232 ft (1,290 m) amsl elevation. The variation of elevations of the prehistoric habitations suggest that the prehistoric Meiss Lake was not dry for long periods of time and had at least some water through most of the Holocene (King 1994).

In December 1964, Meiss Lake flooded to an area of 16 sq mi (10,500 acres; 42.5 sq km), which coincides with the 4,234 ft (1,291 m) amsl elevation contour including its former lake bed and adjacent farms (County of Siskiyou 1996). The County declared the Butte Valley flood a Major Disaster (USACE) and requested emergency relief from the federal government (County of Siskiyou 2017). In early 1965, the U.S. Army Corps of Engineers constructed the Sam's Neck Flood Control Facility, a drainage canal to pump excess floodwater to the Klamath River (NCRWQCB 2008; County of Siskiyou 2017). The drainage canal consists of an outlet from Meiss Lake that travels up Sam's Neck, where a pump lifts water 21 ft (6.4 m) from the valley floor to Rock Creek and ultimately to the Klamath River in Oregon (Kit Novick 1996; County of Siskiyou

2017). Rock Creek is outside the Butte Valley watershed and is a tributary of the Klamath River. By July 12, 1966, USACE was still pumping down Meiss Lake (County of Siskiyou 2017).

Management for the Sam's Neck Flood Control Facility has changed hands several times since its creation. The lift pumps require a contract for electricity and the facility requires maintenance. After completion of the project, USACE payed for one year's worth of power before turning over responsibility to the County. The County never expected to fund the project with taxpayer dollars and intended to hand over responsibility to the direct beneficiaries of the flood control project, originally BVID. BVID did not take over the project and the County authorized a local company to operate one of the lift pumps, with the condition that the company pay for all electric power bills and accept all liability. Months later the Pacific Power and Light Company requested that the County submit payment for a power bill associated with the pumps. After agreeing to pay the power bill, the County Board of Supervisors advised that the County would not be responsible for any further power bills from the pumping facilities thereafter. The Board of Supervisors also discussed that those benefiting from the flood control facility should pay for the power costs of the project or the power transformers should be removed. In the fall of 1967, the Board of Supervisors authorized the Meiss Ranch Company to operate the Flood Control Facility and soon after approved the arrangement between Meiss Ranch and Pacific Power and Light Company on a rolling year-to-year basis. From 1968 to mid-1985, the Flood Control Facility pumped excess floodwater from Meiss Lake at no cost to the County. Meiss Ranch may have made an agreement with BVID for operation of the pumps at the Ranch's expense (County of Siskiyou 2017).

Estimated yearly water volumes pumped from Meiss Lake are shown in Table 2.4. Sam's Neck Flood Control Facility usually only operated from January to April. Public opposition restricted operation of the facility after April due to the impact of the poor lake water quality (turbid and alkaline) on the Klamath River fishery (Kit Novick 1996).

In 1981, Meiss Ranch was purchased by the California Department of Fish and Game (currently CDFW), and the land was designated as the Butte Valley Wildlife Area (BVWA). The Department initially operated and paid for the Flood Control Facility pumps until 1985. The Department notified the County of releasing its operational and monetary responsibility for operating and maintaining the Sam's Neck Canal pumps. The Department outlined its long-term goal of utilizing all surplus water to create wetland habitat, which might eliminate the need for the Flood Control Facility. In 2017, the County submitted a request to the USACE that Sam's Neck Flood Control Facility be abandoned (County of Siskiyou 2017).

Table 2.4: Estimated Volume of Water Pumped From Meiss Lake to The Klamath River (BVWA 1996).

Year	Acre-Feet	Year	Acre-Feet
1968	638	1982	8,930
1969	585	1983	12,456
1970	10,064	1984	7,708
1971	12,545	1985	4,182
1972	14,582	1986	2,271
1973	89	1987	0
1974	9,674	1988	0
1975	4,164	1989	0
1976	142	1990	0
1977	89	1991	0
1978	4,571	1992	0

1979	213	1993	0
1980	4,363	1994	0
1981	0		

Butte Creek

Butte Creek is the largest stream in the Butte Valley Watershed, with headwaters between the Whaleback and Haight Mountains at the southern end of the Watershed (Figure 2.8) (King 1994). Butte Creek historically flowed into Meiss Lake, but has been diverted for agricultural irrigation and spreading grounds for groundwater recharge for much of the 20th century (DOI 1980; Kit Novick 1996). By the mid-20th century, Butte Creek had been sufficiently appropriated and diverted so that flows terminated near Jerome, at the southern Basin boundary (Wood 1960). At normal flows, surplus water after irrigation is diverted into a lava crack or allowed to percolate into porous lava and alluvial deposits for groundwater recharge north of Jerome. Flood flows are diverted into Dry Lake / Cedar Lake to recharge the Butte Valley Basalt water bearing formation, and does not reach Meiss Lake (Kit Novick 1996; County of Siskiyou 1996).

In 1909, while supplying irrigation water for several hundred acres of alfalfa, timothy, clover, and grain crops, Butte Creek disappeared underground at the valley edge and flowed to Meiss Lake via groundwater (USDA 1909). All surface evidence of the lower Butte Creek channel, from the Valley edge to Meiss Lake, has been destroyed by cultivation (King 1994).

Prather, Ikes, Harris, and Muskgrave Creeks

Prather, Ikes, Harris, and Muskgrave Creeks are spring-fed creeks that drain into Meiss Lake. Seikel Creek and Juanita Lake are tributary to Muskgrave Creek. Water from these creeks have excellent mineral quality, are soft with a calcium-magnesium bicarbonate character, and very low in chloride and sulfate (Kit Novick 1996). Springs from the High Cascade Volcanics water bearing formation provide perennial flows for four creeks, but flows vary seasonally (County of Siskiyou 1996). Historically, Harris and Ikes Creeks flowed all year but very low during the summer months. In recent years, Harris, Ikes, and Muskgrave Creeks all dry up in the summer and fall. Upstream of BVWA, Prather Creek is diverted for agriculture and summer flows to Meiss Lake are very low to nonexistent. All four creeks are capable of intense flooding in a short period of time and all floodwater flows into and is managed by BVWA (Kit Novick 1996). CDFW is the only pre-1914 water right holder for Muskgrave, Harris, and Ike's Creek flow within the Basin.

In 1909, Prather Creek flowed directly into the southern end of Meiss Lake, and provided water and electrical power to a dairy (USDA 1909). In the 1940s, farming on the west side of Meiss Lake was accomplished by diverting Muskgrave, Harris, and Ikes Creeks out onto the fields in the winter months to build soil moisture (County of Siskiyou 1996). Today, all pre-1914 water rights to Prather Creek are split between Ralph's Prather Ranch (senior right) and CDFW. Creek flows are utilized by CDFW for wildlife, and enhancement and maintenance of 6,300 acres (25.5 sq km) of wetlands, including Meiss Lake. Water conservation efforts include drainage and reuse between land units for moist-soil management for waterfowl food plants. From 2005 to 2007, the combined total annual flow was 7,500, 18,000, and 11,500 AF (9.3E+06, 2.2E+07, and 1.4E+07 m^3), respectively (SWRCB 2020).

2.2.2 Historical and Current Groundwater Conditions

2.2.2.1 General Groundwater Flow Conditions of Butte Valley – Overview

The major water-bearing formations within the Butte Valley groundwater Basin are Lake Deposits, Butte Valley Basalt, and High Cascade Volcanics. Other formations include Alluvial Fan Deposits and Pyroclastic Rocks (DWR 1998; DWR 2004, see Section 2.2.1.6 for further detail). The boundaries of the Basin mostly coincide with the margins of the topographically flat region formed by Pleistocene occurrences of Meiss Lake and associated occurrence of thick, unconsolidated

Lake Deposits, bounded by the escarpments of volcanic uplands of the High Cascade volcanics along block fault lines on the eastern, northern, and western Basin boundary, and by recent (Quaternary) volcanic basalt flows on the southern boundary. Unlike most California alluvial/sedimentary basins, this Basin is not isolated from the groundwater flow system of the surrounding mountain ranges and uplands, which consist largely of variably permeable volcanic rocks of the High Cascade unit. Highly permeable horizontal contact zones between volcanic flows, vertical shrinkage cracks or joints, and sometimes horizontal flow channels created during cooling of magma are conducive to significant groundwater flow through these volcanic rocks. Hydrogeologically, the Basin is a subbasin of the larger groundwater flow system within the volcanic landscape of the Upper Klamath Basin and the adjacent Modoc Plateau (Wood 1960, Gannett et al., 2010, USGS SIR 2007-5050, Gannett et al., 2012, see Figure 2.20 – Figure 2.22).

Near Butte Valley, the groundwater flow boundaries of the larger 8000 square-mile (5 million acres) Upper Klamath Basin (UKB) groundwater flow system roughly coincide with the watershed boundaries of Butte Valley to the south, which may coincide with a groundwater divide, and the much older, highly degraded volcanic rocks of the Western Cascades, which form a mostly very low permeable boundary of the groundwater flow system against Shasta Valley and the Klamath River Canyon to the west of Butte Valley. To the north and east, the larger regional groundwater flow system extends beyond the Mahogany Mountain ridge into the Lower Klamath Lake basin, the Tule Lake basin, and the watersheds of the Lost River and Upper Klamath River. Gannett et al., 2010, identified the eastern boundary of the larger UKB groundwater flow system as the older, low permeable volcanic rocks along the eastern watershed boundary of the UKB. The northern boundary was identified as a potentially permeable groundwater divide coinciding with the northern UKB watershed boundary. The southern boundary of the regional groundwater system is a permeable groundwater divide north of the UKB watershed boundary against the Pit River watershed. Prior to groundwater development the groundwater divide may have been as far north as Tule Lake, possibly draining Tule Lake toward the Pit River to the south (Gannett et al., 2010).

Groundwater flows from sources of recharge toward places of groundwater discharge. Across the UKB south of the Klamath and Lost Rivers (which includes the Basin), prominent recharge areas include the higher elevations of the volcanic uplands north of Mount Shasta and Medicine Lake Volcano (south and southeast of the Basin) and uplands west of the Basin. Upland recharge from precipitation has been estimated to be 20% of precipitation, on average, across the UKB (Gannett et al., 2010), but is highly variable. The highest fraction of recharge, relative to precipitation, occurs at higher elevations where precipitation is also larger.

From those areas of recharge, groundwater flows north and east toward the topographic and water table low points of the southern UKB, discharging into the Klamath River/Lower Klamath Lake, Lost River, and Tule Lake sink (Wood 1960, Gannett et al, 2010) and also supporting wetlands around those surface water features. The elevations of these regional low drainage points of the UKB groundwater system are at 4082 ft amsl in the Lower Klamath National Wildlife Refuge (Lower Klamath Lake) and at 4037 ft amsl along the Lost River at the California-Oregon border. Groundwater levels in the Tule Lake Basin and on the adjacent Oregon side may be below 4000 ft amsl due to irrigation pumping in those regions, particularly since 2001 (Gannett and Breen, 2015): In the Klamath Valley subarea, OR, and in the Tule Lake subareas, groundwater levels declined by an average 20 – 25 ft between 2000 and 2015 in response to an additional average Klamath Project pumping of 48,000 af/yr. Prior to modern groundwater development, Meiss Lake, at 4230 ft in the southwest area of the Basin, and vegetation in surrounding wetlands may have been subregional groundwater discharge points, as indicated by nearby flowing wells (Wood, 1960).

Gannett et al. (2010) estimated average precipitation in the 8000 square-mile (5 million acre) UKB to be 10 MAF, of which 2 MAF become groundwater recharge. Groundwater discharge into streams of the UKB was estimated to be 1.8 MAF. Discharge to groundwater pumping across the entire UKB, under pre-2001 pumping conditions, was estimated to be 0.2 MAF. Surface outflows from the UKB, in the Klamath River, average 1.5 MAF.

Consumptive agricultural water use (ET) within the UKB was estimated as 0.68 MAF on the Oregon side and 0.07 MAF on the California side. Evapotranspiration from major wetlands was estimated to be 0.22 MAF for Tule Lake and Klamath Wildlife Refuge (not including open water) and 0.46 MAF for Oregon major wetlands (around Upper Klamath Lake, Klamath marsh). Most of these wetland's consumptive use is fed by surface water, which, in return, depends on groundwater discharge for a significant fraction of the total surface water flow.

The broader hydrologic context of the UKB provides the framework for understanding groundwater flow in the Basin (Butte Valley). Importantly, unlike most other California basins that are topographically bounded by surrounding mountains, the Butte Valley Basin, due to its geologic position within the High Cascade volcanics, receives only a small amount of its water by (observable) surface water inflows from its surrounding mountain ranges. Instead, precipitation over the volcanic uplands to the south and west of the Basin readily infiltrates into relatively permeable upland soils, recharging into the underlying High Cascades volcanic aquifer system. Runoff and baseflow feed a few streams to the south of the Basin. However, most streamflow recharges back into underlying highly permeable quaternary basalts before reaching the Basin's southern and western groundwater inflow boundary. The four creeks flowing into Meiss Lake are the main exception.

A potential minimum estimate of "recharge" from subsurface inflow into the Basin is obtained by considering the reported runoff in Antelope Creek, draining an area of about 18.6 square miles, with an annual runoff of approximately 23,000 AF (or 1,200 AF per square mile drainage area). All of its flow recharges groundwater at Antelope Sink south of Cedar Mountain. Butte Creek, which has a drainage area of 178 square miles, has an estimated runoff of 13,000 AF per year before percolating into lava tubes just south of and near the Basin boundary (70 AF per square mile drainage area). Precipitation and vegetation in the Butte Creek and Antelope Creek drainage areas are comparable. Assuming that the difference in runoff per unit drainage area is due to larger groundwater recharge in the Butte Creek drainage area, total groundwater recharge within the Butte Creek drainage area is at least 178 sq,miles x 1200 AF/sq.mile drainage area or 214 TAF per year (including the 13 TAF/yr recharging at the southern Basin boundary). The total recharge of 237 TAF/yr is a lower (minimum) estimate for groundwater recharge in these two drainage areas. Additional groundwater recharge likely occurs in both Butte Creek and Antelope Creek drainage areas, but never returns to runoff in either creek (DWR, 1973).

The drainage area of Meiss Lake tributaries Prather, Ikes, Harris, and Muskgrave Creek is 29 square miles. It had an estimated runoff of 15-20 TAF/yr in the 1970s, some pecolating into groundwater and some flowing into Meiss Lake (DWR 1973). Again assuming that at least 1,200 AF/sq.mile is available for recharge or runoff, an additional 20 – 25 TAF/yr of recharge occur within the Meiss Lake drainage areas, at a minimum.

Precipitation over the Basin itself provides a small amount of direct recharge into the Basin groundwater system (also see Section 2.2.1.7). Irrigation return flows and the occasional flooding provide some limited additional recharge within the Basin. Hence, most groundwater "recharge" to the Basin is groundwater inflow along its southern and western boundaries.

Groundwater outflow from the Basin includes groundwater pumping (for consumptive crop water use) and subsurface outflow into the fractured volcanic rocks of the Mahogany Mountain ridge at the eastern and northeastern boundary of the basin. The subsurface outflow eventually discharges toward the outflow points of the larger regional UKB groundwater flow system (Tule Lake, Klamath and Lost River areas). No gaining stream reaches exist within the Basin. The major surface water feature of the Basin, Meiss Lake, sits atop a low permeable clay layer and is fed by small creeks and groundwater pumping.

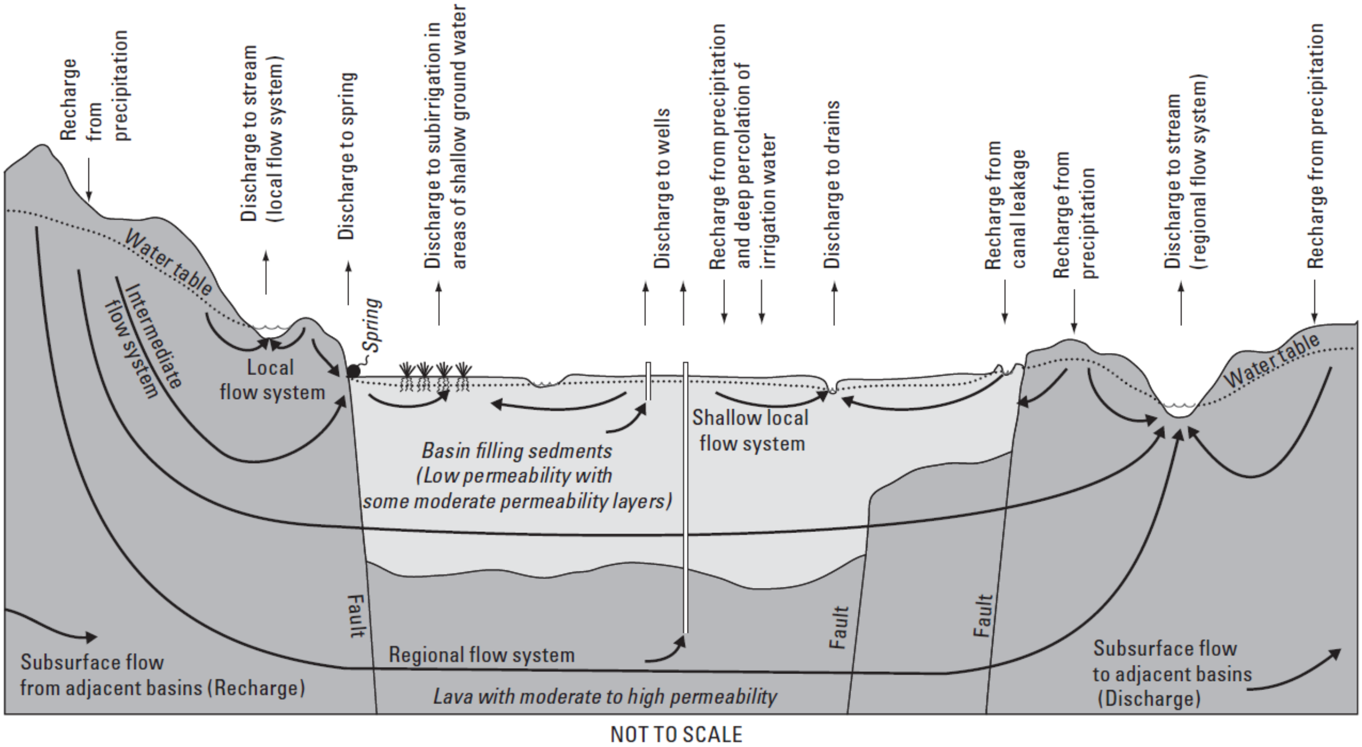


Figure 2.20 (*from Gannett et al., 2010*): Schematic representation of sources of ground-water recharge, flow paths, and mechanisms of ground-water discharge in the upper Klamath Basin, Oregon and California.

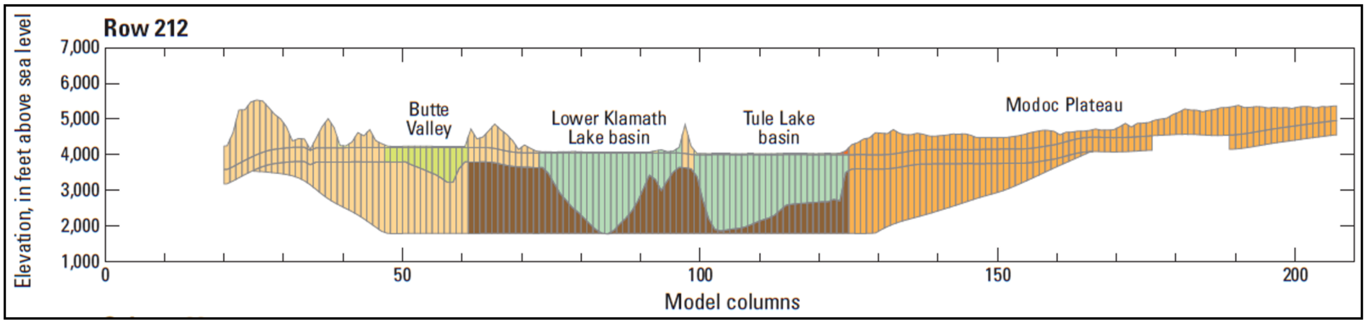


Figure 2.21 (*from Gannett et al., 2012*): Simplified conceptual geologic west-east cross-section through the southern Upper Klamath Basin (UKB), as implemented in a USGS MODFLOW model of the UKB. The Butte Valley sedimentary groundwater basin is shown in light green, the sedimentary groundwater basins of the Lower Klamath Lake basin and Tule Lake basin are shown in dark green, mixed tertiary sedimentary and volcanic deposits in dark brown, and western and eastern tertiary volcanic deposits in beige and orange, respectively.

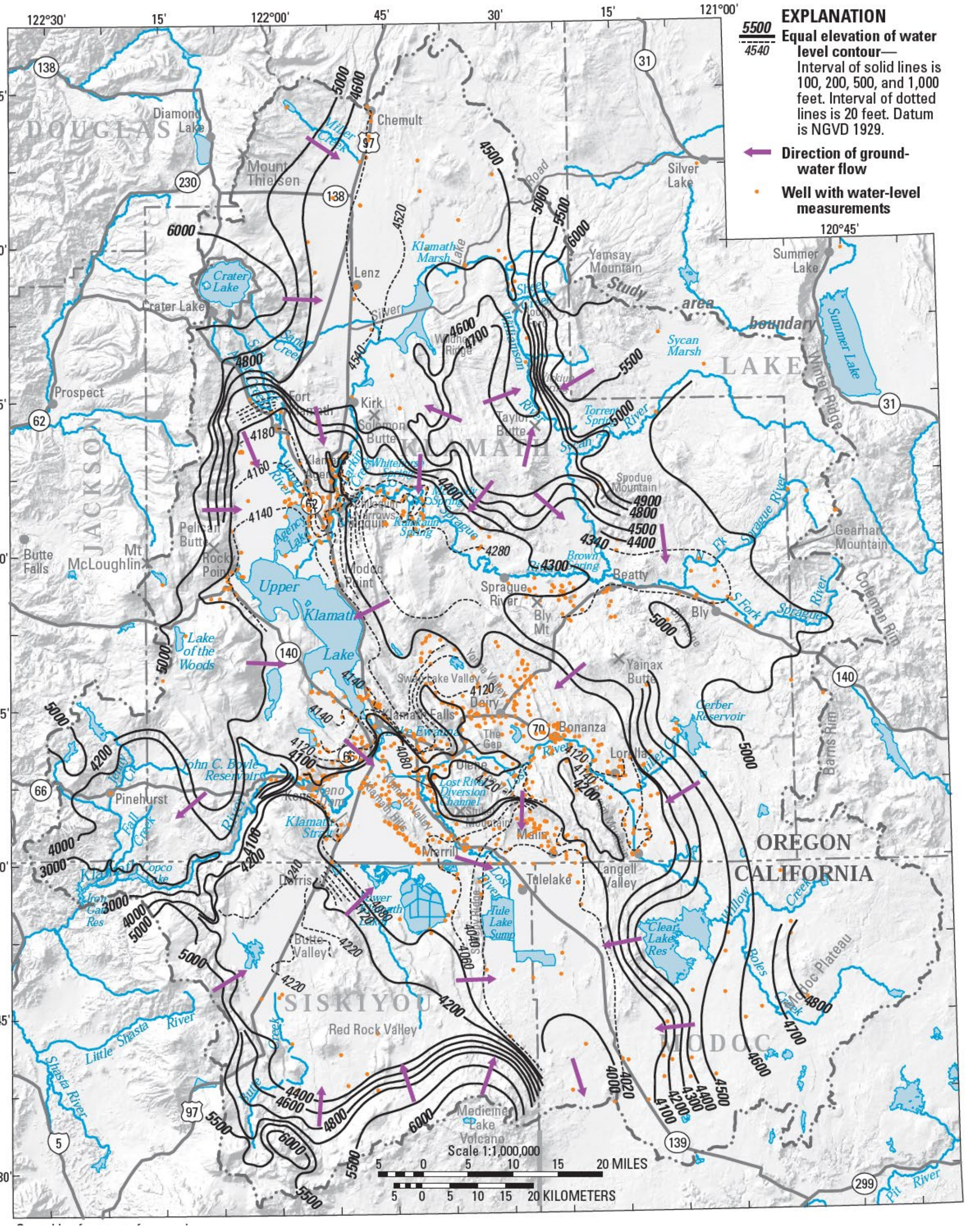


Figure 2.22 (*from Gannet et al., 2010*): Generalized water-level contours and approximate directions of regional groundwater flow in the Upper Klamath Basin (UKB), Oregon and California. The Butte Valley groundwater basin ("Basin") is located in the southwest corner of the UKB. Major recharge areas are located in volcanic uplands to west, south, and southeast of the Basin. Groundwater flows through the Basin to the east and northeast. Hydrogeologically, the Basin is a sub-basin of the larger volcanic-sedimentary UKB groundwater system.

2.2.2.2 Development of Groundwater Resources

Butte Valley's developed land is predominantly used for agricultural production. Development of groundwater as a major source of irrigation was critical for settlement in the Basin. Beginning in 1852, immigrant trains on the Yreka Trail reached Yreka in Shasta Valley by passing through Butte Valley. Nicknamed the "Desert," a lack of water prevented settlement in Butte Valley for many years (County of Siskiyou 1996). In the 1860s and 1880s, homesteads began to be established in Butte Valley (Kit Novick 1996). In 1862, Butte Valley had some ranching activity and the west side of the Valley was harvested for natural grass hay. In 1876, field crops grown along Butte Creek included timothy, red top, oats for hay, wheat and barley. In 1903, alfalfa hay and grain were grown via dry-land farming on 11,000 acres (44.5 sq km) (County of Siskiyou 1996). Settlement in Butte Valley occurred in 1906 when William MacDoel bought 30,000 acres (121 sq km) of land, which he cut up into small farms and sold to experienced German-American Baptist farmers from Iowa and other Midwest states (USDA 1994; County of Siskiyou 1996). However, Butte Valley saw limited agricultural development due to a lack of major surface water and failure of various plans to develop groundwater and surface water irrigation systems (French 1915; County of Siskiyou 1996). Many of these initial farmers left Butte Valley discouraged, impoverished, or bankrupt (USDA 1994; County of Siskiyou 1996). In 1920, the United States Bureau of Reclamation (USBR) attempted to channel surface water from Antelope, Butte, and Bear Creeks to Macdoel, but the project failed. The Butte Valley Irrigation District (BVID) formed in 1921 and currently manages land west of the cities of Macdoel and Mount Hebron. BVID completed a project in 1923 to divert Shovel Creek to irrigate farmland but the creek went dry and most farmers lost their land and left Butte Valley. BVID drilled the first irrigation well in 1929 and has continued to drill groundwater wells as surface water resources have decreased. Since the successful development of deep groundwater wells in 1952, in BVID hundreds of acres of farmland were developed to grow alfalfa, grains, and potatoes (County of Siskiyou 1996). Private groundwater drilling for irrigation spread outside BVID as the technology became more easily accessible. From 1926 to 1994, more than 210 irrigation wells were constructed in Butte Valley. Of the 38 irrigation wells constructed from 1980 to 1994, 20 were drilled in the High Cascade Volcanics water bearing formation and 18 in the Butte Valley Basalt and/or Lake Deposits water bearing formations (Kit Novick 1996).

The development of groundwater resources encouraged agricultural expansion, mostly between the 1950s and 1970s: where 1954 had 12,000 irrigated acres (48.6 sq km; 15% of Basin area), 1970 had 27,700 irrigated acres (DWR 1973), 1976 had 27,500 irrigated acres (111 sq km) (35%), and 2010 had 28,100 irrigated acres plus nearly 3,300 acres of fallow land in rotation with strawberry nursery production (see Section 2.1.1.1, County of Siskiyou 1996; DWR 2010). The agricultural expansion increased groundwater pumping demand for irrigation (County of Siskiyou 1996; Wood 1960). Within Butte Valley, from 1953 to 1979 to 1991, groundwater extraction increased from 22,200 AF (total irrigation: 29,100 AF on 10,400 acres, Wood, 1960) to 62,000 AF to 81,000 AF (on reportedly 45,000 acres, DWR 1998) (2.7E+07, 7.6E+07, 1.0E+08 m3), respectively (DOI 1980; DWR 1998). For comparison, the annual surface water supply in 1998 was about 20,000 AF (2.5E+07 m3). In 1998, the agricultural applied water demand was roughly 2.2 AF/acre per year (0.66 m/yr), of which 1.8 AF/acre (0.54 m/yr) stems from groundwater. In 1998, DWR proposed that total irrigated acreage and water demand in Butte Valley had reached its maximum because nearly all arable land in the Valley was in production (DWR 1998).

2.2.2.3 Groundwater Elevation

Overview

Groundwater levels in Butte Valley show short-term seasonal fluctuations in response to summer pumping and winter recharge and long-term fluctuations in response to wet and dry precipitation cycles (DOI 1980). Historically, the volume of extracted groundwater depends on the availability of surface water, where wet years demand less groundwater compared to dry years (DWR 1998). At the 1980 and 1998 rates of groundwater extraction, groundwater levels and storage decline during years with below average rainfall, but recover during years with average or above average precipitation (DOI 1980; DWR 1998). Current spring groundwater levels have dropped from near ground surface at the beginning of the 20th century to 50 feet (15 m) bgs at the town of Macdoel near the south edge of the Basin (see below). The central and northwest portion of the Basin is still largely undeveloped with relatively shallow water levels between 10 and 40 feet (3.5 and 12 meters) bgs, possibly owing to the National Grassland and the BVWA which together account for roughly 40 percent of the land in Butte Valley.

A limited number of groundwater wells in Butte Valley have been mapped to their connecting water-bearing formation, which includes the three main formations, High Cascade Volcanics, Butte Valley Basalt, and Lake Deposits. Wells that tap into the High Cascade Volcanics are generally limited to the Valley edges, and Butte Valley Basalt wells are limited to the extent of the basalt flow in the south side of the Basin (Figure 2.23). Wells that tap into the Lake Deposits are situated within the Basin floor.

Elevation and Flow Direction

Historical Conditions (1880 - 1979)

Groundwater conditions in the early 1900s provide some observations of the groundwater supply before major settlement in the Basin. In 1907 Butte Valley had a shallow water table with groundwater depths between 1 to 10 ft (0.3 to 3 m) bgs but was typically at 4 to 6 ft (1.2 to 1.8 m) depth (USDA 1909, French 1915).

Springs in Butte Valley were evidence of a confined potentiometric surface above ground surface and occurred in the town of Macdoel and on the hillside south of Meiss Lake (formerly Butte Lake) (USDA 1909; Wood 1960). Bubbling springs were active in the basalt outcrops near Macdoel. Springs near Macdoel had an average 200 parts per million (ppm) dissolved solids. Butte Creek was observed to quickly sink underground soon after entering Butte Valley (named the Butte Creek Sink) but provided irrigation water for several hundred acres of alfalfa, timothy, clover, and grain crops. Following early settlement in 1880 alfalfa crops drew water directly from shallow groundwater (USDA 1909).

As late as the 1960s artesian wells existed near Meiss Lake, suggesting a potentiometric surface existed above ground level in that part of the Basin. Springs existed along the western edge of Butte Valley (Wood 1960). In spring 1979, wells near Meiss Lake (46N/2W-9R1, 9R2, 9N, and 16N1) were observed to flow with potentiometric heads above ground level (DOI 1980). Meiss Lake received regular surface flows from Prather Creek and Muskgrave Creek, however Butte Creek had been sufficiently appropriated and diverted that flows terminated near the town of Macdoel (Wood 1960).

As of 1998 at least two springs still flowed on Holzhauser Ranch on the Butte Valley floor in Sam's Neck approximately 4.5 miles north of Meiss lake. During a groundwater pumping test performed in 1998 at Meiss lake, spring discharge was observed to decrease in the Holzhauser Ranch South Spring from 4.1 gallons per minute (gpm) to 3.7 gpm, a 10% decrease (DWR 1998).

The best qualitative historical assessment of groundwater in Butte Valley is based on observations completed in May 1954 (Figure 2.23). Groundwater flow was eastward and northeastward across the Basin into buried talus and volcanic rocks in the Mahogany Mountain ridge. Groundwater likely flowed through the ridge to supply groundwater flow to the neighboring groundwater basins. East of Dorris, groundwater gradients ranged from 30 to >70 feet per mile toward Mahogany Mountain ridge. The steep gradient may have been caused by barriers to flow due to faulting or a sudden increase in vertical permeability at the northeastern and eastern margin of the lake deposits, where groundwater flows into the High Cascade volcanics of the Mahogany Mountain ridge. Groundwater discharged northeastward and eastward from the Basin move through the fractured volcanic rocks in the Mahogany Mountain ridge or along fault zones toward Lower Klamath Lake and areas to the east. Depth to water table at the Basin boundary southeast of Dorris ranged from 60 to 90 ft (18 – 27 meters) (Wood 1960).

In 1954, the groundwater gradient southwest of Mount Hebron was about 20 feet per mile northeastward (Figure 2.23). Between the towns of Mount Hebron and Macdoel the groundwater surface was nearly flat as the water moved through the highly permeable Butte Valley Basalt. Groundwater in the Lake Deposits water bearing formation northeast of Meiss Lake had a gradient from less than 2 to about 5 feet per mile, increasing to about 10 feet per mile near Cedar Point, at the margin of the Basin (Wood 1960). Local groundwater depressions from irrigation wells occurred in two areas, near Macdoel and west of Inlow Butte.

In 1954, in the west central part of the valley, the groundwater surface sloped gently away from Meiss Lake (Figure 2.23). The lake originally occupied a topographic depression west of its present location, where it was supplied in large part by groundwater seepage and its surface reflected the general level of the adjacent groundwater surface. An earthen dike constructed on higher ground east of the original lake bed bounds the west shore of the current lake, where water has been pumped from the original lake bed and allowed to spread over poorly productive land. The original lake bed is currently cultivated, but being an area of natural groundwater discharge, it must be kept drained to prevent waterlogging. Seepage loss from the present Meiss Lake is restricted by clayey lake deposits which underlie that part of the Basin (Wood 1960).

Current Conditions (1979 - 2020)

Groundwater levels have a seasonal high in the spring and seasonal low in the fall. Groundwater recharge is dependent on the annual precipitation, which has been experiencing a decline in Butte Valley since the early 1980s, as shown in Figure 2.9. The average annual rainfall for the period 1942-1997 was 12.15 in (30.9 centimeters (cm)) (DWR 1998), while decreased precipitation in the past 20 years has brought the average annual rainfall for the period 1979-2020 down to 8.1 in (20.7 cm) per year as shown in Figure 2.9. Rainfall in both “wet” and “dry” years has decreased in the past 50 years.

In 1979, seasonal water-level fluctuations for wells in the High Cascade Volcanics ranged from no change to about 17 ft (5.2 m) and groundwater wells in other water-bearing units ranged from a few feet to about 25 ft (7.6 m) (DOI 1980). As shown in Figure 2.24, groundwater primarily flows toward Dorris, with low gradients in the middle of the valley and high gradients near Dorris. Groundwater levels and gradients are poorly constrained between Macdoel and Mount Hebron due to lack of data.

Chronic lowering of water levels has been observed since 2000, in some wells since the early 1980s. From the spring of 1979 to the spring of 2015, groundwater levels have dropped roughly 30 feet (Figure 2.24 and Figure 2.25). The 2014-2015 water year is the most recent year in Butte Valley with above average annual precipitation, at 9.96 inches Figure 2.9. In 2015, the groundwater gradient in the northeast part of the valley is poorly constrained due to the lack of groundwater data immediately southwest of Dorris. Groundwater gradients in the spring of 2015 are shallow near Macdoel and Mount Hebron due to the highly permeable Butte Valley basalt. Groundwater levels near Meiss Lake are poorly constrained due to lack of data. From the fall of 2014, the seasonal low, to the seasonal high in spring of 2015, groundwater levels vary between 0 to 20 ft, with the least change in the Butte Valley National Grasslands and greatest changes near Dorris, Macdoel and Mount Hebron. Water levels and changes over time are shown on Appendix 2-A.

Historic vs Recent Water Level Dynamics: Review of Long-term Hydrographs

Groundwater levels were relatively stable throughout the Basin during the 1950s, 1960s, and 1970s, where long-term records are available (wells with identifiers WSE418994N1219**643**W, WSE418994N1220**269**W, 418512N1219**183**W, WSE417944N1220**350**W, WSE 417920N1220**617**W, DWR SGMA Data Viewer, 2024). Groundwater pumping and extended drought periods from the mid-1940s to 1950s, late 1980s to mid-1990s (DWR 1998), and frequently since 2001 (only 8 of 23 years with average or above average precipitation, **Figure 2.9**) are major drivers of interannual declines in water levels.

Well “643” is located along Hwy 97, at the eastern edge of the Butte Valley National Grasslands. Water levels in the early 1950s were measured at 12 ft to 16 ft bgs (4222 ft amsl). Water levels rose to less than 10 ft bgs during most of the 1970s. Since 1990, water levels have steadily declined to 23’ bgs in 2023 (4214 ft amsl), slightly recovering in 2024.

Well “269” is located 3.3 miles to the west of well “643”, in the central-west portion of the National Grasslands. Water levels in the early 1950s were measured at 13 ft to 14 ft depth (4228 ft amsL), gradually rose to 1.6 ft bgs in 1975, declined to 10 ft bgs in 1995, rose to 4.5 ft bgs by 1999, and since gradually declined to 15 ft in 2024 (4226 ft amsl), exceeding historical low levels of the early 1950s since 2021.

Well “183” is located 3.8 miles due southeast of well “643”, in the eastern-central agricultural area of Butte Valley, east-northeast of Macdoel. Water levels in the early 1950s were at 22 ft bgs (4224 ft amsl) and rose to less than 20 ft bgs during the late 1950s. Spring water levels remained near 20 ft bgs through the mid-1970s (1975: 17.5 ft bgs), then declined into the early 1980s, and again during the late 1980s and early 1990s. Recovery of spring water levels reached 24 ft bgs in spring 1984, 32 ft bgs in spring 2000, and has gradually declined since then (spring 2021: 53 ft bgs, 4193 ft amsl).

Well “350” is located along Hwy 97, 2.8 miles southwest of the town of Macdoel. Spring water levels in the early 1950s were 31 ft bgs (4229 ft amsl) and rose to 23 ft bgs by the late 1950s and again in 1975. No records exist for the 1980, but spring water levels had declined to 50 ft bgs by 1993, recovering to 35 ft bgs in 2000. Since then, spring water levels have steadily declined, reaching 71 ft (4189 ft amsl) in spring 2024 (with an unusual albeit brief recovery during 2022 and 2023).

Well “617” is located 1.5 miles to the west of well “350”, at the western margin of the irrigated area. Spring water levels in the early 1950s were at 23 ft bgs (4236 ft amsl) and rose slightly to 20 ft bgs by the late 1950s. No measurements exist for the 1960s and 1970s, but spring water levels were at 20 ft bgs in the late 1970s, reached a high of 17.5 ft bgs in the mid-1980s. After declining in the early 1990s to 41 ft bgs (spring 1995), recovery in the late 1990s reached 21.5 ft in spring 1999. After 2000, spring water levels have been steadily declining, with a recovery to 30’ bgs in spring of 2015, reaching a low of 45 ft bgs in spring 2024.

Wells with more recent measurements (since the late 1970s) also show declines in water levels during early 1980s (recovery by mid-1980s), a more significant decline in water levels during drought of the late 1980s and early 1990s with recovery during the wet years of the late 1990s and a general chronic decline since 2000 with sometimes brief recoveries around 2012 and in the late 2010s or around 2020.

Wells near the northern and northeastern margin of the basin have exhibited relatively stable conditions over the past ten years after significant declines post-2000:

WSE419451N1218967W, located near the northeastern boundary of the basin, 1.7 miles southeast of Dorris, had gradually declined from 89 ft bgs in spring of 2000 (4165 ft amsl) to 113 ft bgs (4141 ft amsl) in spring of 2015, but has since stabilized between 100 and 108 ft bgs.

WSE419803N1219570W, located 2.3 miles northeast of Dorris, declined from 62 ft bgs (4201 ft amsl) in spring 2000 to 96 ft bgs (4166 ft amsl) in spring 2013 and has since stayed above that level.

WSE419755N1219785W, 3.3 miles west of Dorris, declined from 42 ft bgs (4217 ft amsl) in spring 2000 to 65 ft bgs (4194 ft amsl) by spring 2017, dropped to 86 ft bgs in 2020 and recovered to 70 ft bgs (4189 ft amsl) since then.

From 1976 to 1977, BVID deepened irrigation wells to increase groundwater resources during a drought. In Spring 1979, the average depth to groundwater in the unconfined system was 25 ft (7.6 m) with a range of 6-48 ft (1.8-14.6 m). The average depth to groundwater in the confined system was 33 ft (10.1 m) with a range of 9-83 ft (2.7-25.3 m) (DOI 1980). Groundwater elevations during the 1980-1981 drought were low enough that BVID had 14 out of 28 wells either dry or surging. From 1983 to 1992, the water table dropped an average of 16 ft (4.9 m) (County of Siskiyou 1996).

Groundwater levels at five different wells from different areas of Butte Valley are shown in Figure 2.26. The hydrographs are characteristic of the overall patterns describe above: relatively stable water levels in the 1970s, a brief decline and partial recovery of water level around 1980, declining water levels during the drought of the late 1980s and early 1990s with strong recovery during the late 1990s, followed by chronic lowering of water levels since 2000, with brief recoveries during the few wetter periods of the past 24 years.

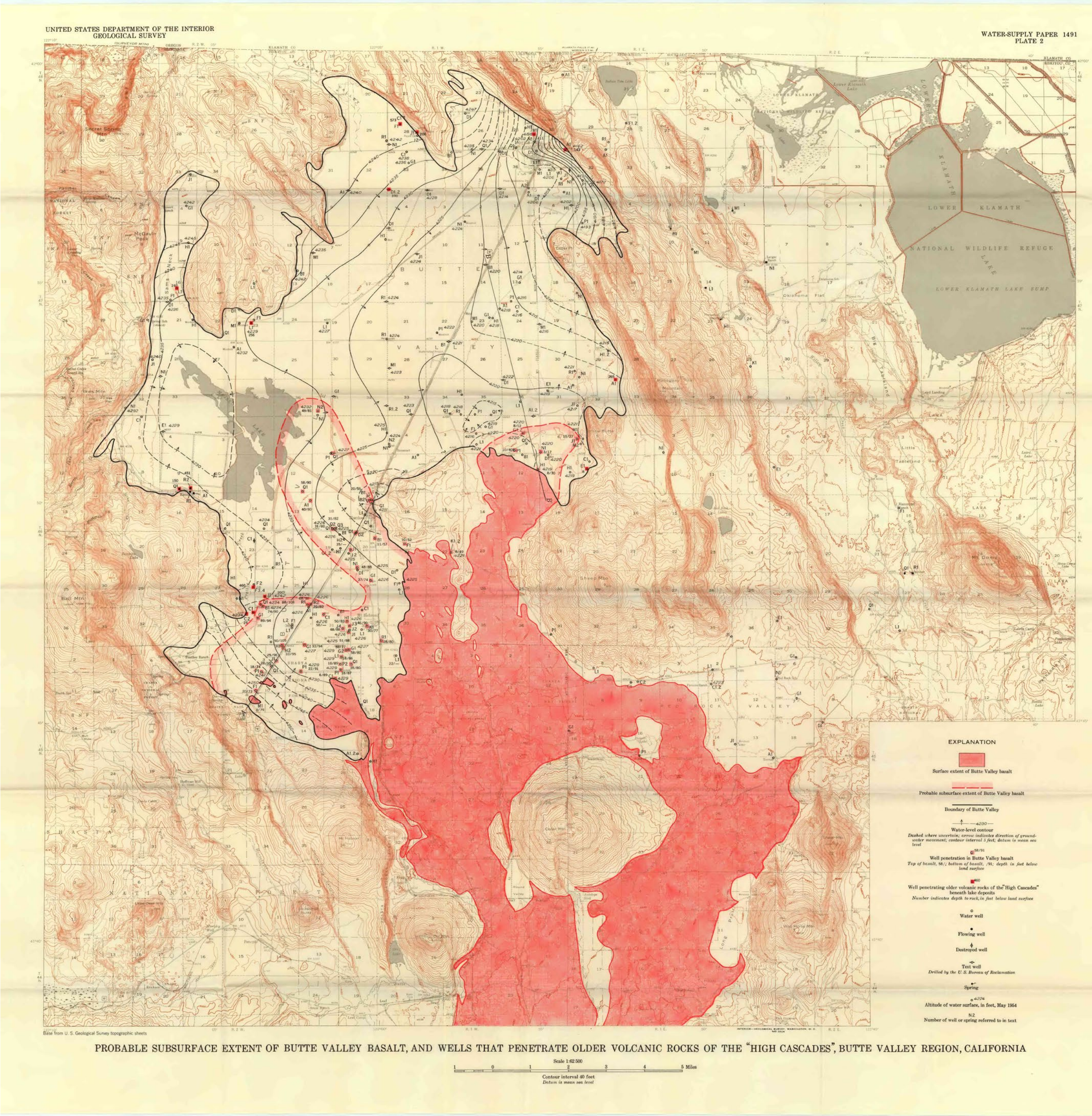
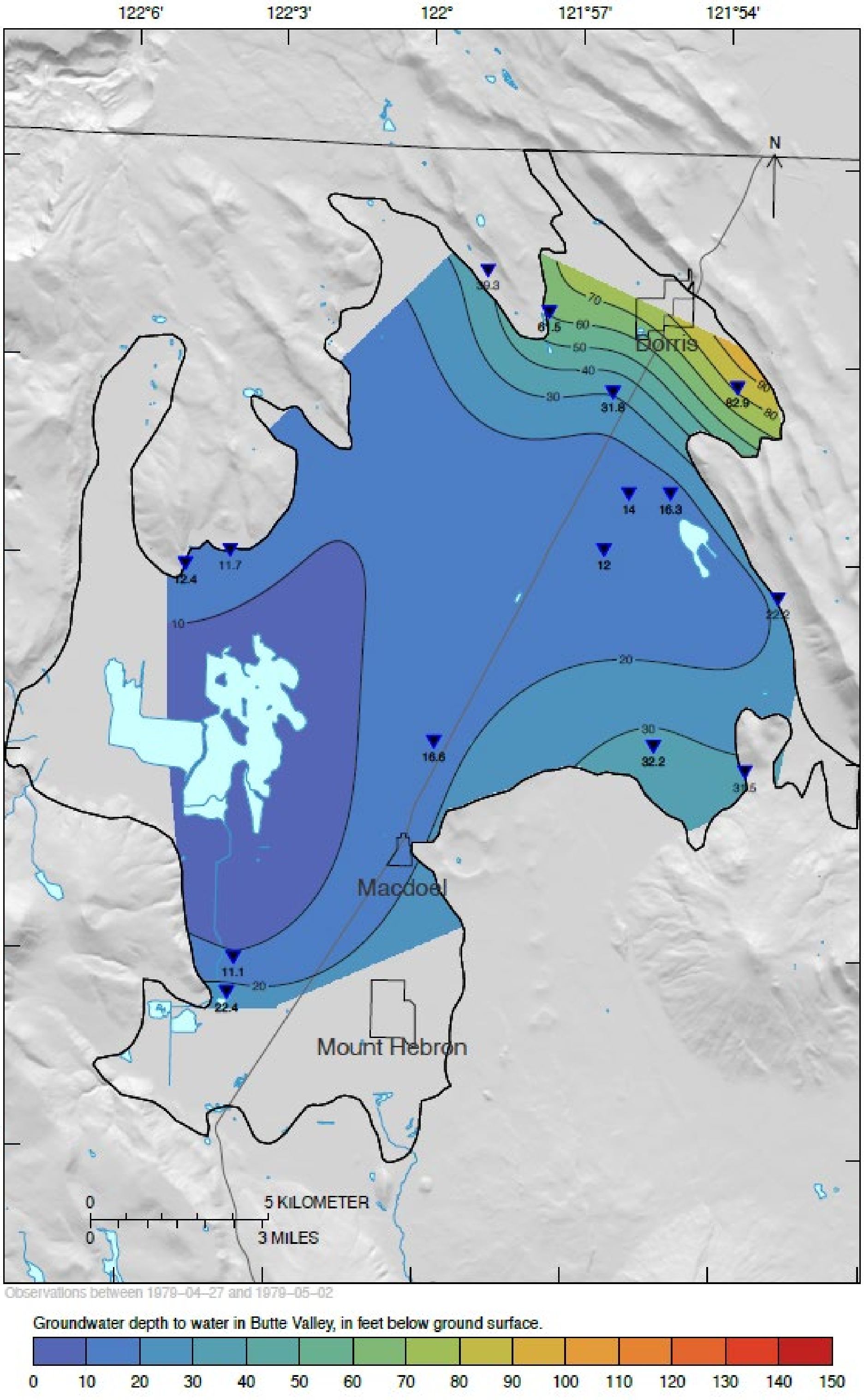


Figure 2.23: Groundwater elevations and flow based on observations during the first week of May 1954 (Wood 1960). The image is high quality so text can be distinguished when zoomed in.



Observations between 1979–04–27 and 1979–05–02

Figure 2.24: Butte Valley Depth to Groundwater, Spring 1979

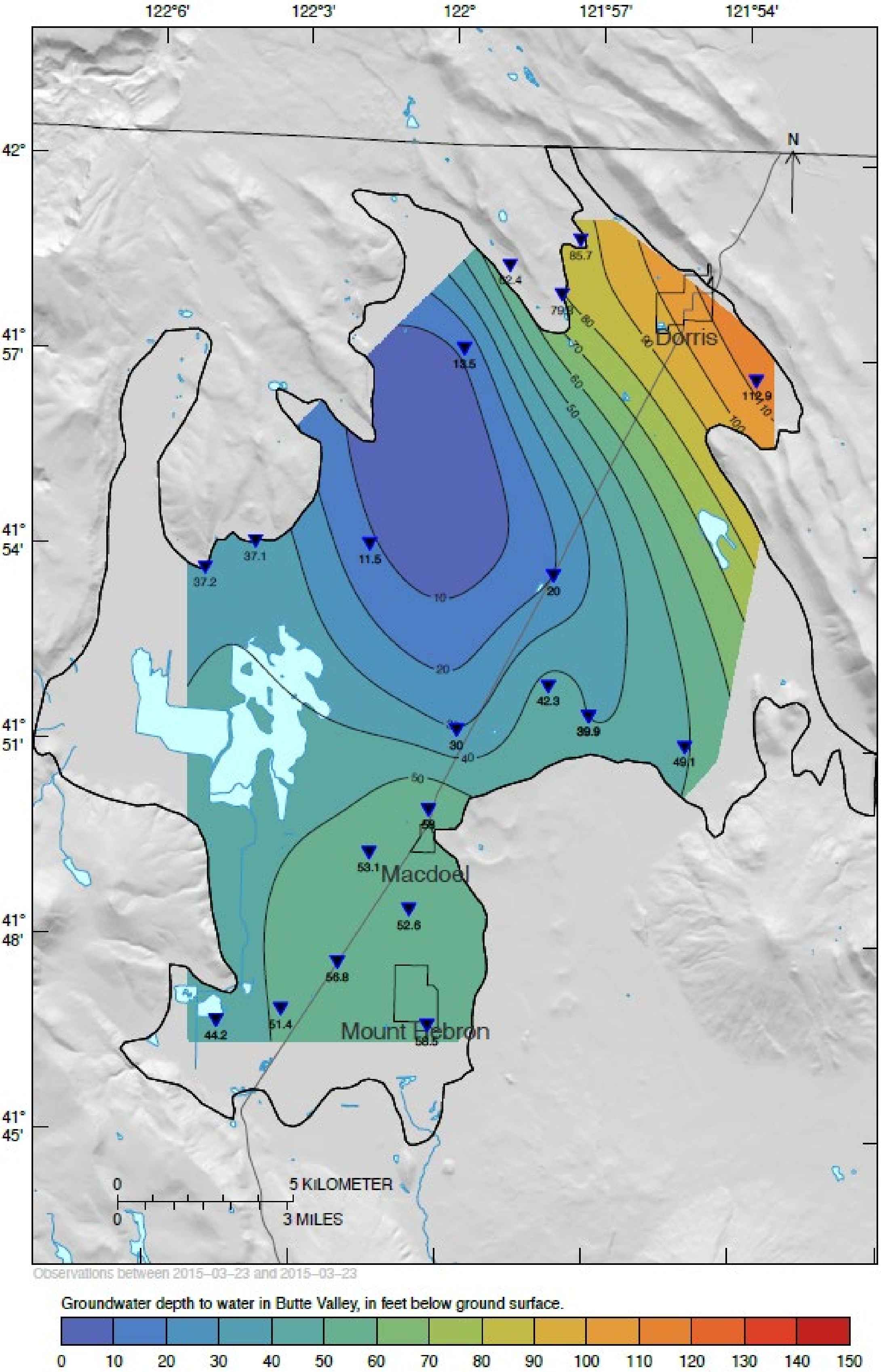


Figure 2.25: Butte Valley Depth to Groundwater, Spring 2015

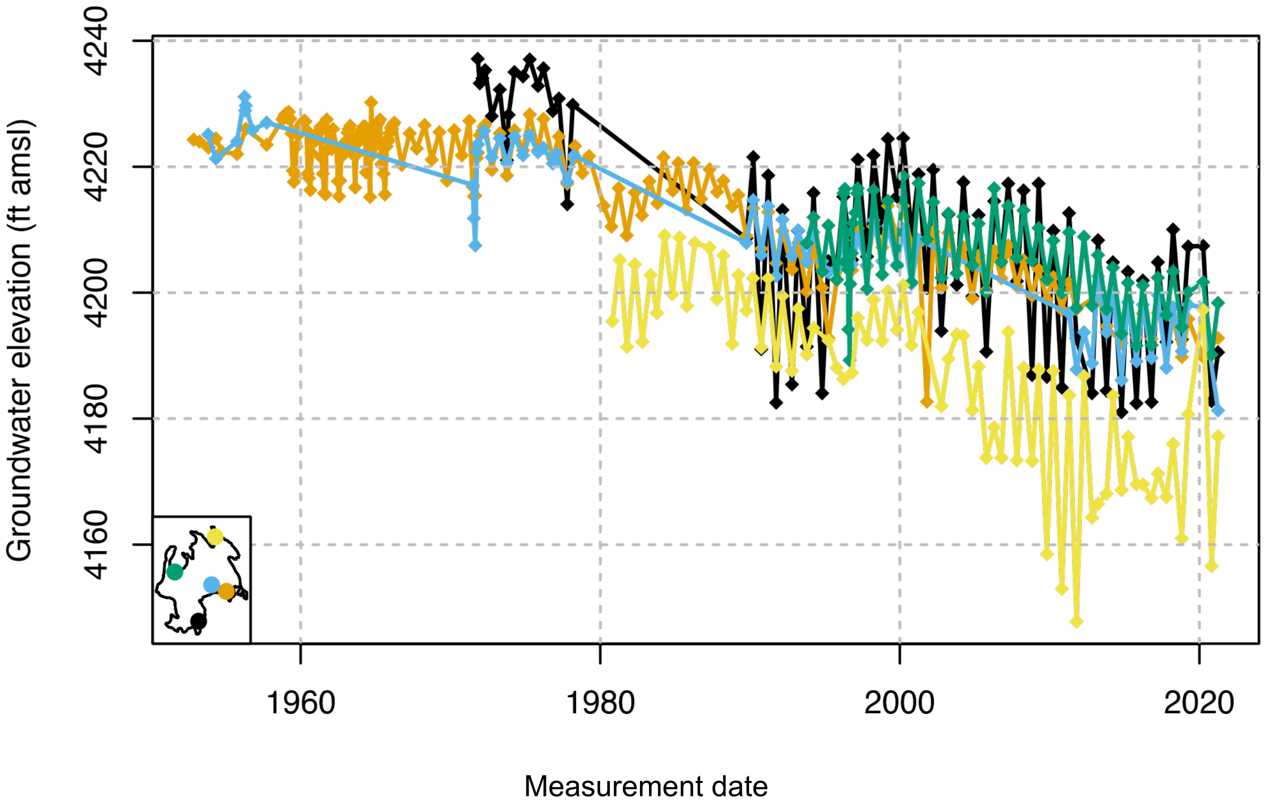


Figure 2.26: Groundwater elevation measurements over time in five wells, one located in each hydrogeologic zone.

2.2.2.4 Estimate of Groundwater Storage and Groundwater Storage Changes

Due to the complexity of the Basin and interbedded nature of alluvial, fluvial, and volcanic deposits within the major aquifer subunits, DWR could not provide an estimate of groundwater storage (DWR 2019d). Most wells in the Basin produce water from the underlying volcanic rock and some wells extract water from the overlying Lake Deposits. All units are hydrologically interconnected and DWR was unable to assign a reasonable specific yield to the volcanic units (Wood 1960; DWR 2004). The High Cascades Volcanic unit is the main unit for both recharge and storage in the Basin (Wood 1960). However, the depth and extent of the unit, which also extends well beyond the Basin boundaries, is not well defined.

A specific yield and storage capacity can be estimated for the unconfined units: Lake Deposits, pyroclastic rocks, and Butte Valley Basalt (DOI 1980). The weighted average specific yield for the unconfined units is calculated to be 9.5% and total groundwater storage capacity is 2,560,000 acre-feet. Specific yield in two well tests by California DWR measured 2% and 13%. Confined storage coefficients in those tests, for wells completed in the High Cascade Volcanics, measured 0.001 to 0.002 (DWR 1998). Specific yield and storativity have also been estimated using the Butte Valley Integrated Hydrologic Model (BVIHM), as described in Section 2.2.3.

Changes in groundwater storage are computed using the reported average Basin specific yield of 9.5% (see above), which is multiplied with the total volume of the aquifer within the Basin that is drained or filled over a specified period of time (DWR, 2013). That volume is obtained as the difference in the water level surface across the basin between two specified years or seasons.

The GSA has employed **two different interpolation methods** to compute a water level surface for a specified year and season (fall or spring of a given water year) from the available water level elevations at monitored wells (including the RMPs):

1. Nonlinear, continuous interpolation using Thin Plate Spline. This method provides for a realistic, continuously distributed mapping of water table depth and water level elevations (e.g., Figures 2.24, 2.25), but is subject to selection of the interpolation method and its parameters.
2. Extrapolation of the water level elevation at a measurement point to the entire Thiessen polygon area associated with that measurement point, yielding a stepwise water level distribution for purposes of computing the aquifer volume filled or drained during a given time period (Figure 2.27). This is a simplified approach that makes a “naïve” (i.e., parameter-free) interpolation of water levels, yet provides a reasonable estimate of storage change across the basin, not dissimilar to any other interpolation method.

The GSA has also used **two different seasons** to compute year-over-year or long-term groundwater storage changes: spring and fall. Spring water levels are recommended by DWR (2013) for computation of storage changes due to absence of water level bias from large well pumping, as spring water levels are measured at the end of the non-pumping season, immediately prior to the year’s irrigation season. Year-over-year fall water level changes provide storage changes that coincide mostly with the duration of a water year.

For the GSA’s previous annual reports (WY2021 and 2022), fall-to-fall change in groundwater elevations were used to calculate change in groundwater storage at the end of each water year, using the nonlinear interpolation method. However, water level data sampled in the fall are subject to potentially larger interannual changes due to groundwater pumping, different periods of short-term recovery from groundwater pumping, and other very localized effects that provide strongly biased results with either water level interpolation method. For groundwater storage change calculations, spring-to-spring change in groundwater levels will be preferable with water levels being regionally more representative and absent of local residual cones of depression. Using spring-to-spring changes in water level also aligns with recommended storage change estimation methods from DWR (DWR 2013).

The calculation has now been updated by using the Thiessen polygon (Voronoi polygon) method of water level extrapolation. A Thiessen polygon identifies the areal extent of the Basin that is closest to a given well. The area of each Thiessen polygon is multiplied by the change in water level at each well to calculate the change in the volume of saturated aquifer thickness. The change in saturated aquifer thickness was then multiplied by the average specific yield for the aquifer material in the Bulletin 118 Groundwater Basin (see equation below). A conceptual illustration of measured wells with their identified Thiessen polygons in Butte Valley groundwater basin is shown in Figure 2.27. Furthermore, a set of wells with consequential spring measurements throughout the recent years is used in the new Thiessen polygon approach to ensure that a more consistent set of measurements is used for the change in storage calculation, which should help avoid variability between years.

$$Annual\ \Delta Storage\ = \sum \Delta Storage\ (polygon)_i = \sum (Area_i \times S_y \times \Delta Head_i)$$

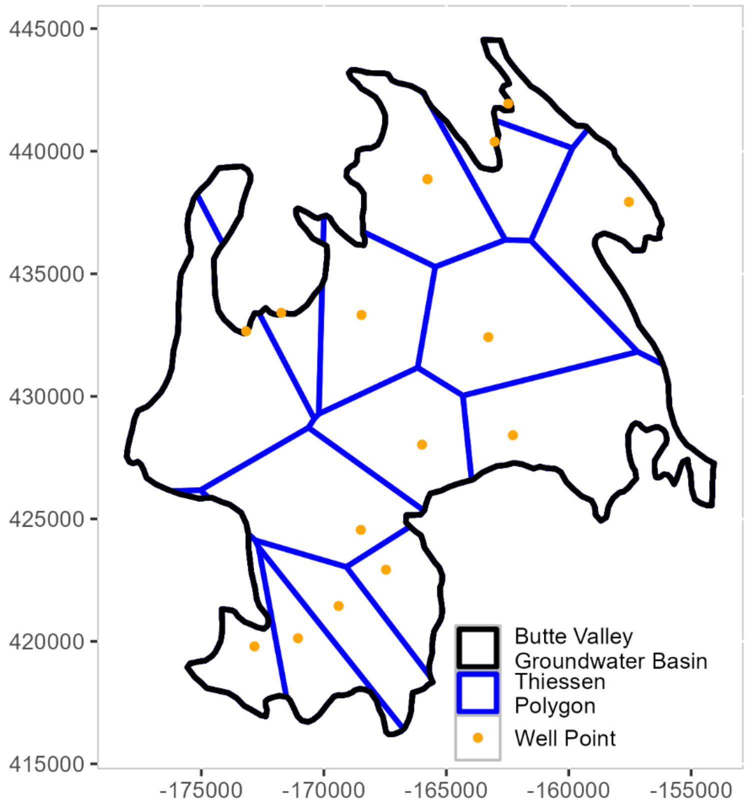


Figure 2.27: Concept of well points and their Thiessen polygons identified (cropped to Bulletin 118 boundary) in Butte Valley groundwater basin

Analysis of Groundwater Storage Changes in 2021, 2022, and 2023

Table 2.5: Groundwater storage changes computed using Fall-to-Fall (F) changes in water levels vs. Spring-to-Spring (S) changes in water levels and using nonlinear interpolation vs. stepwise extrapolation across Thiessen polygons.

WY	Calculated period	Approach	Change in Storage (TAF)	Water Level Surface Estimate by	In GSP Annual Report?
2021	Fall-Fall	GWL based	-28 (-118)*	Nonlinear interpolation	Yes
2022	Fall-Fall	GWL based	-11	Nonlinear interpolation	Yes
2021	Spring-Spring	GWL based	-12	Nonlinear interpolation	No; New analysis
2022	Spring-Spring	GWL based	-6	Nonlinear interpolation	No; New analysis
2023	Spring-Spring	GWL based	2	Nonlinear interpolation	No; New analysis
2021	Spring-Spring	GWL based	-18	Thiessen polygon	No; New analysis
2022	Spring-Spring	GWL based	-12	Thiessen polygon	No; New analysis
2023	Spring-Spring	GWL based	3	Thiessen polygon	No; New analysis

Note: * Value in paratheses is the number with unit conversion error that was reported in WY 2021 Annual Report. The corrected WY 2021 change in storage has been reflected in the WY 2022 Annual Report.

In Butte Valley WY 2021 Annual Report (County of Siskiyou 2022), a total change in groundwater storage (fall to fall) of -118 TAF was reported. Through a review of historic annual report development, a unit conversion error was found in the WY2021 report, which resulted in a storage change 3.2808 times the true size based on the fall water level measurements used at the time and due to an outlier water level measurement. The error was addressed in the WY2022 report, showing that the actual groundwater storage change to report for WY2021 (fall to fall) was -28 TAF, after also correcting for an outlying water level measurement (Figure 14, County of Siskiyou 2023).

Hence, the annual groundwater change, using nonlinear water level interpolation, yielded -28 TAF (F2021) and -11 TAF (F2022). For the same years, spring measurements and using nonlinear interpolation estimated storage changes at -12 and -6 TAF for S2021 and S2022, respectively, and at +2 TAF for S2023. Using the Thiessen polygon approach instead yielded -18, -12, and +3 TAF of groundwater storage change in 2021, 2022, and 2023, respectively. The results of the different approaches (fall-to-fall vs. spring-to-spring, nonlinear interpolation of groundwater levels vs. Thiessen polygon extrapolation) are in reasonable agreement but demonstrate differences in the predicted magnitude of storage change between years. Over the long-term, cumulative storage changes computed with either method are expected to converge.

Long-term Groundwater Storage Changes

Using water level hydrographs that provide spring water levels in the beginning and end year of various longer-term periods since 1990, groundwater storage changes were computed using the Thiessen polygon method over several different periods (Table 2.6). The late 1990s were the last period with significant longer term positive groundwater storage changes. Since 2000 to current, corresponding to what is referred to as the Western U.S. mega-drought (Williams et al. 2020), average groundwater storage decline is estimated to be 6,280 acre-feet/yr. Over the 80,000 acre Basin with an average specific yield of 9.5%, this corresponds to an average annual water level decline of 0.8 ft/yr in 2000-2024, i.e., consistent with observed hydrographs. The highest single-year decline has been observed in 2020-2021, when water levels declined by nearly 18,000 acre-feet in a single year.

The average storage decline since 1990 is 4,200 acft/yr, totaling 142,000 ac ft of storage loss.

Table 2.6: Average annual groundwater storage changes, in acre-feet per year, spring to spring over the period indicated in the first column, based on the number of water level measurements indicated in the 3rd column during both, the start year and end year of the period and using the Thiessen polygon method.

Period (spring to spring)	Period Length in Years	Number of Wells used for Thiessen Polygon Analysis	Groundwater Storage Change [acft / yr]	Period or Water Year Type
1990 - 2000	10	27	799	wetter than average
1990 - 2010	20	at least 12	-2,685	
1990 - 2014	24	20	-4,143	baseline period
1990 - 2024	34	at least 12	-4,198	entire period to date
2000 - 2014	14	21	-7,390	baseline mega-drought
2000 - 2024	24	17	-6,280	mega-drought
2010 - 2024	14	15	-6,359	
2014 - 2017	3	at least 12	-3,211	drought
2014 - 2024	10	at least 12	-4,725	past decade

2017 - 2024	7	12	-5,374	GSA period
2017 - 2018	1	12	4,773	2018 - Below Normal
2018 - 2019	1	12	2,416	2019 - Above Normal
2019 - 2020	1	12	-10,471	2020 - Critical
2020 - 2021	1	12	-17,622	2021 - Critical
2021 - 2022	1	12	-12,191	2022 - Critical
2022 - 2023	1	12	2,976	2023 - Above Normal
2023 - 2024	1	12	-7,502	2024 - Below Normal

2.2.2.5 Groundwater Quality

SGMA regulations require that the following be presented in the GSP, per §354.16 (d): Groundwater quality issues that may affect the supply and beneficial uses of groundwater including a description and map of the location of known groundwater contamination sites and plumes.

Basin Overview

Water quality includes the physical, biological, chemical, and radiological quality of water. The physical property of water of most interest to water quality is temperature. An example of a biological water quality constituent is *E.coli* bacteria , commonly used as an indicator species for fecal waste contamination. Radiological water quality parameters measure the radioactivity of water. Chemical water quality refers to the concentration of thousands of natural and manufactured inorganic and organic chemicals. All groundwater naturally contains some microbial matter, chemicals, and usually has low levels of radioactivity. Inorganic chemicals that make up more than 90% of the "total dissolved solids" (TDS) in groundwater include calcium (Ca^{2+}), magnesium (Mg^{2+}) sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), bicarbonate (HCO_3^{-}), and sulfate (SO_4^{2-}) ions. Water with a TDS concentration of less than 1,000 mg/L is generally referred to as "freshwater." Brackish water has a TDS between 1,000 mg/L and 10,000 mg/L. In saline water, TDS exceeds 10,000 mg/L. Water hardness typically refers to the concentration of calcium and magnesium cations in water.

When one or multiple constituents become a concern for either ecosystem health, human consumption, industrial or commercial uses, or for agricultural uses, the water quality constituent of concern becomes a "pollutant" or "contaminant." Groundwater quality is influenced by many factors – polluted or not – including elevation, climate, soil types, hydrogeology, and human activities. Water quality constituents are therefore often categorized as "naturally occurring," "point source," or "non-point source" pollutants, depending on whether water quality is the result of natural processes, contamination from anthropogenic point sources, or originates from diffuse (non-point) sources that are the result of human activity.

Groundwater in the Basin has been characterized as mixed-cation to magnesium-bicarbonate water, and as sodium bicarbonate water near Dorris. The dissolved-solids content of groundwater in the Basin is commonly less than 360 mg/l, though TDS concentrations have been measured in excess of 1,100 mg/L; locally high TDS values have been attributed to evaporites in localized playa deposits (DWR 1968, 2004). Within Butte Valley, groundwater quality issues have historically included locally high arsenic, iron, manganese, boron, TDS, sodium, calcium, ammonia, hydrogen sulfide, phosphorus, and electrical conductivity (DWR 2004). High TDS and sodium have also been noted in shallow wells with hydraulic continuity to Meiss Lake, where salts from natural inflow and irrigation-return flows are concentrated by evaporation (DWR 2004). The City of Dorris relies on a single groundwater well for water supply, drilled in 1971, which penetrates the volcanic water bearing formations below the lake deposits, reaching a depth of 1, 236 ft (377 m) (Bray & Associates 2015). Previous water supply wells penetrating lake deposits were found to have arsenic levels exceeding the 1962 drinking water standard of 0.05 parts per million (ppm; 1 ppm = 1 mg/L) (DWR 1968). A 1968 DWR investigation suggested the elevated arsenic levels were the result of industrial contamination, the effects of which continue to be an issue in shallow groundwater wells near Dorris (DWR 1968, 2004; Bray & Associates 2015).

Groundwater in the Basin is generally of good quality and has relatively consistent water quality characteristics which meet local needs for municipal, domestic, and agricultural uses. Ongoing monitoring programs show that some constituents, including benzene, 1,2 dibromoethane (EDB), arsenic, and boron exceed water quality standards in parts of the Basin. Exceedances may be caused by localized conditions and may not be reflective of regional water quality. In addition, there are potential risks of increasing salt and nutrient conditions from agricultural and municipal uses of water. Across the majority of the Basin, salt and nutrient concentrations are below levels of concern, with no upward trends. A few isolated areas have higher concentrations.

A report by the NCRWQCB in 2020 prioritized 62 groundwater basins in the North Coast Region with threats to groundwater quality due to excessive salts and nutrients, and categorized Butte Valley as “medium” priority (NCRWQCB and Watt 2020). If accepted by the Regional Board, the categorization will be adopted with Resolution No. R1-2021-0006. Based on the water quality analysis completed by the NCRWQCB, the percentage of wells in the Basin from 2010 to 2020 exceeding 5 mg/L nitrate was 21 - 30%, 10 mg/L nitrate was 10 - 20%, 250 mg/L TDS was 20 40%, and 500 mg/L TDS was <20%. The Basin was assigned a score, for “status and trends in the concentration of salts and nutrients in groundwater,” of 3 out of a range of 1 - 10. Categories in which the Basin had high scores included: hydrogeological basin factor including depth to groundwater and hydrogeologically vulnerable area, reliance on groundwater to supply the basin, and number and density of on-site wastewater treatment systems. The information used in the prioritization process included water quality data from the State Water Board GAMA database and dairy operators under the Waste Discharge Requirements for Dairies (NCRWQCB Order No. R1-20120002), the DWR SGMA Basin Prioritization Process and the seven evaluation factors listed in the Recycled Water Policy (NCRWQCB and Watt 2020).

A summary of information and methods used to assess current groundwater quality in the Basin, as well as key findings, are presented below. A detailed description of information, methods, and all findings of the assessment can be found in Appendix 2-B.

The Water Quality Control Plan for the North Coast Region (NCRWB Basin Plan, NCRWQCB 2018) is the cornerstone regulatory tool for the North Coast Region which sets forth water quality objectives for groundwater (NCRWB Basin Plan Section 3.4). Water quality objectives are the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area. Beneficial uses are not attained when water quality objectives are exceeded. The NCRWB Basin Plan contains groundwater quality objectives for bacteria, chemical constituents, radioactivity, tastes and odors, and toxicity. Groundwater quality objectives are always equal to or more protective than MCLs.

Beneficial uses of groundwater, for purposes of water quality regulations, are defined by the NCRWB Basin Plan. For groundwater, these include “Municipal and Domestic Water Supply (MUN), reflecting the importance of groundwater as a source of drinking water in the Region and as required by the State Board's Sources of Drinking Water Policy [..]. Other beneficial uses for groundwater include: Industrial Water Supply (IND), Industrial Process Water Supply (PRO), Agricultural Water Supply (AGR), and Freshwater Replenishment to Surface Waters (FRSH), among others. Occasionally, groundwater is used for other purposes (e.g., groundwater pumped for use in aquaculture operations).” (NCRWB Basin Plan, page 2-18).

Existing Water Quality Monitoring Networks

Water quality data for at least one constituent – sometimes many - are available for some wells in the Basin but not most. Of those wells for which water quality data are available, most have only been tested once, some have been tested multiple times, and in few cases are tested on a regular basis (e.g. annual, monthly). The same well may have been tested for different purposes (e.g., research, regulatory, or to provide owner information), but most often, regulatory programs drive water quality testing.

For this GSP, all available water quality data, obtained from the numerous available sources, are first grouped by the well from where the measurements were taken. Wells are then grouped into monitoring well type categories. These include:

- *Public water supply wells*: A public water system well provides water for human consumption including domestic, industrial, or commercial uses to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year. A public water system may be publicly or privately owned. These wells are tested at regular intervals for a variety of water quality constituents. Data are publicly available through online databases.
- *State small water supply wells*: Wells providing water for human consumption, serving 5 to 14 connections. These wells are tested at regular intervals – but less often than public water supply wells – for bacteriological indicators and salinity. Data are publicly available through the County of Siskiyou Environmental Health Division but may not be available through online databases.
- *Domestic wells*: For purposes of this GSP, this well type category includes wells serving water for human consumption in a single household or for up to 4 connections. These wells are not typically tested. When tested, test results are not typically reported in publicly available online databases, except when these data are used for individual studies or research projects.
- *Agricultural wells*: Wells that provide irrigation water, stock water, or other water for other agricultural uses, but are not typically used for human consumption. When tested, test results are not typically reported in publicly available online databases, except when these data are used for individual studies or research projects.
- *Contamination site monitoring wells*: Monitoring wells installed at regulated hazardous waste sites and other potential contamination sites (e.g., landfills) for the purpose of site characterization, site remediation, and regulatory compliance. These wells are typically completed with 2 in- (5 cm) or 4 in- (10 cm) diameter polyvinyl chloride (PVC) pipes and screened at or near the water table. They may have multiple completion depths (multi-level monitoring), but depths typically do not exceed 200 ft (60 m) below the water table. Water samples are collected at frequent intervals (monthly, quarterly, annually) and analyzed for a wide range of constituents related to the type of contamination associated with the hazardous waste site.
- *Research monitoring wells*: Monitoring wells installed primarily for research, studies, information collection, ambient water quality monitoring, or other purposes. These wells are typically completed with 2 in- (5 cm) or 4 in- (10 cm) diameter PVC pipes and screened at or near the water table. They may have multiple completion depths (multi-level monitoring), but depths typically do not exceed 200 ft (60 m) below the water table.

Data Sources for Characterizing Groundwater Quality

The assessment of groundwater quality for the Basin was prepared using available information obtained from the California Groundwater Ambient Monitoring and Assessment (GAMA) Program Database, which includes water quality information collected by DWR; SWRCB, Division of

Drinking Water (DDW); Lawrence Livermore National Laboratory (LLNL) special studies; and USGS. These data were augmented with data supplied by CDFW. In addition to utilizing GeoTracker GAMA for basin-wide water quality assessment, GeoTracker was searched individually to identify data associated with groundwater contaminant plumes. Groundwater quality data, as reported in GeoTracker GAMA, have been collected in the Basin since 1952. Appendix 2-B figures show the Basin boundary, as well as the locations and density of all wells with available water quality data for the GSP constituents of interest collected in the past 30 years (1990 to 2020). Within the Basin, a total of 53 wells were identified and used to characterize existing water quality based on a data screening and evaluation process that identified constituents of interest important to sustainable groundwater management.

Classification of Water Quality

To determine what groundwater quality constituents in the Basin may be of current or near-future concern, a reference standard was defined to which groundwater quality data were compared. Numeric thresholds are set by state and federal agencies to protect water users (environment, humans, industrial and agricultural users). The numeric standards selected for the current analysis represent all relevant state and federal drinking water standards and state water quality objectives for the constituents evaluated and are consistent with state and NCRWQCB assessments of beneficial use protection in groundwater. The standards are compared against groundwater quality data to determine if a constituent concentration exists above or below the threshold and is currently impairing or may impair beneficial uses designated for groundwater at some point in the foreseeable future.

Although groundwater is utilized for a variety of purposes, the use for human consumption requires that supplies meet strict water quality regulations. The federal Safe Drinking Water Act (SDWA) protects surface water and groundwater drinking water supplies. The SDWA requires the United States Environmental Protection Agency (USEPA) to develop enforceable water quality standards for public water systems. The regulatory standards are named maximum contaminant levels (MCLs) and they dictate the maximum concentration at which a specific constituent may be present in potable water sources. There are two categories of MCLs: Primary MCLs (1^{o} MCL), which are established based on human health effects from contaminants and are enforceable standards for public water supply wells and state small water supply wells; and Secondary MCLs (2^{o} MCL), which are unenforceable standards established for contaminants that may negatively affect the aesthetics of drinking water quality, such as taste, odor, or appearance.

The State of California has developed drinking water standards that, for some constituents, are stricter than those set at the federal level. Water quality in the Basin is regulated under the NCRWQCB Basin Plan, which lists relevant water quality objectives (WQOs) and beneficial uses. For waters designated as having a Municipal and Domestic Supply (MUN) beneficial use, the Basin Plan specifies that chemical constituents are not to exceed the Primary and Secondary MCLs established in Title 22 of the California Code of Regulations (CCR) (hereafter, Title 22). The MUN beneficial use applies to all groundwater in Butte Valley. The Basin Plan also includes numeric WQOs and associated calculation requirements in groundwater for select constituents in the Basin.

Constituents may have one or more applicable drinking water standard or WQOs. For this GSP, a prioritization system was used to select the appropriate numeric threshold. This GSP used the strictest value among the state and federal drinking water standards and state WQOs specified in the Basin Plan for comparison against available groundwater data. Constituents that do not have an established drinking water standard or WQO were not assessed. The complete list of constituents, numeric thresholds, and associated regulatory sources used in the water quality assessment can be found in Appendix 2-B. Basin groundwater quality data obtained for each well selected for evaluation were compared to a relevant numeric threshold.

Maps were generated for each constituent of interest showing well locations and the number of measurements for a constituent collected at a well (see Appendix 2-B). Groundwater quality data were further categorized by magnitude of detection as a) not detected, b) detected below half of the relevant numeric threshold, c) detected below the relevant numeric threshold, and d) detected above the relevant numeric threshold.

To analyze groundwater quality that is representative of current conditions in the Basin, several additional filters were applied to the dataset. Though groundwater quality data are available dating back to 1952 for some constituents, the data evaluated were limited to those collected from 1990 to 2020. Restricting the time span to data collected in the past 30 years increases confidence in data quality and focuses the evaluation on information that is considered reflective of current groundwater quality conditions. A separate series of maps was generated for each constituent of interest showing well locations and the number of groundwater quality samples collected among the wells during the past 30 years (1990 to 2020) (see Appendix 2-B).

Finally, for each constituent, an effort was undertaken to examine changes in groundwater quality over time at a location. Constituent data collected in the past 30 years (1990 to 2020) were further limited to wells that have two or more water quality measurements. A final series of maps and timeseries plots showing data collected from 1990 to 2020 were generated for each constituent and well combination showing how data compare to relevant numeric thresholds. These maps and timeseries plots for each constituent of interest are provided in Appendix 2-B.

The approach described above was used to consider all constituents of interest and characterize groundwater quality in the Basin. Appendix 2-B contains additional detailed information on the methodology used to assess groundwater quality data in the Basin.

Basin Groundwater Quality

All groundwater quality constituents monitored in the Basin that have a numeric threshold were initially considered. The evaluation process described above showed the following parameters to be important to sustainable groundwater management in the Basin: 1,2 dibromoethane (EDB), arsenic, benzene, boron, nitrate, and specific conductivity. The following subsections present information on these water quality parameters in comparison to their relevant regulatory thresholds and how the constituent may potentially impact designated beneficial uses in different regions of the Basin. Table 2.7 contains the list of constituents of interest identified for the Basin and their associated regulatory threshold.

Table 2.7: Regulatory water quality thresholds for constituents of interest in the Butte Valley Groundwater Basin

Constituent	Regulatory Basis	Water Quality Threshold
1,2 Dibromoethane (µg/L)	Title 22	0.05
Arsenic (µg/L)	Title 22	10
Benzene (µg/L)	Title 22	1
Boron (mg/L)	Basin Plan 90% Upper Limit	0.2
Boron (mg/L)	Basin Plan 50% Upper Limit	0.1
Nitrate (mg/L as N)	Title 22	10
Specific Conductivity (µmhos/cm)	Basin Plan 90% Upper Limit	800
Specific Conductivity (µmhos/cm)	Basin Plan 50% Upper Limit	400

Additional maps and timeseries plots showing all evaluated groundwater quality constituents are presented in Appendix 2-B, including maps of select chemicals typically found associated with point-source contamination, including manufactured organic chemical compounds.

1,2 DIBROMOETHANE (EDB)

The main sources of 1,2 dibromoethane (also known as ethylene dibromide (EDB)) are anthropogenic, stemming from its use as a pesticide and historical use as a gasoline additive. Though most EDB in the environment is from anthropogenic sources, small quantities may be produced in the ocean from natural processes. EDB can enter groundwater through industrial or effluent discharges or through leaching from soils. Potential health effects from exposure to EDB in drinking water include damage to the stomach lining and ingestion of EDB in very high levels is toxic.

(Appendix 2-B). Exceedances of the 0.05 microgram per liter (μg/L) 1° MCL for EDB are highly Recent data for EDB, collected from 1990 to 2020, is available in municipal and monitoring wells near Dorris, a well in Mount Hebron and a well near the southwest boundary of the Basin localized and are restricted to the monitoring wells in Dorris that are associated with known contaminated sites. As shown in Appendix 2-B, though there is some variation, concentrations are generally decreasing over time.

ARSENIC

Arsenic is a naturally occurring element in soils and rocks and has been used in wood preservatives and pesticides. Classified as a carcinogen by the USEPA, the International Agency for Research on Cancer (IARC) and the Department of Health and Human Services (DHHS), arsenic in water can be problematic for human health. Drinking water with levels of inorganic arsenic from 300 to

skin changes and may lead to skin cancer. The Title 22 1° MCL for arsenic is 10 μg/L.o 30,000 parts per billion (ppb; 1 ppb = 1 μg/L) can have effects including stomach irritation and decreased red and white blood cell production (ATSDR 2007a). Long-term exposure can lead to
Arsenic data in the Basin, between 1990 and 2020, are limited to municipal wells in Dorris,
μg/L for arsenic. The three additional wells with arsenic data all have results below the 1μ ° MCL, as Macdoel and Mount Hebron, with several measurements near and along the eastern Basin boundary (Appendix 2-B). Monitoring results for one well in Dorris exceeded the 1 MCL of 10

shown in Appendix 2-B. This is consistent with the results of a recent study that evaluated trends in groundwater quality for 38 constituents in public supply wells throughout California, the results of which also show one well near Dorris with "high" arsenic levels (greater than 10 g/L) based on measurements between 1995 to 2014 (Jurgens et al. 2020). Based on available data, arsenic concentrations are generally observed to be stable or decreasing, as shown in Appendix 2-B.

BENZENE

Benzene in the environment generally originates from anthropogenic sources, though lesser amounts can be attributed to natural sources including forest fires (Tilley and Fry 2015). Benzene is primarily used in gasoline and in the chemical and pharmaceutical industries and is commonly associated with leaking underground storage tank (LUST) sites. Classified as a known human carcinogen by the USEPA and the Department of Health and Human Services, exposure to benzene has been linked to increased cases of leukemia in humans (ATSDR 2007b). Long term exposure can affect the blood, causing loss of white blood cells and damage to the immune system or causing bone marrow damage, resulting in a decrease in the production of red blood
(ATSDR 2007b). The 1o MCL for benzene is 1 milligram per liter (μg/L), as defined in Title 22.o cells and potentially leading to anemia. Acute exposure can cause dizziness, rapid or irregular heartbeat, irritation to the stomach and vomiting and can be fatal at very high concentrations

Recent monitoring for benzene (from 1990 to 2020) includes background monitoring in municipal wells for Mount Hebron and Dorris and in monitoring wells associated with the known contaminated sites. Monitoring data collected in the municipal wells are all below the 1 MCL. As shown in Appendix 2-B, measurements that exceed the 1° MCL are all in the monitoring wells near Dorris, associated with known contaminated sites. Based on available data, these exceedances are highly localized and can be attributed to the contaminant plumes from the known contaminated sites, discussed in Section 2.2.3. Though there is some variability, benzene concentrations are generally seen to be decreasing over time, as illustrated in Appendix 2-B.

BORON

Boron in groundwater can come from both natural and anthropogenic sources. As a naturally occurring element in rocks and soil, boron can be released into groundwater through natural weathering processes. Boron can be released into the air, water or soil from anthropogenic sources including industrial wastes, sewage and fertilizers. If ingested at high levels, boron can affect the stomach, liver, kidney, intestines and brain (ATSDR 2010). The Basin Plan contains a 50% upper limit (UL) for boron of 0.3 mg/L and a 90% UL of 1.0 mg/L.

Over the past 30 years (from 1990 to 2020), concentrations of boron in groundwater have been measured throughout the Basin. Numerous measurements exceed the 50% and 90% upper limits specified in the Basin Plan (Appendix 2-B). While recent monitoring data for boron are distributed throughout the Basin, wells with multiple measurements are mostly limited to areas near Macdoel and Mount Hebron, with an additional two wells at the western and eastern Basin boundaries. As shown in Appendix 2-B, concentrations of boron over time are seen to be relatively stable or decreasing.

SPECIFIC CONDUCTIVITY

Specific conductivity (electrical conductivity normalized to a temperature of 25°C), quantifies the ability of an electric current to pass through water and is an indirect measure of the dissolved ions in the water. Natural and anthropogenic sources contribute to variations in specific conductivity in groundwater. Increases of specific conductivity in groundwater can be due to dissolution of rock and organic material and uptake of water by plants, as well as anthropogenic activities including the application of fertilizers, discharges of wastewater and discharges from septic systems or industrial facilities. High specific conductivity can be problematic as it can have adverse effects on plant growth and drinking water quality.

Specific conductivity measurements, obtained from 1990 to 2020, are limited to areas near Dorris, Macdoel and Mount Hebron, with several additional locations near the Basin boundary (Appendix 2-B). While some measurements do exceed the Basin Plan 50% UL of 400 micromhos per centimeter (µmhos/cm), all measurements are below the Basin Plan 90% UL of 900 µmhos/cm. Available data are relatively stable over time, as seen in Appendix 2-B. Additional monitoring wells in different areas of the Basin are needed to evaluate spatial and temporal trends in specific conductivity.

NITRATE

Nitrate is one of the most common groundwater contaminants and is generally the water quality constituent of greatest concern. Natural concentrations of nitrate in groundwater are generally low. In agricultural areas, application of fertilizers or animal waste containing nitrogen can lead to elevated nitrate levels in groundwater. Other anthropogenic sources, including septic tanks, wastewater discharges, and agricultural wastewater ponds may also lead to elevated nitrate levels. Nitrate poses a human health risk, particularly for infants under the age of 6 months who are susceptible to methemoglobinemia, a condition that affects the ability of red blood cells to carry and distribute oxygen to the body. The 1° MCL for nitrate is 10 mg/L as N.

Recent nitrate data collected in the Basin (1990 to 2020) are concentrated near Dorris, Macdoel and Mount Hebron, with limited data throughout the rest of the Basin (Appendix 2-B). Exceedances are seen to primarily occur in the municipal wells near Macdoel and Mount Hebron; no measurements exceeded the 1 ° MCL for nitrate in the northern section of the Basin. In wells with multiple monitoring events, nitrate concentrations can be seen to generally be decreasing or relatively stable, as illustrated in Appendix 2-B. However, additional monitoring data are needed for a complete determination of spatial and temporal trends in nitrate concentrations.

Contaminated Sites

Groundwater monitoring activities also take place in the Basin in response to known and potential sources of groundwater contamination, including underground storage tanks (SWRCB 2019b). These sites are subject to oversight by regulatory entities, and any monitoring associated with these sites can provide opportunities to improve the regional understanding of groundwater quality. To identify known plumes and contamination within the Basin, SWRCB GeoTracker was reviewed for active clean-up sites of all types. The GeoTracker database shows one open Leaking Underground Storage Tank (LUST) site and two open cleanup program sites with potential or actual groundwater contamination located within the Basin.

Underground storage tanks (UST) are containers and tanks, including piping, that are completely or significantly below ground and are used to store petroleum or other hazardous substances. Soil, groundwater and surface water near the site can all be affected by releases from USTs. A UST becomes a potential hazard when any portion of it leaks a hazardous substance at which point it is classified as LUST. The main constituents of concern due to contamination plumes in the Basin are tetrachloroethylene (PCE) and contaminants associated with releases of gasoline including fuel oxygenates such as methyl tertiary butyl ether (MTBE), benzene, toluene, ethylbenzene and xylenes (this collection of organic compounds is commonly referred to as “BTEX”). Other constituents of concern related to gasoline are lead scavenging compounds, including EDB and 1, 2-dichlororethane.

A brief overview of notable information related to contaminated sites in the Basin is provided below; however, an extensive summary for each of the contamination sites is not presented. The location of the contaminated sites are shown in Figure 2.28.

Dorris PCE Plume

The case (No. 1NSI23) for this cleanup site was opened in September 2013, after tetrachloroethylene (PCE) from an unidentified source was detected in LUST monitoring wells for the Shell site. This case is currently open and inactive (there are currently no regulatory oversight efforts by the Lead Agency).

Calzona Tankways

The case (No. 1NSI045) has been open for this cleanup site since 1988 with gasoline as the potential contaminant of concern. In 2011, the status of this case was changed to open and inactive.

Shell, Dorris

A former petroleum fueling facility, this LUST site is currently vacant. The case (No. 1TSI171) for this site was opened in 1999 following a reported unauthorized petroleum release after removal of seven underground storage tanks (USTs). The petroleum release is known to have affected the soil and shallow groundwater and 11 groundwater monitoring wells have been used to evaluate conditions at the site. Remediation activities have included pilot tests of bioventing and ozone sparging in 2007 and 2008, and full-scale ozone sparging from 2013 to 2019. The most recent review summary report from October 2019 notes that the site does not meet criteria for closure as groundwater quality objectives are not being meet and due to a lack of soil and soil vapor data.

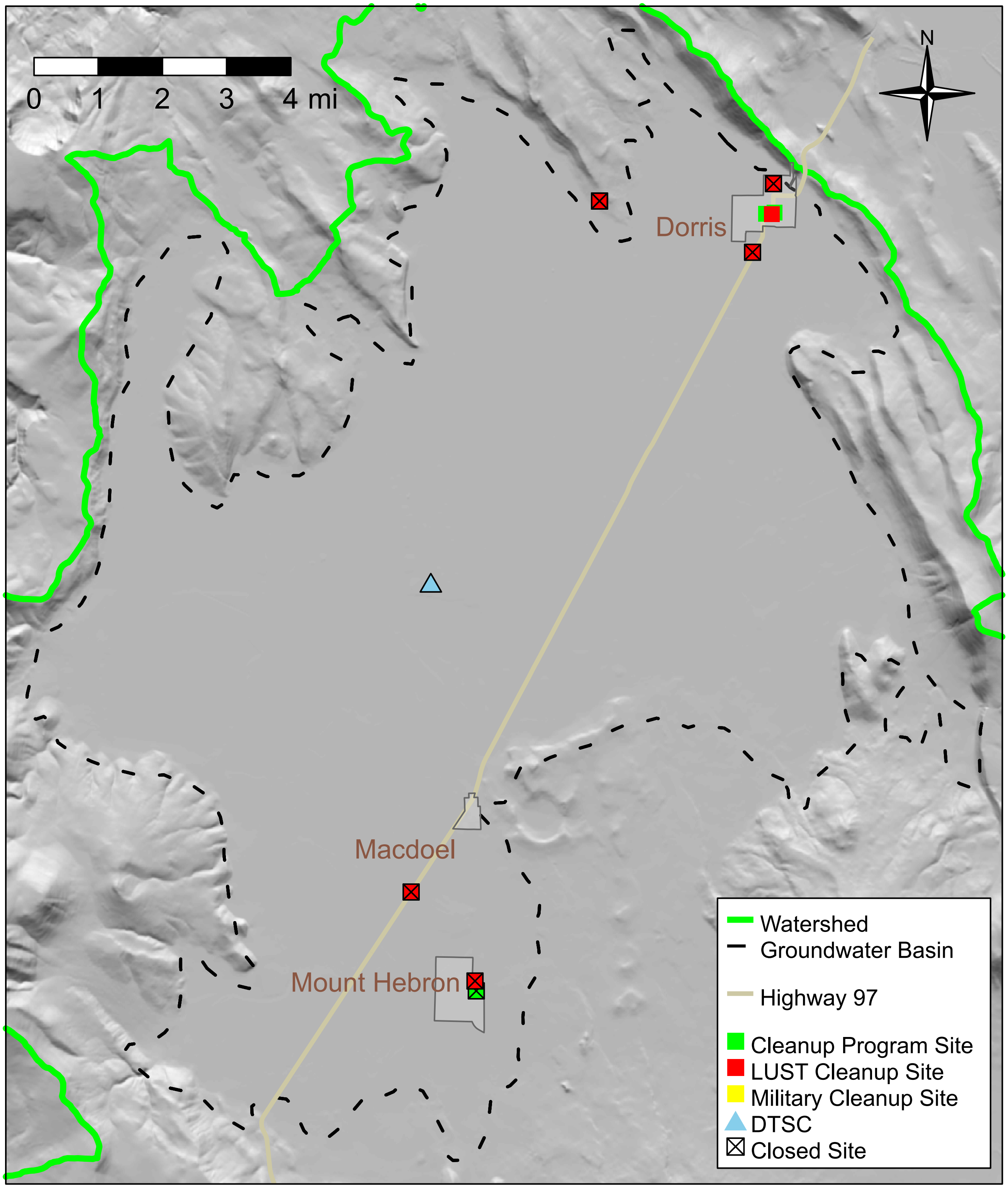


Figure 2.28: Contaminated Sites

While current data is useful to determine local groundwater conditions, additional monitoring is necessary to develop a basin-wide understanding of groundwater quality, and greater spatial and temporal coverage would improve the ability to evaluate trends. From a review of all available information, none of the sites listed above have been determined to have an impact on the aquifer, and the potential for groundwater pumping to induce contaminant plume movement towards water supply wells is negligible. Currently, there is not enough information to determine if the contaminants are sinking or rising with groundwater levels.

2.2.2.6 Seawater Intrusion Conditions

Due to the distance between Butte Valley and the Pacific Ocean, saltwater intrusion is not evident nor of concern and therefore, is not applicable to the Basin.

2.2.2.7 Land Subsidence Conditions

Land subsidence is the lowering of the ground surface elevation. This is often caused by pumping groundwater from within or below thick clay layers. Land subsidence can be elastic or inelastic, meaning that the lithologic structure of the aquifer can compress or expand elastically due to water volume changes in the pore space or is detrimentally collapsed when water is withdrawn (inelastic). Inelastic subsidence is generally irreversible. Elastic subsidence is generally of a smaller magnitude of change, and is reversible, allowing for the lowering and rising of the ground surface and can be cyclical with seasonal changes.

While lake sediments in the Valley floor have some inelastic subsidence risk as groundwater levels drop, land subsidence is not known to be historically or currently significant in the Basin. While groundwater elevations have steadily declined in the past few decades, noticeable land subsidence has not been observed in the Basin. BVID has not seen any pipe breakages nor loss in conveyance capacity in recent memory, which suggests that no noticeable land subsidence has occurred in the BVID management area (Lutz 2021). The City of Dorris has not observed any influence of land subsidence on city pipes (Mckay 2019).

Data Sources

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based remote sensing technique that measures vertical ground surface displacement changes at high degrees of measurement resolution and spatial detail. DWR has made InSAR satellite data available on their SGMA Data Viewer web map in two different forms: point data and a Geographic Information System (GIS) raster, which is point data interpolated into a continuous image or map (DWR 2019c). The point data are the observed average vertical displacements within a 100 by 100 meter area. The raster datasets were processed by TRE ALTAMIRA under contract by DWR for all SGMA High- and Medium-Priority groundwater basins. These are the only data used for estimating subsidence in this GSP as they are the only known subsidence-related dataset available for this Basin. The DWR-funded TRE Altamira InSAR dataset provides estimates of total vertical displacement from June 2015 to September 2019 and is shown in Figure 2.29 using raster data from the TRE Altamira report (DWR 2019c). The provided DWR/TRE Altamira InSAR data reflect both elastic and inelastic subsidence and it can be difficult to isolate a signal solely for only the elastic subsidence amplitude.

Visual inspection of monthly changes in ground elevations typically suggest that elastic subsidence is largely seasonal and can potentially be factored out of the signal, if necessary.

Data Quality

The TRE Altamira InSAR data provided by DWR are subject to compounded measurement and raster conversion errors. DWR has stated that for the total vertical displacement measurements, the errors are as follows:

1. The error between InSAR data and continuous GPS data is 16 mm (0.052 feet) with a 95% confidence level.
2. The measurement accuracy when converting from the raw InSAR data to the maps provided by DWR is 0.048 feet with 95% confidence level.

The addition of both of these errors results in the combined error is 0.1 feet. While not a robust statistical analysis, it does provide a potential error estimate for the TRE Altamira InSAR maps provided by DWR. A land surface change of less than 0.1 ft is within the noise of the data and is likely not indicative of groundwater-related subsidence in the basin.

Data Analysis

The total subsidence raster used for this GSP uses the InSAR point data (DWR 2019c). The point data, which represent approximate areas of 328 x 328 ft (100 x 100 m) squares, are interpolated to a raster with a grid spacing of approximately 3,281 x 3,281 ft (1,000 x 1,000 m) squares. This is a lower resolution than the one available as the DWR/TRE Altamira raster on the online SGMA Data Viewer (DWR 2019c). This effectively smooths out the larger amplitude, small foot print signals. Groundwater extraction-related signals would typically be expected to be larger in scale than these small foot print signals. The subsidence anomaly observed in Butte Valley for the period June 2015 to September 2019 represents an approximately 1,600 x 1,600 ft signal. For comparison, this is not much larger than the area of one center-pivot irrigation plot.

Using the TRE Altamira InSAR Dataset provided by DWR, it is observed that the majority of the vertical displacement values in the Basin are mostly near-zero, especially given the range of 0.1 ft to -0.1 feet of estimated error for the data (see Figure 2.29). These values are largely within or less than the same order of magnitude of the combined data and raster conversion error, suggesting essentially noise or, at least non-groundwater related activity, in the data. Any actual signals at this level could be due to a number of possible activities, including land use change and/or agricultural operational activities at the field scale. For perspective, during this same period, sections of the San Joaquin Valley in California’s Central Valley experienced up to ~3.5 feet of subsidence.

However, there is a localized hotspot near Dorris showing subsidence that may be of a magnitude above the potential instrument error of the InSAR instrumentation (DWR 2019c). Initial estimates of land subsidence between June 2015 to September 2019 are shown in Figure 2.29 using raster data from the DWR/TRE Altamira report (DWR 2019c).

Following detailed inspection of the DWR provided point subsidence data, satellite image review, and communication with the GSA Advisory Board, it seems likely that parcels APN 003-330-100 and 003-210-070 underwent sufficient grading and leveling during the period of record that may constitute a source of error in the apparent subsidence values shown in Figure 2.29. Subsidence throughout the Basin will require periodic reevaluation. At this time, subsidence in and around the highlighted parcels is slightly above potential instrument error that exists in the InSAR data and is either an artifact of significant grading or actual subsidence. The maximum observed subsidence shown in Figure 2.29 is approximately 0.15 ft (46 millimeters (mm)) between June 2015 to September 2019 in the area west of Dorris.

2.2.2.8 Identification of Interconnected Surface Water Systems

SGMA calls for the identification of interconnected surface waters (ISWs) in each GSP. ISWs are defined under SGMA as:

> *23 CCR § 351 (o): “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.*

Several small streams and creeks flow discontinuously along the edges of Butte Valley, primarily on the southern and western flanks of the valley, but there are no recent public records for stream flow except estimates of diversions by water right holders. Historical monitoring of stream flow in Butte Creek at the National Water Information System (NWIS) gauge 11490500 is restricted to a period of record from 1952 to 1960. Records indicate historical peak flows during January to

March in excess of 255 cubic feet per second (cfs) with summertime flows from July to September typically below 10 cfs. The lack of stream gage data for all creeks in the Basin is a major data gap that the GSA plans to address (see Appendix 3-A).

Surface water in the Basin is restricted to Meiss Lake and five creeks: Butte, Prather, Ikes, Harris, and Muskgrave (Figure 2.30). Only short stretches of Ikes, Harris, and Muskgrave Creeks lie within the Basin boundary before terminating at the BVWA Perimeter Canal (Figure 2.7 and Figure 2.31). Section 2.2.1.9 provides an overview of these surface water bodies, many of which go dry in the summer and fall. Section 2.2.2.3 and Appendix 2-A show that historical groundwater level data are generally located far from surface waters. Water level elevations near potential ISWs has been identified as a data gap that the GSA plans to address (see Appendix 3-A).

Generally for all these surface waters, the nearest groundwater contours are deeper than 30 feet (see Appendix 2-A). The nearest wells to Ikes, Harris, and Muskgrave Creeks have groundwater levels typically deeper than 40 feet below ground surface (bgs). Wells to the north and south of Meiss Lake range from 25 to 50 ft bgs, with projected groundwater surfaces of Meiss Lake greater than 30 feet below the lakebed. Groundwater level data at Prather Creek have groundwater levels greater than 30 feet. The four creeks are assumed to be interconnected surface waters possibly providing some recharge where and when they are flowing within the Basin boundary. Meiss Lake is also considered to be an interconnected surface water possibly providing some recharge when not dry. Meiss Lake was also affected by early and mid-20th century development of surface water and groundwater in the basin. The GSA is collecting additional data and filling the discussed data gaps to better understand the dynamics of these potentially interconnected surface waters (see Appendix 3-A).

Butte Creek is a major surface water body in Butte Valley and terminates south of Mount Hebron, where all water is appropriated for irrigation. Large data gaps include the lack of historical flow within the Basin and no nearby groundwater level data. The nearest groundwater well to Butte Creek has groundwater levels ranging from 40 to 80 ft bgs (see Appendix 2-A). Studies of Butte Creek upstream of the Basin suggest that Butte Creek is a losing stream (Todd Sloat Biological Consulting 2012). Butte Creek is therefore considered an interconnected surface water providing some recharge to the Basin groundwater aquifer when flowing in the Basin. Due to the importance of Butte Creek for irrigation and groundwater recharge within the Basin, the GSA is prioritizing addressing the stream gage and groundwater level data gaps (see Appendix 3-A). Additional data will improve future analysis of the interconnected surface water dynamics of Butte Creek.

The Water Quality Control Plan for the North Coast Region (“NCR Basin Plan”) defines the existing beneficial uses of these potentially interconnected surface waters (NCRWQCB 2018) as follows:

- For the Macdeol-Dorris Hydrologic Subarea: MUN, AGR, IND(P), PRO(P), POW, REC1, REC2, COMM, WARM, COLD, WILD, RARE, MIGR, SPWN, AQUA(P)
- Fore Meiss Lake: MUN, AGR, IND(P), PRO(P), GWR, REC1(P), REC2, WARM, COLD, WILD, AQUA(P)
- Where (P) indicates that a potential rather than existing beneficial use, and abbreviations refer to:
    - MUN Municipal and Domestic Supply
    - AGR Agricultural Supply
    - IND Industrial Service Supply
    - PRO Industrial Process Supply
    - GWR Groundwater Recharge
    - POW Hydropower Generation
    - REC-1 Water Contact Recreation
    - REC-2 Non-Contact Water Recreation
    - COMM Commercial and Sport Fishing

- WARM Warm Freshwater Habitat
- COLD Cold Freshwater Habitat
- WILD Wildlife Habitat
- RARE Rare, Threatened, or Endangered Species
- MIGR Migration of Aquatic Organisms
- SPWN Spawning, Reproduction, and/or Early Development
- SHELL Shellfish Harvesting
- AQUA Aquaculture

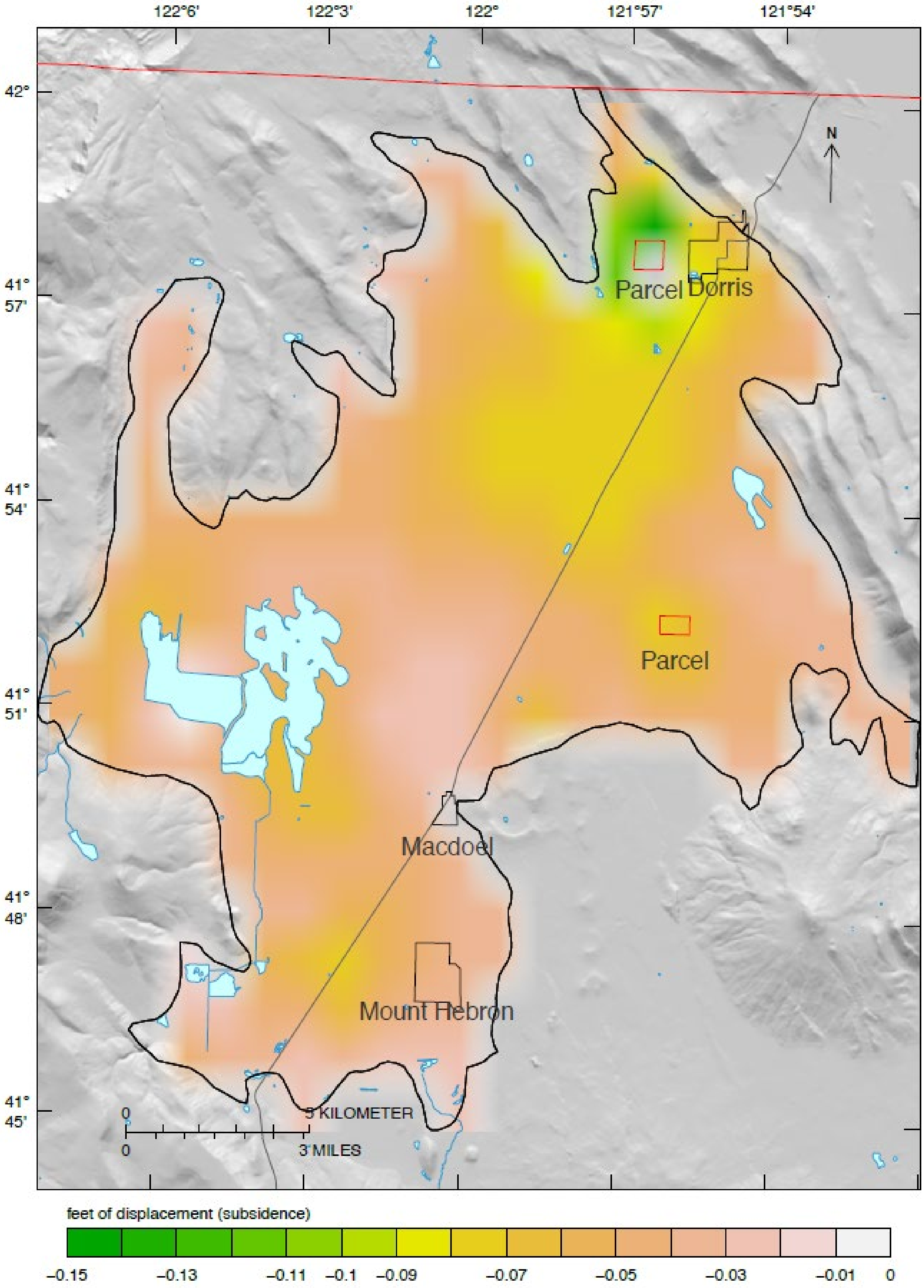


Figure 2.29: InSAR satellite measured total vertical subsidence (feet) between June 2015 and September 2019. Note that the processed InSAR instrument and GIS conversion error is roughly +/-0.1 feet.

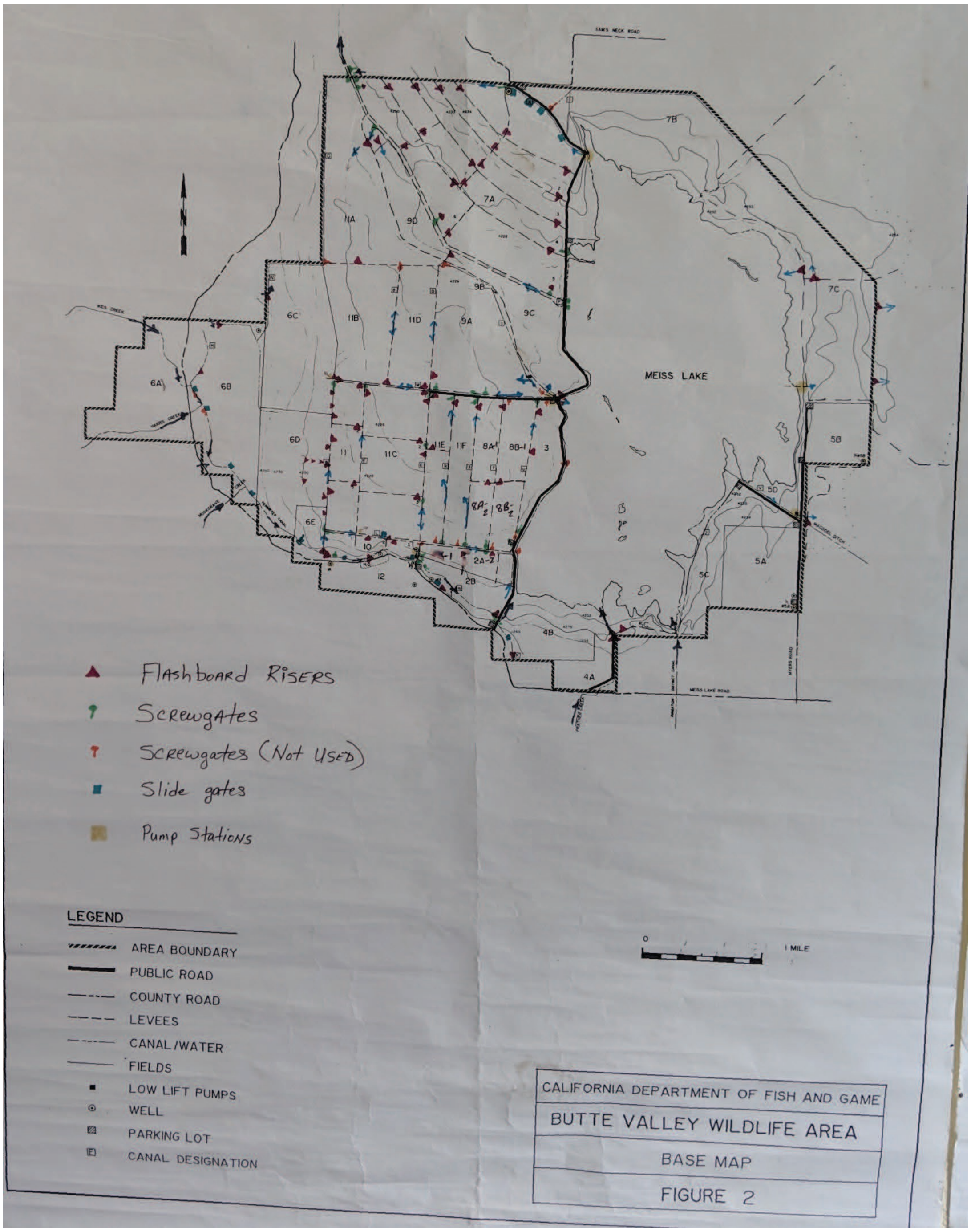


Figure 2.30: Photo of Butte Valley Wildlife Area (BVWA) map taken at the BVWA headquarters, showing that Ikes, Harris, and Muskgrave Creeks terminate at the BVWA Perimeter Canal. Prather Creek terminates in Meiss Lake.

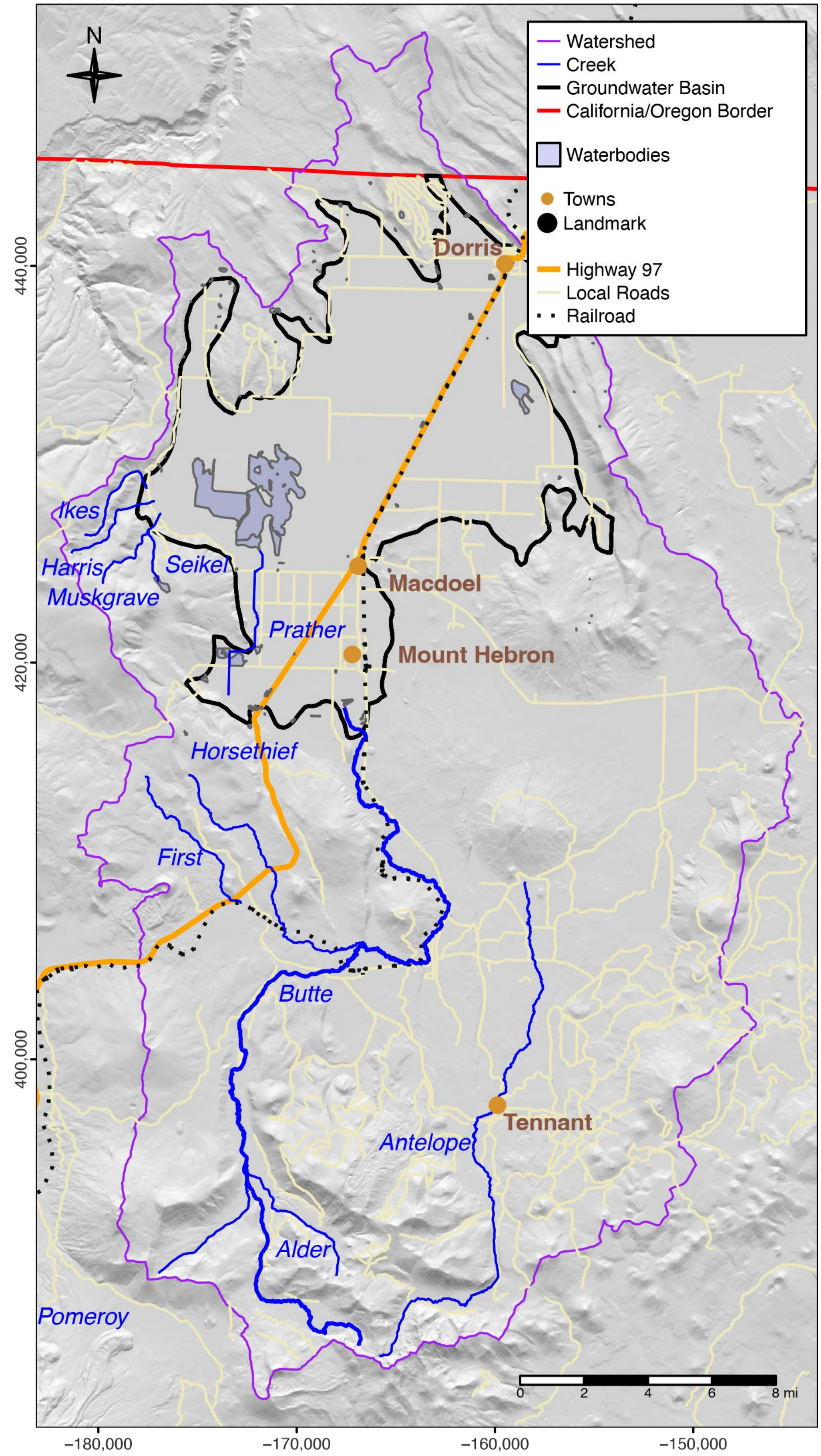


Figure 2.31: Surface Water in the Butte Valley Groundwater Basin.

2.2.2.9 Identification of Groundwater-Dependent Ecosystems

Section 354.16(g) of SGMA requires identification of groundwater dependent ecosystems (GDEs). Section 351(m) of these regulations refers to GDEs as *“ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.”* California Water Code 10727.4(l) further requires that a GSP describes and considers the impacts to GDEs.

In order to adequately consider potential effects of the potential effects of the management of regional groundwater resources on all beneficial uses and users of groundwater and ISWs, including both human and natural beneficial uses, GDEs within the Basin area must be identified and potential effects of the Basin operations on GDEs must be determined. Such information is then used to establish sustainable management criteria (SMC), improve the monitoring network, and define projects and management actions (PMAs) that help improve or maintain conditions for each GDE to achieve the sustainability goal in the basin, as discussed in Chapters 3, 4, and 5, respectively.

Major data gaps within the current analysis of GDEs include unreliable or outdated habitat maps that require local knowledge and study and groundwater level data gaps near potential GDEs. The GSA presents a plan to address these data gaps in Chapter 4 and 5, and Appendix 3-A.

Environmental Beneficial Water Uses and Users within the Basin

To establish sustainable management criteria (SMCs) for the water level and for the depletion of ISW sustainability indicators, GSAs are required to prevent adverse impacts to beneficial users of groundwater and ISW, including environmental uses and users. Thus, identifying these uses and users is the first step to address undesirable results due to water level declines or surface water depletions from groundwater pumping.

The Basin encompasses two California ecoregions as identified by USEPA Level III Ecoregions of California (Griffith et al. 2016):

- Cascade (Ecoregion 4), which covers approximately 1.2% of the Basin area in the west and southwest. This ecoregion is characterized by broad, easterly trending valleys, a high plateau in the east, as well as both active and dormant volcanoes. Its moist, temperate climate supports an extensive and highly productive coniferous forest, while containing subalpine meadows at high elevations.
- Eastern Cascades Slopes and Foothills (Ecoregion 9), which covers the majority of the Basin. This region is in the rain shadow of the Cascade Range, with a more continental climate compared to ecoregions to the west, with greater temperature extremes, less precipitation, and frequent fires. Volcanic cones, plateaus, and buttes are common. Areas of cropland and pastureland in lake basins and larger river valleys provide habitat for migrating waterfowl, such as sandhill cranes, ducks, and geese.

Per 23 California Code of Regulations section 354.8(a)(3), CDFW recommends identifying Department-owned or Department-managed lands within the Basin, and carefully considering all environmental beneficial uses and users of water on Department lands to ensure fish and wildlife resources are being considered when developing the GSP. In the Basin, CDFW owns BVWA and manages Meiss Lake. Additionally, USFS and BLM own about 23.3% and 0.1% of the Basin area, respectively (Figure 2.2).

Freshwater Species within the Basin

The Nature Conservancy (TNC) has provided a list of freshwater species located within each groundwater basin in California and the BVWA tracks species that visit the wildlife area. Many bird species visit Butte Valley because Meiss Lake and BVWA are part of the Pacific Flyway for migrating birds. Based on the combined freshwater species lists, there are a total of thirty-seven species identified by the federal or state governments as endangered, threatened, species of special concern, or watch list within the Basin, including those under review or in the candidate or petition process. Of these species two are endangered species, four are designated as threatened, twenty-two are species of concern or special species, and nine are included on the watch list (Table 2.8) (K. Novick 2009; TNC 2021; CDFW 2021c, 2021b, 2021a).

The predicted habitat for each of these species were evaluated using CDFW's Biogeographic Information and Observation System (BIOS) Viewer, with input from BVWA. BIOS houses many biological and environmental datasets including the California Natural Diversity Database (CNDDB), which is an inventory of the status and locations of rare plants and animals in California. Local knowledge from BVWA indicates bald eagles are common year-round in BVWA, with dozens of eagles in the winter and successful nesting. American white pelicans and yellow headed blackbirds are abundant in the spring and summer and yellow-headed blackbirds nest in BVWA.

Colonial nesting waterbirds nest on the natural islands in Meiss Lake when water is present. No nesting occurs when the lake is dry. During wet cycles, nesting bird species include ring-billed gulls, California gulls (6,000 combined gull nests), Forster's terns (133 nests), double crested cormorants (124 nests), Caspian terns (27 nests), and white pelicans (73 nests). The colony of white pelicans nesting is significant because, as of 2009, there were only three or four other colonies nesting in the state (K. Novick 2009). Additional birds such as ducks, pintail, goose and snow geese migrate through BVWA.

Brief descriptions about these species and their water demand are provided below:

- Bald Eagles live near waterbodies including estuaries, lakes, reservoirs, rivers, and occasionally by coastlines. They rely on a diet predominantly comprised of fish, but that also may include smaller birds including colonial waterbirds, waterfowl and small mammals. Populations have been threatened by hunting, loss of nesting habitat and poisoning from the pesticide DDT.
- The western pond turtle's preferred habitat is permanent ponds, lakes, streams or permanent pools along intermittent streams, associated with standing and slow-moving water. A potentially important limiting factor for the Western pond turtle is the relationship between water level and flow in off-channel water bodies, which can both be affected by groundwater pumping.

Because the Basin is internally drained with no connection to the Klamath River or the sea, there are no anadromous fish populations.

Table 2.8: Freshwater Species in Butte Valley, as identified by BVWA (2009 BVWA Plan Addendum), The Nature Conservancy (TNC 2021) with species status verified by CDFW statewide species lists (CDFW 2021 a,b,c).

Species	Group	Status	Notes
American White Pelican	Birds	Special Concern	Observed in Butte Valley Wildlife Area
An Amphipod	Crustaceans	Special	Nature Conservancy Butte Valley Basin List
Bald Eagle	Birds	Endangered (state only - under review)	Observed in Butte Valley Wildlife Area
Bank Swallow	Birds	Threatened	Nature Conservancy Butte Valley Basin List
Black Tern	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Black-capped chickadee	Birds	Watch list	Observed in Butte Valley Wildlife Area
Burrowing Owl	Birds	Special Concern	Observed in Butte Valley Wildlife Area
California gull	Birds	Watch list	Observed in Butte Valley Wildlife Area
Canvasback	Birds	Special	Nature Conservancy Butte Valley Basin List
Columbia Yellowcress	Plants	Special	Observed in Butte Valley Wildlife Area
Cooper’s hawk	Birds	Watch list	Observed in Butte Valley Wildlife Area
Double-crested cormorant	Birds	Watch list	Observed in Butte Valley Wildlife Area
Golden eagle	Birds	Watch list	Observed in Butte Valley Wildlife Area
Greater sandhill crane	Birds	Threatened	Observed in Butte Valley Wildlife Area
Hot Springs Fimbry	Plants	Special	Nature Conservancy Butte Valley Basin List
Loggerhead shrike	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Long-eared owl	Birds	Special Concern	Observed in Butte Valley Wildlife Area

Table 2.8: Freshwater Species in Butte Valley, as identified by BVWA (2009 BVWA Plan Addendum), The Nature Conservancy (TNC 2021) with species status verified by CDFW statewide species lists (CDFW 2021 a,b,c). ***(continued)***

Species	Group	Status	Notes
Newberry's Cinquefoil	Plants	Special	Nature Conservancy Butte Valley Basin List
Northern harrier	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Northern spotted owl	Birds	Threatened	Observed in Butte Valley Wildlife Area
Oregon Spotted Frog	Herps	Special Concern	Observed in Butte Valley Wildlife Area
Osprey	Birds	Watch list	Observed in Butte Valley Wildlife Area
Pedate Checker-mallow	Plants	Endangered	Nature Conservancy Butte Valley Basin List
Prairie falcon	Birds	Watch list	Observed in Butte Valley Wildlife Area
Redhead	Birds	Special Concern	Nature Conservancy Butte Valley Basin List
Redhead duck	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Sharp-shinned hawk	Birds	Watch list	Observed in Butte Valley Wildlife Area
Short-eared owl	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Swainson's hawk	Birds	Threatened	Observed in Butte Valley Wildlife Area
Tricolored Blackbird	Birds	Special Concern	Nature Conservancy Butte Valley Basin List
Tule white-fronted goose	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Vaux's swift	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Wawona Riffle Beetle	Insects & other inverts	Special	Nature Conservancy Butte Valley Basin List
Western Pond Turtle	Herps	Special Concern	Observed in Butte Valley Wildlife Area
White-faced Ibis	Birds	Watch list	Observed in Butte Valley Wildlife Area

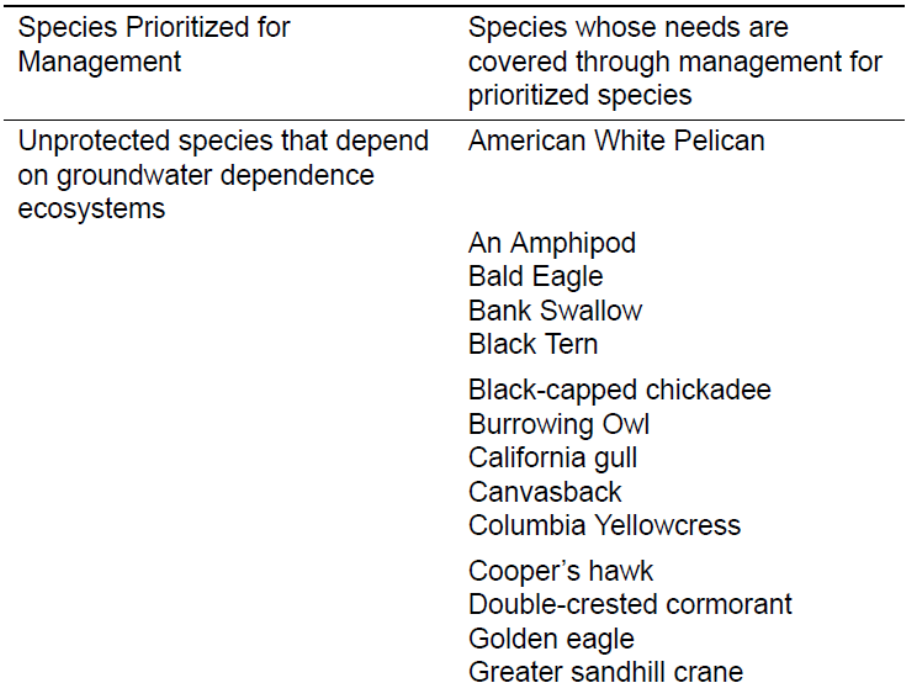
Table 2.8: Freshwater Species in Butte Valley, as identified by BVWA (2009 BVWA Plan Addendum), The Nature Conservancy (TNC 2021) with species status verified by CDFW statewide species lists (CDFW 2021 a,b,c). ***(continued)***

Species	Group	Status	Notes
Yellow warbler	Birds	Special Concern	Observed in Butte Valley Wildlife Area
Yellow-headed Blackbird	Birds	Special Concern	Observed in Butte Valley Wildlife Area

Management Approach

Groundwater dependent species prioritized for management primarily focus on riparian vegetation that is a GDE. Addressing the needs of these species is assumed to cover the needs of other special-status species such as the bank swallow, western pond turtle, and bald eagle that use riverine habitats during their life stage. Additionally, special status species that were not prioritized for management may exhibit flexible life-history strategies, are less susceptible to changing groundwater conditions, and/or have a different nature or lower degree of groundwater dependency. The species prioritized for management, shown in Table 2.9, are considered throughout this GSP. Other species listed in Table 2.8 and Table 2.9 are protected by federal or state agencies. As needed, the GSA will partner with those agencies to protect non-threatened, threatened, and endangered species within the Basin.

Table 2.9: GDE species prioritization for management, as identified by BVWA, The Nature Conservancy, and CDFW (2009 BVWA Plan Addendum, TNC 2021, CDFW 2021 a,b,c). The GSA will work with relevant agencies to manage unprotected and protected species within the Basin.



Species Prioritized for Management	Species whose needs are covered through management for prioritized species
Unprotected species that depend on groundwater dependence ecosystems	American White Pelican
	An Amphipod Bald Eagle Bank Swallow Black Tern
	Black-capped chickadee Burrowing Owl California gull Canvasback Columbia Yellowcress
	Cooper's hawk Double-crested cormorant Golden eagle Greater sandhill crane

Table 2.9: GDE species prioritization for management, as identified by BVWA, The Nature Conservancy, and CDFW (2009 BVWA Plan Addendum, TNC 2021, CDFW 2021 a,b,c). The GSA will work with relevant agencies to manage unprotected and protected species within the Basin. (continued)

Species Prioritized for Management	Species whose needs are covered through management for prioritized species
	Hot Springs Fimbry
	Loggerhead shrike
	Long-eared owl
	Newberry's Cinquefoil
	Northern harrier
	Northern spotted owl
	Oregon Spotted Frog
	Osprey
	Pedate Checker-mallow
	Prairie falcon
	Redhead
	Redhead duck
	Sharp-shinned hawk
	Short-eared owl
	Swainson's hawk
	Tricolored Blackbird
	Tule white-fronted goose
	Vaux's swift
	Wawona Riffle Beetle
	Western Pond Turtle White-faced Ibis
	Yellow warbler
	Yellow-headed Blackbird

Vegetative GDE Identification and Classification

The following section discusses the process of identifying potential GDEs and their classification based on the likelihood that they have access to groundwater. This analysis is carried out using three key building blocks:

- Mapping potential GDEs based on available resources.
- Assign rooting depths based on predominant assumed vegetation type.
- Establish representations of depth to groundwater.
- Identify potential areas where both, depth to groundwater, rooting depth, and presence of potential GDEs confirm likely groundwater-dependence.

The following subsections discuss the process of assembling these four building blocks.

Mapped Potential GDEs

The primary resource used to establish the spatial extent of mapped GDEs is the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset (DWR 2021). The NCCAG dataset includes separate vegetation communities and wetland geospatial data layers for each of the groundwater basins identified in Bulletin 118. These layers identify potential locations of GDEs, which identify the phreatophytic vegetation, perennial streams, regularly flooded natural wetlands, and springs and seeps that may indicate the presence of/and or communities that and depend on groundwater, and therefore can be considered as indicators of GDEs. Representations of mapped potential GDEs from the NCCAG vegetation and wetlands datasets are presented in Figure 2.33 and Figure 2.32, respectively.

An initial review of NCCAG mapped potential GDEs for the Basin and a comparison to an initial review of NCCAG mapped potential GDEs for the Basin and a comparison to available land use mapping resources suggested that riparian communities were not effectively represented in some cases and mapped GDEs were identified in urban, agricultural, or managed vegetated areas. A subset of land uses from the 2010 Siskiyou County land use and land cover (LU/LC) dataset were incorporated into the analysis to more effectively represent mapped potential GDEs for the Basin. Siskiyou County LU/LC classes are presented in Appendix 2-C.

The NCCAG vegetation and wetland layers were overlaid or unioned in a geographic information system (GIS) yielding a dataset where areas mapped as potential vegetation GDEs, wetland GDEs, or both vegetation and wetland GDEs are represented. A union is a geospatial process where the coverage and attributes of multiple layers in all area are combined into one spatial dataset. An intersection is a geospatial process where the coverage and attributes of multiple layers are combined into one spatial dataset only in areas where they share area or overlap. This combined or unioned NCCAG dataset was intersected with the adapted 2010 Siskiyou County LU/LC dataset yielding a combination of classifications for all three datasets for the area covered by either the NCCAG vegetation or wetland datasets. All observed combinations of combined fields were summarized in a master table and grouped into one of the five categories presented in Table 2.10 based on best professional judgment. Additional tables used in this process are presented in Appendix 2-C.

If, as an example, the NCCCAG Wetland dataset identified an area as class “PEM1C” corresponding to a “Palustrine, Emergent, Persistent, Seasonally Flooded” mapped potential wetland GDE and the 2010 Siskiyou County LU/LC dataset assigned the same area a “UR” representing “Urban Residential,” that area was assigned a “Remove Urban/Paved” classification and was subsequently removed. If, as a second example, neither the NCCAG Wetland or Vegetation datasets identified an area as a mapped GDE but the 2010 Siskiyou County LU/LC dataset assigned that area an “NW1” class representing “River or stream (natural fresh water channels),” it was included in the combined representation of mapped GDEs. Combined land use classes a “Retain Check” or “Check Remove Irrigated” classification were qualitatively evaluated using aerial imagery and included or removed based on best professional judgement.

Assumed Rooting Zone Depths

Rooting zone depths were assigned to all combined or concatenated values for the NCCAG vegetation, NCCAG wetland, and Siskiyou County land use and land cover dataset using a simple decision tree approach. An assumed dominant or representative vegetation was assumed for the best available dataset for each area or polygon within the mapped potential GDE dataset. Classifications from the NCCAG vegetation dataset were used to assign rooting zone depths based on a presumably higher level of mapping accuracy and more descriptive classes with values such as “wet meadow” or “willow shrub” present within the Basin. Classifications from the NCCAG wetland dataset were then used given their presumed lower level of accuracy and more general vegetative community classification with values such as “palustrine, emergent, persistent, seasonally flooded” and “riverine, upper perennial, unconsolidated bottom, permanently flooded.”

All vegetation classification in areas mapped by either the NCCAG vegetation or wetland datasets were compared to mapped 2010 Siskiyou County LU/LC and a predominant or representative vegetation was assigned based on best professional judgment.

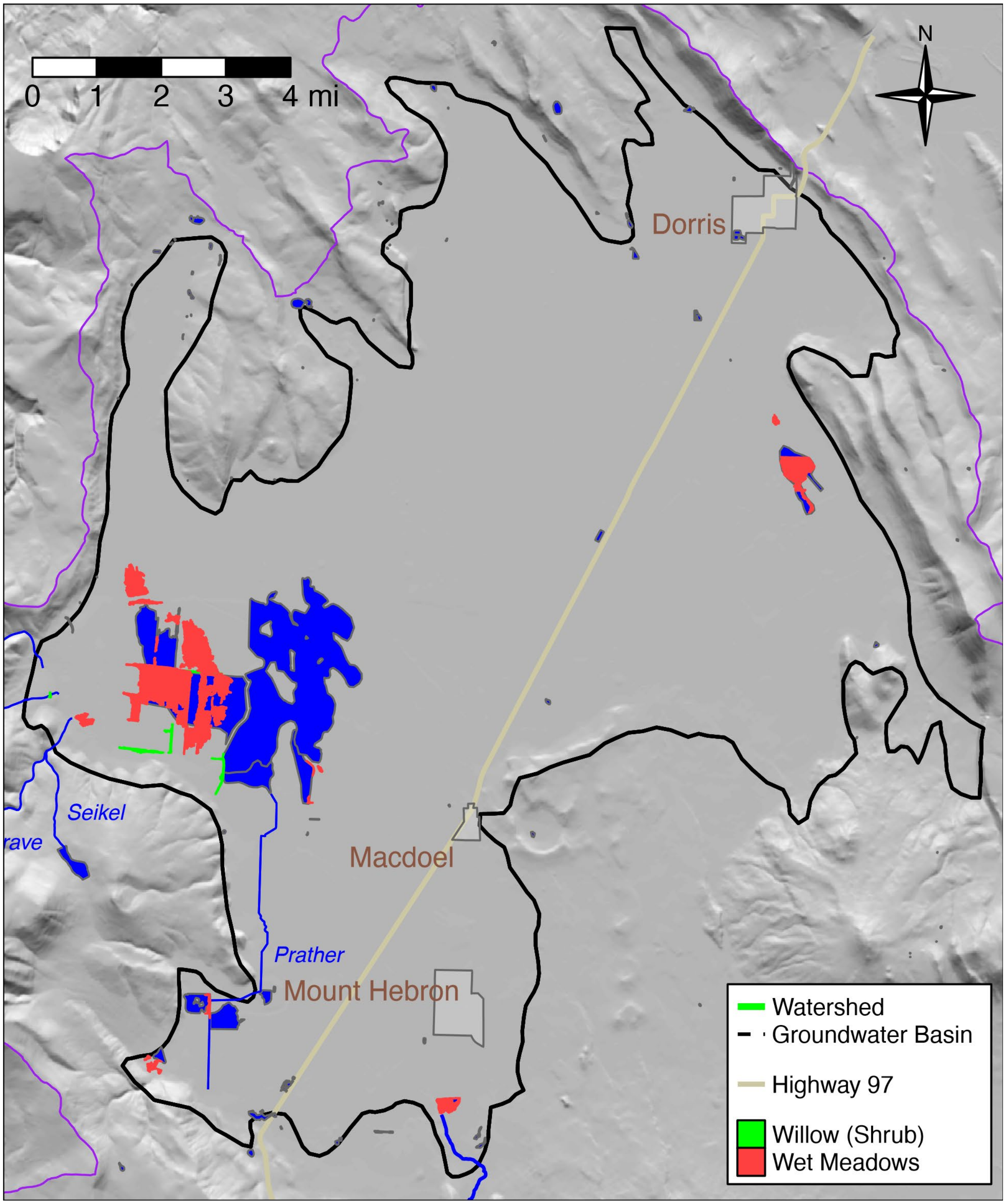


Figure 2.32: Vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes). Identified by the DWR Natural Communities Commonly Associated with Groundwater (NCCAG) dataset. The data included in the Natural Communities dataset do not represent DWRs determination of a 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.

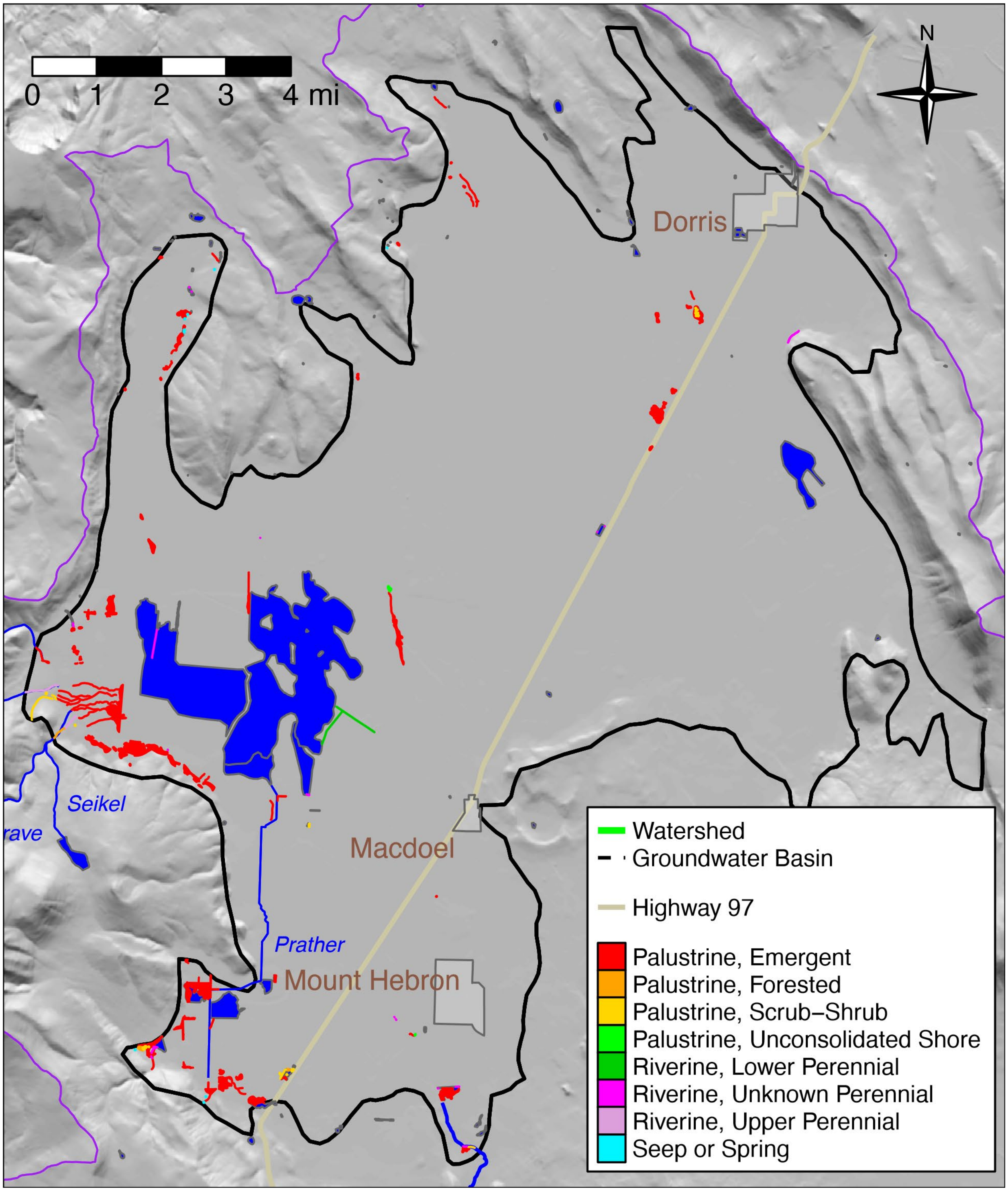


Figure 2.33: Wetland features commonly associated with the surface expression of groundwater under natural, unmodified conditions. Identified by the DWR Natural Communities Commonly Associated with Groundwater (NCCAG) dataset. The data included in the Natural Communities dataset do not represent DWRs 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.

A review of available literature served as the foundation for assigning assumed rooting zone depths for each vegetative class present in the aggregated mapped representation of potential GDEs. Vegetation classifications were grouped into three broad categories based on best professional judgment. The relationship between mapped vegetation categories and assumed predominant or representative vegetation is presented in Table 2.11, Table 2.12, and Table 2.13 for the NCCAG vegetation, NCCAG wetland, and 2010 Siskiyou County LU/LC datasets, respectively.

All classes directly referring to willows as well as those referring to scrub or forested areas were assumed to be effectively represented by an assumed 13.1 ft. rooting zone depths for willows. Relevant literature suggests a range for willow rooting depths of 2.62 ft. to 7.35 feet (Niswonger1and and Fogg 2008) indicating that this assumed depth of 13.1 is relatively conservative while additional resources suggest that rooting zone depths of 13.1 feet are consistent with mean values for deciduous broadleaf trees which would have deeper rooting depths than willows (Fan et al. 2017).

Other vegetation classes do not specifically identify predominant species and are therefore assumed to be emergent and limited to grasses, forbs, sedges, and rushes that are common in wetland communities. Rooting zone depths are assigned as the mean or maximum of mean values from aggregated measures presented in relevant literature (Schenk and Jackson 2002). Assumed rooting zone depths were generally conservative given the absence of the consistent and comprehensive coverage identifying predominant species for each community and reflected best professional judgment based on the broad classes of vegetation that could reasonably be present.

Table 2.10: Field Used to Create a Combined Representation of Mapped Potential GDE Coverage.

Action	Classification Description
Retain_Natural	Siskiyou/DWR mapping indicates natural vegetation present.
Retain_Check	Siskiyou/DWR mapping indicates natural vegetation may be present therefore retain or verify before removing
Remove_Ag	Siskiyou/DWR mapping indicates agricultural land is present which could warrant polygon removal.
Remove Urban_Paved	Siskiyou/DWR mapping indicates urban/paved land is present which could warrant polygon removal
Check_Remove_Irrigated	Siskiyou/DWR mapping indicates non-native irrigated land is present which could warrant polygon removal.

Table 2.11: Assumed Rooting Zone Depth and Representative Vegetation for Classes Within the NCCAG Vegetation Dataset.

Wetland Community Class	Assumed Rooting Zone Depth (ft.)	Assumed Representative Vegetation
Wet Meadow	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Willow (Shrub)	13.1	Willow

Table 2.12: Assumed Rooting Zone Depth and Representative Vegetation for Classes Within the NCCAG Wetland Dataset.

Wetland Community Class	Assumed Rooting Zone Depth (ft.)	Assumed Representative Vegetation
Palustrine, Emergent, Persistent, Seasonally Flooded	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Palustrine, Scrub-Shrub, Seasonally Flooded	13.1	Willow
Riverine, Unknown Perennial, Unconsolidated Bottom, Semipermanently Flooded	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Palustrine, Forested, Seasonally Flooded	13.1	Willow
Palustrine, Unconsolidated Shore, Seasonally Flooded	13.1	Willow
Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Riverine, Upper Perennial, Unconsolidated Bottom, Permanently Flooded	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Palustrine, Emergent, Persistent, Semipermanently Flooded	4.8	Grasses, Forbs, Sedges, and Rushes Mean Rooting Depth
Seep or Spring	9.6	Grasses, Forbs, Sedges, and Rushes Max Rooting Depth

Table 2.13: Assumed Rooting Zone Depth and Representative Vegetation for Classes Within the Siskiyou County Land Use and Land Cover Dataset.

Land Use/ Land Cover Class	Assumed Rooting Zone Depth (ft.)	Assumed Representative Vegetation
River or stream (natural fresh water channels)	13.1	Willow

Depth to Groundwater

Mapped representations of depth to groundwater were calculated consistent with the standard approach (e.g., TNC Best Practices for using the NC Dataset, 2019), as the difference between land surface elevation and interpolated groundwater elevation above mean sea level. Altogether, depth to groundwater conditions were developed for 23 periods between spring of 2008 and the fall of 2019. These periods represent water level data every 6 months from spring of 2008 to fall of 2019, with equal amounts of fall and spring periods. These grid or raster geospatial datasets were developed by interpolating between observed groundwater elevations obtained from the CASGEM Program and assumed elevations at surface water features using ordinary kriging

(Wackernagel 1995). Representations of depth to groundwater for each of the 23 periods are presented in Appendix 2-C.

Depth to Groundwater Assumptions and Data Gaps

The Butte Valley groundwater level network has good coverage over the center of the Basin, which gives good confidence on the GDE analysis. However, data gaps in the groundwater level network along the Basin edges may cause overestimation of depth to groundwater, particularly in Sam's Neck, the northern edge of the Basin, the western edge near Ikes, Harris, and Muskgrave Creeks, the western edge near Prather Creek, and south edge near Butte Creek. To complete a preliminary and conservative GDE analysis of these areas based on existing knowledge, the elevation of springs along the immediate edge of the valley sediments and mapped by the USGS were added as "water level" measurements for purposes of interpolating the water table within the Basin. Further rationale for this choice is provided in the next section. These additional "water level" data provide a more conservative, albeit only approximate, estimate of depth to water table for the GDE analysis in areas near the Basin boundaries for this preliminary analysis. The preliminary analysis identifies areas with potential GDEs, but is not used to set specific sustainable management criteria until better data are available, e.g., from planned expansion of the groundwater level network. Instead, potential GDEs with high uncertainty due to lack of direct groundwater level data are identified as data gaps to be addressed during the implementation of the Plan.

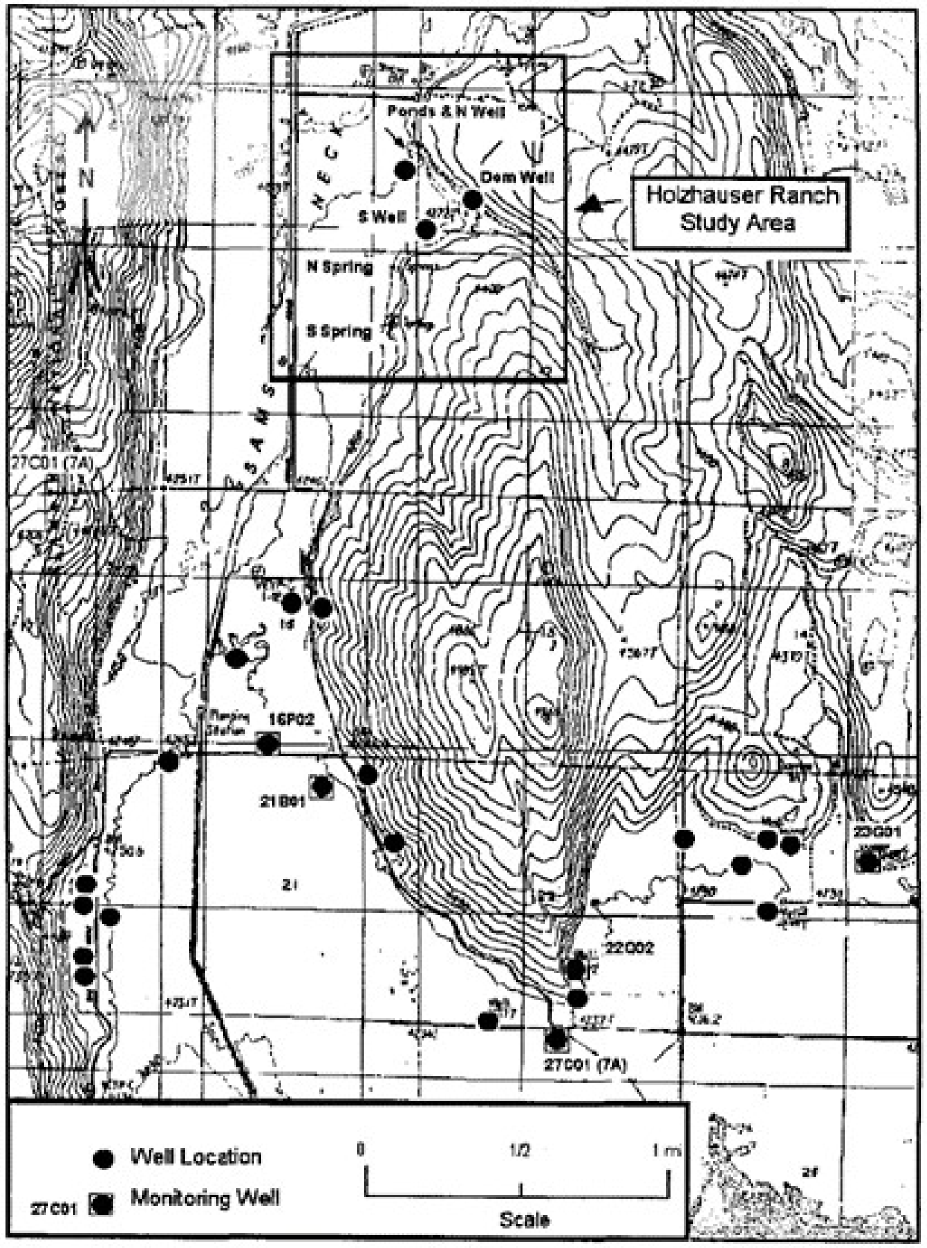


Figure 9. Holzhauser Ranch Location Map

Figure 2.34: Map from the 1998 DWR study. Well 7A is near the map bottom, above the legend. The studied springs are on the northeast side of Sam's Neck, within the boxed study area.

Spring to Groundwater Connection in Butte Valley

Spring interconnectivity is largely inferred by results from a 5.5-day pump test conducted by DWR in August 1997. During the pump test, two springs on Holzhauser Ranch in Sam's Neck were observed during pump operation on CDFW well 7A. This well is also referred to by the abbreviated DWR State Well Number (SWN) code 27C01. During pumping on this well, flow in two springs in Sam's Neck was observed to decline by 10 percent. This indicates that the wells and springs share hydraulic interconnectivity and likely are not separated by a major impermeable layer or represent a discontinuous perched water bearing formation. The location of the Holzhauser Ranch springs and CDFW Well 7A studied by DWR during the 1997 well interference study are shown on the figure below (DWR 1998).

Relationship Between Rooting Zone Depths and Depth to Groundwater

This subsection discusses the method used to evaluate the relationship between assumed rooting zone depths and depth to groundwater for each mapped potential GDE area.

Grid-Based GDE Analysis

The grid-based analysis relied on the grid or raster-based representations of depth. This grid-based analysis was carried out using three general geospatial processing steps.

The first step involved computing an area-weighted statistical representation of depth to groundwater for each mapped potential GDE area using the zonal statistics function available in many GIS programs. This zonal statistics function identifies which cells of the depth to groundwater grid or raster dataset fall within the bounds of each mapped potential GDE polygon and then computes an area-weighted average for that area. This zonal statistics analysis was carried out for each of the 23 representations of depth to groundwater between spring 2008 and fall 2018 yielding 23 columns summarizing the average depth to groundwater for each mapped potential GDE area. The 23 periods used in the analysis represent water levels every 6 months from spring 2008 to fall 2018.

The second step involved simply subtracting the calculated depth to groundwater for each mapped potential GDE from the assumed rooting zone depth that was previously assigned based on assumed predominant vegetation. This field calculation was carried out in GIS for each of the 23 representation of depth to groundwater and was added as a new field for each calculation.

The third step of the grid-based geospatial processing effort involved identifying which mapped potential GDE areas can reasonably be assumed to have access to groundwater for each period. Mapped potential GDEs where the difference between assumed rooting zone depth and computed depth to groundwater was positive were assumed to be connected to groundwater for that season and year representation as the rooting zone depth was greater than the depth to groundwater. Conversely, mapped potential GDEs where the difference between assumed rooting zone depths and computed depth to groundwater was negative suggested that roots did not have access to groundwater. These areas were therefore assumed to be disconnected from groundwater for that season and year representation of conditions.

Results of this grid-based analysis of mapped potential vegetative GDEs and their classification as connected or disconnected to groundwater for each of the 23 periods is presented in Appendix 2-C. Mapped potential vegetative GDEs were then further characterized based on the percentage of years when vegetation with their assumed rooting zone depth would reasonably have access to groundwater. Areas with assumed predominant vegetation types that would have access to groundwater for greater than 50% of all periods are categorized as “likely connected” to groundwater for this grid-based analysis. Areas with assumed vegetation that do not appear to have access to groundwater for greater than 50% of the period of record are assumed to be “likely disconnected” from groundwater. This is reasonable based on the quality of groundwater level data in Basin, where historical data are only available every six months, in the spring and fall. A potential GDE with vegetation connected to groundwater every spring will be labeled as “likely connected.” Disconnection from groundwater for greater then 50% of periods indicates a multi-year lack of groundwater in the rooting zone.

Assumptions and Uncertainty

The approach developed and carried out to identify and evaluate GDEs within the Basin represents a conservative application of best available science through the formulation of reasonable assumptions. Representations of mapped potential GDEs were developed based on available geospatial datasets, though these resources cannot be assumed to be definitive. The vegetation classes present in the datasets and outlined in the Mapped Potential GDEs section above are broad and could reasonably represent an array of vegetation types requiring the development of conservative assumptions to guide the assignment of assumed rooting zone depths. Groundwater conditions were represented by the interpolation of observed conditions in the Basin's well network. These interpolated groundwater elevations may not reflect smaller scale variations in conditions both in space (less than 500 meters) and time (sub-seasonal). Because the groundwater elevations used herein represent regional, seasonal trends, they cannot capture the impact of perched aquifers on GDE health.

Notably, GDEs are not necessarily static and can vary in time and space depending on water year type and other environmental conditions. As such, this analysis is not intended to be a definitive cataloging of each class of GDE, but rather an initial survey of the maximum possible extent of above-ground, vegetated GDEs in the Shasta Basin. A physical determination of GDEs must show that roots are connected to groundwater, which would require an infeasible subsurface geophysical survey across the Butte Basin to inform the GSP.

Mapped Potential GDE Classification

A tabular summary of the grid-based GDE classifications for each mapped potential GDE area was developed. Potential mapped GDEs were grouped into two categories corresponding to areas assumed to be:

- Potential GDE;
- Potentially not a GDE.

Areas where the grid-based analysis showed that the mapped potential vegetative GDE was likely connected to groundwater were categorized as "potential GDE." Similarly, areas that were shown to be disconnected from groundwater were considered a "potentially not a GDE." The distribution of categorized GDEs for the Basin is presented in Figure 2.35 and Table 2.14.

The current map of likely connected GDEs are located in areas where direct groundwater levels are not available or areas with a short historical record. Consequently the current list of potential GDEs is considered tentative and dependent on collection of additional groundwater level data. Since GDEs in the Basin are considered a data gap, all GDEs currently labeled as "potentially not a GDE" will be reviewed with future GDE analysis updates. Since the submittal of the GSP in December 2021, work has been done to fill data gaps related to GDEs. New monitoring sites, rain and stream gages, and groundwater level monitoring sites, have been added to fill data gaps in areas near potential GDEs, as shown in Figure 2.3.6.

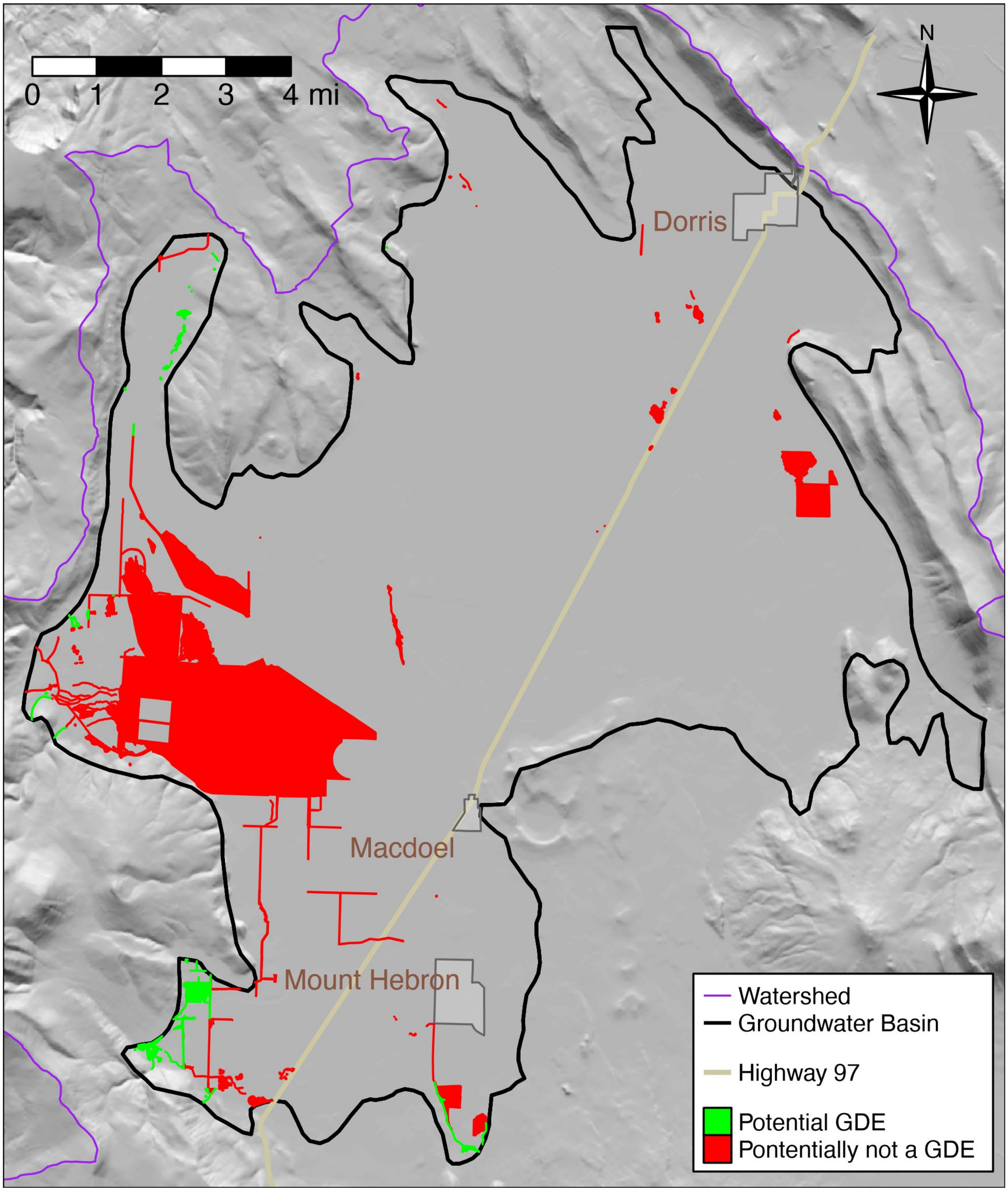


Figure 2.35: Categorized GDEs for the Basin.

Table 2.14: Distribution of Mapped Potential GDEs into Vegetative and Riparian GDE Categories.

Grid Classification	GDE Categorization	Area (Acres)	% of Mapped Potential GDE Area
Assumed GDE	Likely connected to groundwater	131	10.30%
Assumed not a GDE	Likely disconnected from groundwater	1,134	88.98%

Progress on GDE Data Gap

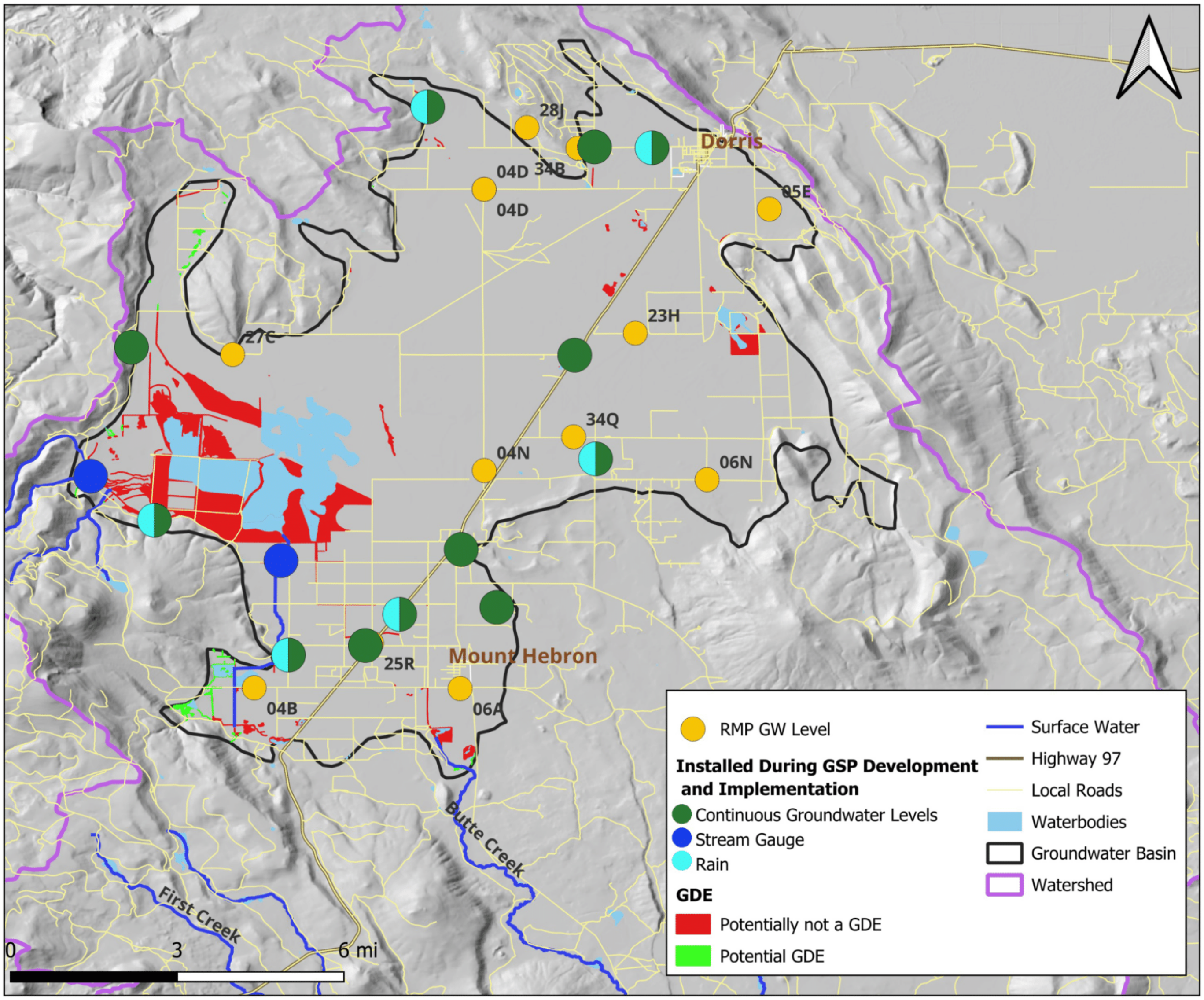


Figure 2.36: Categorized GDEs and Monitoring Stations Installed during GSP Development and Implementation for the Basin.

2.2.3 Water Budget Information

The historical water budget for the Butte Valley hydrologic watershed and the Bulletin-118 (B118) basin were estimated for the period October 1989 through September 2018 (i.e., water years 1990 through 2018). using the Butte Valley Integrated Hydrologic Model (BVIHM), which extends over the entire watershed. This 29-year model period includes water year types ranging from very dry (e.g., 2001 and 2014) to very wet (e.g., 1999 and 2006). On an interannual scale, it includes a multi-year wet period in the late 1990s and a multi-year dry period in the late 2000s and mid-2010s. The BVIHM used for the original GSP submitted in 2022 has been reevaluated and results have been enhanced by a more refined geology, and therefore a new set of hydrogeological parameters. Ahead of the 2027 GSP evaluation, the model will be fully recalibrated.

Annual water budgets for the BVIHM watershed area and for the (smaller) B118 basin are shown in Figure 2.37 to Figure 2.40 and monthly values of selected budget components are shown in Figure 2.41 for each of the four example water years. Table 2.15 and Table 2.16 show a summary of these budgets, and details are provided in Appendix 2-D. The following two sections provide an overview of BVIHM, which is used to determine the full water budget for the two relevant subsystems of the B118 basin: the irrigated land subsystem (including crops and soils) and the groundwater subsystem. The water budget also includes the total water budget of the B118 basin. Separately, water budgets for the watershed are presented for context, including the groundwater subsystem budget, the irrigated land subsystem budget, and the total water budget for the watershed (including the B118 basin contained within the watershed). The second section provides a description of the water budget shown in the figures and tables below and explains the water budget dynamics in the context of the B118 basin hydrogeology and hydrology described in previous sections. This sub-chapter provides critical rationale for the design of the monitoring networks, the design of the sustainable management criteria (SMCs), and the development of project and management actions (PMAs) (Chapters 3 and 4).

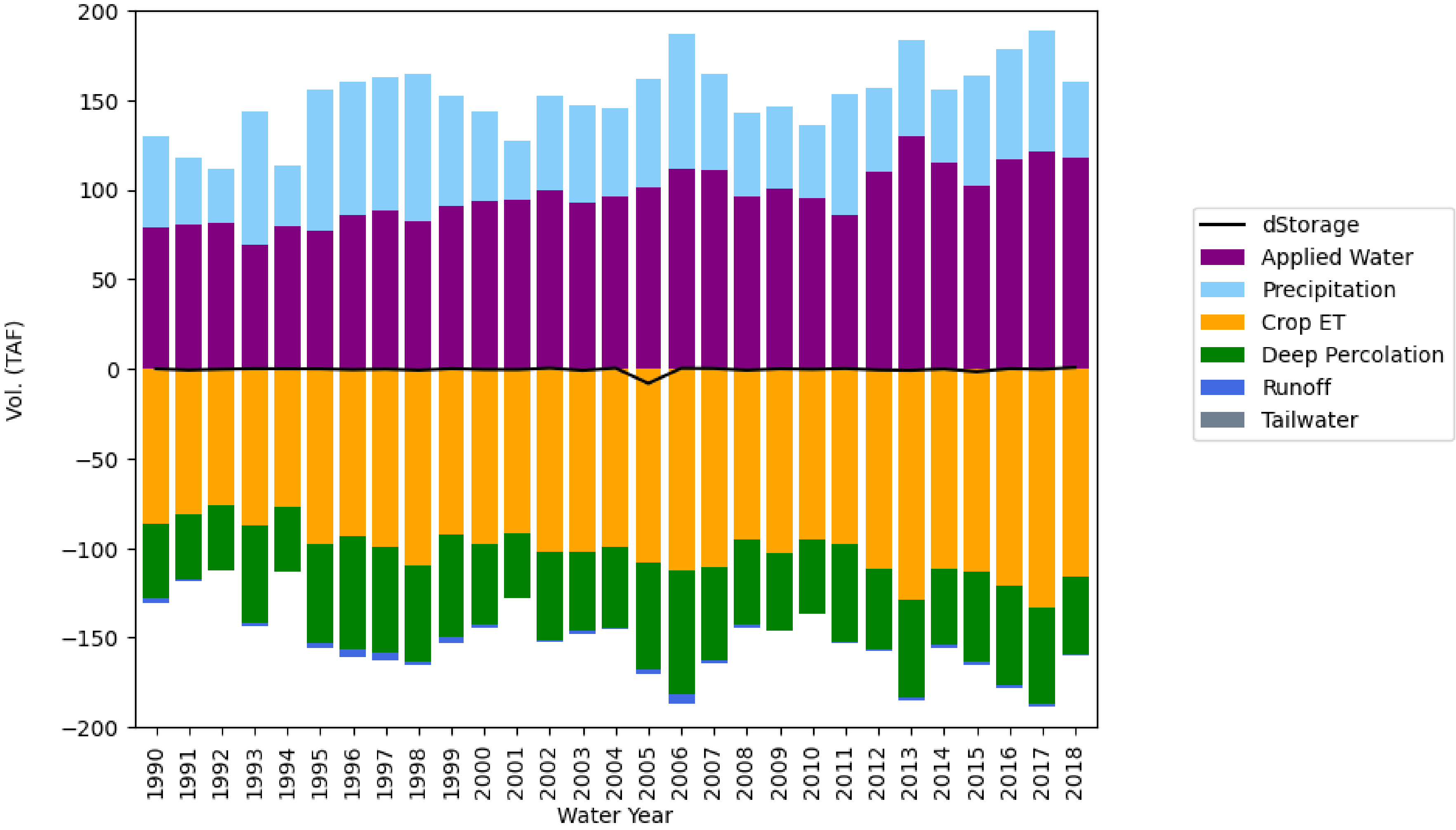


Figure 2.37: Annual water budgets for the irrigated land (land use, crop, soil) subsystem within the Butte Valley Integrated Hydrologic Model (BVIHM) model area. dStorage: change in storage within the land subsystem (within the uppermost portion of the unsaturated zone, including the crop/vegetation root zone). Crop ET: actual ET from crops, lawns, and natural vegetation. Deep percolation: deep percolation from the upper portion of the unsaturated zone, assumed to be equal to groundwater recharge for the same year. Runoff: surface runoff from precipitation. Tailwater: tailwater return flows, assumed to become groundwater recharge.

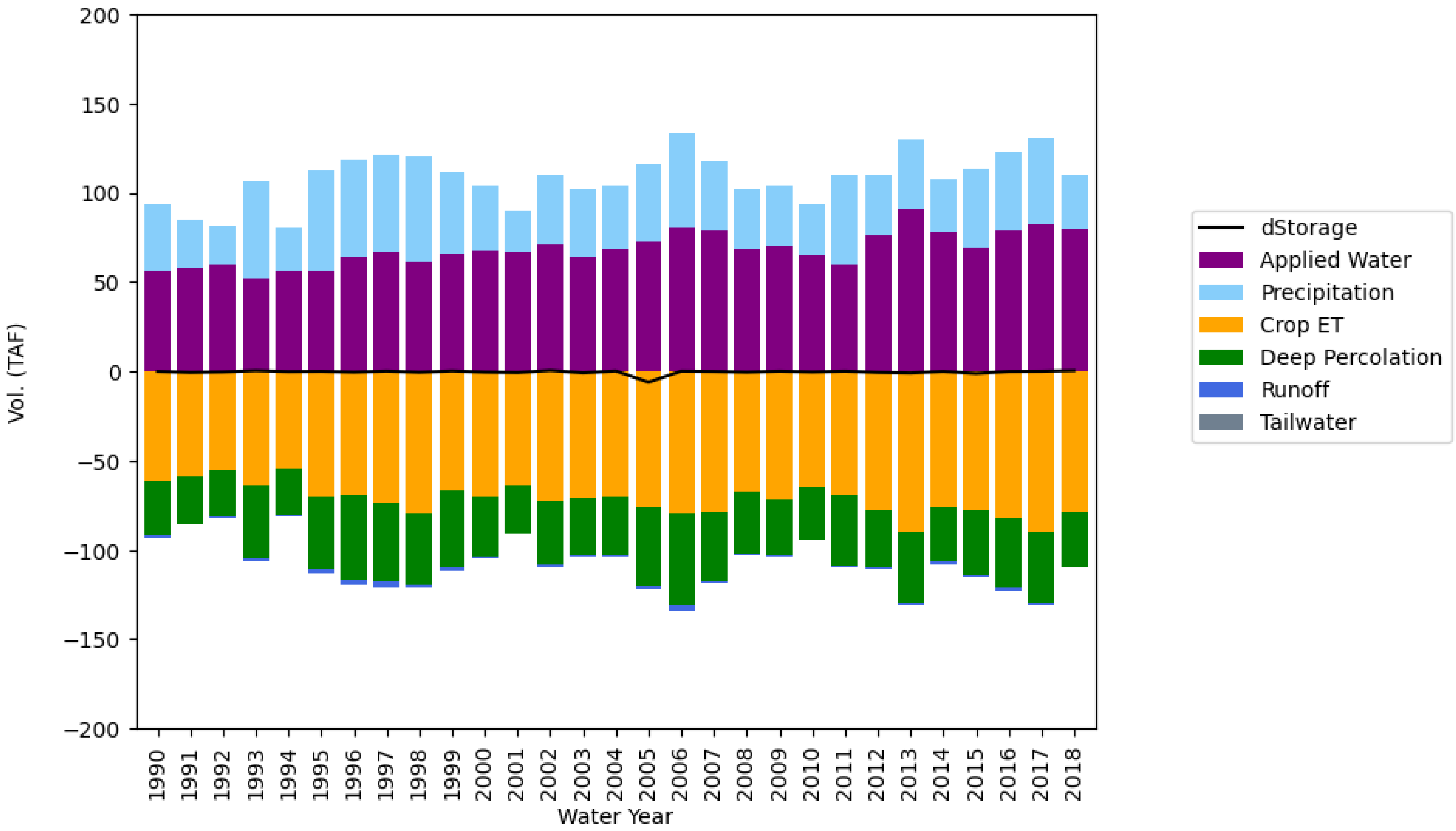


Figure 2.38: Annual water budgets for the irrigated land (land use, crop, soil) subsystem within the Bulletin-118 (B118) Basin. dStorage: change in storage within the land subsystem (within the uppermost portion of the unsaturated zone, including the crop/vegetation root zone). Crop ET: actual ET from crops, lawns, and natural vegetation. Deep percolation: deep percolation from the upper portion of the unsaturated zone, assumed to be equal to groundwater recharge for the same year. Runoff: surface runoff from precipitation. Tailwater: tailwater return flows, assumed to become groundwater recharge.

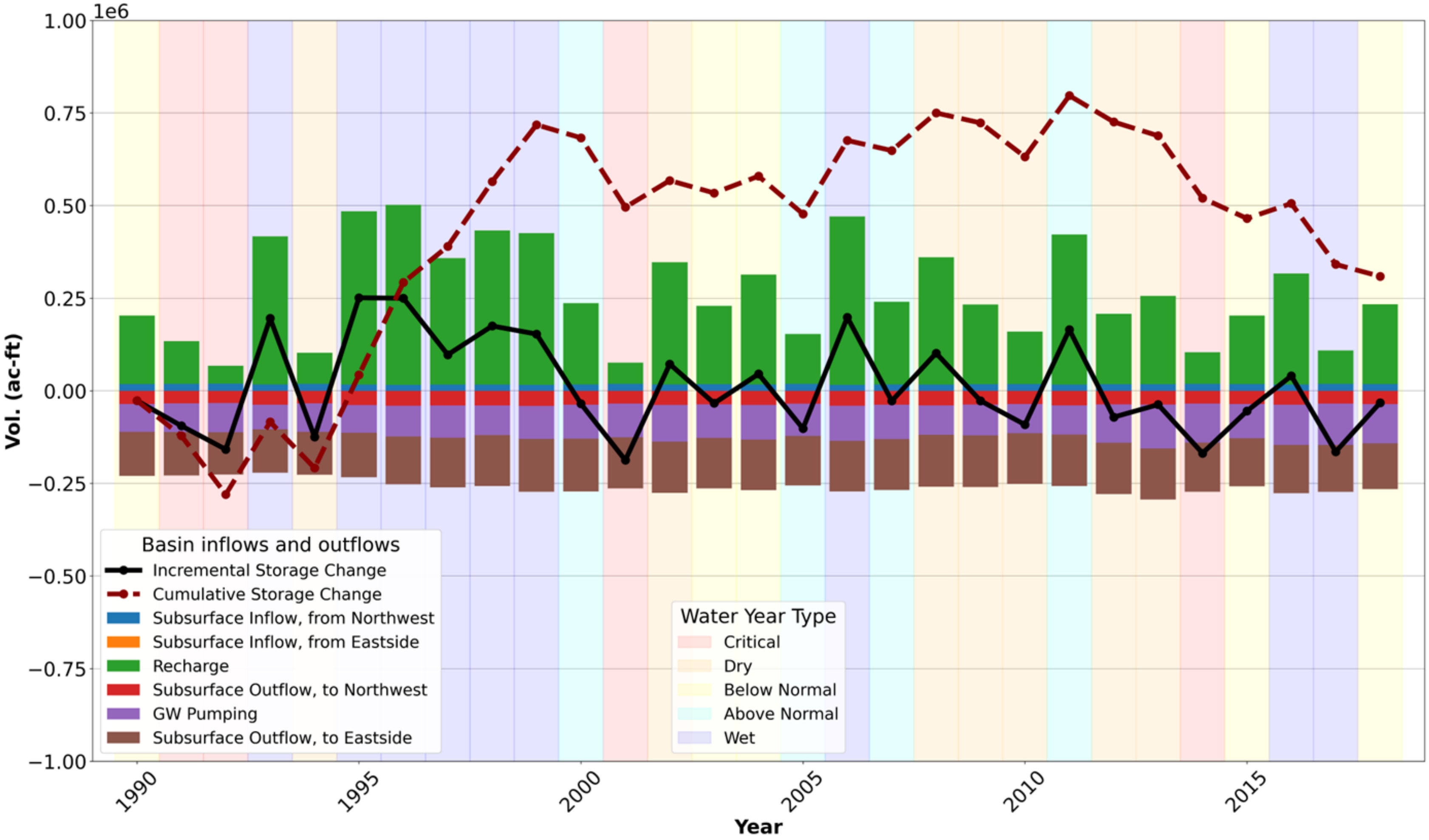


Figure 2.39: Annual groundwater systems budgets for the Butte Valley Integrated Hydrologic Model (BVIHM) model area. Incremental Storage Change: annual change in groundwater storage. Cumulative Storage Change: cumulative change in groundwater storage from the beginning time period. Subsurface Inflow from Northwest: lateral inflow to the BVIHM area from Northwest. Subsurface Inflow from Eastside: lateral inflow to the BVIHM area from Eastside. Recharge: landscape recharge to groundwater. Subsurface Outflow to Northwest: lateral groundwater outflows from the BVIHM area to Northwest. GW pumping: groundwater pumping (identical to AW in the land subsystem budget). Subsurface Outflow to Eastside: lateral groundwater outflows into Eastside.

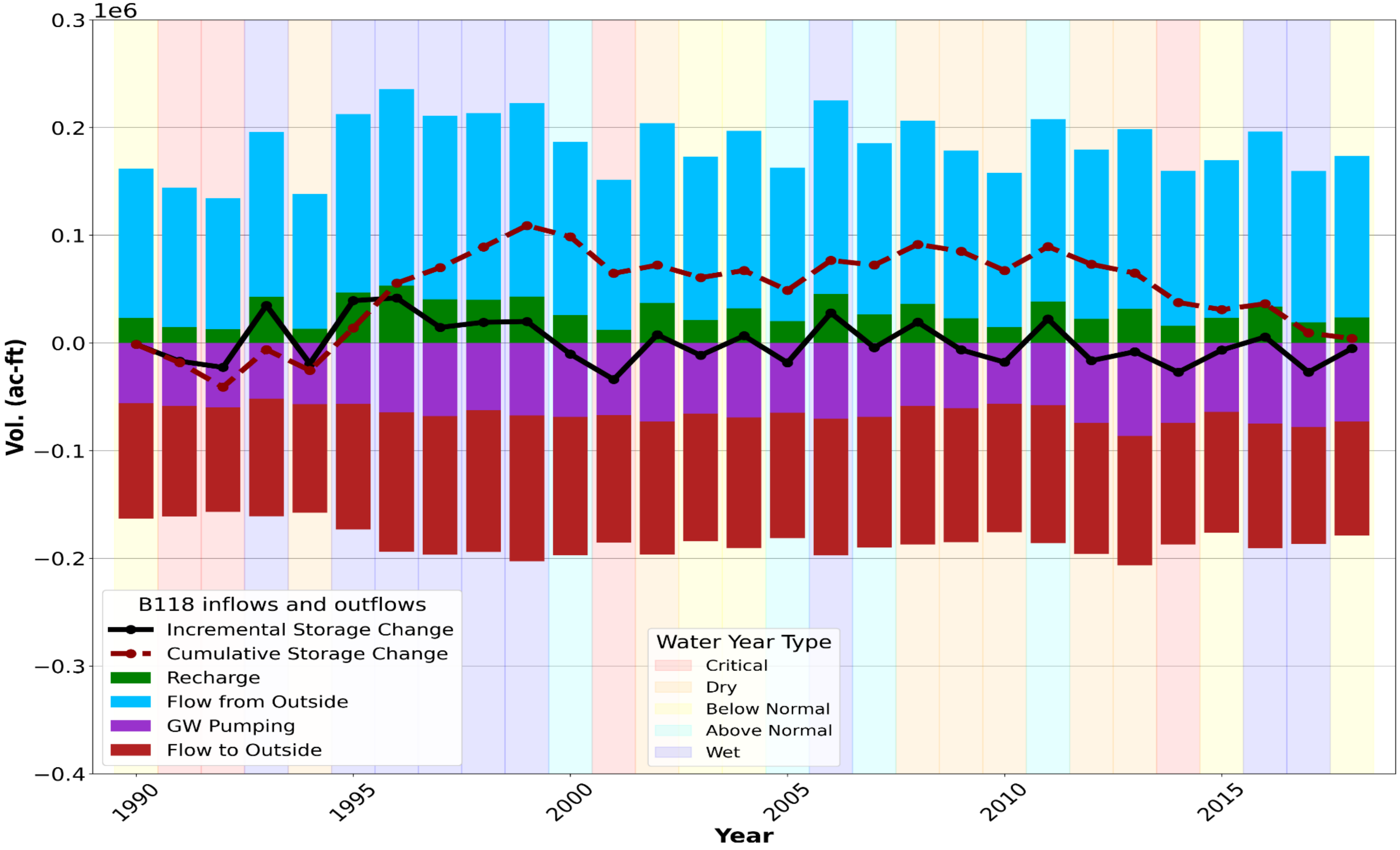


Figure 2.40: Annual groundwater systems budgets for the Bulletin-118 (B118) Basin. Incremental Storage Change: annual change in groundwater storage. RECHARGE: landscape recharge to groundwater (identical to the sum of Deepperc tot and Tailwater in the land subsystem budget). Flow from Outside: lateral groundwater flows into the Basin from the surrounding volcanic aquifer system. Flow to Outside: lateral groundwater flows out of the Basin into the surrounding volcanic aquifer system. GW pumping: groundwater pumping (identical to AW in the land subsystem budget).

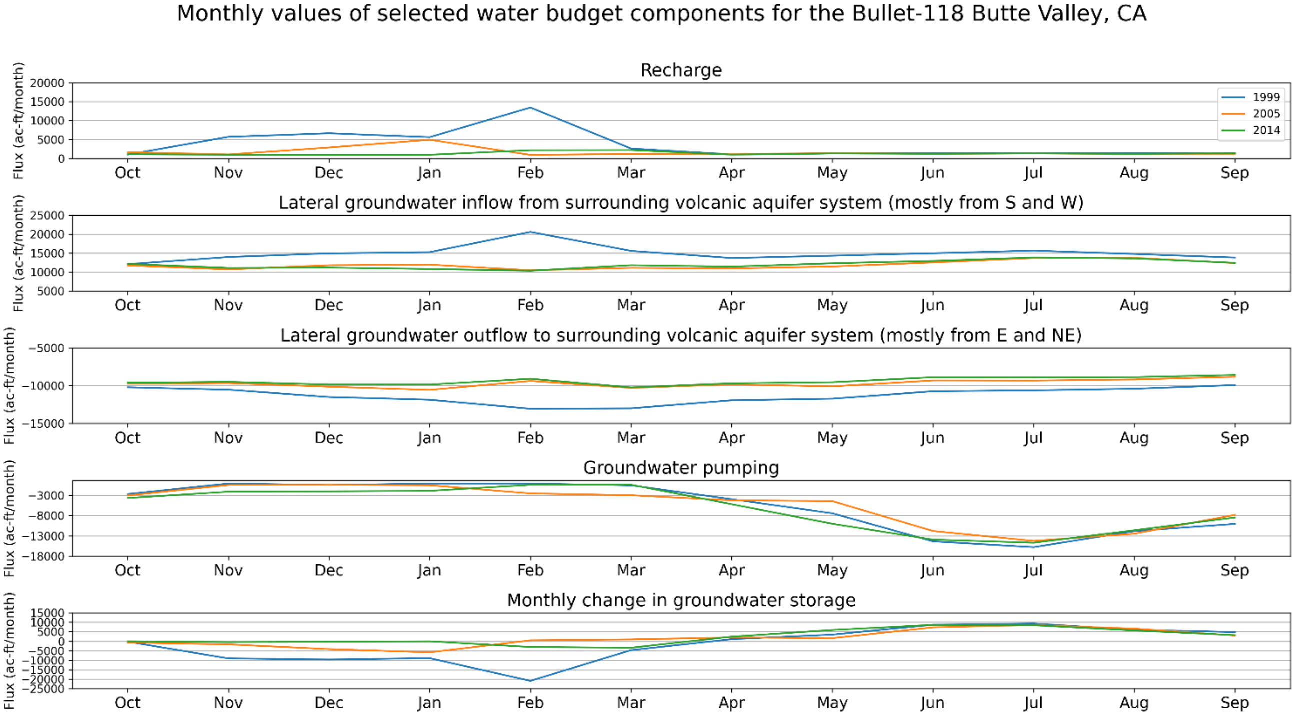


Figure 2.41: Monthly values of selected water budget components in the groundwater subsystem of the Bulletin-118 (B118) Basin in three example water years: 1999 (Wet year, blue), 2005 (Avg. year, orange), and 2014 (Dry year, green).

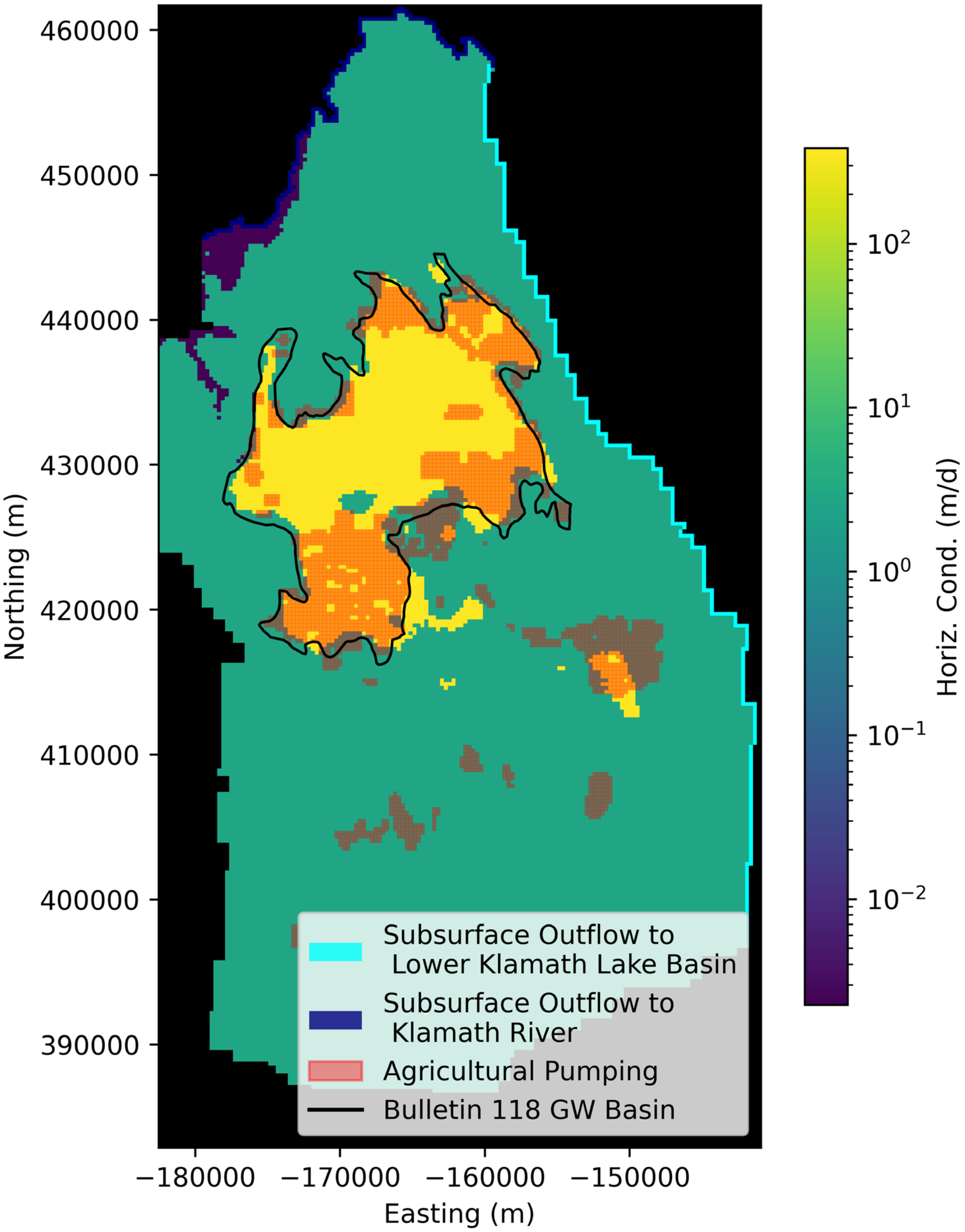


Figure 2.42: The hydrogeologic zones, model domain, and boundary conditions used in the BVIHM simulation of the surrounding watershed and Basin. Subsurface outflow to the east of the simulation area is represented through a general head boundary condition (light blue model cells). Groundwater-surface water interaction between the volcanics and Klamath River are simulated by setting constant head boundary conditions corresponding to the stream surface elevation (dark blue). In BVIHM, "agricultural pumping" includes pumping in BVWA to irrigate managed wetlands and grains. The irrigated land (L) budget refers only to lands identified as "Agricultural Pumping".

Table 2.15: Annual values (TAF) for water budget components simulated in the irrigated land (L) or soil subsystem of Butte Valley ("Agricultural Pumping" areas in the previous figure).

This includes areas of managed wetlands receiving pumped groundwater (see Appendix 2-D). This water budget does not include other non-irrigated lands. Positive values are water entering the soil volume: precipitation (Precip), surface water (SW), groundwater irrigation (GW); negative values are water leaving the soil volume: evapotranspiration, including evaporation from managed wetlands (ET), recharge (Deepperc) to the aquifer. The overall change in soil water storage (dStor) can be negative or positive in different water years. Note: Tailwater values are zero throughout the estimated period (WY 1990-2018).

	BVIHM area	B118	BVIHM area	B118	BVIHM area	B118	BVIHM area	B118	BVIHM area	B118	BVIHM area	B118
	AW		ETcrop		Deepperc		Precip		Runoff		dStor	
Minimum	69.2	52.0	-132.8	-90.2	-69.6	-51.0	30.6	21.6	-4.5	-3.3	-8.0	-6.0
25th percentile	85.7	61.9	-111.1	-77.9	-54.9	-39.6	45.9	33.6	-2.2	-1.7	-0.5	-0.4
Median	95.5	67.6	-99.4	-70.6	-48.7	-35.8	53.7	39.0	-1.5	-1.1	0.0	0.1
75th percentile	110.4	76.1	-93.6	-66.2	-43.2	-31.0	67.8	48.6	-0.7	-0.6	0.3	0.2
Maximum	129.9	90.8	-75.9	-54.4	-36.1	-26.3	82.1	58.7	-0.2	-0.1	0.9	0.6

Table 2.16: Annual values (TAF) for the groundwater budget components simulated with MODFLOW in the BVIHM area and in the B118 Basin (Bulletin 118 groundwater basin).

Positive values are water entering the aquifer: recharge from the soil zone, lateral subsurface inflow (FROM OUTSIDE) from outside of the B118 basin; negative values are water leaving the aquifer: lateral subsurface outflow (TO OUTSIDE) to outside of the B118, groundwater pumping (WELLS). The overall change in water stored (dSTORAGE) in the aquifer can be both negative and positive in different water years. Note that recharge used in the groundwater model was estimated with PRMS, even in "Agricultural Pumping" areas (irrigated lands) identified in the previous figure. PRMS estimates for recharge are generally lower than those estimated by the soil water budget model for the irrigated lands (Appendix 2-D).

	BVIHM area	B118	B118	B118	BVIHM area	B118	BVIHM area	B118
	RECHARGE		FROM OUTSIDE	TO OUTSIDE	WELLS		dSTORAGE	
Minimum	48.5	12.4	121.8	-135.5	-118.8	-86.3	-187.3	-34.0
25th percentile	141.7	20.2	143.2	-126.9	-94.4	-70.4	-91.4	-17.0
Median	219.5	25.8	157.1	-119.6	-88.9	-65.7	-27.3	-5.2
75th percentile	343.7	38.5	167	-112.4	-79.0	-58.7	101.6	19.2
Maximum	485.8	53.1	182.5	-97.0	-66.5	-51.9	251.2	41.7

2.2.3.1 Summary of Model Development

BVIHM was developed to support the development and implementation of this GSP. The simulation domain of BVIHM is a subset of the simulation domain for the USGS groundwater model of the Upper Klamath Basin (Gannett, Wagner, and Lite 2012). The BVIHM approximately corresponds to the western half of the Upper Klamath groundwater model domain that is south of the Klamath River. In other words, it represents the southwestern portion of the 2012 USGS Upper Klamath groundwater model domain. As such the simulation domain is much larger than the Basin and somewhat larger, but fully inclusive of the Watershed. The design of the simulation domain honors the fact that the Basin is a hydraulically well-connected sub-basin within the much larger regional volcanic aquifer system of the Upper Klamath Basin and Modoc Plateau (Gannett et al. 2007).

More specifically, the BVIHM simulation domain's northern boundary follows the Klamath River from Keno downstream past Rock Creek's confluence with the Klamath River, near the California Oregon border. From there the western simulation boundary includes most of the Shovel Creek watershed, then follows the western Butte Valley watershed boundary on its western and southern boundary. The southern boundary is also the southern boundary of the Upper Klamath Basin. The simulation domain follows the southern Upper Klamath Basin boundary (the northern boundary of the Sacramento River watershed) eastward to its intersection with Davis Road, immediately west of Little Glass Mountain. The eastern and northeastern boundary of the BVIHM domain does not follow any specific geographic features. From Davis Road, at the southeast corner of the simulation domain, the boundary runs due north to ephemeral source waters of Willow Creek near the northern boundary of Klamath National Forest, approximately follows northward along the westside of Willow Creek to near Souza Lake, then connects to a line from near Chip Butte along the eastern margin of the Mahogany Range to Little Tom Lake and to the northern model boundary with the Klamath River at Keno (Figure 2.42).

In BVIHM, the three hydrologic subsystems within the simulation domain (surface water, land/soil, and groundwater) are simplified into two subsystems that are explicitly modeled with BVIHM: the land/soil subsystem and the groundwater subsystem. This simplification was reasonable because:

- All water available to the Basin is via lateral groundwater inflow from the surrounding watershed.
- Because the Basin groundwater system is continuous with and hydraulically well-connected to the much larger, relatively permeable volcanic aquifer system underlying much of the simulation domain.

This two-subsystem simplification for purposes of developing model information for the GSP is also reasonable because of the high infiltration capacity of the volcanic soils of the surrounding Watershed and the lack of surface water features throughout the Watershed. The few creeks (described above) featured within the Watershed typically recharge into the groundwater subsystem upgradient and outside of the Basin. The model did not attempt to capture in any detail surface water features near its eastern boundary (Souza Lake, Little Tom Lake).

Importantly, with this simplification, all applied water, including groundwater pumped for the Butte Valley Wildlife Area (BVWA), is considered to originate from groundwater. And all surface runoff is assumed to have recharged into the (volcanic) groundwater basin outside of the Basin itself. A known existing model shortcoming is the very simplified representation of the surface water operation described above for the BVWA. However, to the degree that runoff from the four creeks captured by BVWA is predominantly used by wetland ET, the small amount of recharge from the relatively impermeable soils within the BVWA is appropriately captured by the model.

The BVIHM is based on three separate software modules:

- The land/soil subsystem of the irrigated landscape is simulated using the data from Davids Engineering (Appendix 2-D). The output from this model include spatio-temporally distributed groundwater pumping (all applied water needs simulated by this module) and spatiotemporally distributed groundwater recharge. The spatial discretization is equal to individual land use polygons in the DWR land use surveys of 2000, 2010, and 2014. The temporal discretization is daily.
- The land/soil subsystem and the surface subsystem of the entire watershed are simulated using the USGS PRMS software. This simulation module generates spatio-

temporally distributed groundwater recharge for the 1989 to 2018 simulation period. The spatial discretization is 888 ft (271 m). The temporal discretization is daily.

- The groundwater subsystem is simulated with the USGS MODFLOW 2005 software (Harbaugh 2005; Markstrom et al. 2008) using the pumping from the Davids Engineering model and recharge output from the USGS PRMS land subsystem simulation as input for the 29-year groundwater subsystem simulation. The transient, three-dimensional groundwater simulation has a spatial discretization of 888 ft (271 m), variable vertical discretization, a temporal discretization of daily time-steps with a monthly "stress period." The latter means that daily pumping and recharge are aggregated to monthly average values (and kept constant within a calendar month). This is consistent with common basin modeling practice.

The three simulation modules are explicitly coupled: the 29-year output from the DE and PRMS simulations is generated first, then provided to the MODFLOW groundwater simulation. The explicit coupling (rather than intrinsic, more integrated coupling) is possible since historical groundwater levels throughout the Basin and over the entire simulation period are sufficiently deep that significant feedback to the land/soil subsystem are absent or negligible for purposes of this simulation:

- There is no groundwater interaction with the soil zone.
- Recharge is applied directly to the groundwater module, assuming that monthly recharge rates are that same month's deep percolation.

Full documentation on BVIHM can be found in Appendix 2-D. The model is not calibrated and simulation results represent preliminary estimates.

Natural lands: Land/soil Subsystem Model Summary

A deterministic, distributed-parameter, physical-process-based watershed model for the Upper Klamath Basin was recently developed by the USGS using the publicly available software PRMS 5.0 (Risley 2019). This model includes the entire BVIHM simulation domain. The model is discretized into small sub-watershed units called hydrologic response units (HRUs). An HRU is defined as an area within the watershed defined by similar hydrologic, climatologic, vegetation, slope, and soil properties. Within the BVIHM simulation domain, this model distinguishes approximately 30 HRUs. For each HRU, the model simulates snow processes, plant interception of rainfall, infiltration, surface runoff, soil water storage, evapotranspiration, and groundwater recharge. It also simulates streamflow at the HRU outlet. The model uses daily time-step and uses daily precipitation and minimum and maximum daily air temperature as input, provided by the PRISM group at Oregon State University (Figure 2.43; see Markstrom et al. 2008). The model is calibrated against streamflow data at several long-term gages operated within the Upper Klamath Basin. For BVIHM, the Upper Klamath Basin PRMS model represents the surface water and land/soil subsystem. Surface water simulated only included major streams downgradient from Butte Valley. Recharge computed by the land/soil module of PRMS was used as input to the MODFLOW-based groundwater module of BVIHM, described below.

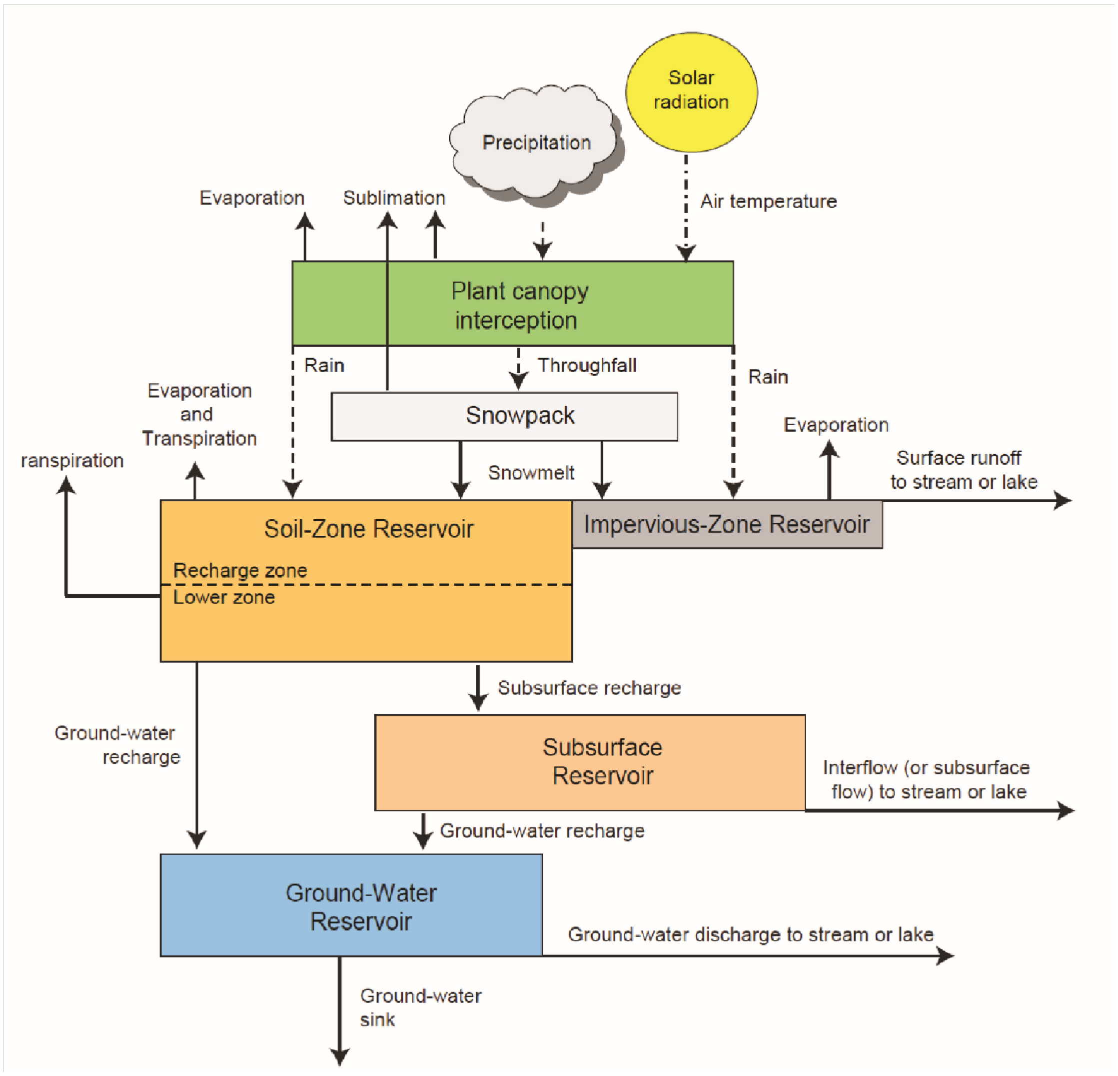


Figure 2.43: Schematic diagram of a watershed and its climate inputs (precipitation, air temperature, and solar radiation) simulated by PRMS (from Markstrom et al., 2008).

Irrigated Agriculture, Wetlands, and Developed (Urban) Lands: Land/Soil Subsystem Model Summary

The PRMS model of the Upper Klamath Basin was considered adequate for estimating recharge in the BVIHM simulation domain, outside of irrigated or developed areas. Groundwater pumping and recharge from irrigated agriculture, wetlands, and developed (urban) lands was obtained using the crop root zone water model (CRZWM) developed by Davids Engineering (2020, see Appendix 2-D). CRZWM considers the water fluxes into and out of the root zone of crops, urban, and wetland vegetation: precipitation and applied water are inputs to this subsystem, ET (from applied water and from precipitation), surface runoff from precipitation and irrigation, and deep percolation (from applied water and from precipitation, here assumed to be equal to recharge) are outputs from the subsystem (Figure 2.44).

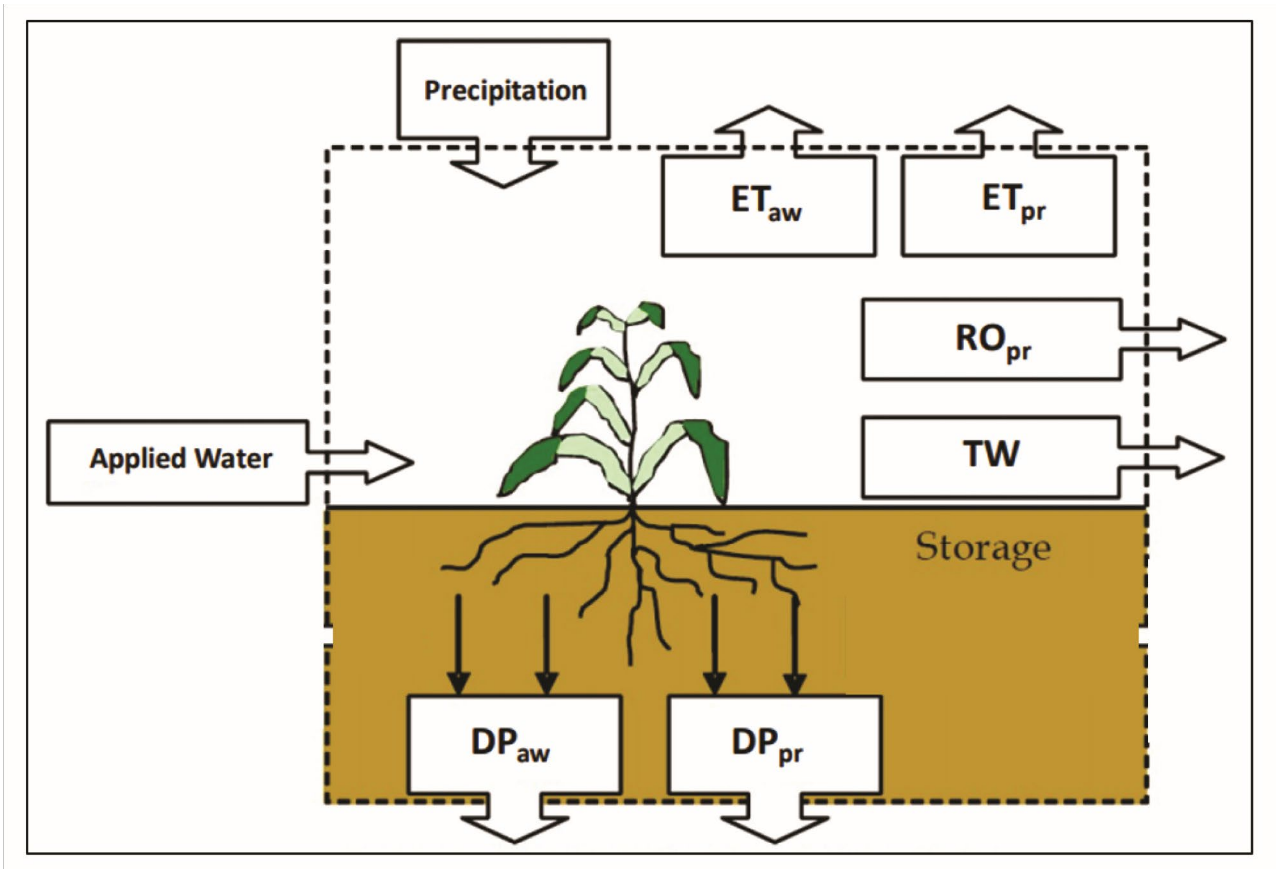


Figure 2.44: Conceptualization of fluxes of water into and out of the crop root zone (modified from Davids Engineering, 2020 in Appendix 2-D).

CRZWM uses information about crop and land use type, soil type, irrigation system, daily precipitation, and daily ET measured for the 29-year simulation period, to compute daily estimates of recharge and pumping. Crop types and irrigation information were obtained from DWR land use surveys available for 2000, 2010, and 2014. For simulation purposes, each year of the simulation period was assigned the land use survey year closest in time. Soils information was obtained from the National Soil Survey. Precipitation data was provided by the PRISM group at Oregon State University. Unique to CRZWM, the ET measurements are based on remote sensing data obtained throughout the 1989 to 2018 period. These data were combined with local climate information to estimate ET. The ET and precipitation information is used to compute applied water, runoff, and deep percolation (recharge) as a function of crop type, soils, and irrigation system.

Groundwater Subsystem Model Summary

Overview

The groundwater module of BVIHM is a MODFLOW finite difference groundwater simulation model of the groundwater (GW) subsystem that also encompasses the entire BVIHM simulation domain. The purpose of the groundwater model is to simulate the temporal and spatial distribution of groundwater flow, groundwater hydraulic heads, and water table location throughout and beyond the Watershed's heterogeneous aquifer system. These simulation outcomes are driven in the model by the hydrogeologic properties across the simulation area and by the spatially and temporally variable dynamics of

- Recharge (groundwater module input from the land/soil module, Figure 2.43).

- groundwater pumping (groundwater module input from the land/soil irrigated lands module, Figure 2.44).
- The subsurface inflows and outflows at the boundaries of the simulation domain (computed by the groundwater module of BVIHM) including relatively smaller groundwater-surface water exchanges at the Klamath River, and much larger subsurface outflows toward the lower Klamath Lake basin and the Tule Lake basin.

Simulation Domain Boundary Conditions

Insignificant amounts of groundwater are leaving or entering the simulation domain at the watershed boundaries of Butte Valley and the Upper Klamath Basin on the western and southern portion of the simulation domain. This boundary is considered a “no-flow” boundary. On the northern boundary, the Klamath River is considered a “constant head boundary,” defined by the elevation of the Klamath River. The Klamath River falls from about 4100 ft amsl at Keno, north of Butte Valley to about 3200 ft at the northwestern corner of the simulation domain, one-thousand feet below Butte Valley (the lowest surface elevation in the simulation domain). Gannett, Wagner, and Lite (2012) provide streamflow gains for this mostly gaining section of the Klamath River, originating from groundwater inflows, including springs and associated creeks on either side of the Klamath River.

The southernmost part of the eastern boundary is thought to follow the general landscape gradient and approximately parallels groundwater flow lines hypothesized by Gannett et al. (2007). It is considered a “no-flow boundary” (i.e., flow occurs alongside this boundary). The central and northern portion of the eastern boundary is simulated as a “general head” boundary, allowing for unrestricted outflow (or inflow) toward the east and northeast. The outflow across this boundary is computed by the model using a user-defined estimate of the hydraulic conductivity and thickness of the volcanic aquifer system in the area to the east of the boundary, and by water level conditions well to the east of Butte Valley, described in the following paragraph.

The USGS groundwater model of the Upper Klamath Basin (Gannett, Wagner, and Lite 2012) was investigated to find areas east of and closest to the eastern BVIHM simulation domain where water levels during its 1989 to 2004 simulation period remained relatively unchanged, either because groundwater levels were controlled by surface water features (groundwater discharge into streams or lakes) or otherwise remained unchanged. A line was thus defined and average 1989 to 2004 water levels in the Upper Klamath Basin groundwater model on this line were mapped. The northern end of this line begins at the Klamath River at the mouth of the Klamath Strait Drain, follows that Drain and West Canal south, wraps around the west- and southside of the Lower Klamath National Wildlife Refuge and follows the tunnel that connects the Refuge with the Tule Lake Basin. In the Tule Lake Basin, the line wraps around the west- and southside of Tule Lake, and from Tule Lake’s southeast corner follows a regional north-south groundwater convergence zone south toward the Upper Klamath Basin’s southern watershed boundary (Figure 2.45). For each general head boundary cell, the general head is that in the nearest cell of the defined head line, and the general head conductance parameter considers the distance to that cell and the effective hydraulic conductivity between these two cells (Figure 2.45).

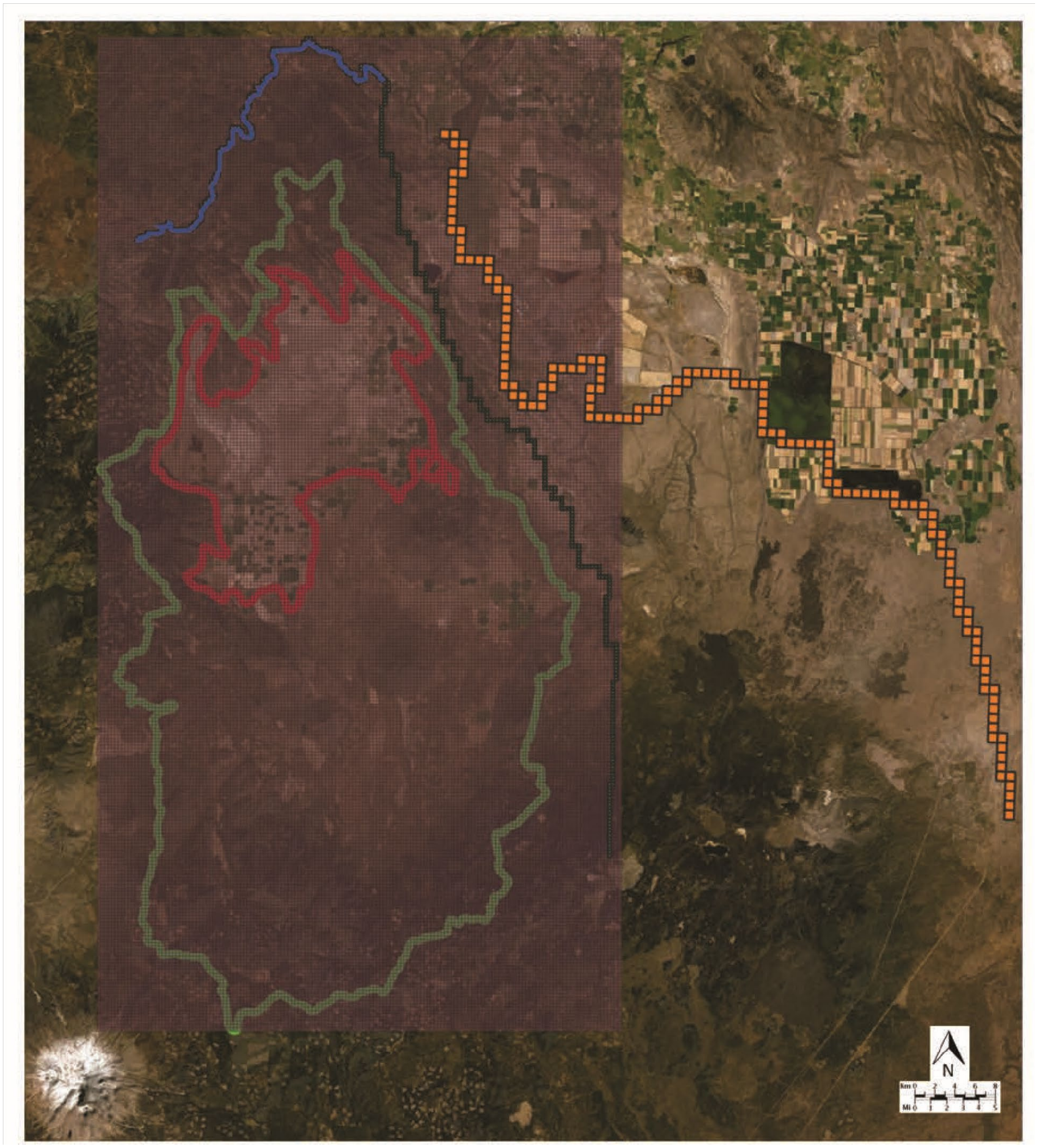


Figure 2.45: Butte Valley watershed (green boundary), Butte Valley groundwater basin (red boundary), the BVIHM "general head" boundary (dark green-brown line to the northeast and east of the watershed), the Klamath River as a "prescribed head" boundary (dark blue line to the north of the watershed), and the line of defined heads (orange) used for computing the distance between the "general head" boundary and known heads.

Flow from the general head boundary is a function of the aquifer transmissivity between the dark green-brown and the orange line, and of the hydraulic head gradient between those two lines. The defined heads along the orange line are obtained from the USGS Upper Klamath Basin groundwater model.

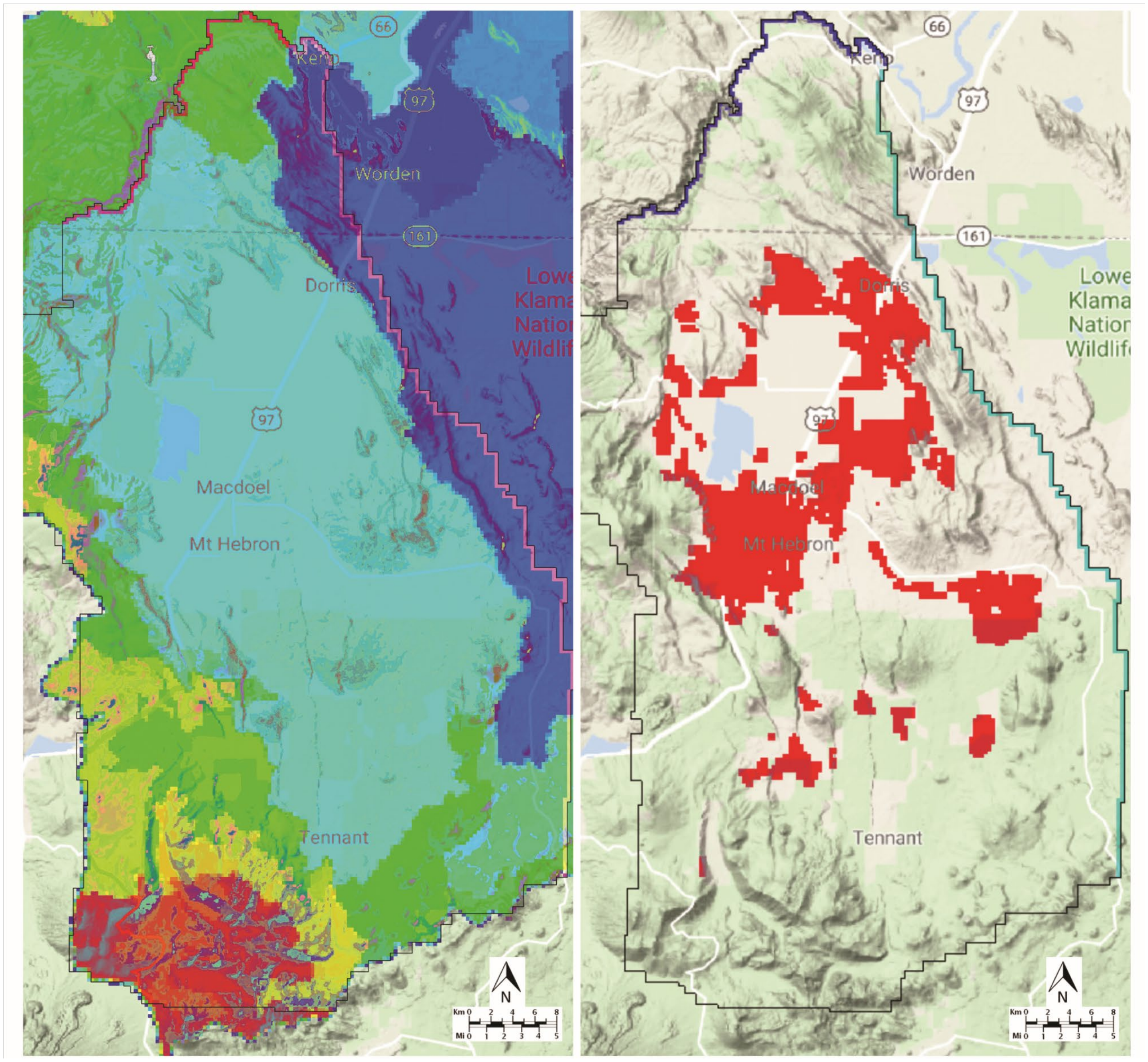


Figure 2.46: Spatial distribution of long-term average recharge (left, red: highest amounts of recharge, dark blue: lowest amounts of recharge) and location of areas with groundwater pumping (irrigated land, right). Black outline: BVIHM simulation domain boundary.

General Groundwater Flow Dynamics and Direction

For the BVIHM simulation domain, most of the precipitation occurs in the mountains to the south and west of Butte Valley, where it also recharges the volcanic aquifer system (Figure 2.46). Recharge may be preceded by surface runoff into a nearby creek that later disappears into the subsurface through recharge. Groundwater from that dominant recharge zone flows northward, northeastward, and eastward across Butte Valley and Redrock Valley, where significant amounts of the groundwater are pumped for irrigation and subsequently lost to ET (Figure 2.46). However, groundwater pumping is significantly less than estimated recharge. Hence, significant amounts of groundwater discharge laterally through the lakebed, alluvial, and volcanic aquifer system of the Butte Valley and the Upper Klamath Basin toward the Lower Klamath groundwater basin, toward an area east of the Butte Valley watershed south of the Lower Klamath groundwater basin, and possibly toward the Tule Lake groundwater basin, which is separated from Butte Valley groundwater basin by the larger volcanic aquifer system in this region (Gannett et al. 2007; Gannett, Wagner, and Lite 2012).

2.2.3.2 Description of Historical Water Budget Components

The section describes the full water budget of the Basin including inflows to the Basin, outflows from the Basin, and the fluxes from the irrigated land/soil subsystem, L, to the groundwater subsystem, GW.

Figure 2.37 to Figure 2.40 show the water budgets for the two subsystems. Fluxes between subsystems are shown twice: in the subsystem from where the flux originates as output (negative flux, analogous to an account withdrawal at a bank), and in the subsystem into which the flux occurs as input (positive flux, analogous to an account deposit at a bank).

This section also describes storage changes in the subsystems. An increase in storage over a period of time occurs when fluxes into a subsystem exceed fluxes out of the subsystem over that period of time, similar to deposits exceeding the amount of withdrawals in a bank account where the account balance increases. In Figure 2.37 to Figure 2.40, a storage increase is depicted as additional negative bar length needed to balance the negative bar length (fluxes out of the subsystem) with the positive bar length (fluxes into the subsystem). In other words, storage increase is depicted as if it were a negative flux. This is consistent with accounting principles in hydrologic modeling.

Similarly, a decrease in storage over a period of time occurs when fluxes into a subsystem are less than the fluxes out of the subsystem over that period of time (similar to withdrawals from a bank account exceeding the deposits into the bank account: the account balance decreases). In Figure 2.37 to Figure 2.40, a storage decrease is depicted as additional positive bar length needed to balance the positive bar length (fluxes into the subsystem) with the negative bar length (fluxes out of the subsystem). In other words, storage decrease is depicted as if it were a positive flux, consistent with hydrologic modeling practice.

Basin Inflows

There are two inflows in the historic water budget: precipitation on the valley floor (to L), and subsurface inflow or mountain front recharge from the surrounding quaternary volcanics underlying the upper watershed (to GW):

- *Precipitation (to L)*: Rainfall on the valley floor is a key input for the PRMS and CRZWM model which results in deep percolation. Groundwater recharge (from L to GW) occurs when root zone water storage exceeds its water holding capacity due to precipitation and/or irrigation amounts exceeding evapotranspiration needs.
- *Subsurface Inflow (to GW)*: The BVIHM domain includes the entire Butte Valley watershed. Recharge (across the landscape or in creeks) outside the Basin becomes groundwater flow, some of which flows into the Basin. BVIHM is used to compute monthly and annual subsurface inflows from the upper watershed across the Basin boundary, within the larger volcanic aquifer system of the region and into the unconsolidated deposits within the Basin.

Discussion

Precipitation is highly variable - more variable than any other Basin input/output flux. Precipitation amounts to the Basin range from about 22 TAF per year to nearly 60 TAF per year. Median precipitation is 39 TAF. Precipitation has declined significantly over the last two decades relative not only to the simulated first decade, but also relative to the second half of the 20th century.

While precipitation is significant, subsurface inflows are more than twice as large, ranging from 122 to 183 TAF per year, with a median of 157 TAF per year. The median total water supply to the Basin is about 198 TAF annually.

Basin Outflows

The two outflows in the historic water budget component are evapotranspiration (ET; from L) and subsurface outflow (from GW):

- *Evapotranspiration*: Evapotranspiration is the consumptive water use in the Basin, from crops and from natural vegetation (from L). Evapotranspiration loses water in the Basin to the atmosphere.
- *Subsurface Outflow*: Subsurface outflow from the Basin within the larger regional volcanic aquifer system is dominantly to the East and Northeast. Additionally there is some subsurface outflow to the North through less permeable tertiary volcanics. Volcanics of the Western Cascades to the Northwest are of very low permeability and prevent draining of the Basin toward the Klamath River near Rock Creek.

Discussion

Median consumptive use (evapotranspiration or ET) in the Basin is 71 TAF. This flux is highly variable depending on water year type, despite the fact that irrigation can buffer significantly against drought conditions. However, significantly more land is fallowed in dry years and natural vegetation has significantly reduced evapotranspiration in dry years, when it can fall below 55 TAF per year. On the other hand, it can reach 90 TAF in wet years. Median ET is over 80% higher than median precipitation. The discrepancy is even larger in dry years. Some ET is buffered against precipitation variability through soil water storage and irrigation.

Subsurface groundwater outflow from the basin amounts to 120 TAF per year (median), varying from 97 to 136 TAF per year. Subsurface outflow represents nearly 60% of the total Basin outflow (with the remainder going to ET). Seasonally, outflow is consistently highest in the late winter months and lowest in the fall, corresponding to groundwater levels being highest in spring and lowest in the fall. Basin outflow is necessary to maintain water levels in the Basin well above the regional groundwater outflow points near the Lower Klamath Lake/Lost River/Tule Lake areas (see Section 2.2.2.1).

ET represents only 40% of the total Basin outflow, which demonstrates that net groundwater use in the Basin does not exceed recharge including subsurface inflows to the Basin, thus maintaining groundwater outflow from the basin. Precipitation, evapotranspiration, and recharge estimates for the upper watershed have significant uncertainties, hence, the exact amount of groundwater inflow into and outflow out of the basin must also be regarded as highly uncertain.

Flows Between Land (Soil) Zone and Groundwater

All other fluxes depicted in the two subsystem water budgets of the Basin are flows between the land/soil subsystem and the groundwater system:

- *Recharge (from L to GW)*: Recharge from the land surface occurs primarily in winter months when there are larger amounts of precipitation and limited evapotranspiration. This results in excess water in the soil zone leading to deep percolation. Surface runoff and irrigation return flows are small and are also considered to become groundwater recharge, since the Basin has no surface drainage.

- *Groundwater Pumping for Applied Water (from GW to L)*: Groundwater pumping is the only applied water for irrigation in the Basin. Groundwater pumping is limited to the spring and summer, from April to September, when recharging is nearly negligible. As described above, the relatively small amounts of surface water irrigation are effectively simulated as (creek) recharge outside the Basin boundary and groundwater pumping within the Basin boundary.

Discussion

Surface runoff (1.1 TAF per year) is a small fraction compared to deep percolation. It was assumed to eventually evaporate. Future model updates may allocate some fraction of runoff instead to recharge. Deep percolation in the irrigated areas was estimated by Davids Engineering to supply a median 36 TAF of recharge to groundwater (see Appendix 2-D). This is about one-third of the total water applied to or precipitated onto the Basin landscape (median of the sum of precipitation and applied water: 97 TAF).

The PRMS median estimate for Basin recharge (used in the groundwater model) is 26 TAF per year. This is significantly less than the estimate by Davids Engineering (36 TAF per year). For consistency with recharge estimates for non-agricultural lands, the groundwater model uses the (lower) PRMS estimate of recharge, even for agricultural lands for which Davids Engineering would provide (higher) recharge estimates. Future versions of BVIHM will address this discrepancy in recharge estimates based on ongoing monitoring and data collection in the Basin.

Annual groundwater pumping is quite variable, ranging from 52 TAF to 86 TAF, with a median of 66 TAF per year. Pumping, while highly variable, has significantly increased during the 1989 to 2018 period, somewhat mirroring the declining trend in precipitation.

Using the PRMS recharge estimate, the resulting median net pumping of 40 TAF per year represents 25% of the total subsurface inflows from the upper Watershed, where net pumping is the difference between pumping and recharge. Even if subsurface inflows were substantially overestimated because the PRMS model overestimated upland recharge, groundwater pumping is unlikely to exceed total available Basin inflows.

Change in Storage

Soil Zone Storage: As seen in the Soil Water Budget plots, there is minimal interannual change in the soil water storage, most likely due to the low storage capacity of the soil zone.

Aquifer Storage: Groundwater is the largest storage component in the Basin. Annual changes in groundwater storage range from as much as 42 TAF increase to as much as 34 TAF in decrease over a 12-month period. There is a significant long-term trend indicating some groundwater depletion. Only few years had a net positive groundwater storage change: 1993, 1996 to 1999, 2006, and 2011. Median decline in Basin groundwater storage, between 1991 and 2018, was 5.2 TAF per year. The change in storage is reflected in a steady decline in groundwater levels in many parts of the Basin, particularly in the eastern and northeastern part of the Basin. With lower water levels in the Basin, the simulations also show a decrease in groundwater outflow to areas east and northeast of the Basin due to reduced gradients across the general head boundary.

2.2.3.3 Groundwater Dynamics in the Butte Valley Aquifer System: Key Insights

The Butte Valley groundwater basin is an alluvial basin surrounded by a late tertiary and quaternary volcanic watershed that historically has had high rates of winter precipitation due to its altitude, but little surface expression of flows and no surface storage reservoirs or canals connecting to any surface reservoirs. Most excess precipitation readily percolates into the subsurface, recharging a permeable volcanic aquifer system. Groundwater flows across the Basin toward groundwater sinks (discharge to surface water, pumping) in areas to the east and northeast of the Basin. Groundwater discharges into the Klamath River to the north through low permeability, tertiary volcanics. Groundwater discharges toward the lower Klamath Lake basin, the Lost River, and Tule Lake through late tertiary and quaternary volcanics. Winter rains fill the aquifer system between October and April (Figure 2.41).

Groundwater pumping within the Basin leads to lower net outflow into areas to the east of the Basin, thus leading to a lower hydraulic gradient that connects the Basin to the areas east/northeast of the Basin, where groundwater discharges into surface water features or is pumped out. This creates a natural longer-term lowering of water levels superimposed on seasonal water level lowering during the dry season. Water levels are highest near the southern and western valley margin and slope toward the Klamath River, lower Klamath Lake basin and Tule Lake basin.

Seasonal variability of recharge is accentuated by year-to-year climate variability: Years with low precipitation lead to lower recharge from the surrounding watershed, hence less subsurface inflow to the Alluvial Basin from the quaternary volcanics, but also less outflow to areas to the east. Again, this leads to lower groundwater levels in the Basin. Over the past thirty years, a decrease in precipitation and a commensurate increase in groundwater pumping have both led to less groundwater being discharged eastward, lessening the hydraulic gradient through the regional aquifer systems east of the Basin, thus lowering water levels within the Basin.

Any significant long-term decrease or increase of long-term precipitation totals over the Watershed will lead to commensurate lowering or raising, respectively in the average slope of the water table from the valley margins toward the lower Klamath Lake Basin groundwater elevation, leading to a dynamic adjustment of water levels, even under otherwise identical land use and land use management conditions.

Similarly, any increase or reduction in groundwater pumping leads to a decrease or increase in groundwater storage until the change in groundwater elevation is sufficient that the subsurface outflow is increased or decreased reducing any further changes in storage.

2.2.4 Future Water Budget

The future projected water budget contains all of the same components as the historical water budget; for a description of those terms, see Section 2.2.3.

To inform long-term hydrologic planning, the future projected water budget was developed using the following method:

1. Observed weather and streamflow parameters from water years 1991 to 2011 were used multiple times to make a 50-year “Base case” climate record (see Appendix 2-D for details). The Base case projection represents a hypothetical future period in which climate conditions are the same as conditions from 1991 to 2011.
2. The climate-influenced variables Precipitation (as rain), Reference Evapotranspiration (ETref), and tributary stream inflow were altered to represent four climate change scenarios:

   a. Near-future climate, representing conditions in the year 2030.
   b. Far-future climate, representing central tendency of projected conditions in the year 2070.
   c. Far-future climate, Wet with Moderate Warming (WMW), representing the wetter extreme of projected conditions in the year 2070.
   d. Far-future climate, Dry with Extreme Warming (DEW), representing the drier extreme of projected conditions in the year 2070.

3. BVIHM was run for the 50-year period of water years 2022 to 2071 for the Base case and all four-climate change projected scenarios.

For convenience, the scenarios described in points 2a-2d above will be referenced as the Near, Far, Wet and Dry future climate scenarios. Additional tables and figures for all five future climate scenarios are included in Appendix 2-D.

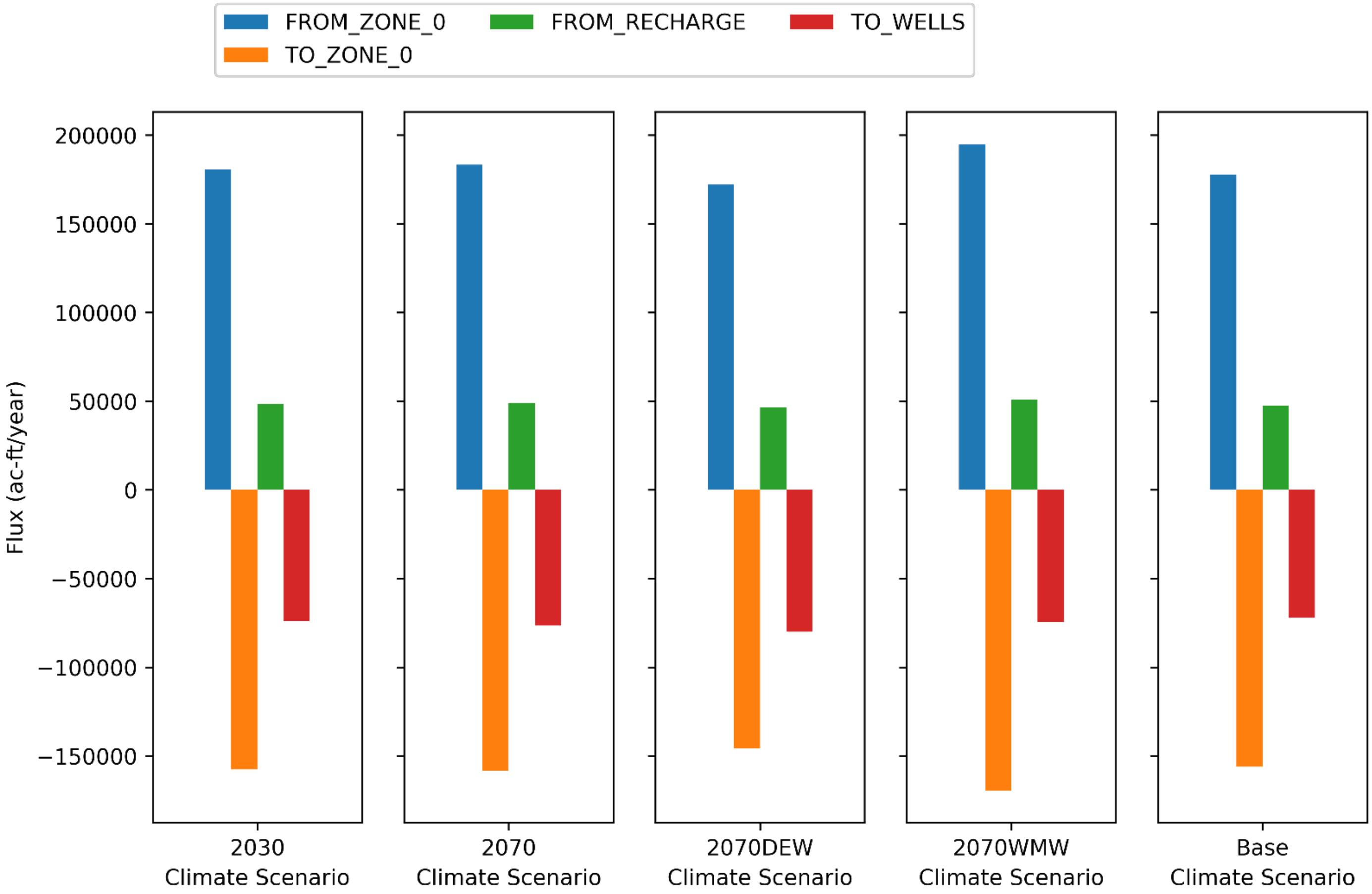


Figure 2.47: Water Budget components for different future climate scenarios.

Method Details

The climate record for the projected 50-year period of water years October 2021 to September 2071 was constructed from model inputs for the years 1991 to 2011. The minimum bound of 1991 was imposed by ETref data, which is not available prior to the BVIHM historical period; the maximum bound of 2011 was imposed by DWR change factors, which are only available through (Appendix 2-D).

Under their SGMA climate change guidance, DWR provided a dataset of “change factors” which each GSA can use to convert local historical weather data into four different climate change scenarios (DWR 2018). Change factors are geographically and temporally explicit. Geographically, a grid of 1/16-degree resolution cells covers the extent of California; for each of these cells, one change factors applies to each month, 1911 to 2011.

The change factor concept is intended to convert all past years to a single near or far future year; for example, imagine that in a hypothetical grid cell, the 2030 (Near) scenario change factor for ET ref in March 2001 was 5%. This would imply that, under the local results of the global climate change scenario used to inform this guidance, if March 2001 had occurred in the year 2030, there would be 5% more ET in that grid cell than historically observed.

Implications

The 2030 (Near) and 2070 central tendency (Far) scenarios predict similar rainfall conditions to the Base case, while the 2070 DEW (Dry) and 2070 WMW (Wet) scenarios show less and more cumulative rain, respectively. Conversely, all scenarios predict higher future ET than the Base case.

More groundwater is held in aquifer storage in the Wet scenario, and less in the Dry scenario. However, interannual variability is a greater driver of storage change than climate change scenarios (i.e., in future year 2045 the difference between the Wet and Dry scenarios was ~5 TAF, but the range in overall interannual variability in each scenario is greater than 40 TAF).

Conversely, the impact of future climate conditions on recharge in the upper watershed and subsurface flows is highly dependent on which scenario is selected. Near and Far scenarios show minimal differences from historical Base case flow conditions. The Dry scenario shows some periods of notably reduced flow, while the Wet scenario shows some years with much higher flow than historical Base case flow conditions.

Importantly, under all climate change scenarios, water table conditions remain stable over the long-term and are likely avoid minimum threshold (MT) exceedances. Future climate scenarios represent historic cropping patterns and therefore assume no expansion of irrigated lands beyond their historical footprint. Future scenarios therefore represent stable land use conditions. The lack of significant downward water level adjustment is a result of the fact that the surface water basin is closed, and because even the dry-hot year future scenario does not represent conditions that are more stressful than the most recent 10-year period.

2.2.5 Sustainable Yield

2.2.5.1 Conceptual Basis for Estimating Sustainable Yield

Sustainable Yield in a Closed Groundwater Basin

In a closed groundwater basin, all inflow to and outflow from the groundwater basin come from and go back to the overlying landscape, streams, and lakes. On the inflow side, this includes recharge from losing streams, soil water percolation to the water table, and irrigation return flows under irrigated landscapes. On the outflow side of the groundwater budget, this includes discharge to wells, to gaining streams (baseflow) and to groundwater-dependent ecosystems (GDEs). Groundwater level and storage changes are directly related to the water mass balance of the landscape and surface water system overlying the basin: the annual storage change is equal to the difference between the sum of annual inflows from lakes, streams, and landscape recharge ("deposits") and the sum of annual outflow to wells, streams, and GDEs ("withdrawals"). If "deposits" exceed "withdrawals", groundwater storage increases (water levels rise). If "deposits" are less than "withdrawals", groundwater storage decreases (water levels fall).

SGMA 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)).

With respect to the water level and groundwater storage sustainable management indicators (SMCs), this means that water levels and groundwater storage must be in a long-term dynamic equilibrium. To the degree that recent long-term average historic "deposits" do not match "withdrawals" as defined above, the resulting average annual decline in groundwater storage must be addressed by either increasing the amount of "deposits" or by decreasing the amount of "withdrawals" or a combination of both, without causing additional undesirable outcomes with any of the sustainability indicators.

Hypothetically applied to the average annual groundwater storage changes that have been measured in the Butte Valley Basin, this principle would suggest that groundwater pumping must be reduced by 5 TAF/yr to 7 TAF/yr or external sources of water for MAR would have to be found in that amount (Table 2.17, also see Section 2.2.2.4). For the period for which pumping has been estimated (1990 – 2023), average pumping was 67 TAF/yr and average measured groundwater storage decline was 4.2 TAF/yr. For the mega-drought period from 2000 to 2023, average pumping was 70 TAF/yr and the average measured groundwater storage decline was 6.3 TAF/yr. For more recent periods since 2010, average pumping is higher (73 – 76 TAF/yr), while groundwater storage changes remain at 4.7 – 6.4 TAF/yr).

Table 2.17: Average groundwater pumping over several different time periods (Section 2.2.3.1) and the corresponding average measured groundwater storage change (Section 2.2.2.4). Groundwater pumping was estimated using the soil/landscape-subsystem model. Groundwater storage change was measured using measured changes in water levels in the Basin and specific yield.

Time Period	Estimated Pumping (TAF/ Year)	Measured Groundwater Storage Change (TAF/year)
Average 1990-2023	67	-4.2
Average 1990-2000	61	+0.8
Average 1990-2010	63	-2.7
Average 1990-2014	65	-4.1
Average 2000-2014	68	-7.4
Average 2010-2023	73	-6.4
Average 2014-2023	74	-4.7
Average 2017-2023	76	-5.4
Average 2000-2023	70	-6.3

Sustainable Yield in an Open Groundwater Basin

In an open groundwater basin, significant subsurface inflows and/or outflows occur that must be accounted for in the water budget. The subsurface inflows add to the “deposits” in the water budget, while the subsurface outflows add to the “withdrawals” from the water budget. After accounting for these subsurface inflows and outflows, the sustainable yield of the groundwater basin, equivalent to a closed groundwater basin, is that which allows long-term dynamic equilibrium water levels and groundwater storage to remain sufficiently high to avoid undesirable results.

As described in Section 2.2.2.1., Butte Valley Basin is an open groundwater basin, that is, it is a sub-basin of the larger UKB groundwater system. The Basin has limited surface water inflows with creeks under losing conditions and likely disconnected from groundwater (Sections 2.2.1.9 and 2.2.2.9). Recharge from creeks and Meiss Lake are conservatively neglected for the water budget computation (Section 2.2.3).

Under the developed groundwater conditions of the past 70 years, Butte Valley groundwater pumping for crop irrigation has been able to capture some of the naturally occurring subflow through the Basin, which enters on its southern and western boundary (subsurface inflow) and leaves through its eastern and northeastern boundary (subsurface outflow). The onset of groundwater pumping in the mid-20th century primarily affected the outflow through the Basin’s northern and northeastern boundary toward Lower Klamath Lake / Lost River / Tule Lake (see Sections 2.2.2.1 and 2.2.2.2). The development of groundwater may also have captured ET from groundwater-dependent ecosystems (Wood, 1960).

Given the open nature of the Basin and the lack of large interaction with overlying surface water features or extensive GDEs, the largest “deposits” to and “withdrawals” from the Basin are subsurface inflow, recharge within the Basin (“deposits”), groundwater pumping within the Basin, and subsurface outflow (“withdrawals”). Neither subsurface inflow nor subsurface outflow can be measured or remotely observed and must be estimated using models. They are estimated to be the largest terms in the water budget (Section 2.2.3).

Subsurface inflow is primarily a function of the amount of recharge from precipitation upgradient of the Basin, in the volcanic uplands to the south and west (Section 2.2.3). In the Basin, groundwater pumping is significantly less than the long-term average amount of “deposits” (subsurface inflow and Basin recharge, Section 2.2.3) thus sustaining a large amount of subsurface outflow. The amount of subsurface outflow to the east and northeast is primarily driven by the difference between “deposits” (subsurface inflows and recharge within the Basin) and groundwater pumping. In other words, the subsurface outflow dynamically adjusts to the balance between “deposits” and groundwater pumping:

- Under long-term dynamically stable “deposits” conditions, any change in groundwater pumping will cause a commensurate inverse change in subsurface outflow (more pumping leads to less outflow and less pumping leads to more outflow).
- Under long-term dynamically stable groundwater pumping conditions, any change in “deposits” will cause a commensurate change in subsurface outflow (less “deposits” will cause an equal decline in subsurface outflow).
- Subsurface outflow will dynamically adjust as long-term “deposits” may change (e.g., mega-drought) while groundwater pumping also changes (e.g., increased pumping due to drought conditions).

With respect to Butte Valley, the dynamic adjustment of the outflow to changes in either “deposits” or groundwater pumping or both is associated with two key conditions that are relevant to sustainable yield and sustainable management of the basin:

1. It may take years to decades before subsurface outflow achieves it’s new equilibrium condition in response to changes in “deposits” or groundwater pumping. However, it’s initial dynamic reaction to such changes in “deposits” and groundwater pumping will be observable as soon as such changes occur.

2. The amount of subsurface outflow controls the average elevation of the water table in the Basin above the downgradient regional (UKB) groundwater discharge points (see Textbox 1)

Regarding the first key condition, the preliminary, uncalibrated version of BVIHM used for the water budget calculations indicates that the time for the Basin to reach new equilibrium conditions following a long-term change in either “deposits” or groundwater pumping for the Basin is on the order of several decades, but significant changes in water level and groundwater storage changes, beyond reactions to the specific water year type within the Basin may be observable within a five-year period, suggesting that it is reasonable to expect that PMAs will yield observable improvements in the water balance of the Basin within a five year period after initiation.

Regarding the second key condition, it follows that subsurface outflow must be increased to stop the chronic lowering of water levels and groundwater storage over the past 23 years. Absent significant sources of additional groundwater recharge (adding to the “deposits”), the Basin’s only option to achieve that is to decrease the amount of groundwater pumping. Were the Basin closed, the previous section already determined that a decline in groundwater pumping of 5 TAF/yr to 7.5 TAF/yr relative to recent groundwater pumping rates may achieve a balance. For the open basin, a sensitivity analysis was performed (see Textbox 2) to show at what level, relative to 1980’s assumed 62 TAF/yr groundwater pumping, future groundwater pumping would sustain groundwater levels at 2020 average water level conditions (assumed to be 30 ft lower than in 1980, corresponding to a 15% decline in subsurface outflow relative to 1980). Since the analysis is based on equilibrium conditions, this pumping level is an approximate estimate of sustainable yield. Here are some examples of how to interpret Table T2.1 from the sensitivity analysis textbox, Textbox 2:

- If “deposits” in the future, R2020, will be the same as under 1980 conditions, and “deposits” amount to 180 TAF/yr (as estimated by BVIHM, Section 2.3), 2020 water level conditions would be afforded by a sustainable yield that is 129% of 1980 groundwater pumping (62 TAF) or 80 TAF/yr.

- If “deposits” in the future, R2020, will be 95% of 1980 conditions, and “deposits” in 1980 amounted to 180 TAF/yr, then a reasonable sustainable yield would be 114% of 1980 pumping or 71 TAF/yr.
- If “deposits” in the future, R2020, will be 90% of 1980 conditions, and “deposits” in 1980 amounted to 180 TAF/yr, then a reasonable sustainable yield would be 100% of 1980 pumping or 62 TAF/yr.
- If 1980 “deposits” were smaller than estimated by BVIHM, for example, 130 TAF/yr, then the three sustainable yield values above would be 116%, 106%, and 95% of 1980 pumping, 72, 66, and 59 TAF/yr, respectively.
- If 1980 “deposits” were higher than estimated by BVIHM, for example, 250 TAF/yr, then the three sustainable yield values above would be 145%, 125%, and 105% of 1980 pumping, 90, 78, and 65 TAF/yr, respectively.

2.2.5.2 Reported Estimates of Safe Yield

DOI, 1980 reports that there is no long-term chronic decline in water levels in Butte Valley and that “the ultimate safe groundwater-supply (pumpage) is 102,00 acrefeet” (page 2 of DOI 1980). The source for 102 TAF/yr safe yield estimate was DWR, 1973, Bulletin 105-4, Supporting Studies Appendix, p.19. No other estimates of safe yield or sustainable yield have been reported for the Basin (California DWR,1973).

Textbox 1 - Understanding why subsurface outflow from the Basin exerts critical control on the average water level elevation in the Basin

The Basin is a subbasin of the larger UKB groundwater system (Section 2.2.2.1). The groundwater discharge points of the Basin's subsurface outflow are the Lower Klamath Lake, Lost River, and Tule Lake, and possibly pumpers in those regions. The Basin is located upgradient of and approximately 200 ft higher than those groundwater discharge points (Section 2.2.2.1). Average water level elevations in the Basin are primarily a function of subsurface outflow from the basin. Why is that?

Groundwater flow is governed by the basic principles of Darcy's Law, which states:

groundwater flux = hydraulic conductivity x hydraulic gradient

The subsurface outflow from the Basin, in a simplified conceptual manner, can be understood as the groundwater flux from the eastern/northeastern boundary of the Basin to the groundwater discharge points further east. The hydraulic conductivity in the above equation therefore refers to the properties of the volcanic rocks separating the Basin from the groundwater discharge points to the east. And the hydraulic gradient is the average slope of the water table between the eastern/northeastern boundary of the Basin and the groundwater discharge points to the east.

The hydraulic conductivity of the region between the Basin and the groundwater discharge points is highly variable, unknown, but does not change in time. To understand why the Basin's average water level is controlled by the subsurface outflow, that is the groundwater flux through volcanics east of the Basin, we rearrange the above equation and obtain:

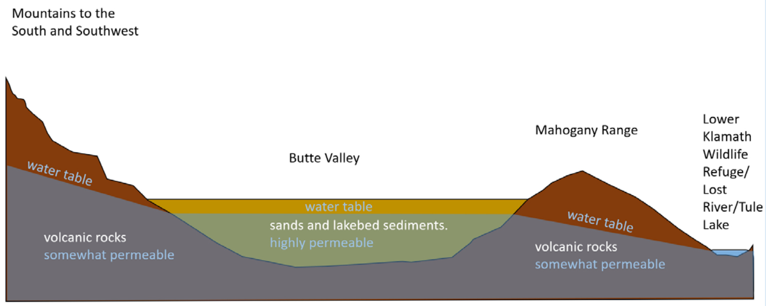
hydraulic gradient = groundwater flux / hydraulic conductivity

The equation now shows that the hydraulic gradient of the water level between the eastern/northeastern boundary of the Basin and the groundwater discharge points is directly proportional to the groundwater flux, that is, the subsurface outflow from the basin.

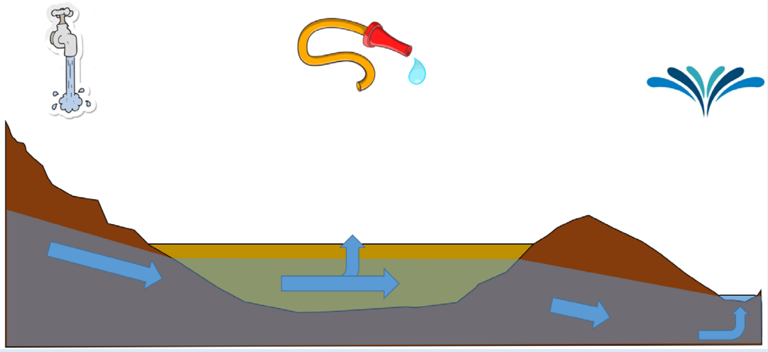
Since the elevation of the groundwater discharge points (Lower Klamath Wildlife Refuge/Lost River/Tule Lake) does not change, a change in the hydraulic gradient will, at equilibrium conditions, lead to a change in the water level elevation at the eastern/northeaster boundary of the Basin, which in turn controls the average water level elevation in the Basin.

Textbox 1 - Understanding why subsurface outflow from the Basin exerts critical control on the average water level elevation in the Basin [continued]

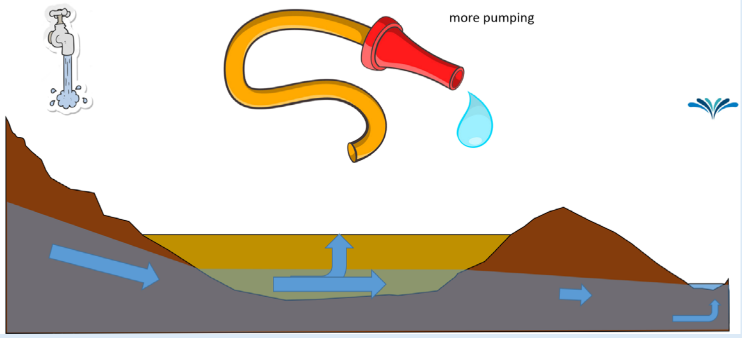
Simplified Conceptual South/Southwest to North/Northeast Cross-Section Butte Valley



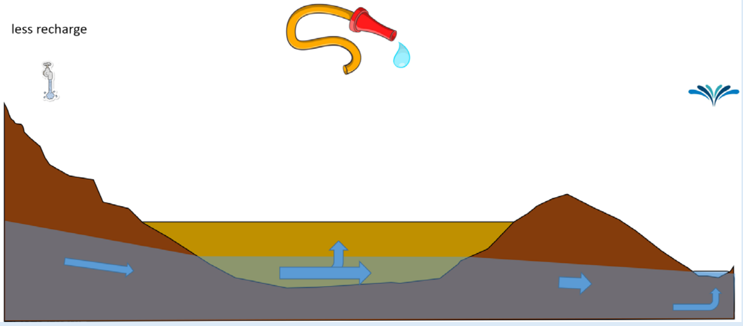
How Does Water Level Elevation Change in Such a System?



Same recharge, more pumping => less outflow from Butte Valley to "drain"



Less recharge, same amount of pumping => less outflow from Butte Valley to "drain"



Textbox 1 - Understanding why subsurface outflow from the Basin exerts critical control on the average water level elevation in the Basin [continued]

To the degree that groundwater outflow from the Basin is reduced by groundwater pumping – or by a reduction in "deposits", i.e., groundwater inflow from the volcanic uplands to the south and west of the Basin or Basin recharge – a proportionally smaller hydraulic gradient to the groundwater discharge points will develop at equilibrium conditions.

Practically speaking, and oversimplifying the exact outcome, a reduction of subsurface outflow by, for example, 30%, will lead to a reduction in the hydraulic gradient to the groundwater discharge points by 30%, and thus the elevation difference between water levels in the Basin and water levels at the groundwater discharge points will be reduced by 30%, once new groundwater flow equilibrium conditions are reached.

The time needed to reach equilibrium conditions is a function of the permeability and storage capacity of the groundwater system upgradient, within, and downgradient of the Basin, but is expected to be years to decades, given the size of the regional groundwater flow system that the Basin is part of. However, initial dynamic changes in water levels in response to changes in pumping, groundwater inflow, and recharge are readily observed on annual and seasonal time scales.

For groundwater management, the important corollary to understanding water level changes in the Basin as a response to changes in subsurface outflow toward downgradient groundwater discharge points is that those subsurface outflows must be maintained to establish stable water level conditions in the Basin. The subsurface outflow must be increased to counter long-term chronic declines in water levels, either by increasing subsurface inflow, Basin recharge, or by decreasing groundwater pumping.

Thus far, this conceptual outline above has assumed that the groundwater discharge points to the east remain constant in elevation. However, some or most of the groundwater discharge points maybe associated with pumping in the Tule Lake and Klamath Valley areas in both California and Oregon (Gannett et al., 2012). Due to significantly increased pumping in those areas after the year 2000, median groundwater levels in those areas, between 2000 and 2014, have declined by 30 ft (Klamath Valley) and nearly 25 ft (Tule Lake) (Gannett and Breen, 2015). These areas are 15 to 25 miles east of the Basin boundary. It is hydrogeologically plausible that the observed decline in groundwater levels in the areas that likely are the groundwater discharge points for the Butte Valley Basin subsurface outflow have affected or will eventually affect water levels along the eastern/northeastern boundary of the Basin and, hence, impact average water levels in the Basin. However, the degree and time scale over which such impacts may occur are highly uncertain. A modeling study to assess such outcomes has not yet been initiated.

Textbox 2 - Sensitivity Analysis: Relating observed water level changes in the Basin to increased pumping and decreased subsurface inflow.

Applying Darcy's law, as explained in the previous textbox, to the Basin, the following assumptions will be made:

- The average water level elevation in the Basin around 1980 was 4230 ft amsl
- The average water level elevation in the Basin around 2020 was 4200 ft amsl (30 ft lower)
- The average water level elevation at the groundwater discharge points is 4030 ft amsl

A 30 ft decline in water levels by 2020 is a 15% reduction of the difference in elevation between the Basin and the groundwater discharge points relative to 1980 conditions (4230 ft amsl minus 4030 ft amsl = 200 ft). It is therefore a 15% reduction in the hydraulic gradient and the subsurface outflow to the groundwater discharge points east of the Basin.

Using a simple mass balance approach for 1980 and 2020, we obtain the following relationships:

$$O1980 = R1980 - P1980$$

$$O2020 = R2020 - P2020$$

where:

O1980 and O2020 are the subsurface outflow in 1980 and 2020, respectively

R1980 and R2020 are the "deposits" (subsurface inflow and Basin recharge) in 1980 and 2020, respectively

P1980 and P2020 is the groundwater pumping in 1980 and 2020, respectively.

From the above, we know that O2020 = 0.85 x O1980 (15% lower in 2020 than in 1980).

P2020 is expressed relative to P1980 (pumping in 2020 and 1980, respectively), using a multiplier x (%). Similarly, R2020 is expressed as a fraction y of R1980, the "deposits" in 1980. Then, for given y, P1980, and R1980, the following two equations are used to compute O1980 and the relative increase or decrease in pumping since 1980, x:

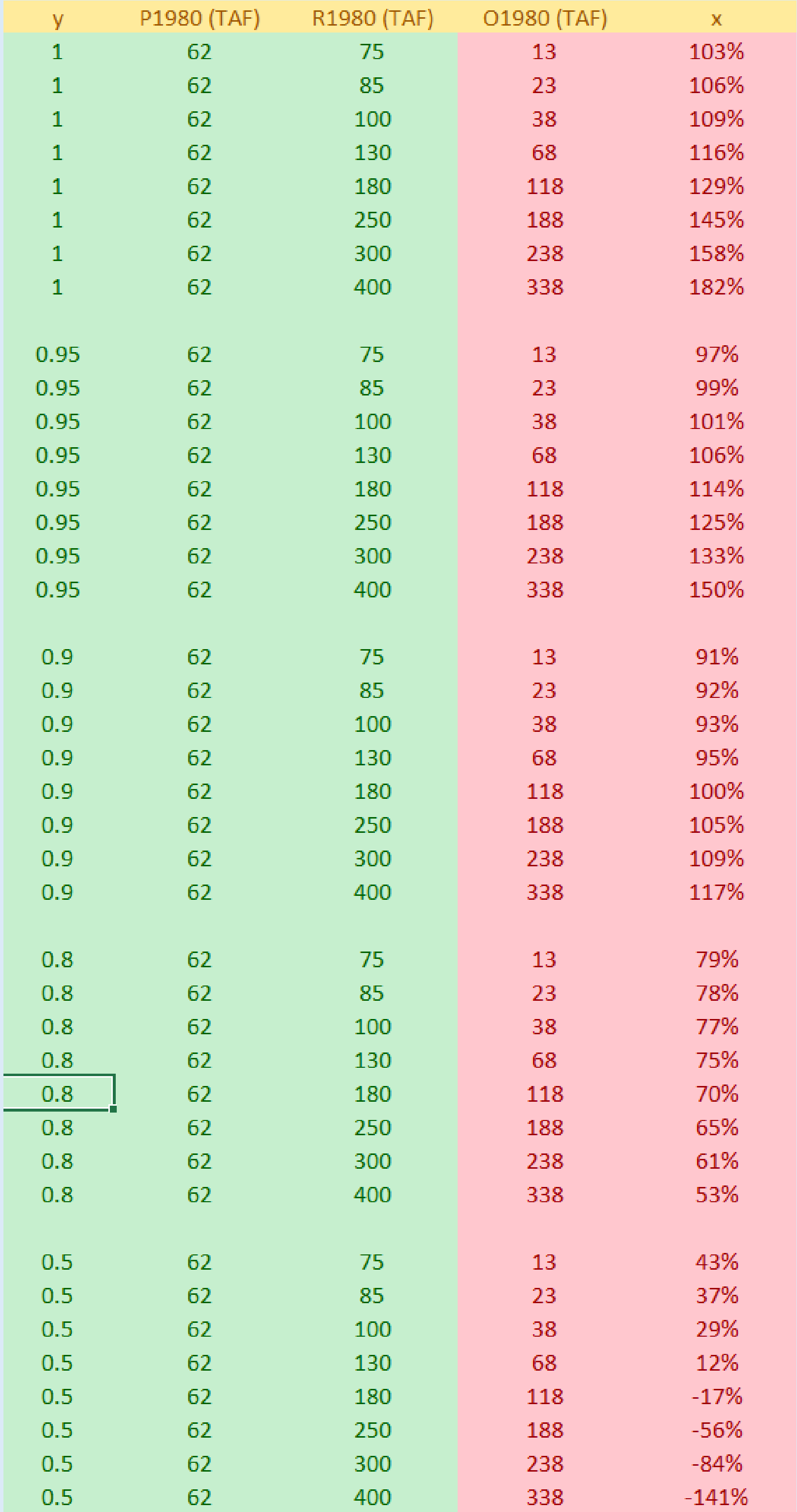
$$O1980 = R1980 - P1980$$

$$x = (y\ R1980 - z\ \ O1980) / P1980$$

A table for a range of plausible y, P1980, R1980, and commensurate O1980 was prepared to show how the observed 15% change in subsurface outflow between 1980 and 2020 may be explained by x, the change in groundwater pumping since 1980. For 1980, groundwater pumping was assumed to be 62 TAF (Section 2.2.2.2).

The analysis assumes equilibrium conditions in 1980 and in 2020. Hence, the fraction x provides a simple (and therefore approximate) estimate of the relative change in pumping to P1980 that provides long-term stable groundwater table and storage conditions at 2020 water level elevations, which are near the MO and well above the MT.

Textbox 2 - Sensitivity Analysis: Relating observed water level changes in the Basin to increased pumping and decreased subsurface inflow [continued]



y	P1980 (TAF)	R1980 (TAF)	O1980 (TAF)	x
1	62	75	13	103%
1	62	85	23	106%
1	62	100	38	109%
1	62	130	68	116%
1	62	180	118	129%
1	62	250	188	145%
1	62	300	238	158%
1	62	400	338	182%
0.95	62	75	13	97%
0.95	62	85	23	99%
0.95	62	100	38	101%
0.95	62	130	68	106%
0.95	62	180	118	114%
0.95	62	250	188	125%
0.95	62	300	238	133%
0.95	62	400	338	150%
0.9	62	75	13	91%
0.9	62	85	23	92%
0.9	62	100	38	93%
0.9	62	130	68	95%
0.9	62	180	118	100%
0.9	62	250	188	105%
0.9	62	300	238	109%
0.9	62	400	338	117%
0.8	62	75	13	79%
0.8	62	85	23	78%
0.8	62	100	38	77%
0.8	62	130	68	75%
0.8	62	180	118	70%
0.8	62	250	188	65%
0.8	62	300	238	61%
0.8	62	400	338	53%
0.5	62	75	13	43%
0.5	62	85	23	37%
0.5	62	100	38	29%
0.5	62	130	68	12%
0.5	62	180	118	-17%
0.5	62	250	188	-56%
0.5	62	300	238	-84%
0.5	62	400	338	-141%

Table T2.1 Sensitivity analysis that shows the relationship between the observed decline in water levels over the past 40 years and possible increases in groundwater pumping (x).

2.2.5.3 Estimation of Sustainable Yield with BVIHM

Using the uncalibrated BVIHM, the sustainable yield is estimated as the long-term average annual groundwater pumping rate in the Basin that does not cause an undesirable result. Guided by the two previous analyses, one assuming that the Basin were a closed basin and the other accounting for the fact that the Basin is an open basin, a sensitivity analysis with BVIHM showed that, under climate conditions equal to the past 23 years, an average pumping rate of 65 TAF/yr leads to long-term dynamically stable groundwater storage and water level conditions (Appendix 2-D)

2.2.5.4 Setting the Sustainable Yield

The sustainable yield “means 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.” (California Water Code Section 10721 (w)).

Chapter 2 defines the water budget analysis and Chapter 3 defines undesirable results. Based on the three analyses presented in this section, the analytical estimate of a sustainable yield assuming simple closed basin conditions, the analytical estimate of a sustainable yield assuming open basin conditions, and the analysis of a sustainable yield using a preliminary version of BVIHM suggest that the **sustainable yield is 65 TAF/yr**.

After accounting for the fact that this includes groundwater pumping for BVWA (Meiss Lake riparian vegetation/wetlands), the sustainable yield likely is the **same or slightly smaller than 1980 levels of groundwater pumping in the Basin**. It represents a **10% to 15% reduction in groundwater pumping estimated for recent periods, since 2010**. The sustainable yield is equal to the average estimated groundwater pumping rate during the baseline period from 1990 to 2014. **It is a 10% reduction of average groundwater pumping over the past 23 year period during which chronic lowering of water levels has been observed**.

Chapter 4 defines projects and management actions (PMAs) that the GSA will implement, as well as PMAs that will be implemented as needed to avoid future undesirable results. PMAs that will be implemented in the near-term include a Well Inventory and Mitigation Program, a Groundwater Allocation Program, and a Groundwater Demand Management Program; (see Chapter 4). Ongoing monitoring data collection, updated simulations, analyses, and technical-scientific assessments will guide the selection and design of PMAs to ensure effective and efficient responses that will avoid undesirable results. PMAs will be implemented to ensure groundwater extraction is within the sustainable yield of the Basin.

Whether and by how much sustainable yield may need to be further refined will be a function of the stabilization of water levels and groundwater storage that is achieved once pumping has been adjusted to not exceed 65 TAF/yr. For example, irrigation efficiency improvements result in a reduction in groundwater pumping, but may also reduce recharge.

The sustainable yield will be reassessed at least with every five-year plan update, given the then implemented PMAs and the resulting observed improvements in chronic lowering of water levels. Future simulations and assessments will also consider measured changes in climate and update future climate predictions. Climate change may further impact the sustainable yield of the Basin.

Chapter 3

SUSTAINABLE MANAGEMENT CRITERIA

3.1 INTRODUCTION TO SUSTAINABLE MANAGEMENT CRITERIA AND DEFINITION OF TERMS

This section characterizes sustainable groundwater management in the Butte Valley groundwater basin (Basin) through the description of an overall sustainability goal for the Basin, and through the definition and quantification of sustainable management criteria (SMC) for each of the sustainability indicators. Building on the Basin conditions described in Chapter 2, this section describes the processes and criteria used to define the undesirable results, measurable objectives (MO), and minimum thresholds (MT) for each sustainability indicator.

The following terms, defined below, are used throughout this chapter.

Sustainability Goal: The overarching goal for the Basin with respect to managing groundwater conditions is to ensure the absence of undesirable results.

Sustainability Indicators (SI): Six indicators defined under the Sustainable Groundwater Management Act (SGMA): chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded groundwater quality, land subsidence, and depletions of interconnected surface water (ISW). These indicators describe groundwater-related conditions in the Basin and are used to determine the occurrence of undesirable results (23 CCR 354.28(b)(1)-(6).).

Sustainable Management Criteria (SMC): Minimum thresholds (MT), measurable objectives (MO), and undesirable results consistent with the sustainability goal that must be defined for each sustainability indicator.

Undesirable Results: Conditions, defined under SGMA as:

"… one or more of the following effects caused by groundwater conditions occurring throughout a basin:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon [….]
2. Significant and unreasonable reduction of groundwater storage.
3. Significant and unreasonable seawater intrusion.
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses.
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water." (Wat. Code § 10721(x)(1)-(6).)

Minimum / Maximum Thresholds (MT): a numeric value that defines an undesirable result. Groundwater conditions should not exceed the MT defined in the groundwater sustainability plan (GSP). The term "minimum threshold" is predominantly used in SGMA regulations and applied to most sustainability indicators. The term "maximum threshold" is the equivalent value but used for sustainability indicators with a defined maximum limit (e.g., groundwater quality).

Measurable Objectives (MO): specific and quantifiable goals that are defined to reflect the desired groundwater conditions in the Basin and achieve the sustainability goal within 20 years. MOs are defined in relation to the six undesirable results and use the same metrics as MTs.

Interim Milestones: periodic goals (defined every five years, at minimum), that are used to measure progress in improving or maintaining groundwater conditions and assess progress towards the sustainability goal.

Representative Monitoring Points (RMP): for each sustainability indicator, a subset of the monitoring network, where MTs, MOs, and milestones are defined.

Project and Management Actions (PMAs): creation or modification of a physical structure / infrastructure (project) and creation of policies, procedures, or regulations (management actions) implemented to achieve Basin sustainability.

3.1.1 Updates to Sustainable Management Criteria

The Butte Valley GSA received a determination letter from the California Department of Water Resources (DWR) on January 18, 2024. This letter deemed the Butte Valley Basin GSP, originally submitted on January 28, 2022, incomplete and identified two deficiencies in the GSP. As a result, Sections of the GSP that relate to the groundwater level sustainability indicator have been revised to address these deficiencies and corrective actions.

The two potential deficiencies were identified as:

Deficiency 1: The GSP does not include a reasonable assessment of overdraft conditions and reasonable means to mitigate overdraft.

Deficiency 2: The GSP does not establish sustainable management criteria for chronic lowering of groundwater levels in a manner substantially compliant with the GSP regulations.

A full summary of the deficiencies, corrective actions, and how the revisions to the GSP chapters and appendices address each can be found in Appendix 3-D.

3.2 SUSTAINABILITY GOAL

The overall sustainability goal of groundwater management in Butte Valley is to maintain groundwater resources in ways that best support the continued and long-term health of the people, the environment, and the economy in the Basin for generations to come. This includes managing groundwater conditions for each of the applicable sustainability indicators in the Basin so that:

- Groundwater elevations and groundwater storage are not significantly declining below their historically experienced range, protecting the existing well infrastructure from outages and protecting interconnected surface water (ISW) and groundwater-dependent ecosystems (GDEs).
- Groundwater quality is suitable for beneficial uses in the Basin and is not significantly or unreasonably degraded.
- Significant and unreasonable land subsidence is prevented in the Basin. Infrastructure and agricultural production in Butte Valley remain safe from permanent subsidence of land surface elevations.

3.3 MONITORING NETWORKS

The monitoring networks detailed here support data collection to monitor the chronic lowering of groundwater levels, reduction of groundwater in storage, land subsidence, and degraded groundwater quality sustainability indicators. The monitoring networks for each sustainability indicator are critical to demonstrating the Basin’s sustainability over time. No monitoring networks are included for the seawater intrusion and ISW sustainability indicators, as they are not applicable in the Basin (see Chapter 2). After data gaps are addressed (see Appendix 3-A and Chapter 4) a monitoring network and SMCs may be set for ISWs.

Per 23 CCR Section 354.34, monitoring networks should be designed to:

- Demonstrate progress towards achieving MOs described in the Plan.
- Monitor impacts to the beneficial uses or users of groundwater.
- Monitor changes in groundwater conditions relative to MOs and minimum or maximum thresholds.
- Quantify annual changes in water budget components.

The monitoring networks for each sustainability indicator are critical to demonstrating the Basin's sustainability over time.

Monitoring networks are required to have sufficient spatial density and temporal resolution to evaluate the effects and effectiveness of Plan implementation and represent seasonal, short-term, and long-term trends in groundwater conditions and related surface conditions. Short-term is considered here to be a timespan of 1 to 5 years, and long-term is considered to be 5 to 20 years.

There is no rule for the spatial density and frequency of data measurement required for each monitoring network. These values are specific to monitoring objectives, the parameter to be measured, level of groundwater use, and Basin conditions, among other factors. A description of the existing and planned spatial density and data collection frequency is included for each monitoring network.

Detailed descriptions, assessments and plans for improvement of the monitoring network and protocols for data collection and monitoring are addressed for each sustainability indicator in the following sections.

In summary, there are four monitoring networks: a water level monitoring network, streamflow gages, a water quality monitoring network, and a land subsidence monitoring system Figure 3.1. The water level and water quality monitoring networks utilize two independent but overlapping networks of wells, the latter utilizes satellite remote sensing. Detailed descriptions, assessments and plans for future improvement of the well monitoring network and protocols for data collection and monitoring are addressed for each sustainability indicator in the following sections.

Table 3.1. Summary of monitoring networks, metrics and number of sites for sustainability indicators.

Sustainability Indicator	Metric	Number of Sites in Current Network
Chronic Lowering of Groundwater Levels	Groundwater level	13
Reduction of Groundwater Storage	Volume of water per year, computed from water level changes	Uses groundwater level network
Groundwater Quality	Concentration of selected water quality parameters	7
Land subsidence	Land surface elevation	Spatially continuous
Interconnected Surface Water and Groundwater-Dependent Ecosystems	Groundwater level	Uses groundwater level network

a This table only includes monitoring networks used to measure sustainability indicators. It does not include additional monitoring necessary to monitor the various water budget components of the basin, described in Chapter 2, or to monitor the implementation of project and management actions (PMAs), which are described in Chapter 4.

b Land surface elevation changes are monitored through satellite remote sensing.

Identification and Evaluation of Potential Data Gaps

Per 23 CCR Section 351, data gaps are defined as, "a lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation and could limit the ability to assess whether a basin is being sustainably managed." A detailed discussion of potential data gaps, and strategies for resolving them, is included as Appendix 3-A. Data gaps are primarily addressed in this chapter through the 'Assessment and Improvement of Monitoring Networks,' associated with each sustainability indicator in the Basin. Of particular focus for the monitoring networks are the adequacy of the number of sites, frequency of measurement, and spatial distribution in the Basin. In addition to the monitoring network-specific data gaps, information was identified that would be valuable to collect. This information is valuable to support increased understanding in the Basin setting, understanding of conditions in comparison to the SMCs, data to calibrate or update the model, and to monitor efficacy of PMAs. These additional monitoring or information requirements depend on future availability of funding and are not yet considered among the GSP Representative Monitoring Points (RMPs). They will be considered as potential RMPs and may eventually become part of the GSP network at the five-year GSP update. The list includes:

- Streamflow gauges on ephemeral streams near the Basin Boundaries and Butte Creek, outside the Basin boundaries.
- Groundwater level monitoring wells near potential GDEs and potential ISWs to establish groundwater levels for use in Butte Valley Integrated Hydrogeologic Model (BVIHM) model calibration, as part of GDE/ISW identification and monitoring, and for measuring PMA efficacy.
- Domestic well monitoring for both water quality and groundwater levels.
- Improved estimation of evapotranspiration (ET) from key crops, natural vegetation.
- Additional biological data that would be useful for monitoring and evaluation of GDEs.

Streamflow gages and some more monitoring stations for continuous groundwater levels and rainfall have already been installed as part of the GSP implementation (Figure 2.32). The GSA will be working with a biologist in 2025 to further fill data gaps on existing GDEs in the Basin. Additionally, the GSA will be coordinating with the California Department of Fish and Wildlife (CDFW), and the North Coast Regional Water Quality Control Board (NCRWQCB) throughout this process.

A detailed discussion of these potential data gaps, suggested approaches, and monitoring prioritization can be found in Appendix 3-A and **Chapter 5**.

Monitoring Network to Fill Identified Data Gaps

Butte Valley groundwater monitoring includes the California Statewide Groundwater Elevation Monitoring Program (CASGEM) program by the Department of Water Resources (DWR), which has maintained periodic records of groundwater elevation since the 1950s. Butte Valley climate monitoring includes one DWR California Irrigation Management Information System (CIMIS) climate station site near Macdoel and two United States National Oceanic and Atmospheric Administration (NOAA) weather stations near Mount Hebron and the City of Dorris. There are no permanent or long-term streamflow gages in the Basin.

To supplement historical monitoring stations, the groundwater sustainability agency (GSA) developed nine locations around Butte Valley to collect continuous groundwater level data, eight sites to collect precipitation data, two sites with soil water content sensors, and one surface water flow station located on Butte Creek just south (outside) of the Basin boundary. Sites are shown on Figure 3.2 and Figure 3.3. The network of continuous wells provides tools and resources for farmers to connect to their own stations using a password protected website.

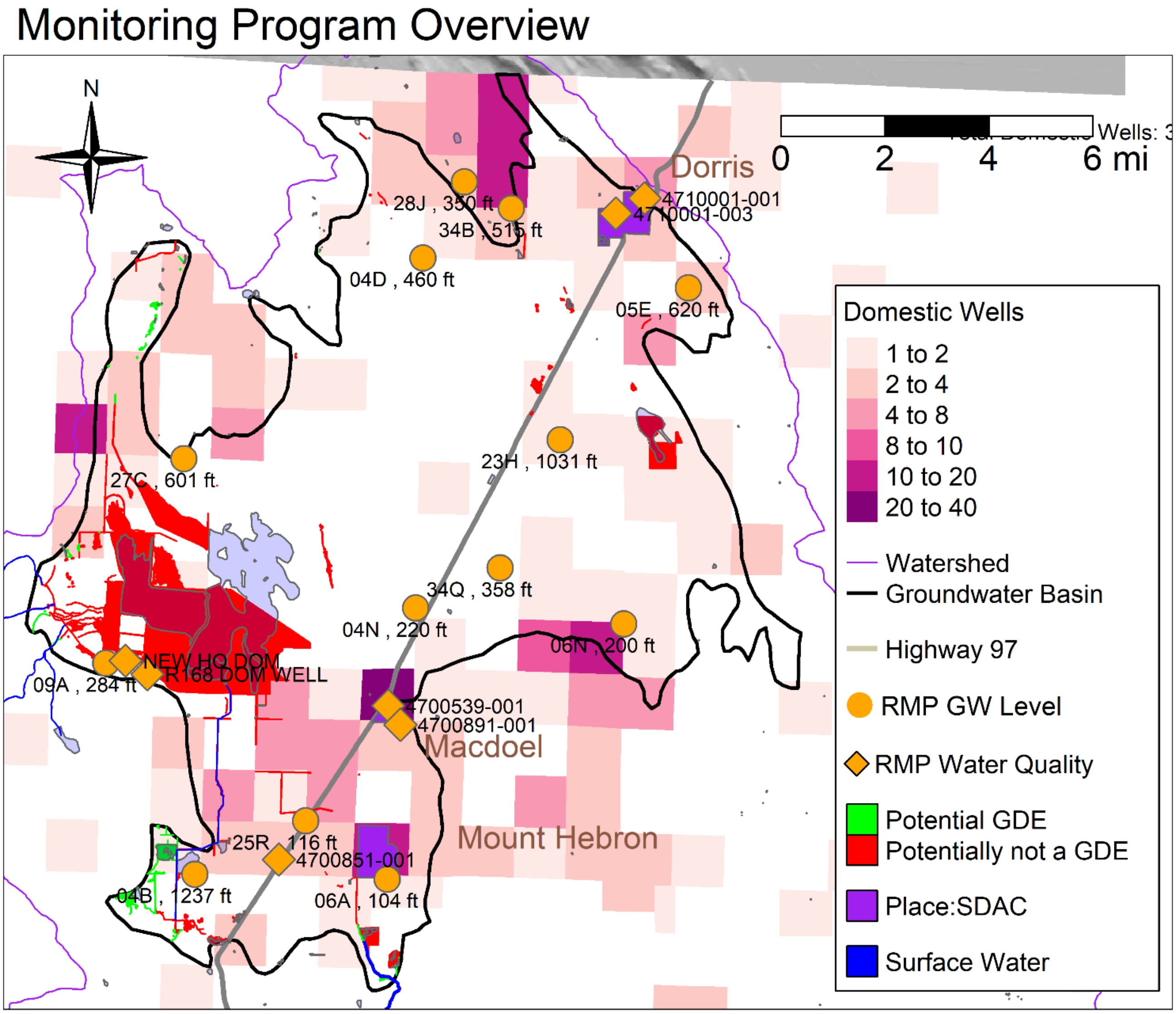


Figure 3.1. The current overall monitoring network in Butte Valley

An evaluation of ET by strawberry grown for propagation in Butte Valley (a major crop in the Basin) is ongoing and the results are anticipated to be published in 2022 or 2023. The eddy covariance- and energy balance-based research station used to collect data for the study was deployed during the 2020 and 2021 growing seasons in eastern Butte Valley over a field of drip irrigated strawberries.

Significant data gaps exist in the historical records of flow and surface water conditions. Historical surface water flow observations are from a brief period of record from 1952 through 1960 at a United States Geological Survey (USGS) station along Butte Creek and monthly self-reporting by California State Water Resources Control Board (SWRCB) surface water right appropriation holders. The USGS also maintained a station along Antelope Creek from 1952 to 1979; however, Antelope Creek does not flow to Butte Valley.

The GSA received implementation funding to expand monitoring in Butte Valley and the surrounding watershed (Watershed) to resolve data gaps related to groundwater and surface water, and to select the location of a proposed Snow Water Equivalent (SWE) station in the upper watershed.

Several data gaps were identified during the GSP development which are intended to be resolved during implementation. Identified data gaps and the current status of resolution include:

- Insufficient model inputs used for the geologic model and numerical groundwater model including data quantifying the depth and distribution of key geologic features such as the total depth of alluvial sediment in the basin and the geometry of the sediment in relation to volcanic deposits which likely inter-finger the alluvial deposits. To resolve this data gap:
    - The Airborne Electromagnic (AEM) survey data from the Department of Water Resources study was used to improve the geologic model of Butte Valley.
    - The inclusion of significant structural features like faults was improved through improvements in the geologic modeling software Leapfrog Works.
    - Additional historical groundwater observations were located for upland areas in the watershed to improve groundwater numerical model calibration.
    - Groundwater numerical model calibration was further refined with a higher-resolution model moving from 8-layers to 11-layers within the MODFLOW numerical model.
- Insufficient data on climate variables such as site-specific evapotranspiration for unusual crops grown in Butte Valley like high elevation nursery strawberries, precipitation trends across the valley, the lack of a Butte watershed Snow Water Equivalent (SWE) station for accurate hydrologic modeling, and significant data gaps in historical NOAA precipitation data due to variable maintenance over time.

    To resolve this data gap:
    - A multi-season evapotranspiration study of strawberries was conducted in collaboration with the Hydrologic Sciences graduate group of UC Davis
    - Six Davis Instruments rain gauges were installed on volunteer properties throughout the Butte Valley basin to improve understanding of precipitation patterns across the basin.
    - The selection of a new SWE station is ongoing. No new location has been identified.
    - Data analysis of the historical NOAA precipitation data has concluded that due to significant data gaps during high winds and rainy days, the Mount Hebron station currently located at Goosenest Ranger Station may under-count actual precipitation.
- Insufficient data on significant hydraulic and hydrogeologic features, like geochemical and isotope data to quantify the flow paths, ages, and recharge elevations of groundwater, the absence of any surface water flow data since the 1970s, and potential interconnected surface water.

    To resolve this data gap:
    - A groundwater sampling study is planned for summer 2024
    - Surface flow stations have been built and are undergoing rating curve development on Harris Creek, Prather Creek, and Butte Creek at existing engineered structures near the basin boundaries. Valid flow data is not yet available due to the field effort required to develop accurate site-specific rating curves.

  - Interconnected surface waters will be validated by a combination of field study and advanced desktop analysis. This effort has not begun but is planned for the 2024-2025 water year.
- Insufficient validation of the extent and accuracy of proposed GDE maps and
  To resolve this data gap:
  - Interconnected surface waters will be validated by a combination of field study and advanced desktop analysis. This effort has not begun but is planned for the 2024-2025 water year.
- Estimates of groundwater storage require further study. Due to the significant contribution of the surrounding High Cascade Volcanic unit which is not an alluvial deposit in the Bulletin 118 basin boundary, the specific yield and storativity are calculated through calibration of the integrated hydrogeologic model.
- To resolve this data gap:
  - Additional pump test data is required which has not been collected or analyzed.
  - Additional numerical model calibration is required which is ongoing.
- Groundwater extraction is not reported to the GSA so no groundwater extraction data is available for calibration.
- To resolve this data gap:
  - The GSA is continuing outreach and requests to pumpers to voluntarily contribute their groundwater meter data.

- Groundwater quality includes data gaps in both spatial and temporal coverage.
- To resolve this data gap:
  - A groundwater sampling effort is planned for summer 2024.

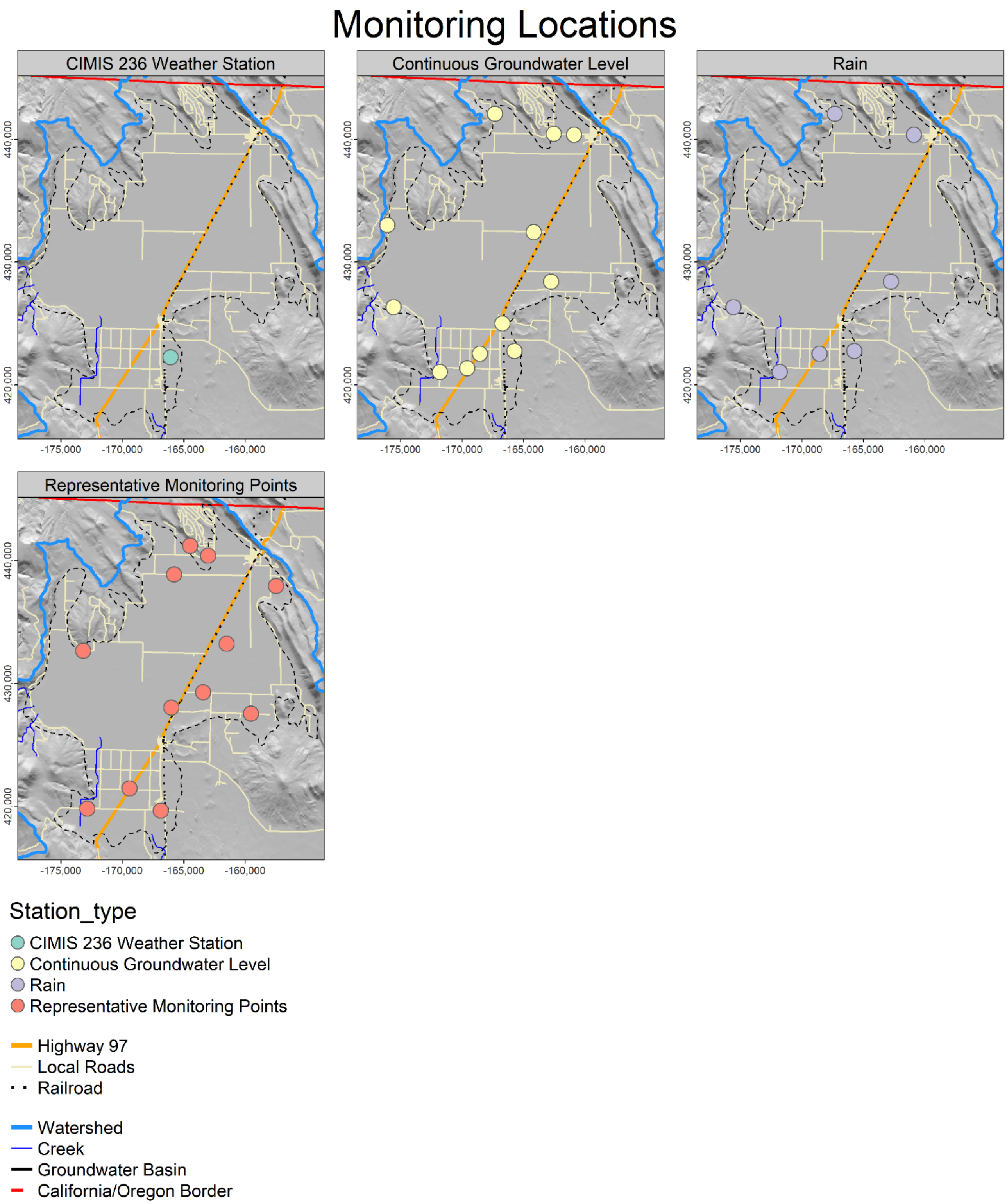


Figure 3.2. The location of continuous monitoring stations in Butte Valley.

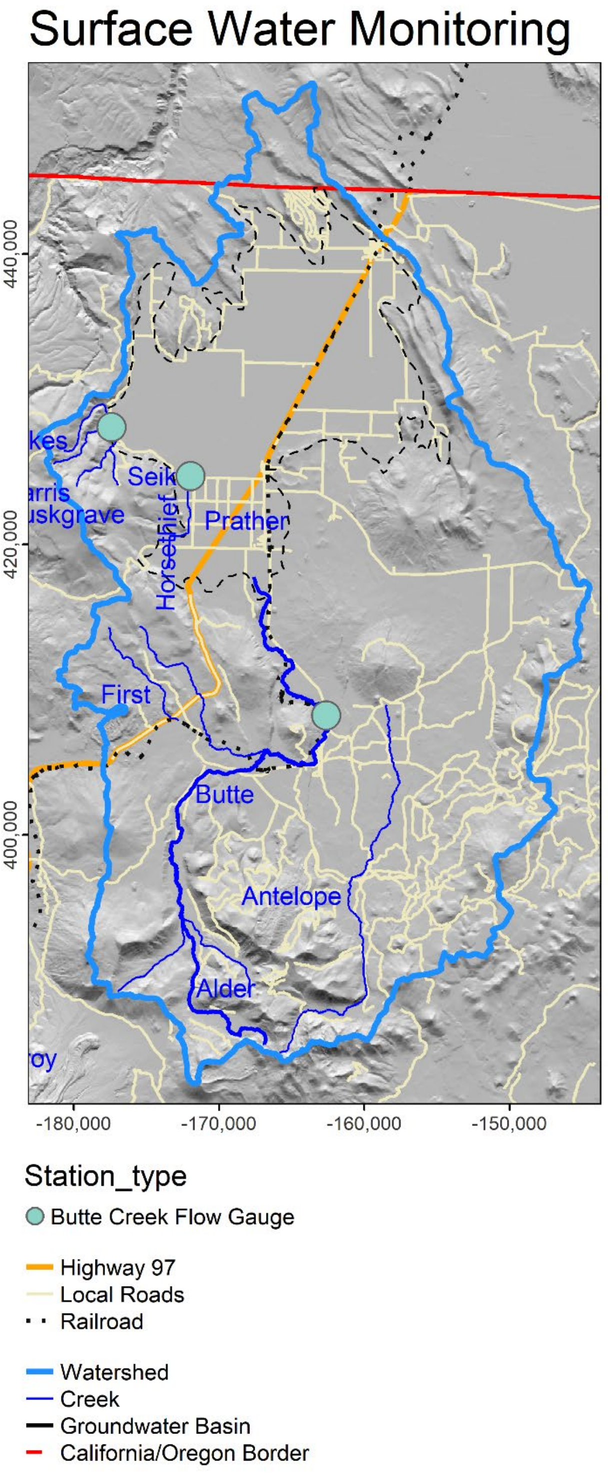


Figure 3.3 The location of continuous surface water monitoring stations in Butte Valley.

Network Enrollment and Expansion

With the exception of stream flow and land subsidence, monitoring is done on wells. Some wells will be monitored for water level, some for water quality, some for both. Prior to enrolling wells into the GSA monitoring network, wells will be evaluated, using the selection criteria listed below, to determine suitability. The selection criteria for potential wells to be added to the monitoring network include the following:

- Well location
- Monitoring History
- Well Construction Information
- Well Access

Well Location

The location and design of a well network is important to ensure adequate spatial distribution, coverage and well density. Locations important for groundwater monitoring include sufficient spatial representation of GSP projects and management actions, many of which are Basin-wide. Statistical methods will be used to aid in extrapolating from a limited number of monitoring sites to the entire Basin. Additionally, the network includes the major water-bearing formations including the Butte Valley Basalt, Lake Deposits, and High Cascade Volcanics.

Monitoring History

Wells with a long monitoring record provide valuable historical groundwater level or water quality data and enable the assessment of long-term trends.

Well Information

In addition to well location, information about the construction of the well, including the well depth and screened interval(s) provides context, such as which water bearing formation is being sampled. Basin groundwater users tap into three major water-bearing formations, which occur at different depths in separate areas of the Basin. Well information is therefore critical for an effective well network that efficiently monitors groundwater conditions. For wells that are candidates for being added to the well network, the GSA will continue to verify well information, e.g., with well logging.

Well Access / Agency Support

In order to be valuable to the monitoring network, the ability to gain access to the well to collect samples at the required frequency is critical.

Wells in existing monitoring programs are not evenly distributed (e.g., water quality well locations are mostly near population centers), leaving sections of the remainder of the Basin without monitoring data. The planned additional wells are intended to gather groundwater data representative of different land uses and activities and representative of all three geologic units. Such an expansion will improve upon the existing spatial coverage in the Basin. Any wells added to the monitoring network will be evaluated using the criteria listed above to ensure well suitability. The spatial density and monitoring frequency of the monitoring network will be evaluated at least every five years to ensure that the monitoring network is representative of Basin conditions and enables evaluations of seasonal, short-term (1 to 5 years) and long-term (5 to 20 years) trends.

The expansion of the monitoring network will be completed in several steps during GSP implementation. The first step will involve coordination with those agencies already implementing existing monitoring programs in the Basin (see Chapter 2). Wells in these existing monitoring networks (water level or water quality) will be evaluated using the selection criteria and suitable wells will be selected for the GSA Monitoring Network.

The second step will involve identification of additional existing wells in the Basin that could be included in the monitoring network and evaluation of these wells using the selection criteria. Following identification of additional suitable existing wells, analyses will be conducted to determine whether additional wells are required to achieve sufficient spatial density, are representative of land uses in the Basin, and include monitoring in key areas identified by stakeholders. If additional sites are required to ensure sufficient spatial density, then existing wells may be identified, or new wells may be constructed at select locations, as required.

Finally, the monitoring frequency and timing that enable evaluation of seasonal, short-term, and long-term trends will be determined and coordination will be conducted between existing monitoring programs and the GSA to develop an agreement for data collection responsibilities, monitoring protocols and data reporting. With coordination between the GSA and existing monitoring programs ("agencies"), monitoring will be conducted by GSA or agency program staff or their contractors. For water quality, samples are analyzed at contracted analytical labs. To prevent bias, samples will be collected at the same time (i.e., within +/- 30 days) each year.

3.3.1 Groundwater Level Monitoring Network

3.3.1.1 Description of Monitoring Network

This section describes the process used to select wells as potential Representative Monitoring Points (RMPs) for monitoring the groundwater level sustainability indicator. These wells are mapped in Figure 3.4 and listed in Table 3.2.

The objective of the groundwater level monitoring network design is to capture sufficient spatial and temporal detail of groundwater level conditions to assess groundwater level changes over time, groundwater flow directions, and hydraulic gradients between aquifers and surface water features. The monitoring network is critical for the GSA to show compliance with SGMA and quantitatively show the absence of or improvement of undesirable results. The design of the monitoring network must enable adequate spatial coverage (distribution, density) to describe groundwater level conditions at a local and Basin-wide scale for all beneficial uses. Revisions to the monitoring network and schedule will be considered after review of the initial five years of monitoring data and as part of any future GSP updates, and as necessary with changes to landowner participation.

Monitoring Network Development

Considerations for making the RMP selections include, in order of priority: spatial coverage, date of last water level observation, and inclusion in existing monitoring programs (such as CASGEM or the continuous transducer measurement network).

Spatial Coverage Criteria

DWR guidance on monitoring networks (DWR 2016d) recommends a range of well densities to adequately monitor groundwater resources, with a minimum of 0.2 wells and a maximum of 10 wells per 100 sq mi (259 sq km). Because the Basin covers approximately 125 sq mi (326 sq km), these recommendations would translate directly into a range from 1 to 13 RMP wells, evenly spaced in the Basin. To provide some continuity with previous monitoring efforts, and to provide some redundancy in the event of inaccessible wells, a network of potential RMPs was selected using a coverage radius of 1.25 mi (2.0 km).

Measurement Schedule

The water elevation in RMP wells will be measured, at a minimum, twice per year to capture the fall-low and spring-high water levels (Table 3.2). In some wells, transducers may provide daily or higher-resolution water elevation measurements.

For wells to be future candidates for the RMP network, at least 10 years of data must be collected, especially when those data are used to adopt future changes in SMC levels (e.g., to fill data gaps for ISWs and GDEs, see Chapter 2). This ensures a minimum baseline for the well and is consistent with, e.g., 23 CCR Section 358.2(c)(3), which requires alternative GSPs to have operated sustainably for at least 10 years and include data covering at least 10 years.

Selected Groundwater Level RMP Network

Existing wells considered for the RMP network were public supply wells, and CASGEM wells that include agriculture and domestic wells. Wells selected as RMP candidates (Table 3.2) had a minimum of 10 years of mostly continuous (twice annual) water level measurements. To achieve sufficient spatial coverage, the 5-square mile buffer zone (1.25 mile radius) was mapped around each selected well. The final groundwater level RMP network provides broad coverage of the Basin (Figure 3.4). The groundwater level well network has excellent coverage, especially of the most developed areas of the Basin. But data gaps exist in some of the less developed areas of the Basin, in Sam’s Neck, Butte Valley Wildlife Area (BVWA), and Butte Valley National Grasslands. Additionally, very few wells are located near creeks, lakes, and other surface water bodies mostly near the southern boundary of the Basin.

Table 3.2. Existing and planned elements of the groundwater level monitoring network.

Name of Network	Well Name	State Well Number	Map Name	Target Area	Geologic Formation	Sample Schedule
CASGEM	418948N1220832W001	47N02W27C001M	27C	Meiss Lake	Deep Lake Sediment, High Cascade Volcanics	Twice Annual
CASGEM	417786N1220041W001	45N01W06A001M	06A	Mount Hebron	Butte Valley Basalt	Twice Annual
CASGEM	417789N1220759W001	45N02W04B001M	04B	South West Butte Valley	Data Gap	Twice Annual
CASGEM	417944N1220350W001	46N02W25R002M	25R	Butte Valley Irrigation District	Butte Valley Basalt	Twice Annual
CASGEM	418544N1219958W001	46N01W04N002M	04N	South Mid Valley	Lake Deposits	Twice Annual
CASGEM	418661N1219587W001	47N01W34Q001M	34Q	South Mid Valley	Lake Deposits	Twice Annual
CASGEM	418512N1219183W001	46N01E06N001M	06N	East Valley	Lake Deposits	Twice Annual
Municipal	NA	NA	NA	City of Dorris Well #6	High Cascade Volcanics	Monthly*
CASGEM	419662N1219633W001	48N01W34B001M	34B	West of City of Dorris	High Cascade Volcanics	Twice Annual
CASGEM	419755N1219785W001	48N01W28J001M	28J	NW Butte, Mahogany Mtn F.Z.	High Cascade Volcanics	Twice Annual
CASGEM	419519N1219958W001	47N01W04D002M	04D	North Mid Valley Nested	Lake Deposits	Twice Annual
CASGEM	419520N1219959W001	47N01W04D001M	04D	North Mid Valley Nested	Lake Deposits	Twice Annual
CASGEM	418371N1221105W001	NA	09A	Meiss Lake	Alluvium and High Cascade Volcanics	Twice Annual*
CASGEM	419451N1218967W001	47N01E05E001M	05E	East of Dorris	Data Gap	Twice Annual
CASGEM	419021N1219431W001	47N01W23H002M	23H	East Valley	Data Gap	Twice Annual
Expanded GSA Monitoring Network	TBA	TBA	TBA	Sam's Neck, National Grasslands, Butte Valley Wildlife Area, Butte Creek, Prather Creek, Meiss Lake		Twice Annual

Note:
(*) The well began groundwater level measurements in 2015 and SMC cannot be set until 10 years of data is available (2025)

3.3.1.2 Assessment and Improvement of Monitoring Network

The very small number of monitoring wells near surface water bodies, including Meiss Lake, Butte Creek, Prather Creek, Ikes, Harris, and Muskgrave Creeks, and various springs leaves significant uncertainty about the hydraulic gradients between the groundwater aquifer and surface water features in the Basin. Based on current knowledge and groundwater depths in nearby wells, these surface water bodies are either losing streams or disconnected from groundwater, in some cases possibly sustained via perched aquifers (see Section 2.2.2.6). Expanding the network to include representative wells adjacent to key surface water bodies will close data gaps regarding the connection of surface water to the groundwater aquifer in the Basin.

Water level measurements near potential GDEs in the Basin are also lacking. The potential GDEs in Butte Valley are relatively small and exist on the Basin edges and areas not covered by the current network. The connection of these potential GDEs to the Basin aquifer and therefore their GDE status is a major data gap (see Section 2.2.2.7). Progress has been made to resolve this data gap since the submittal of the GSP in December 2021. Groundwater level and surface flow monitoring sites have been added in areas identified as ISW, and areas near potential GDEs. These added monitoring sites are shown in Figure 2.32, in Chapter 2 of this GSP.

As the existing monitoring network has data gaps in several key areas of the Basin, an expansion of the network is required to adequately characterize and monitor groundwater levels in the Basin. Data gaps exist in spatial coverage, well information and representation of all land uses and beneficial uses and users in the Basin. Expansion of the network will be informed by the process outlined in Section 3.3.1.1. The current biannual monitoring schedules are sufficient to evaluate seasonal trends, though installation of data loggers could produce monthly or daily data that could be valuable in the evaluation of some PMA pilots. An assessment and expansion of the monitoring network is planned within the first five years of GSP implementation, and repeated evaluations of the network will occur on a five-year basis.

3.3.1.3 Monitoring Protocols for Data Collection and Monitoring

Groundwater level data collection may be conducted remotely via telemetry equipment or with an in-person field crew. Appendix 3-B provides the monitoring protocols for groundwater level data collection. Establishment of these protocols will ensure that data collected for groundwater levels are accurate, representative, reproducible, and contain all required information. All groundwater level data collection in support of this GSP is required to follow the established protocols for consistency throughout the Basin and over time. These monitoring protocols will be updated as necessary and will be re-evaluated every five years.

3.3.2 Groundwater Storage Monitoring Network

This GSP will adopt groundwater levels as a proxy for groundwater storage. The groundwater level network described in Section 3.3.1., will also serve as the groundwater storage monitoring network. The network currently provides reasonable coverage of the major water-bearing formations in the Basin and will provide reasonable estimates of groundwater storage. The network also includes municipal, agricultural, and municipal wells of shallow to deep depths. Expansion of the network to close data gaps will benefit the characterization of both the groundwater level and storage sustainability indicators.

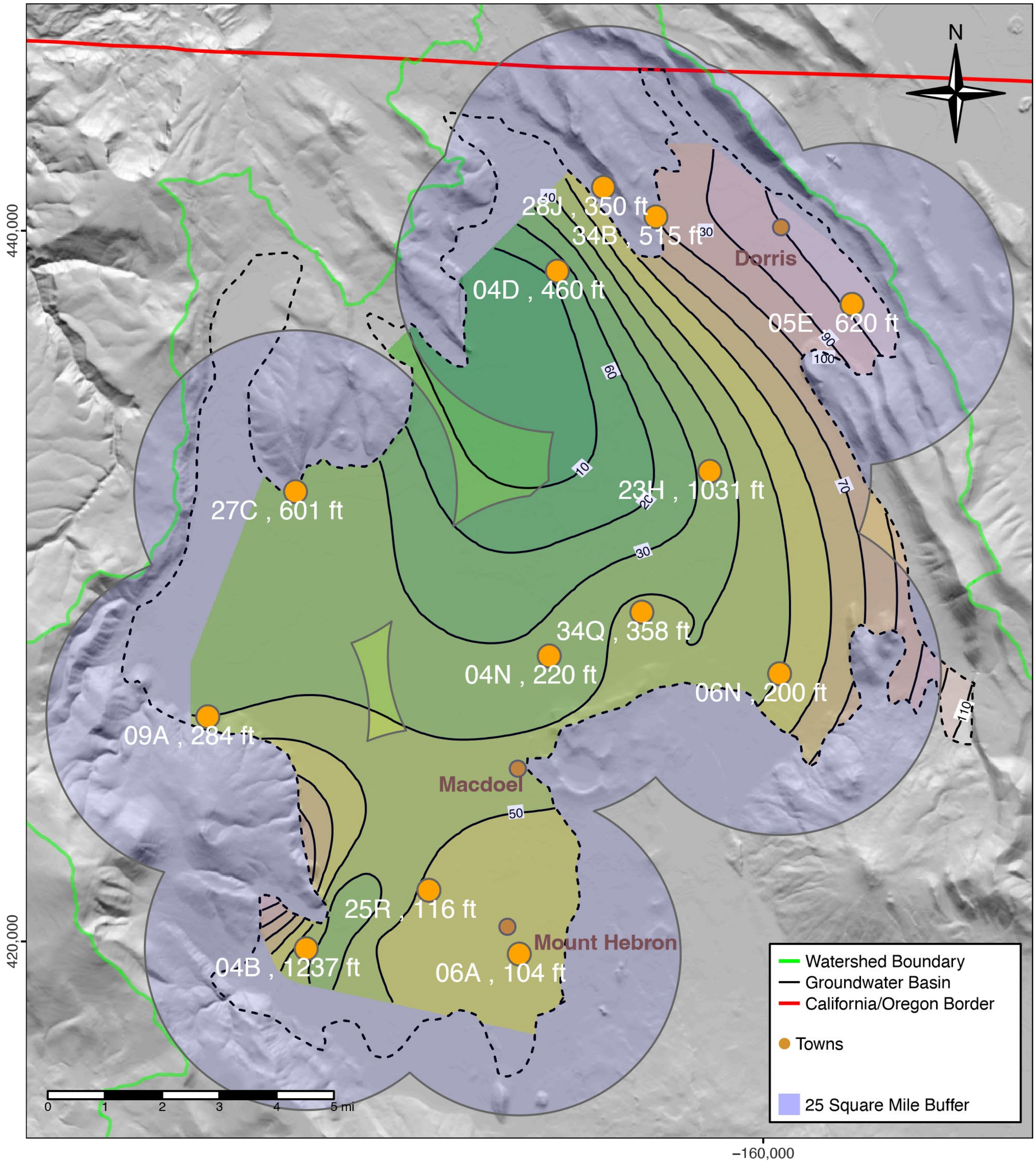


Figure 3.4: Representative monitoring points (RMP) in the water level monitoring network. Well names corresponding to the shorthand names on the map are shown in Table 2.

Historic groundwater storage changes are computed with BVIHM (see Chapter 2.2.3). Throughout the implementation period of this Plan, updates of BVIHM provide updated time series of groundwater storage changes at least every five years.

The change in observed groundwater level data is used to obtain groundwater storage changes for the most recent, non-simulated period. The change in groundwater level is calculated at wells with measurements in the spring season from the previous year to the current year. These wells have water level data collected through the biannual DWR measurement collection, continuous data loggers, and locally collected manual measurements. The locations of these wells is used to identify Thiessen polygons which define the areal extent which is closest to a given well rather than any other well. The Thiessen polygons are then cropped to the extent of the Bulletin 118 groundwater basin to calculate storage change for the Butte groundwater basin. The average specific yield of the Bulletin 118 groundwater basin is used to inform the storativity of the aquifer system where the water level change occurs. The change in saturated aquifer thickness is calculated by multiplying the change in water level at each well by its area of influence, i.e. Thiessen polygon. The change in groundwater storage is then calculated by multiplying the change in saturated thickness by the specific yield. Further explanation of this method, and a conceptual illustration of measured wells with their identified Thiessen polygons in Butte Valley groundwater basin is shown in **Chapter 2.2.2**.

3.3.3 Groundwater Quality Monitoring Network

3.3.3.1 Description of Monitoring Network

The objective of the groundwater quality monitoring network design is to capture sufficient spatial and temporal detail to measure groundwater conditions and assess groundwater quality changes over time. The monitoring network is critical for the GSA to show compliance with SGMA and quantitatively show the absence or improvement of undesirable results. The network data will provide a continuous water quality record for future assessments of groundwater quality.

Existing wells used for monitoring groundwater quality in the Basin include public water supply wells and monitoring wells from DWR, California Department of Fish and Wildlife (CDFW), and SWRCB, which are shown in Figure 3.5. However, wells in these existing networks do not cover the entire Basin. Areas of the Basin with no representative wells, such as Sam's Neck and the middle of the Basin, are data gaps. However, historic and current land use (natural vegetation, some irrigated forage) does not pose significant known risks for groundwater contamination. Existing wells in those areas can be added to the network if well information such as the well depth and well screen dimensions are also known. Well logging or a camera inspection, where a camera is lowered into the well, may be used to obtain unknown well construction information.

The initial groundwater quality well network relies primarily on existing programs that are located within and near the semi-urban areas of the Basin. Initially, the groundwater quality monitoring network is based on wells that are regularly sampled as part of existing monitoring programs for the constituents for which SMCs are set: arsenic, nitrate, and specific conductivity (Table 3.3). Data from these existing programs are not representative of groundwater quality associated with agricultural irrigation, or stock watering (the basin has no or insignificant groundwater discharge to streams). The locations of the existing wells in the proposed well network are shown in Figure 3.5, with details in Table 3.3. Initial monitoring schedules are shown in Table 3.3.

With improvements (Section 3.3.3.2), the design of the monitoring network will eventually enable adequate spatial coverage (distribution, density) to describe groundwater quality conditions at a local and Basin-wide scale for all beneficial uses.

Table 3.3. Existing and planned elements of the groundwater quality monitoring network.

Name of Network	Agency	Well Name	Constituent	Frequency
Municipal / Public Supply	City of Dorris	4710001-001, 4710001-003	Arsenic	Every 9 yrs
			Nitrate	Every 9 yrs Annually
			Specific Conductivity	Every 9 yrs
	Goosenest District Office (USFS)	4700851-001	Nitrate	Annually
			Specific Conductivity	No official monitoring schedule
	Macdoel Waterworks	4700539-001	Nitrate	Annually
			Specific Conductivity	No official monitoring schedule
	Juniper Village Farm Labor Housing	4700891-001	Nitrate	Annually
Domestic Well	Butte Valley Wildlife Area (CDFW)	NEW HQ DOM, R168 DOM WELL	Nitrate	Annually
			Specific Conductivity	Annually
Expanded GSA Monitoring Network		A minimum of 3 wells; sites to be determined	Nitrate, Specific Conductivity	Frequency to be determined.

3.3.3.2 Assessment and Improvement of Monitoring Network

As the existing monitoring network has limited spatial coverage and is not representative of all land uses in the Basin, an expansion of the network is required to adequately characterize and monitor groundwater quality in the Basin. An assessment and expansion of the monitoring network is planned within the first five years of GSP implementation. An expanded monitoring network will occur through a combination of adding suitable existing wells and construction of new wells. Further evaluations of the monitoring network will be conducted on a five-year basis, at minimum, particularly with regard to the sufficiency of the monitoring network in meeting the monitoring objectives.

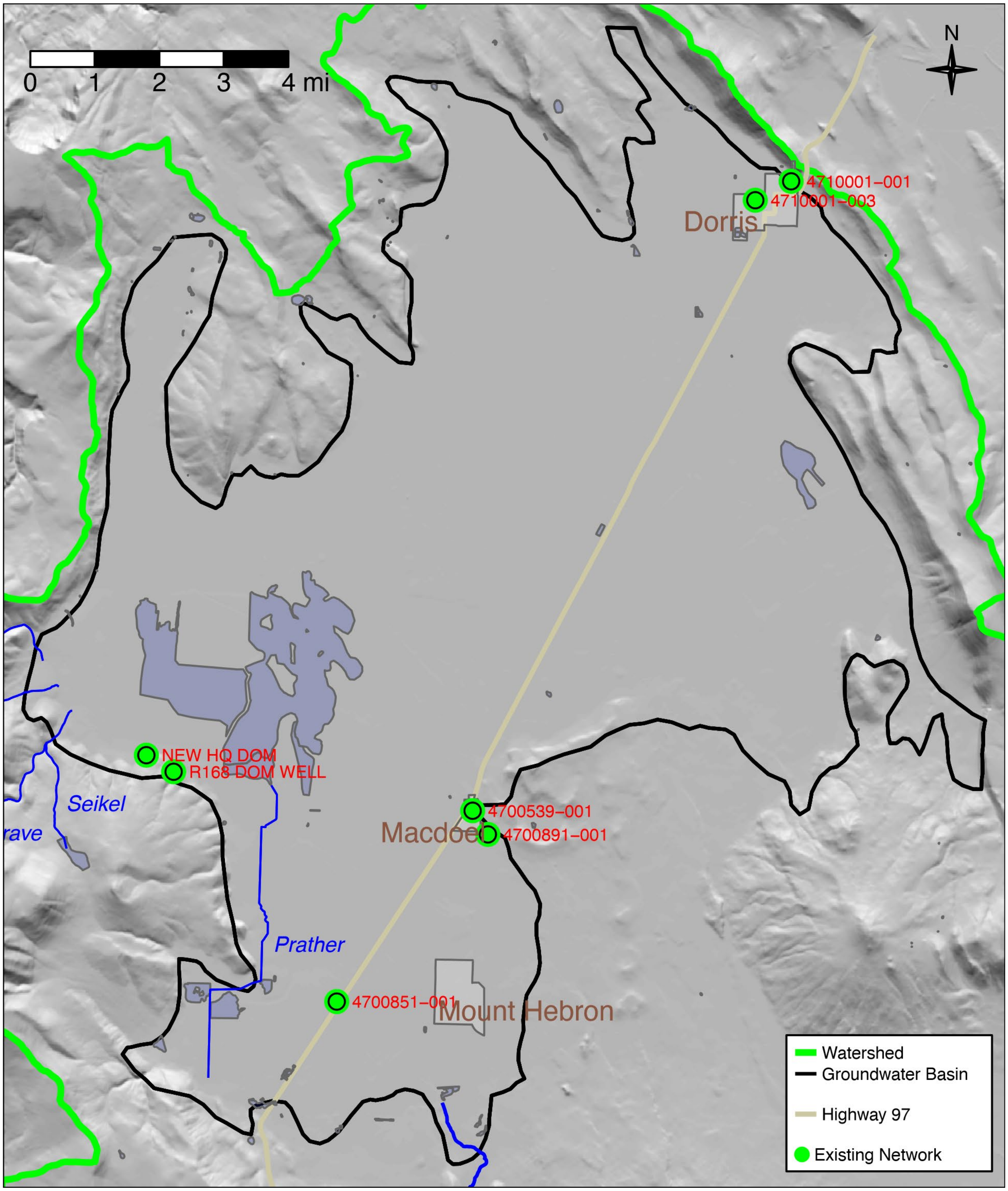


Figure 3.5: Existing water quality monitoring network. Wells along Highway 97 are public supply wells and wells near Meiss Lake are wells volunteered by CDFW. This current monitoring network is planned to be expanded.

An evaluation of the monitoring network, for both spatial density and monitoring frequency suitability will be included in the design of the monitoring network, as discussed in Section 3.3.1. Data gaps have been identified, particularly in spatial coverage, well information and representation of all land uses and beneficial uses and users in the Basin. These data gaps will be resolved through well logging, addition of suitable existing wells, and construction of new wells. The location and number of these wells will be informed by the evaluation completed as part of the monitoring network design.

3.3.3.3 Monitoring Protocols for Data Collection and Monitoring

Sample collection will follow the USGS National Field Manual for the Collection of Water Quality Data (Wilde 2008; USGS 2015) and Standard Methods for the Examination of Water and Wastewater (Rice, Bridgewater, and American Public Health Association 2012), as applicable, in addition to the general sampling protocols listed in Appendix 3-B.

3.3.4 Subsidence Monitoring Network

3.3.4.1 Description of Monitoring Network

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based remote sensing technique that measures vertical ground surface displacement changes at high degrees of measurement resolution and spatial detail. DWR provides vertical displacement estimates derived from InSAR data collected by the European Space Agency Sentinal-1A satellite and processed under contract by TRE ALTAMIRA Inc. The InSAR dataset has spatial coverage for much of the Basin and consists of two data forms: point data and a Geographic Information System (GIS) raster, which is point data interpolated into a continuous image or map. The point data are the observed average vertical displacements within a 100 by 100 m area. The InSAR data covers the majority of the Basin as point data and entirely as an interpreted raster dataset. The dataset provides good temporal coverage for the Basin with annual rasters (beginning and ending on each month of the coverage year from 2015 to 2019), cumulative rasters, and monthly time series data for each point data location. These temporal frequencies are adequate for understanding short-term, seasonal, and long-term trends in land subsidence.

Representative Monitoring

The DWR / TRE ALTAMIRA InSAR data will be used to monitor subsidence in Butte Valley. There are no explicitly identified representative subsidence sites because the satellite data consists of thousands of points. Figure 2.25 shows the coverage of the subsidence monitoring network, which will monitor potential surface deformation trends related to subsidence. Data from the subsidence monitoring network will be reviewed annually. The subsidence monitoring network allows sufficient monitoring both spatially and temporally to adequately assess that the measurable objective is being met.

3.3.4.2 Assessment and Improvement of Monitoring Network

It is currently sufficient for the monitoring network to be based on InSAR data from DWR / TRE ALTAMIRA, which adequately resolves land subsidence estimates in the Basin spatially and temporally. However, data gaps exist in the subsidence network, including the lack of data prior to 2015 and no Continuous Global Positioning System (CGPS) stations to ground-truth the satellite data. The DWR/TRE ALTAMIRA InSAR dataset is the only subsidence dataset currently available for the Basin and only has data extending back to 2015. Historical subsidence data prior to 2015 is currently unavailable. Compared to satellite data, CGPS stations offer greater accuracy and higher frequency and provide a ground-truth check on satellite data. However, there are no CGPS or borehole extensometer stations located within or near the Basin boundary. Due to lack of subsidence since 2015 (see Section 2.2.2.5), no future CGPS or borehole extensometer stations are proposed for the Basin at this time. If subsidence becomes a concern in the future, then installation of CGPS stations and/or borehole extensometers can be proposed. The subsidence monitoring network will be used to determine if and where future CGPS or ground-based elevation surveys would be installed. In addition, if subsidence anomalies are detected in the subsidence monitoring network, ground truthing, elevation surveying, and GPS studies may be conducted.

3.3.4.3 Monitoring Protocols for Data Collection and Monitoring

The subsidence monitoring network currently depends on data provided by DWR through the TRE ALTAMIRA InSAR Subsidence Dataset. Appendix 3-B describes the data collection and monitoring completed by DWR contractors to develop the dataset. The GSA will monitor all subsidence data annually. If any additional data become available, they will be evaluated and incorporated into the GSP implementation. If the annual subsidence rate is greater than minimum threshold, further study will be needed.

3.3.5 Interconnected Surface Water Monitoring Network

This GSP will adopt groundwater levels as a proxy for measuring sustainability of interconnected surface water (ISW) and groundwater-dependent ecosystems (GDE). The groundwater level network described in Section 3.3.1. will also serve as the ISW and GDE monitoring network. The network currently provides the best available coverage of areas where ISWs and GDEs have been identified for further analysis. Expansion of the network to close data gaps will benefit the characterization of both the groundwater level and ISW and GDE sustainability indicators.

As outlined above and in chapter 2, significant data gaps currently exist with respect to ISWs and GDEs. These are being addressed during the first five-year implementation period through installation of additional stream gages, monitoring wells, biological monitoring, and data analysis that will provide the basis for relating water levels to the impacts to beneficial uses and users of ISWs and GDEs.

3.4 SUSTAINABLE MANAGEMENT CRITERIA

3.4.1 Groundwater Elevation

3.4.1.1 Identification of Undesirable Results

SGMA defines undesirable results related to groundwater levels as chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the GSP planning and implementation horizon. Lowering of water levels during a period of drought is not the same as (and does not constitute) chronic lowering of groundwater levels “if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods” (California Water Code 10721(x)(1)).

Multiple discussions, driven by stakeholders and with input from technical advisors, the GSA, and members of the public, were used to define what constitutes an undesirable result due to the chronic lowering of groundwater levels. During development of the GSP, concerns that were identified by stakeholders and the advisory committee related to groundwater level decline included:

- The number of domestic, public or agricultural wells going dry.
- The reduction in the pumping capacity of existing wells.
- The need for deeper well installations or lowering of pumps.
- The significant reduction in spatial coverage and/or health of ISWs and GDEs in the Basin

Based on additional recent input from stakeholders, the advisory committee, and the GSA identified the undesirable result as a significant, non-mitigatable long-term reduction in the viability of groundwater to support environmental uses and users or to supply private, agricultural, industrial, and municipal production wells over the planning and implementation period of this GSP. Domestic wells were identified as the wells most vulnerable to well failure. Specifically, the failure of more than 20% of domestic wells (more than approximately 40-50 domestic wells) over the planning and implementation period of this GSP was identified as a non-mitigable outcome.

The sustainability goal and the undesirable results above provide the qualitative basis for the **quantitative identification of undesirable results**, which must be based on evaluating conditions at individual representative monitoring sites in the Basin, as described in **Section 3.3.1**:

Operationally, an undesirable result for groundwater levels occurs if the fall low water level observation (i.e., the minimum elevation in any given water year) in more than 25% (more than 3 wells with the current monitoring network) of the representative monitoring sites in the Basin fall below their respective minimum thresholds (MT) over two consecutive years. Groundwater levels that fall below the MT repeatedly would indicate the failure of a succession of projects and management actions (PMAs; see Chapter 5) over a significant area of the basin.

No other federal, state, or local standards exist for chronic lowering of groundwater elevations.

The operational, quantitative definition of the undesirable result considers short-term climate and hydrologic variability and focuses on longer-term trends in groundwater levels outside of individual water year types. The 25% threshold means that undesirable results would occur when more than three of the representative monitoring points fall below their minimum thresholds over two consecutive years. Using a value of more than three wells in the definition ensures consideration of conditions at multiple locations in the Basin, as opposed to localized changes in groundwater levels. Defining undesirable results as occurrences over a timespan longer than one year focuses the definition on persistent declines in groundwater levels as opposed to an isolated event. A singular year of lowering of groundwater levels during dry or critically dry conditions is not considered significant and unreasonable if precipitation conditions, or implementation of project and management actions recover groundwater levels in the subsequent year or years.

Additionally, the representative monitoring points used to define an undesirable result have varying well depths. There are large variations in the depths of groundwater wells in the RMP network, ranging from 104 to 1,237 ft, with some at unknown depths. This variation in well depth may result in some wells going dry as isolated occurrences, as opposed to being reflective of Basin-wide conditions. As minimum thresholds for groundwater levels are defined at individual sites (see **Section 3.3.1**), isolated areas may experience temporary decreases below the minimum threshold that are not representative of overall conditions in the Basin.

This quantitative definition of undesirable results was determined following discussions during advisory committee and Board meetings, with input from committee members, members of the public, and technical advisors. The definition of undesirable results considers the ability of the GSA to mitigate for individual wells falling dry. The mitigation is designed to avoid detrimental economic impacts on users that rely on groundwater. The GSA is also aware of the need to maintain the Human Right to Water (AB 685), i.e. the right to safe, clean, affordable, and accessible water. Consideration of impacts to domestic well users, and the GSA's ability to mitigate impacts to domestic wells is a major component of both the qualitative and quantitative undesirable result definitions. The GSA recognizes that under this definition, individual wells may still go dry without an undesirable result occurring. From 2015 through 2042, based on the well outage analysis included as Appendix 3-C, 12 percent of all domestic wells or 28 domestic wells that were not already dry in 2015, may be at risk of going dry if water levels across the Basin fall to the minimum threshold. This is well below the fraction of total domestic wells (20%, or 48 wells, see above) identified as the maximum domestic well outages that can reasonably be mitigated by the GSA. Many of the shallowest wells are private domestic wells. Using one or several shallow domestic wells to indicate the occurrence of undesirable results in the Basin is impractical in the SGMA context, and not an accurate reflection of overall Basin conditions. On the other hand, private shallow domestic wells may fail for a variety of reasons, including deterioration due to age, equipment exceeding its useful life, or a drop in groundwater level below the screened portion of the well. Private wells which are adversely impacted by a lowering of groundwater levels may be mitigated through well deepening or construction of a deeper well to ensure a continued viable water supply.

To address the issue of wells falling dry, the GSA is developing a well mitigation program to address impacts to domestic and municipal well owners. The development and implementation of this plan will be managed by a Domestic Well Advisory Group, a subcommittee that will work closely with the Butte Valley Advisory Committee and the GSA. Details on the progress and overall timeline for this effort can be found under **Chapter 4: Project and Management Actions.** The GSA will be working with the Office of Emergency Services and other relevant local, state and federal agencies to develop and acquire revenue sources to assist well owners in mitigating well outages. Based on the revised well failure analysis (see Appendix 3-C), a total of 14 domestic wells from 2023 to 2042 are estimated to be at risk of well outages if groundwater levels fall to the minimum threshold. If assumed to occur gradually over this entire 19-year period, that would equate to around one well per year falling dry, a number that the GSA considers reasonable to mitigate.

Undesirable results were defined to consider all beneficial uses and users, including the agricultural users that form the foundation of the economy in the Basin. Defining undesirable results to occur with a single well going dry would result in detrimental impacts to these users, and consequently to the Basin's economy, Therefore the advisory committee and the GSA Board agreed to define the undesirable result associated with groundwater levels as more than 25% of the RMPs falling below their minimum thresholds for two consecutive years.

Undesirable results have been defined based on a consideration of social, environmental, and economic perspectives and were designed with consideration for agricultural, municipal, and environmental uses and users in the Basin. The sustainable management criteria are defined in a way that allows groundwater levels to decline from current conditions temporarily during the GSP implementation period, with the ultimate objective of long-term maintenance of groundwater levels within the measurable objective range. The gap between minimum thresholds and measurable objectives is designed to allow operational flexibility for droughts and provide time to see benefits from implemented PMAs. The minimum thresholds and measurable objectives are described in detail in subsequent sections.

Potential Causes of Undesirable Results

- Basin's groundwater pumping currently exceeds the estimated sustainable yield of the Basin (see updated sustainable yield discussion in Chapter 2.2.5). The long-term, multi-decadal decline in water levels in the Basin is due to changes in the balance between Basin inflows (Basin recharge and subsurface inflows into the Basin) and Basin outflows (groundwater pumping, ET from the water table, and subsurface outflows). A reduction in subsurface Basin outflows forces the groundwater system toward a new dynamic equilibrium such that water levels in the Basin reach a new, lower average water level elevation. The lower mean water level elevation reduces the hydraulic gradient between the Basin and the larger Upper Klamath Basin (UKB) groundwater discharge locations near Tule Lake, the Lost River, and the Klamath River. The gradient reduction is approximately proportional to the Basin subsurface outflow reduction. This causes water levels to gradually decline until the new dynamic equilibrium is achieved, possibly over years to decades before stabilizing dynamically (i.e., with seasonal fluctuations) around a larger mean depth (lower mean water level), while still following seasonal and interannual (dry year/wet year) patterns (see Chapter 2). There are several possible causes that would continue to lower water levels and cause undesirable results if water level decline continued to levels below the MT:
- Continued groundwater pumping above the sustainable yield, or further significant increase in Basin pumping volumes, leading to lower subsurface outflow from the Basin, forcing the groundwater system to a new dynamic equilibrium at a lower mean water level.

- A significant reduction in natural or irrigation recharge in the Basin as a result of climate change, or other causes that reduce groundwater inflow from the Basin's land surface, affecting subsurface outflow from the Basin and forcing the groundwater system to a new dynamic equilibrium at a lower mean water level.
- A significant reduction in groundwater inflow from surrounding volcanic uplands as a result of reduced recharge across the watershed, thus also reducing subsurface outflow from the Basin and forcing the groundwater system to a new dynamic equilibrium at a lower mean water level.
- A significant lowering of water levels in the regions downgradient of the Basin due to groundwater pumping in areas to the east and northeast of the Mahogany Mountain ridge, particularly near the natural groundwater discharge points near Tule Lake, Lost River and the Klamath River, eventually leading to regional lowering of water levels across the Upper Klamath Basin, while maintaining long-term hydraulic gradients from UKB recharge areas to these groundwater discharge areas. In the Basin, this also forces the groundwater system to a new dynamic equilibrium at a lower mean water level.

Changes in pumping distribution and volume may occur due to significant rural residential, agricultural, and urban growth that depend on groundwater as a water supply. Climate change or an extended drought can lead to rainfall reductions, prolonged periods of lowered groundwater levels, and reduced recharge.

Reductions in groundwater flowing into the Basin may also result from expansion of groundwater wells outside the Basin border, within the larger watershed upgradient and downgradient from the Basin. Relevant policies regarding management of groundwater outside the Basin are discussed in Section 2.1.4.

The Basin is significantly interconnected with the volcanic groundwater system of the surrounding Watershed. Most precipitation in the larger watershed occurs to the south and southwest of the Basin and flows via recharge and groundwater rather than in streams toward and into the Basin. Groundwater not used for consumptive use in the Basin is discharging via the subsurface to the east and northeast of the Basin into the adjacent volcanic groundwater system and out of the Watershed. Water levels in the Basin are therefore significantly controlled by groundwater recharge into the volcanic groundwater system upgradient and downgradient of the Basin (Chapter 2).

Climate change is expected to raise average annual temperatures and intensify rainfall periods while extending dry periods. Together with resulting vegetation changes in surrounding uplands, climate change may significantly increase or decrease recharge compared to historic conditions (Figure 3.9; see CDWR 2021). If climate change were to lead to reduced recharge in surrounding uplands, upgradient and downgradient from the Basin, upgradient groundwater inflow to the Basin and water levels downgradient of the Basin will be lower, thus reducing the equilibrium water level in the Basin. On the other hand, if climate change leads to future increased recharge in the surrounding uplands, this would be raising water levels in the Basin.

The GSA will coordinate with relevant agencies and stakeholders within the Basin and the larger Watershed to implement PMAs to sustainably manage groundwater levels in the Basin.

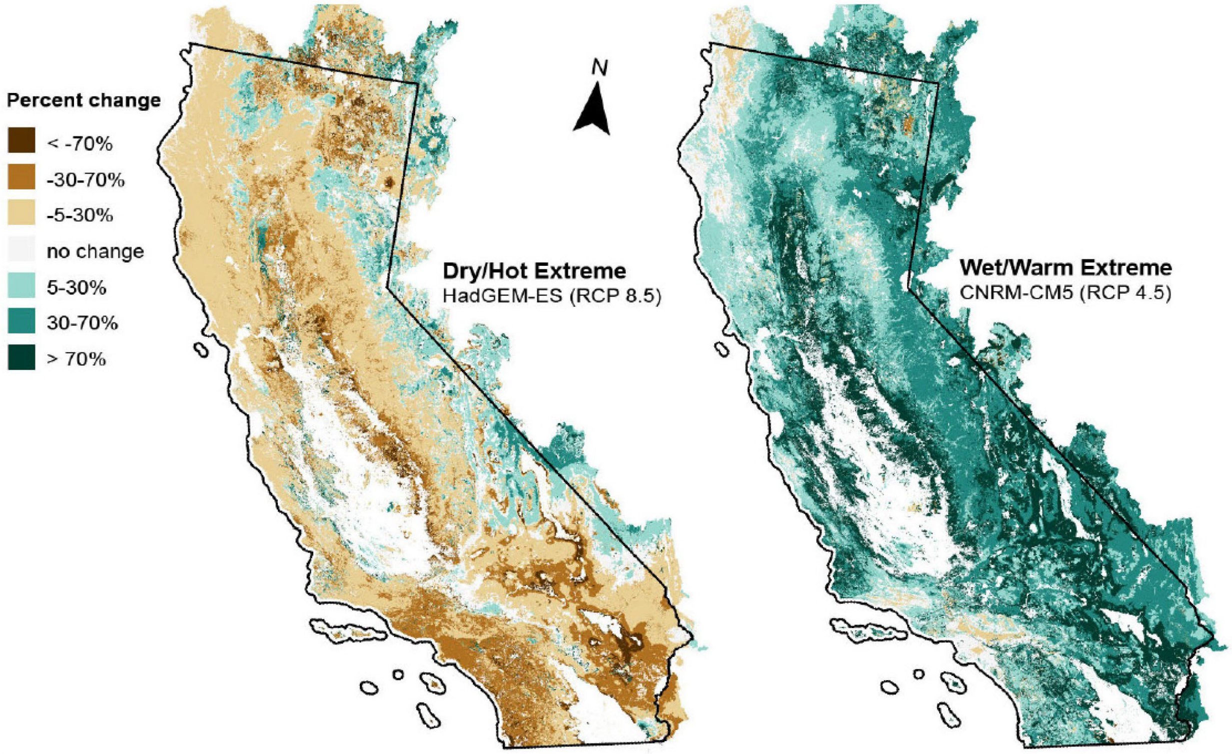


Figure 3.6. Relative change in average annual natural recharge, not accounting for irrigation return flows, under two possible future climate scenarios (CDWR 2021).

Potential Effects of Undesirable Results on Beneficial Uses and Users of Groundwater

Undesirable results associated with chronic lowering of groundwater levels primarily impact groundwater users and environmental users such as groundwater dependent ecosystems.

- **Municipal Drinking Water Users** - Undesirable results due to declining groundwater levels can adversely affect current and projected municipal users, causing increased costs for potable water supplies.
- **Rural and/or Agricultural Residential Drinking Water Users** - Falling groundwater levels can cause shallow domestic and stock wells to go dry, which may require well owners to drill deeper wells or lower pumps, both of which may pose financial burdens to well owners if not mitigatable by the GSA. Under undesirable result conditions, based on the well outage analysis (Appendix 3-C), 12 percent of wells (currently estimated as 28 domestic wells, given the number of domestic and “missing” planned use wells identified in DWR’s OSWCR database) may be impacted by well outages, well below the 20% of domestic wells that the GSA considers mitigatable. Additionally, the lowering of the water table may lead to decreased groundwater quality drinking water wells.
- **Agricultural Users** - Excessive lowering of groundwater levels could necessitate changes in irrigation practices and crops grown and could cause adverse effects to property values and the regional economy.
- **Environmental Uses** – Lowered groundwater levels may result in a significant reduction of groundwater supply to ISWs and GDEs. This may result in insufficient connection of ISWs and GDEs to groundwater which may result in impaired GDE health or overall reduction of spatial coverage in the Basin. The spatial extent of ISWs and GDEs and their interactions with groundwater is not well defined at this time, but will be addressed through additional monitoring and studies.

Undesirable results associated with chronic lowering of groundwater levels were defined such that associated MTs avoid the impacts listed above. Impacts to beneficial users in the first three groups above, at the MT, will be addressed through project and management actions, including development of a well mitigation program (see Chapter 4). To avoid undesirable results to environmental uses, the GSA will expand upon historic monitoring and assessment efforts to fill data gaps, and then adjust the definition of undesirable result, as necessary to include metrics for GDEs. A key component of implementation slated for the first five years of GSP implementation includes working with biologists to clarify GDE location and spatial extent, and to identify key metrics for tracking GDE health. Groundwater level monitoring sites as well as stream gages have already been added in areas identified as potential GDEs in Chapter 2, as shown in Figure 2.32 to ensure tracking of groundwater conditions and inflow from the watershed in these areas.

3.4.1.2 Minimum Threshold

The GSP regulations define minimum thresholds for chronic lowering of groundwater levels as "the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results" and shall be supported by "the rate of groundwater elevation decline based on historical trends, water year type, and projected water use in the basin" and "potential effects on other sustainability indicators". (23 CCR § 354.28)

Minimum thresholds (MT) for groundwater levels in the Basin are defined using existing groundwater level data, have been developed in consultation with the GSA advisory committee and stakeholders and are set to avoid undesirable results. This definition stems from the goal of slowing and then stopping or reversing the chronic lowering of water levels observed over the past 24 year well before 2042. MTs consider ongoing groundwater decline, mitigatable impacts, and provide operational flexibility during the implementation period, with the ultimate goal of reaching and sustaining groundwater levels at the measurable objective (MO).

The MTs are set using a combination of historical measured water level depths, to enable a "soft landing" glide-path through the year 2042. Groundwater levels might decline beyond baseline (pre-2015) levels but remain above the MT while PMAs are implemented to achieve the measurable objective (MO). PMAs for groundwater levels are described in Chapter 4.

MTs are tailored to each individual well in the representative monitoring network, to accommodate differences in groundwater conditions across the Basin. Well hydrograph models projected 2042 groundwater elevations based on average chronic lowering of water levels during the period 1999 to 2014, as shown in Figure 3.8. The RMP hydrographs are included in Appendix 3-C. All MTs were chosen to account for the natural delayed response of groundwater levels to PMAs (Figure 3.7).

Thresholds were set after consideration of the undesirable results and an analysis of projected well outages (see Section 3.4.1.5). A well outage is defined by the inability to pump groundwater from the affected well due to declining groundwater levels. Results from the well outage analysis indicate that if water levels across the Basin fall to the selected MT, only 12 percent of shallow domestic wells in the Basin may be at risk for well outages, 10 total agricultural wells, and no public supply wells will be at risk of a well outage.

The MTs are specific to each RMP. The following mathematical method was used to set the MT at each RMP in a hydrologically consistent manner such that the undesirable results identified above are avoided when water levels are at the MT:

A regression line is fitted to the fall water level measurements at the RMP for the 15-year period from fall 1999 to fall 2014. The slope or beta (β) of the regression line corresponds to the average rate of decline in fall water levels, measured in feet per year, over this 15-year period. The water level depth of the regression line in fall 2014 is denoted as "WL_Depth_Regression_F2014" in the equation below (Figure 3.8).

The MT is computed by extending the regression line to 2042, then "bending" it to a flattening landing approach by allowing for at most 75% of the total decline that the regression curve provides for the 27-year period from fall 2014 to fall 2041 (immediately prior to the January 1, 2042 SGMA compliance date):

$$MT(\text{measured as water depth})$$

$$= \text{WL Depth Regression F2014 } [ft] + 0.75 * \beta[ft/yr] * 27[yr])]$$

The 75% value (0.75 in the above equation) was selected such that the undesirable result identified above is avoided at the MT. Specifically, using this value avoids the mitigation of more than approximately 12% of existing domestic wells due to wells falling dry, thus providing substantial buffer against the undesirable outcome of more wells falling dry than the GSA can mitigate (more than 20% of domestic wells, see description of undesirable results above). At the same time, the MTs allow for operational flexibility when water levels fall below the MOs to implement project and management actions in a timely manner to avoid significant and unreasonable undesirable results from occurring within the planning horizon. For sufficient operational flexibility, the difference between the MT and minimum MO (see below), is set to be at least 5 feet (ft). Additionally, for wells where the MT based on the above equation would be below the screen depth, the MT is set at 5 ft above the total well depth.

The well failure analysis (see Appendix 3-C) estimates the number of well outages. It was conducted first through an evaluation of reported wells from DWR's OSWCR in Butte Valley groundwater basin. Then, domestic and public well outages are estimated using the most available well construction information (i.e., well depth, top of perforation) and groundwater levels at the reported well locations, which are interpolated using groundwater level measurements across the basin. A well outage was defined as less than 10 ft of the wet depth to bottom of well. The analysis shows that the estimated number of domestic well outage in 2015 is 45 out of the total 247 domestic and public wells identified from OSWCR. The estimated additional domestic well outages from 2015 to 2023 is 14 (6% of the total), and the estimated additional domestic well outages after 2023 to minimum threshold levels is 14 (6% of the total). Ten additional agricultural well outages compared to the condition in 2015 are anticipated if the groundwater levels fall to the minimum threshold. No public supply well outages are anticipated if groundwater levels fall to the minimum threshold. The well failure analysis was repeated using additional methods, including considering top of screen information, where available, and a statistical trend analysis. Results independently confirmed these well outage estimates between 2015, 2023, and at the MT.

Table 3.4 shows, for each RMP, the most recent fall water level (2020), the lowest historic water level measurement and the year of that observation, the value of the regression line in fall 2014 ("*WL_Depth_Regression_F2014*"), the slope (β) of the regression line, the depth of the MT the final MT, and the MO.

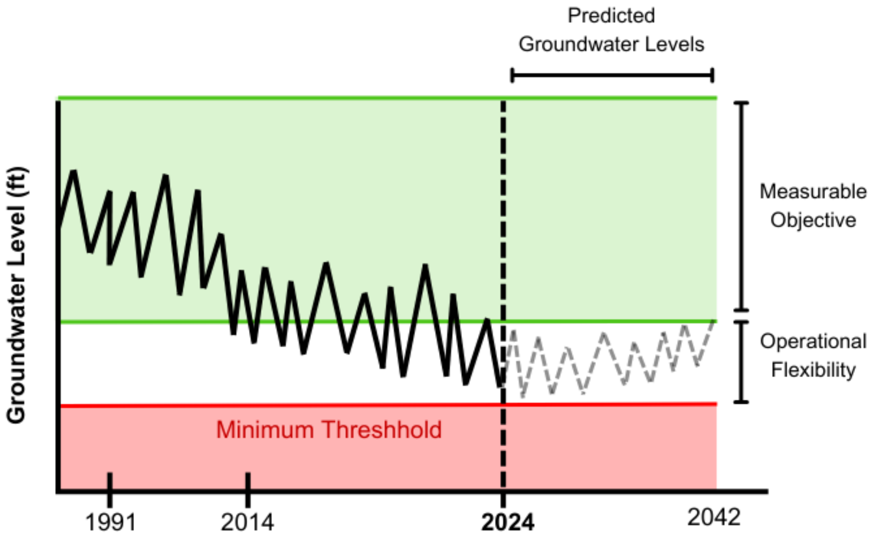


Figure 3.7: The goal for groundwater levels is to slow any groundwater level decline during GSP implementation, with measurable flattening of long-term trends by 2032 and with the ultimate objective of increasing levels to the MO. Increasingly strict management actions need to be implemented to slow and stop the decline in a timely fashion, were chronic lowering of water levels to continue.

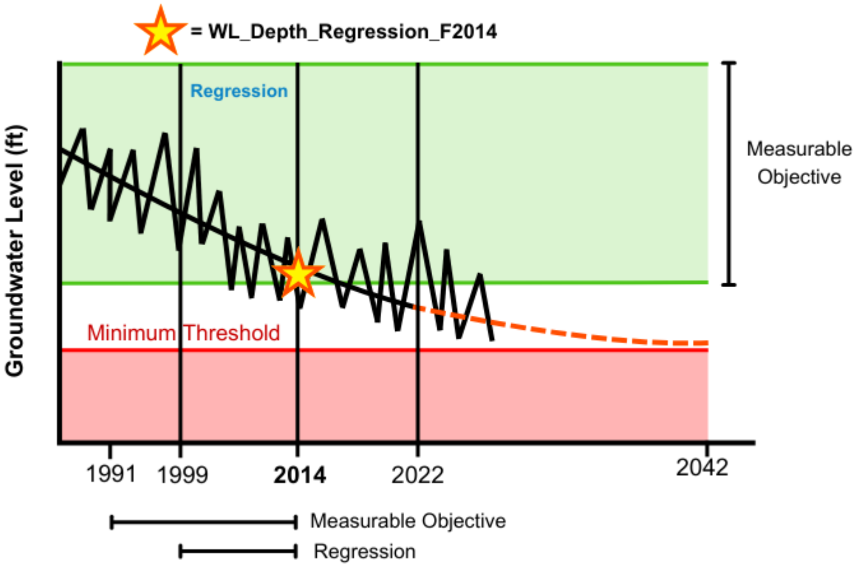


Figure 3.8: Visual description of the MT on a hydrograph.

Table 3.4. Groundwater level (WL) minimum thresholds (MT), with units of feet above mean sea level (ft amsl). Abbreviations: minimum threshold (MT), measurable objective (MO), water level (WL), minimum (Min), and maximum (Max).

Representative Monitoring Point/Well	Fall 2020 WL	Historic Low WL (Year)	WL Depth Regression F2014	Regression Slope (ß) (ft/yr)	MT	MO Min	MO Max
417786N1220041W001	4182.78	4181 (2014)	4181	-1.7954	4163**	4181	4225
417789N1220759W001	4211.91	4202 (2016)	4215	-0.5916	4203	4213	4237
417944N1220350W001	4207.83	4184 (2015)	4200	-0.5218	4185***	4190	4225
418512N1219183W001	NA*	4190 (2018)	4195	-0.6810	4181	4193	4214
418544N1219958W001	4208.32	4208 (2019)	4211	-0.8111	4195	4211	4224
418661N1219587W001	NA*	4186 (2014)	4186	-1.1004	4163	4186	4214
418948N1220832W001	NA*	4189 (1996)	4193	-1.1538	4170	4193	4216
419021N1219431W001	NA*	4202 (2015)	4204	-0.7407	4189	4203	4216
419451N1218967W001	4143.53	4129 (2009)	4145	-0.1611	4124***	4129	4158
419519N1219958W001	4226.49	4227 (2018)	4229	-0.3302	4223	4229	4237
419520N1219959W001	4230.34	4231 (2020)	4232	-0.3095	4226	4231	4242
419662N1219633W001	4161.66	4162 (2020)	4166	-1.3362	4139	4161	4199
419755N1219785W001	4168.5	4169 (2020)	4192	-1.0284	4171	4187	4217

Note:

(*) No fall measurements in 2019 and 2020.

(**) The MT was moved to 5 feet above its bottom of well screen (104 feet below ground surface, 4158 feet above mean sea level).

(***) The MT was moved to 5 feet below the MO.

In addition to setting MTs and MOs at each RMP well, interim milestones are also set to define a path to achieving measurable objective groundwater levels on or before 2042. These thresholds are intended to help evaluate progress towards reaching groundwater levels in the measurable objective range, and are defined at 5-year intervals throughout the GSP implementation period. The interim milestones are tailored to each RMP and are set based on the MT and MO. The interim milestones are set incrementally, with groundwater levels reaching the MO range in 2037. The values for these interim threshold are shown in Table 3.5.

Table 3.5. Groundwater level (WL) minimum thresholds (MT), with units of feet above mean sea level (ft amsl) and interim milestones in 2027, 2032, and 2037. Abbreviations: minimum threshold (MT), measurable objective (MO), water level (WL), minimum (Min), and maximum (Max).

Representative Monitoring Point/Well	MT	MO Min	MO Max	Interim Milestone 2027	Interim Milestone 2032	Interim Milestone 2037
417786N1220041W001	4163**	4181	4225	4172	4177	4181
417789N1220759W001	4203	4213	4237	4208	4211	4213
417944N1220350W001	4185***	4190	4225	4188	4189	4190
418512N1219183W001	4181	4193	4214	4187	4190	4193
418544N1219958W001	4195	4211	4224	4203	4207	4211
418661N1219587W001	4163	4186	4214	4175	4180	4186
418948N1220832W001	4170	4193	4216	4182	4187	4193
419021N1219431W001	4189	4203	4216	4196	4200	4203
419451N1218967W001	4124***	4129	4158	4127	4128	4129
419519N1219958W001	4223	4229	4237	4226	4228	4229
419520N1219959W001	4226	4231	4242	4229	4230	4231
419662N1219633W001	4139	4161	4199	4150	4156	4161
419755N1219785W001	4171	4187	4217	4179	4183	4187

3.4.1.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MOs for groundwater levels are established to provide an indication of desired levels that are sufficiently protective of beneficial uses and users. MOs are defined on a well-specific basis, with consideration for historical groundwater level data.

The MO is defined separately for each RMP, as shown in Figure 3.8. The MO is a range of water levels rather than a single threshold. The upper limit of the MO is the highest observed water level at a RMP in the period from years 1991 to 2014 and the lower limit of the MO is the lowest observed water level at a RMP in the period 1991 to 2014, regardless of whether the water level was observed in the spring or fall season. This will eliminate the threat of well outages and protect beneficial uses in the Basin. MOs are shown in Table 3.4.

The difference in groundwater levels between the lower limit of the MO and MT gives a margin of operational flexibility, or margin of safety, for variation in groundwater levels due to seasonal, annual, or drought variations. Groundwater levels might drop in drought years but rise in wet years to recharge the aquifer and offset drought years. The operational flexibility is shown in Table 3.6. As can be seen from this table, the minimum MO (the lowest historically observed water level depth) is less than 30 feet above the selected MT for most RMP.

3.4.1.4 Path to Achieve Measurable Objectives

The GSA will support achievement of the MOs by reducing the amount of groundwater pumping to the sustainable yield of 65 TAF per year as identified in Chapter 2.2.5, by monitoring groundwater levels, and by coordinating with agencies and stakeholders within the Basin to implement PMAs. The GSA will also monitor compliance of Basin groundwater extraction with the identified sustainable yield, to the extent possible, through collection of groundwater extraction data through flowmeters on representative wells. The GSA will review and analyze groundwater level data to evaluate any changes in groundwater levels resulting from groundwater pumping or from PMAs. Using monitoring data collected as part of GSP implementation, the GSA will develop information (e.g., hydrograph plots, BVIHM model information) to demonstrate that PMAs are operating to maintain or improve groundwater level conditions in the Basin and to avoid unreasonable groundwater levels. Should groundwater levels drop to a trigger or MT as the result of GSA project implementation, the GSA will implement measures to address this occurrence. This process is illustrated in Figure 3.9.

To manage groundwater levels, the GSA will partner with local agencies and stakeholders to implement PMAs. PMAs are presented in further detail in Chapter 4. Implementation timelines and approximate costs are discussed in Chapter 5. Examples of possible GSA actions include stakeholder education, outreach and support for impacted stakeholders, development and implementation of a well mitigation program, groundwater demand management, and development of a preliminary groundwater allocation program.

Where the cause of groundwater level decline is unknown, the GSA may choose to conduct additional or more frequent monitoring and initiate additional groundwater modeling. The need for additional studies on groundwater levels will be assessed throughout GSP implementation. The GSA may identify knowledge requirements, seek funding, and help to implement additional studies.

Table 3.6. Operational flexibility for each representative monitoring well and MA triggers, with units of feet above mean sea level (ft amsl).

Representative Monitoring Point/Well	Top of Screen (ft)	Bottom of Screen (ft)	Measurable Objective Maximum (MO max) (ft)	Measurable Objective Minimum (MO Min) (ft)	Minimum Threshold (MT) (ft)	Operational Flexibility (MO min - MT) (ft)
417786N1220041W001	4222	4158	4225	4181	4163	18
417789N1220759W001	Data Gap	Data Gap	4237	4213	4203	10
417944N1220350W001	4190	4144	4225	4190	4185	5
418512N1219183W001	4216	4096	4214	4193	4181	12
418544N1219958W001	Data Gap	Data Gap	4224	4211	4195	16
418661N1219587W001	4181	3937	4214	4186	4163	23
418948N1220832W001	4079	3829	4216	4193	4170	23
419021N1219431W001	Data Gap	Data Gap	4216	4203	4189	14
419451N1218967W001	4167	4069	4158	4129	4124	5
419519N1219958W001	Data Gap	4045	4237	4229	4223	6
419520N1219959W001	Data Gap	3785	4242	4231	4226	5
419662N1219633W001	4222	3745	4199	4161	4139	22
419755N1219785W001	4079	4019	4217	4187	4171	16

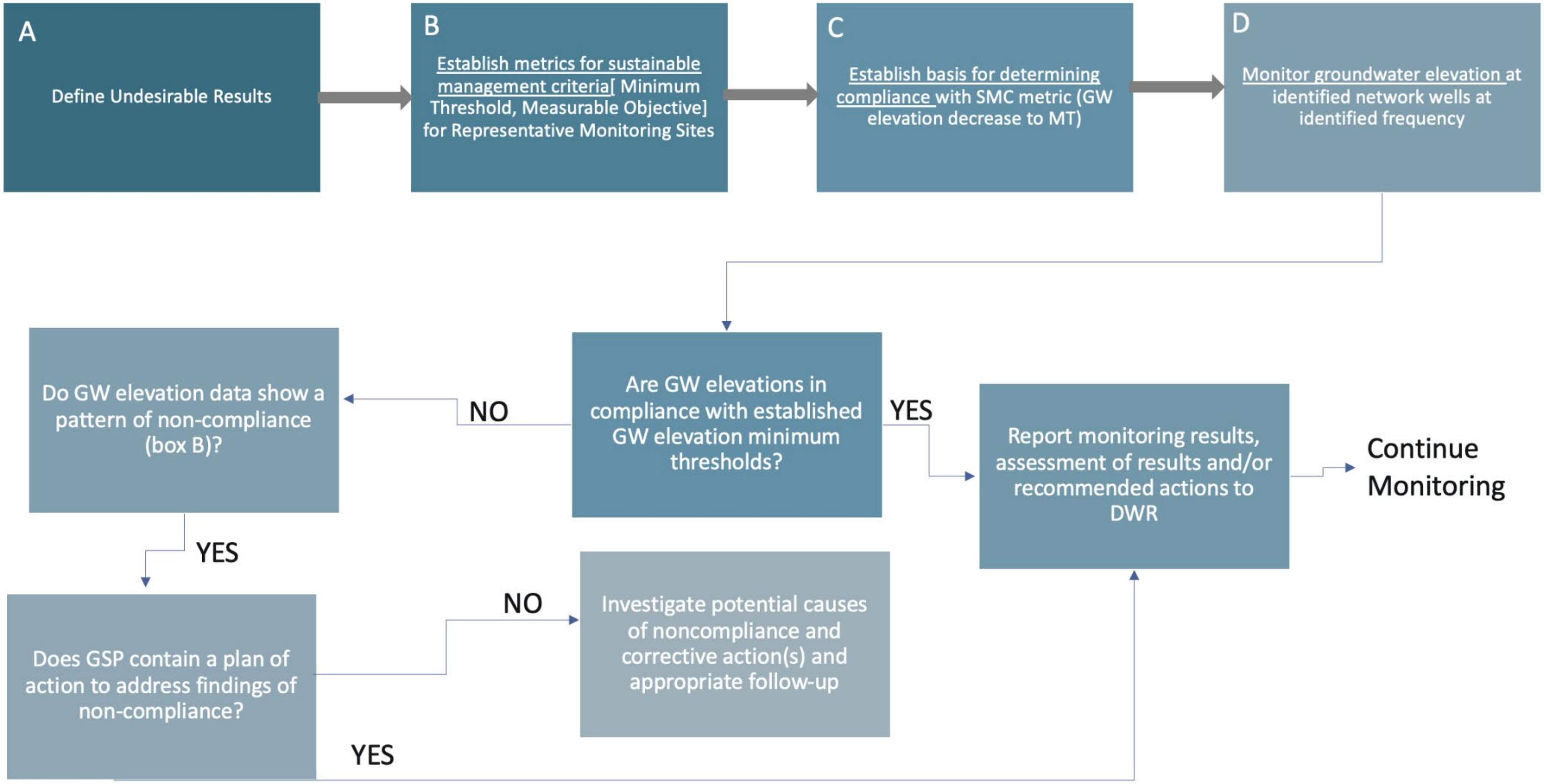


Figure 3.9. Groundwater level SMC flow chart. The flow chart depicts the high-level decision making that goes into developing SMCs, monitoring to determine if criteria are met, and actions to be taken based on monitoring results. Actions are described in Chapter 5.

Interim Milestones

Groundwater levels are managed to reach the MO by 2042. Interim milestones for groundwater levels were established through review and evaluation of measured groundwater level data and future projected fluctuations in groundwater levels and planned implementation of PMAs. Based on the historical groundwater levels presented in Appendix 3-C, where most hydrographs show leveling off of groundwater decline from 2014 to 2020, all interim milestones are set simply to remain within the MO for each RMP. This interim milestone is already met by most RMP. Remaining wells are expected to reach MO through MAs. At future five-year assessments, the GSA will evaluate if these interim milestones need to be adjusted based on observed groundwater conditions.

3.4.1.5 Minimum Threshold Effects on Beneficial Uses and Users

Groundwater level MT will primarily impact beneficial uses and users reliant on groundwater and environmental users such as ISWs and GDEs.

To better understand the effect on beneficial uses and users, specifically domestic well users, a well failure risk analysis was performed, which is presented in Appendix 3-C. The analysis provides an estimate of the undesirable result that would occur if water levels declined to the MT. Due to data gaps related to well construction details and groundwater levels, the well failure risk analysis focuses on interpolated groundwater elevation data to assess the aggregated risk of wells not being able to pump water due to low water levels (“well outages”). Groundwater levels were interpolated for fall 2015 (dry year) and fall 2023 (most recent fall conditions). Wells were classified by well type (public and domestic) and the geologic formation identified at the bottom of the perforated interval. Results indicate that if water levels were lowered from 2015 levels to the MT throughout the Basin, an estimated 18 to 28 domestic wells, 10 agricultural wells, and zero public supply wells would be at risk of well outage. Well outage risk is unevenly distributed across the basin due to varying well characteristics between geologic formations and varying water level declines (see Appendix 3C).

The following provides greater detail regarding the potential impact of poor groundwater level on several major classes of beneficial users:

- **Municipal Drinking Water Users** - declining groundwater levels can adversely affect current and projected municipal users, causing increased costs for potable water supplies.
- **Rural and/or Agricultural Residential Drinking Water Users** - Falling groundwater levels can cause shallow domestic and stock wells to go dry, which may require well owners to drill deeper wells. The well outage analysis shows, at the minimum threshold, 12% of domestic/shallow wells in the Basin would be susceptible to well outages. Additionally, the lowering of the water table may lead to decreased groundwater quality in drinking water wells.
- **Agricultural Users** - Excessive lowering of groundwater levels could necessitate changes in irrigation practices and crops grown and could cause adverse effects to property values and the regional economy.
- **Environmental Uses** - Deep groundwater levels may result in significant and unreasonable reduction of groundwater flow toward ISWs and GDEs, which may adversely impact ecological habitat and resident species, resulting in reduced spatial coverage and/or health. Currently, in the Basin the location of ISWs and GDEs is a data

gap that will be addressed by PMAs including the development of data and mitigation strategies to achieve the MT.

To avoid undesirable outcomes to the first three beneficial user groups, to the degree they occur at water levels above the MT, the GSA will develop a well mitigation program (Chapter 4). To avoid undesirable outcomes to the fourth group of beneficial uses, the GSA will expand upon historic monitoring and assessment efforts to fill data gaps, then develop mitigation programs or adjust MTs at relevant RMP in future updates to the GSP as needed. The MO is already protective of GDEs, where they exist, as it preserves baseline water levels.

3.4.1.6 Relationship to Other Sustainability Indicators

MTs are selected to also avoid undesirable results for other sustainability indicators. In the Basin, groundwater levels are directly related to groundwater storage and GDEs outside of streams. The relationship between groundwater level MTs and MTs for other sustainability indicators are discussed below.

- **Groundwater Storage -** Groundwater levels are closely tied to groundwater storage, with high groundwater levels related to high groundwater storage. The groundwater storage MTs use the water level MTs as a proxy.
- **Groundwater Quality -** Protecting groundwater quality is critically important to all who depend upon the groundwater resource. A significant and unreasonable condition for degraded water quality is exceeding drinking water standards for constituents of concern in supply wells due to PMAs proposed in the GSP. Groundwater quality could potentially be affected by PMA induced changes in groundwater elevations and gradients. These changes could potentially cause poor quality groundwater to flow towards supply wells that would not have otherwise been impacted.
- **Subsidence -** The MT for land subsidence is to not cause significant additional land subsidence. The water level MT (“extended soft landing”) prevents the subsidence MT from being exceeded.
- **Interconnected Surface Water** – Depletion of ISWs due to groundwater pumping and impacts to GDEs are closely tied to groundwater levels. Significant data gaps and gaps in analysis exist. For the ISW MTs, it is therefore most reasonable to use the water level MTs as a proxy.

3.4.1.7 Information and Methodology Used to Establish Minimum Thresholds and Measurable Objectives

The MTs were selected based on historical groundwater level trends and stakeholder input. A detailed discussion of groundwater level trends and current conditions is described in Section 2.2.2.1. In establishing MTs for groundwater levels, the following information was considered:

- Feedback about groundwater level concerns from stakeholders.
- An assessment of available historical and current groundwater level data from wells in the Basin.
- An assessment of potential well outages based on possible MTs.
- Collection of well information regarding water bearing formation, depth, and screen characteristics.
- Results of the completed numerical groundwater model, BVIHM, indicating groundwater flow conditions (Chapter 2).

- Input from stakeholders resulting from the consideration of the above information in the form of recommendations regarding MTs and associated MAs.
- Two analytical approaches as well as the numerical model and resulting future water budget indicates and supports the finding that the basin chronic lowering of water levels can be stopped if pumping does not exceed the sustainable yield of 65 TAF per year. This requires a 10% - 15% reduction in groundwater pumping relative to recent periods. This revised GSP includes a groundwater allocation PMA and a groundwater demand management PMA to achieve and assess such pumping reductions by the end of the first five-year implementation period.

3.4.2 Groundwater Storage

Groundwater levels are selected as the proxy for groundwater storage. Hence, the SMCs are identical (Section 3.4.1). According to the USGS, estimates of groundwater storage rely on groundwater level data and sufficiently accurate knowledge of hydrogeologic properties of the aquifer. Direct measurements of groundwater levels can be used to estimate changes in groundwater storage (USGS 2021). As groundwater levels fall or rise, the volume of groundwater storage changes accordingly, where unacceptable groundwater decline indicates unacceptable storage loss. The hydrogeologic model outlined in Chapter 2 provides the needed hydrogeologic properties of the aquifer.

Protecting against chronic lowering of groundwater levels will directly protect against the chronic reduction of groundwater storage as the lowering of groundwater levels would directly lead to the reduction of groundwater storage. There cannot be a reduction in groundwater storage without a commensurate, observable reduction in water levels. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

An undesirable result from the reduction of groundwater in storage occurs when reduction of groundwater in storage interferes with beneficial uses of groundwater in the Basin. Since groundwater levels are being used as a proxy, the undesirable result for this sustainability indicator occurs when groundwater levels drop below the extended MT (Table 3.5), as defined by the undesirable result for the chronic lowering of groundwater levels. This should avoid significant and unreasonable changes to groundwater storage, including long-term reduction in groundwater storage or interference with the other sustainability indicators. Possible causes of undesirable reductions in groundwater storage are increases in well density or groundwater extraction or increases in frequency or duration of drought conditions.

The MT for groundwater storage for this GSP is the MT for groundwater levels. Information used to establish MTs and MOs for groundwater levels can be found in Section 3.4.1. Since groundwater storage is defined in terms of water level, Section 3.4.1.2 for the water level indicator equally applies to define the relationship of the groundwater storage SMC to other sustainability indicators.

The MO for groundwater storage is the MO for groundwater levels as detailed in Section 3.4.1.3. The path to achieve MOs and interim milestones for the reduction in groundwater storage sustainability indicator are the same MOs and interim milestones as for the chronic lowering of groundwater levels sustainability indicator detailed in Section 3.4.1.4.

3.4.3 Degraded Groundwater Quality

Groundwater quality in the Basin is generally well-suited for the municipal, domestic, agricultural, and other existing and potential beneficial uses designated for groundwater in the Water Quality Control Plan for the North Coast Region (Basin Plan). Existing groundwater quality concerns within the Basin are identified in Section 2.2.2.3 and the corresponding water quality figures and detailed water quality assessment are included in Appendix 2-B. In Section 2.2.2.3, constituents that are identified as groundwater quality concerns include 1,2 Dibromoethane (ethylene dibromide; EDB), arsenic, benzene, boron, nitrate, and specific conductivity.

SMCs will be defined for a select group of constituents: arsenic, nitrate, and specific conductivity. 1,2 Dibromoethane (ethylene dibromide; EDB) and benzene are already being monitored and managed by the NCRWQCB through the Leaking Underground Storage Tank (LUST) program.

Boron is naturally occurring. As such, SMC for EDB, benzene and boron are not needed. An SMC is defined for arsenic because, while it can be naturally occurring, there is arsenic contamination near Dorris from an unknown historical industrial source. Due to the localized contamination, arsenic SMCs are only defined for wells near Dorris. The GSA will monitor the naturally occurring constituents to track any possible mobilization of elevated concentrations.

The role of the GSA is to provide additional local oversight of groundwater quality, collaborate with appropriate parties to implement water quality projects and actions, and to evaluate and monitor, as needed, water quality effects of projects and actions implemented to meet the requirements of other SMCs. All future PMAs implemented by the GSA will be evaluated and designed to avoid causing undesirable groundwater quality outcomes. Federal and state standards for water quality, water quality objectives defined in the Basin Plan, and the management of known and suspected contaminated sites within the Basin will continue to be managed by the relevant agency. Groundwater in the Basin is used for a variety of beneficial uses which are protected by the NCRWQCB through the water quality objectives adopted in the Basin Plan.

Available historic and current groundwater quality monitoring data and reporting efforts have been used to establish and document conditions in the Basin, as discussed in Section 2.2.2.3. These conditions provide a baseline to compare with future groundwater quality and identify any changes observed, including those due to GSP implementation.

Groundwater quality monitoring in the Basin in support of the GSP will rely on the monitoring network described in Section 3.3.3. Groundwater quality samples will be collected and analyzed in accordance with the monitoring protocols outlined in Section 3.3.3.3. The monitoring network will use information from existing programs in the Basin that already monitor for the constituents of concern, and programs where constituents could be added as part of routine monitoring efforts in support of the GSP. New wells will be incorporated into the network as necessary to fill data gaps.

Because water quality degradation is typically associated with increasing rather than decreasing concentration of constituents, the GSA has decided to not use the term “minimum threshold” in the context of water quality, but instead use the term “maximum threshold.” The use of the term maximum threshold for the water quality SMC in this GSP is equivalent to the use of the term MT in other SMCs or in the SGMA regulations.

3.4.3.1 Undesirable Results

Degraded groundwater quality is considered an undesirable result if concentrations of constituents of concern exceed defined MTs or if a significant trend of groundwater quality degradation is observed for the identified constituents of concern. Groundwater quality changes that occur due to SGMA activities, including current groundwater use and management, may constitute an undesirable result.

For purposes of quantifying and evaluating the occurrence of an undesirable result, the concentration data are aggregated by statistical analysis to obtain spatial distributions and temporal trends. Specifically, statistical analysis is performed to determine the ten-year linear trend in concentration the $75conc75_{th}$ percentile, $trend75_{10year}$, is obtained. Similarly, the moving two-year average

con-th at each well. This trend is expressed unitless as percent relative concentration change per

year. From the cumulative distribution of all 10-year trends observed across the monitoring

network,

$_{2year}$, is obtained. Concentrations are expressed in their respective concentration units concentrations are computed at each well, and from their cumulative distribution the 75 percentile, (µg/L, mg/L, or micromhos). For purposes of this GSP, a "water quality value" is defined by combining the measures of trend and concentration.

$$Water\ quality\ value = Maximum(trend75_{10year} - 15\%,\ conc75_{2year} - MT)$$

The undesirable result is quantitatively defined as:

$$Water\ quality\ value\ is > 0$$

This quantitative measure assures that water quality remains constant and does not increase by more than 15% per year, on average over ten years, in more than 25% of wells in the monitoring network. Mathematically this can be expressed by the following equation:

$$\boldsymbol{trend75_{10year}[\%] - 15\% \leq 0}$$

It also assures that water quality does not exceed MTs for concentration in more than 25% of wells in the monitoring network. Values for MTs are defined in Section 3.4.3.4. Mathematically, this second condition can be expressed by the following equation:

$$\boldsymbol{conc75_{2year} - MT \leq 0}$$

The water quality value is the maximum of the two terms on the left-hand side of the above two equations. If either of them exceeds zero, that is, if either of them does not meet the desired condition, then the water quality value is larger than zero and quantitatively indicates an undesirable result.

MTs align with applicable water quality regulations. Groundwater regulatory thresholds are defined by federal and state drinking water standards and Basin Plan water quality objectives. Due to emphasis on local governance, Basin Plan water quality objectives are considered in addition to state or federal drinking water standards. The Basin Plan may set more stringent standards to address local water quality issues or set separate less stringent water standards depending on the beneficial uses (e.g., for agricultural irrigation and stock watering vs. drinking water). With the current Basin Plan, the Butte Valley groundwater aquifer is designated with the beneficial use Municipal and Domestic Supply (MUN) but use of irrigation wells can be managed so that the Basin Plan groundwater water quality objectives are not applicable: if irrigation occurs at agronomic rates (tracked by the user), the irrigation water is only enough for the crops and will not reach the underlying groundwater to cause or contribute to a water quality problem. Then water quality is only evaluated based on values that are harmful to the crop being irrigated.

Due to limited surface water resources in the Basin, groundwater has an important role in supporting beneficial uses including agriculture (a significant part of the local economy), domestic use and municipal water supply. Groundwater is also an important component of streamflow and its water quality benefits instream environmental resources and wildlife. These beneficial uses, among others, are protected by the NCRWQCB through the water quality objectives adopted in the Basin Plan. The Basin Plan defines the existing beneficial uses of groundwater in the Basin: Municipal and Domestic Supply (MUN), Agricultural Supply (AGR), Industrial Service Supply (IND), and Native American Culture (CUL). Potential beneficial uses include Industrial Process Supply (PRO) and Aquaculture (AQUA).

Significant and unreasonable degradation of groundwater quality is the degradation of water quality that would impair beneficial uses of groundwater within the Basin or result in failure to comply with groundwater regulatory thresholds including state and federal drinking water standards and Basin Plan water quality objectives. Based on the State's 1968 antidegradation policy, water quality degradation that is not consistent with the provisions of Resolution No. 68-16 is degradation determined to be significant and unreasonable. Furthermore, the violation of water quality objectives is significant and unreasonable under the State's antidegradation policy. The NCRWQCB and the State Water Board are the two entities that determine if degradation is inconsistent with Resolution No. 68-16.

Federal and state standards for water quality, water quality objectives defined in the Basin Plan, and the management of known and suspected contaminated sites within the Basin will continue to be managed by the relevant agency. The role of the GSA is to provide additional local oversight of groundwater quality, collaborate with appropriate parties to implement water quality projects and actions, and to evaluate and monitor, as needed, water quality effects of projects and actions implemented to meet the requirements of other SMCs.

Sustainable management of groundwater quality includes maintenance of water quality within regulatory and programmatic limits (Section 2.2.2.3) while executing GSP PMAs. To achieve this goal, the GSA will coordinate with the regulatory agencies that are currently authorized to maintain and improve groundwater quality within the Basin. This includes informing the NCRWQCB of any issues that arise and working with NCRWQCB to rectify the problem. All future PMAs implemented by the GSA will be evaluated and designed to avoid causing undesirable groundwater quality outcomes. Historic and current groundwater quality monitoring data and reporting efforts have been used to establish and document conditions in the Basin, as discussed in Section 2.2.2.3. These conditions provide a baseline to compare with future groundwater quality and identify any changes observed due to GSP implementation.

Potential Causes of Undesirable Results

Future GSA activities with potential to affect water quality will be monitored and may include changes in location and magnitude of basin pumping, declining groundwater levels and changes to both planned and incidental groundwater recharge mechanisms. Altering the location or rate of groundwater pumping could change the direction of groundwater flow which may result in a change in the overall direction in which existing or future contaminant plumes move thus potentially compromising ongoing remediation efforts. Similarly, recharge activities could alter hydraulic gradients and result in the downward movement of contaminants into groundwater or move groundwater contaminant plumes towards supply wells.

Land use activities that may lead to undesirable groundwater quality include industrial contamination, pesticides, sewage, animal waste, and other wastewaters, and natural causes. Industrial application of wood preservatives can elevate arsenic. Fertilizers and other agricultural activities can elevate analytes such as nitrate and specific conductivity. Wastewater and animal waste can elevate nitrate, and specific conductivity. The GSA cannot control and is not responsible for natural causes of groundwater contamination but is responsible for how PMAs may impact groundwater quality (e.g., through mobilization of naturally occurring contaminants). Natural causes (e.g., local geology and soils) can elevate analytes such as arsenic and specific conductivity. For further detail, see Section 2.2.2.3.

Groundwater quality degradation associated with known sources will be primarily managed by the entity currently overseeing these sites, the NCRWQCB. In the Basin, existing leaks from underground storage tanks (USTs) are currently being managed, and though additional degradation is not anticipated from known sources, new leaks may cause undesirable results due to constituents that, depending on the contents of an UST, may include petroleum hydrocarbons, solvents, or other contaminants.

Agricultural activities in the Basin are dominated by alfalfa, grain and hay, and strawberry. Alfalfa and pasture production have low risk for fertilizer-associated nitrate leaching into the groundwater (Harter et al. 2017). Grain production is rotated with alfalfa production, usually for one year, after which alfalfa is replanted. Grain production also does not pose a significant nitrate-leaching risk. Animal farming, a common source of nitrate pollution in large, confined animal farming operations, is also present in Butte Valley, but not at stocking densities of major concern (Harter et al. 2017). Strawberry production has a potentially high risk for nitrate leaching (Harter et al. 2017) even using advanced irrigation methods due to its shallow rooting depth (Gardenas et al. 2005; Zaragosa et al. 2017). In Butte Valley, strawberry production focuses on plant propagation of daughter plants, which differs in management from berry production. They are regularly grown in a three-year rotation with a grain crop (low nitrate leaching risk) and fallowing (low nitrate leaching risk). With respect to arsenic, a DWR study suggested that the contamination near Dorris stemmed from an unknown historical industrial source (DWR 1968).

3.4.3.2 Maximum Thresholds

MTs for groundwater quality in the Basin were defined using existing groundwater quality data, beneficial uses of groundwater in the basin, existing regulations, including water quality objectives under the Basin Plan, Title 22 Primary Maximum contaminant levels (MCLs), and Secondary MCLs, and consultation with the GSA advisory committee and stakeholders (see Section 2.2.2.3.). Resulting from this process, SMCs were developed for three constituents of concern in the Basin: arsenic, nitrate, and specific conductivity. Although 1,2 Dibromoethane (ethylene dibromide; EDB) and benzene are identified as a potential constituent of concern in Section 2.2.2.3, no SMC is defined for either constituent as current 1,2 Dibromoethane and benzene data are associated with leaking underground storage tanks (LUST) where the source is known and monitoring and remediation are in progress. These sites will be taken into consideration with PMAs undertaken by the GSA, as applicable. Boron does not have an SMC because it is naturally occurring.

The selected MTs for the concentration of each of the three constituents of concern and their associated regulatory thresholds are shown in Table 3.7.

Triggers

The GSA will use concentrations of the identified constituents of concern as triggers for preventive action, in order to proactively avoid the occurrence of undesirable results. Trigger values and associated definitions for specific conductivity are the values and definitions listed in the Basin Plan. The Basin Plan specifies two upper limits for specific conductivity, a 50% upper limit, or 50 percentile value of the monthly means for a calendar year and a 90% upper limit or 90 percentile values for a calendar year. The Title 22 water quality objectives for the remaining analytes are incorporated by reference into the Basin Plan and the triggers provided in Table 3.7 correspond to half and 90% of the Title 22 MCL.

Method for Quantitative Measurement of Maximum Thresholds

Groundwater quality will be measured in representative monitoring wells as discussed in Section 3.3.3. Statistical evaluation of groundwater quality data obtained from available water quality data obtained from the monitoring network will be performed and evaluated using a water quality value using the equation above. The MT for concentration values are shown in Table 3.7. Figure 3.10 shows example "thermometers" for each of the identified constituents of concern in Butte Valley groundwater basin with the associated MT, range of MO, and triggers.

Table 3.7: Constituents of concern and the associated maximum thresholds. Maximum thresholds also include a 15 percent average increase per year over 10 years in no more than 25 percent of wells, and no more than 25 percent of wells exceeding the MT for the concentration listed here.

Constituent	Maximum Threshold	Regulatory Threshold
Arsenic (only wells near Dorris)	5 μg/L, trigger only μg/L, trigger only μg/L, MT	10 μg/L (Title 22)
Nitrate as Nitrogen	5 mg/L, trigger only mg/L, trigger only mg/L, MT	10 mg/L (Title 22)
Specific Conductivity	250 micromhos, trigger only	250 micromhos (Basin Plan Upper Limit – 50% of monthly means in a calendar year must be less or equal to 250 micromhos)
	500 micromhos, trigger only	500 micromhos (Basin Plan Upper Limit - 90% of samples in a calendar year must be less or equal to 500 micromhos)
	900 micromhos, MT	900 micromhos (Title 22)

3.4.3.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MOs for water quality are established to provide an indication of desired water quality at levels that are sufficiently protective of beneficial uses and users. MOs are defined on a well-specific basis, with consideration for historical water quality data.

Description of Measurable Objectives

The groundwater quality MOs for wells within the GSA monitoring network, where the concentrations of constituents of concern historically have been below the MTs for water quality in recent years, is to continue to maintain concentrations at or below the current range, as measured by long-term trends. To establish a quantitative MO that protects uses and users from unreasonable water quality degradation, the GSA has decided to establish a list of constituents of concern (COCs). The MO is defined using those COCs, which include arsenic, nitrate, and specific conductivity.

Specifically, for these COCs, the MO is to maintain groundwater quality at a minimum of 75% of wells monitored for water quality within the range of the water quality levels measured over the past 30 years (1990 to 2020). In addition, no significant increasing long-term trends should be observed in levels of constituents of concern.

3.4.3.4 Path to Achieve Measurable Objectives

The GSA will support the protection of groundwater quality by monitoring groundwater quality conditions and coordinating with other regulatory agencies that work to maintain and improve the groundwater quality in the Basin. All future PMAs implemented by the GSA will comply with State and Federal water quality standards and Basin Plan water quality objectives and will be designed to maintain groundwater quality for all uses and users and avoid causing unreasonable groundwater quality degradation. The GSA will review and analyze groundwater monitoring data as part of GSP implementation in order to evaluate any changes in groundwater quality resulting from groundwater pumping or recharge projects (anthropogenic recharge) in the Basin. The need for additional studies on groundwater quality will be assessed throughout GSP implementation. The GSA may identify knowledge requirements, seek funding, and help to implement additional studies.

Using monitoring data collected as part of project implementation, the GSA will develop information (e.g., time-series plots of water quality constituents) to demonstrate that PMAs are operating to maintain or improve groundwater quality conditions in the Basin and to avoid unreasonable groundwater quality degradation. Should the concentration of a constituent of interest increase to its MO (or a trigger value below that objective specifically designated by the GSA) as the result of GSA project implementation, the GSA will implement measures to address this occurrence. This process is illustrated in Figure 3.11.

If a degraded water quality trigger is exceeded, the GSA will investigate the cause and source and implement MAs as appropriate. Where the cause is known, PMAs with stakeholder education and outreach will be implemented. Examples of possible GSA actions include notification and outreach with impacted stakeholders, alternative placement of groundwater recharge projects, and coordination with the appropriate water quality regulation agency. PMAs are presented in further detail in Chapter 4.

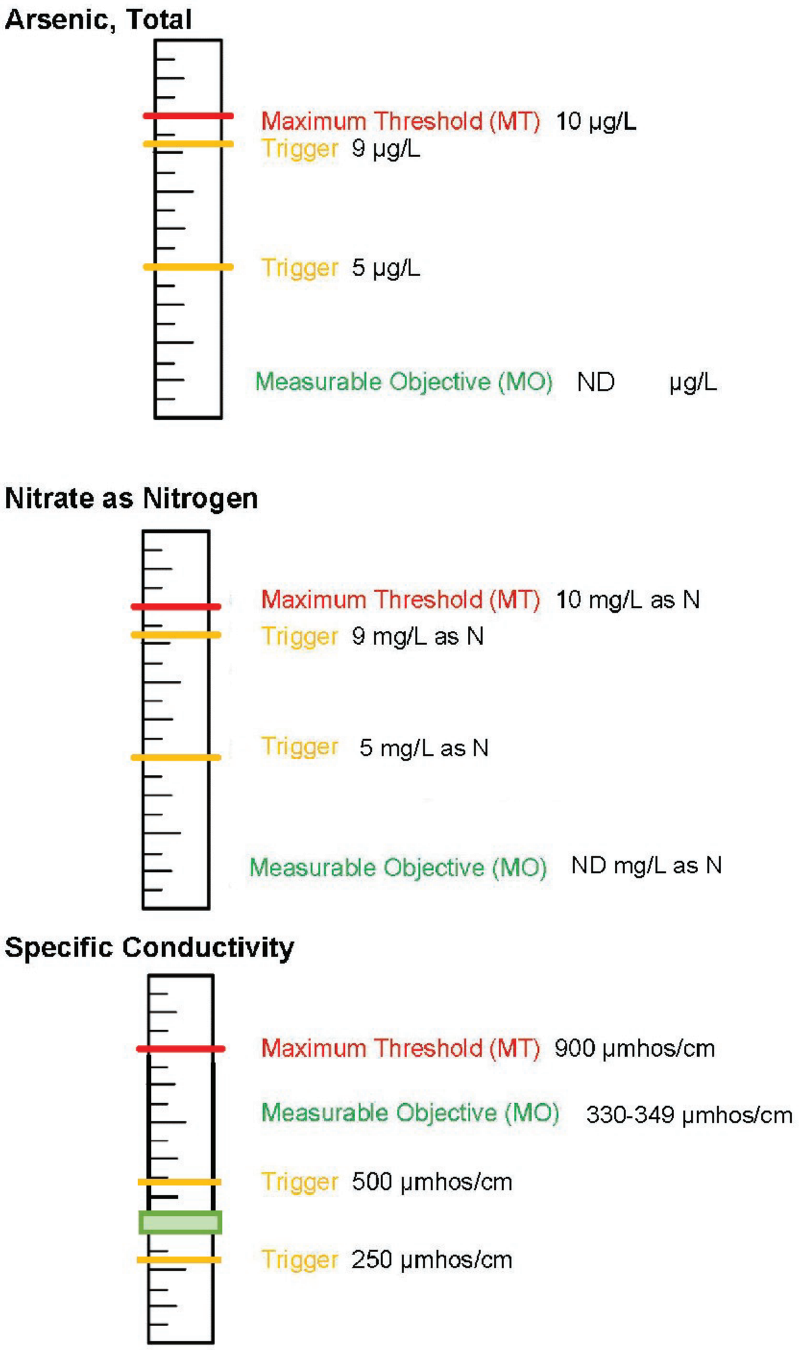


Figure 3.10: Visual Representation of the SMCs of Arsenic, Nitrate, and Specific Conductivity for Well 4710001-003 of the Monitoring Network. MOs are specific to each well in the monitoring network. If the measurable objective is higher than one of the triggers, then that particular trigger is not applicable to that well.

Exceedances of arsenic, nitrate, and specific conductivity will be referred to the NCRWQCB. Where the cause of an exceedance is unknown, the GSA may choose to conduct additional or more frequent monitoring.

Interim Milestones

As existing groundwater quality data indicate that groundwater in the Basin generally meets applicable state and federal water quality standards, the objective is to maintain existing groundwater quality. Interim milestones are therefore set equivalent to the MOs with the goal of maintaining water quality within the historical range of values.

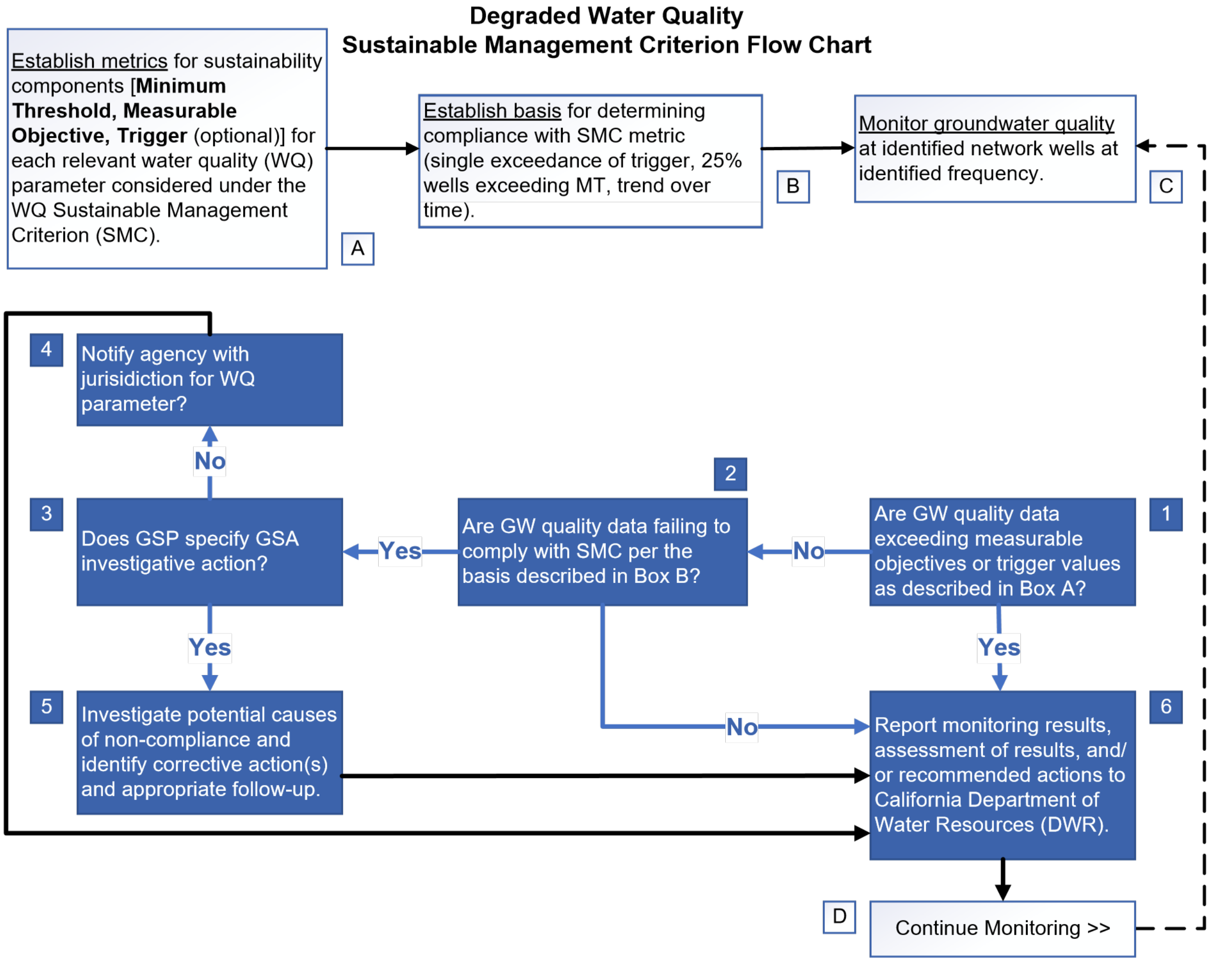


Figure 3.11: Degraded SMC criteria flow chart. The flow chart depicts the high-level decision making that goes into developing SMC, monitoring to determine if criteria are met, and actions to be taken based on monitoring results.

3.4.3.5 Effects on Beneficial Uses and Users

Concerns over potential or actual non-attainment of the beneficial uses designated for groundwater in the Basin are and will continue to be related to certain constituents measured at elevated or increasing concentrations, and the potential local or regional effects that degraded water quality have on such beneficial uses.

The following provides greater detail regarding the potential impact of poor groundwater quality on several major classes of beneficial users:

- **Municipal Drinking Water Users** - Under California law, agencies that provide drinking water are required to routinely sample groundwater from their wells and compare the results to state and federal drinking water standards for individual chemicals. Groundwater quality that does not meet state drinking water standards may render the water unusable or may cause increased costs for treatment. For one municipal supplier in the Basin, shallow impacted wells forced the city to develop a new supply well to access deep unaffected groundwater (Bray & Associates 2015).
- **Rural and/or Agricultural Residential Drinking Water Users** - Residential structures not located within the service areas of the local municipal water agency will typically have private domestic groundwater wells. Such wells may not be monitored routinely and groundwater quality from those wells may be unknown unless the landowner has initiated testing and shared the data with other entities. Degraded water quality in such wells can lead to rural residential use of groundwater that does not meet potable water standards and results in the need for installation of new or modified domestic wells and/or well-head treatment that will provide groundwater of acceptable quality.
- **Agricultural Users** - Irrigation water quality is an important factor in crop production and has a variable impact on agriculture due to different crop sensitivities. Impacts from poor water quality may include declines in crop yields, crop damage, or alter which crops can be grown in the area.
- **Environmental Uses** - Poor quality groundwater may result in migration of contaminants which could impact GDEs or instream environments, and their resident species, to which groundwater contributes.

3.4.3.6 Relationship to Other Sustainability Indicators

Groundwater quality cannot typically be used to predict responses of other sustainability indicators. However, groundwater quality may be affected by groundwater levels and reductions in groundwater storage. In addition, certain implementation actions may be limited by the need to achieve MTs for other sustainability indicators.

- **Groundwater Levels** - Declining water levels can potentially lead to increased concentrations of constituents of concern in groundwater and may alter the existing hydraulic gradient and result in movement of contaminated groundwater. Changes in water levels may also mobilize contaminants that may be present in unsaturated soils. The MTs established for groundwater quality may influence groundwater level MTs by affecting the location or number of projects, such as groundwater recharge, in order to avoid degradation of groundwater quality.
- **Groundwater Storage** - The groundwater quality MTs will not cause groundwater pumping to exceed the sustainability yield and therefore will not cause exceedances of the groundwater storage MTs.
- **Depletion of Interconnected Surface Waters** - The groundwater quality MT does not promote additional pumping or lower groundwater levels near interconnected surface waters. The groundwater quality MT does not negatively affect ISWs.
- **Seawater Intrusion** - This sustainability indicator is not applicable in this Basin.
- **Subsidence** - The groundwater quality MT does not promote additional pumping or lower groundwater levels and therefore does not interfere with the subsidence MT.

3.4.3.7 Information and Methodology Used to Establish Maximum Thresholds and Measurable Objectives

The constituents for which SMC were considered were specifically selected due to measured exceedances in the past 30 years, known groundwater contamination at LUST sites, and/or stakeholder input and prevalence as a groundwater contaminant in California. A detailed discussion of the concerns associated with elevated levels of each constituent of interest is described in Section 2.2.2.3. As the constituents of concern were identified using current and historical groundwater quality data, this list may be reevaluated during future GSP updates. In establishing MT for groundwater quality, the following information was considered:

- Feedback about water quality concerns from stakeholders.
- An assessment of available historical and current groundwater quality data from production and monitoring wells in the Basin.
- An assessment of historical compliance with Federal and state drinking water quality standards and water quality objectives.
- An assessment of trends in groundwater quality at selected wells with adequate data to perform the assessment.
- Information regarding sources, control options and regulatory jurisdiction pertaining to constituents of concern.
- Input from stakeholders resulting from the consideration of the above information in the form of recommendations regarding MTs and associated MAs.

The historical and current groundwater quality data used in the effort to establish groundwater quality MTs are discussed in Section 2.2.2.3. Based on a review of these data, applicable water quality regulations, Basin water quality needs, and information from stakeholders, the GSA reached a determination that the state drinking water standards (MCLs and water quality objectives [WQOs]) are appropriate to define MTs for groundwater quality. These MTs are summarized in Table 3.6. The established MTs for groundwater quality protect and maintain groundwater quality for existing or potential beneficial uses and users. For most analytes, the MTs align with the state standards listed in Title 22 of the California Code of Regulations (CCR), which lists the state regulations for drinking water.

New constituents of concern may be added with changing conditions and as new information becomes available.

3.4.4 Subsidence

3.4.4.1 Undesirable Results

An undesirable result occurs when subsidence substantially interferes with beneficial uses of groundwater and land uses. Subsidence occurs as a result of compaction of fine-grained aquifer materials (i.e., clay) due to the chronic lowering of water levels. The fine-grained sediment in the lake deposits may have some land subsidence risk when groundwater levels drop. Undesirable results would occur when substantial interference with land use occurs, including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, including flooding agricultural practices. As there has not been any historical documentation of subsidence in the Basin, it is reasonable to declare that measurable land subsidence caused by the chronic lowering of groundwater levels occurring in the Basin would be considered an unreasonable result. This is quantified as pumping induced subsidence greater than the minimum threshold of 0.1 feet (0.03 meters) in any single year, essentially zero subsidence accounting for measurement error.

3.4.4.2 Minimum Thresholds

The MT for land subsidence in the Basin is set at no more than 0.1 feet (0.03 meters) in any single year, resulting in no long-term permanent subsidence. This is set at the same magnitude of estimated error in the InSAR data (+/- 0.1 feet [0.03 meters]), which is currently the only tool available for measuring basin-wide land subsidence consistently each year in the Basin.

The MTs selected for land subsidence for the Basin area were selected as a preventative measure to ensure the maintenance of current ground surface elevations and as an added safety measure for potential future impacts not currently present in the Basin and nearby groundwater Basins. This avoids significant and unreasonable rates of land subsidence in the Basin, which are those that would lead to a permanent subsidence of land surface elevations that would impact infrastructure and agricultural production in Butte Valley and neighboring groundwater Basins. There are currently no other state, federal, or local standards that relate to this sustainability indicator in the Basin.

3.4.4.3 Measurable Objectives

MOs are defined under SGMA as described above in Section 3.1. Within the Basin, the MO for subsidence is established to protect beneficial uses and users. The guiding MO of this GSP for land subsidence in the Basin is the maintenance of current ground surface elevations. This MO avoids significant and unreasonable rates of land subsidence in the Basin, which are those that lead to a permanent subsidence of land surface elevations that impact infrastructure and agricultural production.

The lake sediments in Butte Valley offer some land subsidence risk; however, there is no historical record of subsidence in the Basin (see Section 2.2.2.5). Recent InSAR data show no significant subsidence occurring during the period of mid-June 2015 to mid-September 2019 (see Figure 2.25 in Chapter 2).

Land subsidence in the Basin is expected to be managed through the implementation period via the sustainable management of groundwater pumping through the groundwater level MO, MT, and interim milestones. The margin of safety for the subsidence MO was established by setting a MO to maintain current land surface elevations and opting to monitor subsidence throughout the GSP implementation period. This is a reasonable margin of safety based on the past and current aquifer conditions (see Section 2.2.2.5).

3.4.4.4 Path to Achieve Measurable Objectives

Land subsidence in the Basin will be quantitatively measured by use of InSAR data (DWR-funded TRE ALTAMIRA or other similar data products). If there are areas of concern for inelastic subsidence in the Basin (i.e., exceedance of MTs) observed in the InSAR data, then ground-truthing studies could be conducted to determine if the signal is potentially related to changes in land use or agricultural practices, or from groundwater extraction. If subsidence is determined to result from groundwater extraction, then ground-based elevation surveys might be needed to monitor the situation more closely. At each interim milestone, subsidence data will be reviewed for yearly and five-year subsidence rates to assess continued compliance with the MT.

3.4.4.5 Effects of Undesirable Results on Beneficial Uses and Users

Subsidence can result in substantial interference with land use including significant damage to critical infrastructure such as canals, pipes, or other water conveyance facilities, as well as breaking of building foundations and tilting of structures. Other effects include flooding of land, including residential and commercial properties, and negative impacts on agricultural operations.

Subsidence is closely linked with declining groundwater levels: a decline in groundwater levels can trigger land subsidence.

3.4.4.6 Relationship to Other Sustainability Indicators

Managing groundwater pumping and avoiding the undesirable result of chronic lowering of groundwater levels will reduce the risk of land subsidence. Additionally, land subsidence directly causes a reduction in groundwater storage.

3.4.5 Depletion of Interconnected Surface Waters

3.4.5.1 Background

The sustainable management criteria for the depletion of interconnected surface waters (ISW) sustainability indicator was set based on groundwater levels. As detailed in the data gap discussion in Section 3.3, there are data gaps associated with ISWs and GDEs in the Basin. Groundwater level and surface flow monitoring stations have been added in the effort to resolve this data gap but this work is ongoing. Surface water features in the Basin identified as interconnected include Meiss Lake, and the five creeks: Butte, Prather, Ikes, Harris, and Muskgrave (see Section 2.2.8 in Chapter 2). The interconnection between these surface water features and groundwater is not well understood, and a field study and advanced desktop analysis is planned for 2024-2025 (see data gap discussion under Section 3.3).

3.4.5.2 Groundwater Elevations as a Proxy for Depletion of Interconnected Surface Water Undesirable Results, Minimum Thresholds, and Measurable Objectives

Depletion of interconnected surface waters is measured by the volume or rate of surface water depletion due to groundwater pumping. Due to the difficulty in quantifying this metric, as well as the general lack of knowledge around the factors that influence depletion of surface water flow in the Basin, the groundwater level sustainable management criteria are used as a proxy for depletion of interconnected surface water sustainable management criteria. This is considered the best available metric for this sustainability indicator while work is underway to verify and assess interconnected surface waters in the Basin. While the direct correlation between groundwater levels and interconnected surface waters in the Basin is currently not well understood, both groundwater level monitoring locations and flow stations have already been added to better understand this correlation in the Basin. Achieving the sustainable yield of the basin early in the 2027-2032 GSP implementation period requires groundwater pumping to be reduced to average groundwater pumping during the baseline period of 1990-2014. This is anticipated to terminate chronic lowering of water levels and, due to the reduced pumping, may address some or all of any potential additional depletion of ISWs (above baseline conditions) that may have occurred due to higher groundwater pumping since 2015.

Generally, significant and unreasonable depletion of surface water due to groundwater extraction, in ISWs that support GDEs in the Basin, is considered an undesirable result. In practice, this is currently defined to occur with the occurrence of undesirable results for the groundwater level sustainability indicator and is quantitively defined in the same way. If a significant and unreasonable decline in groundwater elevations is avoided, this should prevent significant and unreasonable surface water depletion, under current understanding of correlation between groundwater levels and surface water depletion. Similarly, measurable objectives and minimum thresholds for the ISW indicator rely on sustainable management criteria set for the groundwater level sustainability indicator.

3.4.5.3 Path to Achieve Measurable Objectives

See discussion for the groundwater level sustainability indicator under Section 3.4.1.4.

3.4.5.4 Effects of Undesirable Results on Beneficial Uses and Users

Undesirable results for the depletion of ISWs will primarily impact flow into Meiss Lake and GDEs. This may reduce viable GDE habitat area, quality of the habitat and may impact GDE health. This may occur through a reduction in the quantity of water available for GDEs, and subsequent reductions in flow rates, and/or reduction in the quality of available water due to potential increases in temperature, and decreases in dissolved oxygen content. Other beneficial uses and users that may be impacted may include a reduction in the scenic or recreational uses of these surface water bodies.

3.4.5.6 Relationship to Other Sustainability Indicators

Managing groundwater pumping and avoiding the undesirable result of chronic lowering of groundwater levels will reduce the risk of interconnected surface water depletion.

Chapter 4

PROJECT AND MANAGEMENT ACTION

4.1 INTRODUCTION AND OVERVIEW

To achieve this Plan's sustainability goal by 2042 and avoid undesirable results as required by Sustainable Groundwater Management Act (SGMA) regulations, multiple projects and management actions (PMAs) have been developed for implementation by the groundwater sustainability agency (GSA). This section provides a description of PMAs necessary to achieve and maintain the Butte Valley groundwater basin (Basin) sustainability goal and to respond to changing conditions in the Basin. This chapter has been updated as part of the revisions to the Butte Valley GSP, made to address deficiencies in the determination issued by the Department of Water Resources (DWR) on the Butte Valley Groundwater Sustainability Plan (GSP), issued by DWR on January 18, 2024.

PMAs are described in accordance with §354.42 and §354.44 of the SGMA regulations. Projects generally refer to infrastructure features and other capital investments, their planning, and their implementation, whereas management actions are typically programs or policies that do not require capital investments, but are geared toward engagement, education, outreach, changing groundwater use behavior, adoption of land use practices, etc. PMAs discussed in this section will help achieve and maintain the sustainability goal and measurable objectives (MO), and avoid the undesirable results identified for the Basin in Chapter 3. These efforts will be periodically assessed during the implementation period, at minimum every five years (see Chapter 5).

In developing PMAs, priorities for consideration include effectiveness toward maintaining the sustainability of the Basin, minimizing impacts to the Basin's economy, seeking cost-effective solutions for external funding and prioritizing voluntary and incentive-based programs over mandatory programs. As the planned or proposed PMAs are at varying stages of development, complete information on construction requirements, operations, permitting requirements, overall costs, and other details are not uniformly available.

A description of the operation of PMAs as part of the overall GSP implementation is provided in Chapter 5. After GSP adoption, the GSA will prioritize certain PMAs for feasibility reviews and preliminary engineering studies. Based on review and study results, PMAs may move forward to implementation.

In Butte Valley, the PMAs are designed to achieve three major objectives:

- To prevent chronic lowering of groundwater levels.
- To protect wells from outages.
- To protect beneficial users of groundwater.

The identified PMAs reflect a range of options to achieve the goals of the GSP and will be completed through an integrative and collaborative approach with other agencies, landowners, beneficial users, and stakeholders. Few PMAs will be implemented by the GSA alone. The GSA considers itself to be one of multiple parties collaborating to achieve overlapping, complementary, and multi-benefit goals across the integrated water and land use management nexus in the Basin. Furthermore, PMAs related to water quality will be most successful if implemented to meet the multiple objectives of collaborating partners. For many of the PMAs, the GSA will enter into informal or formal partnerships with other agencies, non-governmental organizations (NGOs), or individuals. These partnerships may take various forms, from GSA participation in informal technical or information exchange meetings, to collaborating on third-party proposals, projects, and management actions, to leading proposals and subsequently implementing PMAs.

The GSA and individual GSA partners will have varying but clearly identified responsibilities with respect to permitting and other specific implementation oversight. These responsibilities may vary from PMA to PMA or even within individual phases of a PMA. Inclusion in this GSP does not forego any obligations under local, state, or federal regulatory programs. Inclusion in this GSP also does not assume any specific project governance or role for the GSA. While the GSA does have an obligation to oversee progress towards groundwater sustainability, it is not the primary regulator of land use, water quality, or environmental project compliance. It is the responsibility of the implementing partner agency to collaborate with appropriate regulatory agencies to ensure that the PMAs for which the lead agency is responsible are in compliance with all applicable laws. The GSA may choose to collaborate with regulatory agencies on specific overlapping interests such as water quality monitoring and oversight of projects developed within the Basin.

PMAs are classified under four categories: demand management for groundwater, supply augmentation, habitat improvement, and groundwater recharge. Demand management projects reduce the demand for groundwater and can include projects such as irrigation efficiency improvements. Surface water supply augmentation projects contribute to increases in surface water in the Basin. Habitat improvement projects can include restoration and upland management projects and groundwater recharge projects. Examples of project types within these three categories are shown in Table 4.1. Three tiers are used to separate PMAs by timeline for implementation. Note that the tiered system is **not necessarily indicative of priority for implementation**. Additionally, PMAs are not organized within tiers in priority order. Please refer to the "circumstances for implementation" part of each PMA description, or the "status" and "anticipated timeframe" columns of **Table 4.1** for more information on implementation timelines of individual PMAs. The three tiers used to categorize PMAs are:

1. **TIER I**: **PMAs that were already being implemented at the time of GSP submittal and are anticipated to continue to be implemented.**
2. **TIER II**: **PMAs with initiation and early implementation planned in 2022 through 2027 by individual member agencies.**
3. **TIER III**: **Additional PMAs that may be implemented in the future, as necessary (initiation and/or implementation in the 2027 to 2042 time period).**

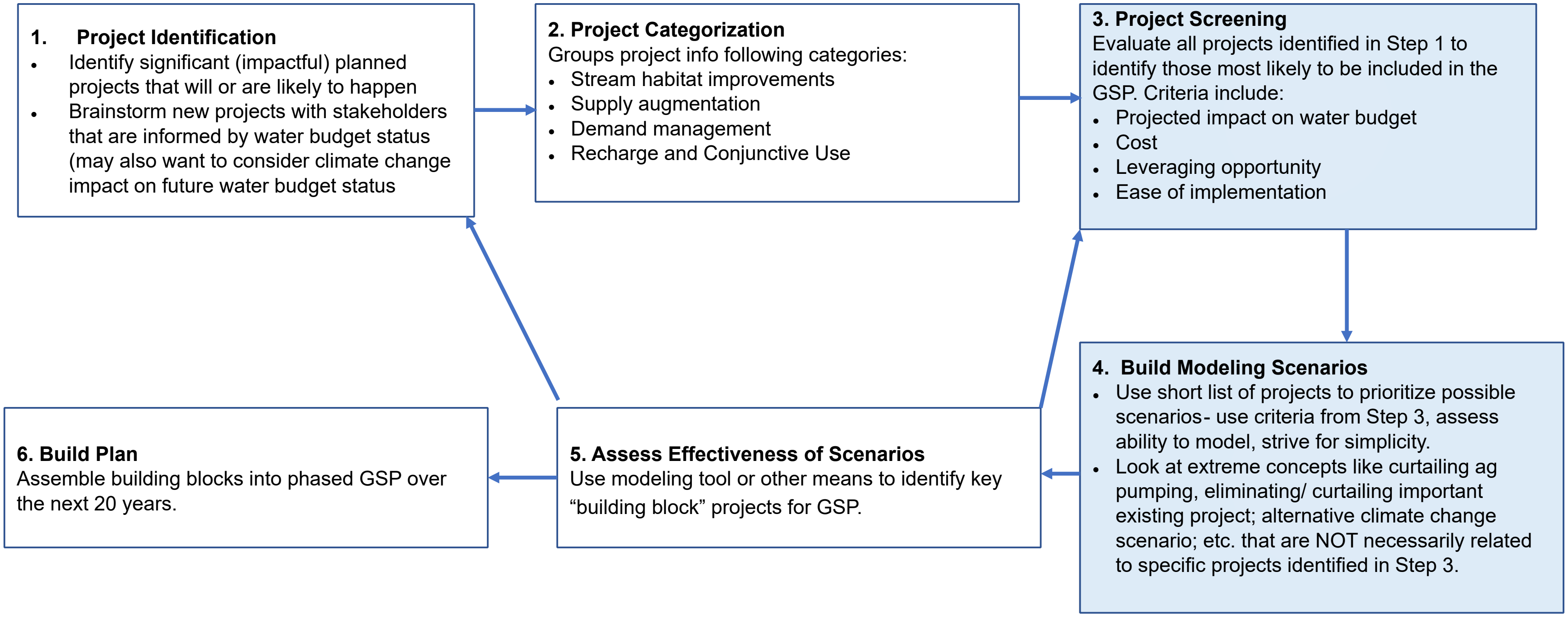
A general description of existing and ongoing (Tier I) PMAs is provided in Section 4.2, Tier II PMAs in Section 4.3, and Tier III PMAs in Section 4.4. The process of identifying, screening, and finalizing PMAs is illustrated in Figure 4.1. Existing and planned projects were first identified from different through review of reports, documents, and websites. Planned and new projects also received stakeholder input in their identification. These projects were then categorized into the three categories: supply augmentation, demand management, stream habitat improvement, and groundwater recharge. In the next step, all projects were evaluated to identify those with the highest potential to be included in the GSP. Using the Butte Valley Integrated Hydrogeological Model (BVIHM), the effectiveness of each project, or a combination of projects, will be assessed to identify those projects that, if implemented, will bring the Basin into sustainability. Monitoring will be a critical component in evaluating PMA benefits and measuring potential impacts from PMAs. More details on how projects will be evaluated and a road map to discuss feasibility and potential for success of each project (or a combination of projects) is presented in Chapter 5.

Funding is an important part of successfully implementing a PMA. The ability to secure funding is an important component in the viability of implementing a particular PMA. Funding sources may include grants or other fee structures (Appendix 5-C). Under the Sustainable Groundwater Management Implementation Grant Program Proposition 68, grants can be awarded for planning activities and for projects with a capital improvement component. As such, funds for reimbursing landowners for implementation of PMAs, including land fallowing and well-shut offs, currently cannot be obtained under this program. Funding will also be sought from other local, state, federal, and private (NGO) sources.

The existing PMAs have been extracted from the following documents:

- Supply Enhancement (in Streams)
    - Butte Valley Wildlife Area (BVWA) / California Department of Fish and Wildlife (CDFW)

  - United States Forest Service (USFS) website
- Demand Management (of Groundwater)
  - City of Dorris
  - County of Siskiyou General Plan
  - Siskiyou County Code of Ordinances
  - Permit required for groundwater extraction for use outside the basin from which it was extracted (Title 3, Chapter 13 - Groundwater Management, Siskiyou County Code of Ordinances)
  - Siskiyou County Groundwater Use Ordinance (Title 3, Chapter 13, Article 7 - Waste and
  - Unreasonable Use, Siskiyou County Code of Ordinances)
  - Well Drilling Permits
    - Siskiyou County Well Drilling Permits (Standards for Wells, Title 5, Chapter 8 of Siskiyou County Code of Ordinances)
- Recharge
  - Existing reports, proposals



1. Project Identification
- Identify significant (impactful) planned projects that will or are likely to happen
- Brainstorm new projects with stakeholders that are informed by water budget status (may also want to consider climate change impact on future water budget status

2. Project Categorization
Groups project info following categories:
- Stream habitat improvements
- Supply augmentation
- Demand management
- Recharge and Conjunctive Use

3. Project Screening
Evaluate all projects identified in Step 1 to identify those most likely to be included in the GSP. Criteria include:
- Projected impact on water budget
- Cost
- Leveraging opportunity
- Ease of implementation

4. Build Modeling Scenarios
- Use short list of projects to prioritize possible scenarios- use criteria from Step 3, assess ability to model, strive for simplicity.
- Look at extreme concepts like curtailing ag pumping, eliminating/ curtailing important existing project; alternative climate change scenario; etc. that are NOT necessarily related to specific projects identified in Step 3.

5. Assess Effectiveness of Scenarios
Use modeling tool or other means to identify key “building block” projects for GSP.

6. Build Plan
Assemble building blocks into phased GSP over the next 20 years.

Figure 4.1: Process for identification and prioritization of PMAs. Further details, such as authority and finalized prioritization, are shown in Chapter 5.

Table 4.1: Projects and Management Actions Summary.

Tier	Title	Description	Lead Agency	Category	Status	Anticipated Timeframe	Targeted Sustainability Indicator(s) / Benefits
Tier I PMAs							
I	Well Drilling Permits	Siskiyou County Well Drilling Permits (Standards for Wells, Title 5, Chapter 8 of Siskiyou County Code of Ordinances).	County of Siskiyou	Demand Management	Existing/ Ongoing	Active	Groundwater levels, Interconnected surface water.
I	Groundwater Use Restrictions	Prohibition of the use of groundwater underlying Siskiyou County for cannabis cultivation (Article 7, Chapter 13, Title 3 of Siskiyou County Code of Ordinances).	County of Siskiyou	Demand Management	Existing/ Ongoing	N/A	Groundwater levels
I	Permit required for groundwater extraction for use outside the basin from which it was extracted (Siskiyou County Code of Ordinances)	Permit requirement for extraction of groundwater underlying the Basin for use outside the Basin.	County of Siskiyou	Demand Management	Existing/ Ongoing	Active	Groundwater levels
I	Abandonment of Sam's Neck Flood Control Facility	Expand the wetlands in the Butte Valley Wildlife Area to store all Meiss Lake floodwater and eliminate the need for the Sam's Neck Flood Control Facility.	CDFW	Supply Enhancement	Completed	Completed	Groundwater levels
I	City of Dorris Water Conservation	Water conservation measures outlined in the City of Dorris Municipal Code	City of Dorris	Demand Management	Active	Active	Groundwater levels

Tier	Title	Description	Lead Agency	Category	Status	Anticipated Timeframe	Targeted Sustainability Indicator(s) / Benefits
I	Groundwater Use Restrictions	Prohibition of the use of groundwater underlying Siskiyou County for cannabis cultivation (Article 7, Chapter 13, Title 3 of Siskiyou County Code of Ordinances).	County of Siskiyou	Demand Management	Existing/ Ongoing	N/A	Groundwater levels
I	Kegg Meadow Enhancement and Butte Creek Channel Restoration	Restoration of a properly functioning, resilient wetland ecosystem and aquatic habitat in Kegg Meadow by returning streamflow to the original meadow/channel elevations. Reverting stream to original channel will rewet overall meadow and restore riparian habitat. The site is 1 to 2 acres in size.	USFS	Supply Enhancement	Completed	Completed	Habitat restoration Groundwater recharge
I	Permit required for groundwater extraction for use outside the basin from which it was extracted (Siskiyou County Code of Ordinances)	Permit requirement for extraction of groundwater underlying the Basin for use outside the Basin.	County of Siskiyou	Demand Management	Active	Active	Groundwater levels
I	Upland Management	Upland management includes removal of excess vegetation. This can occur on US Forest Service, Bureau of Land Management, or private land.	USFS	Supply Enhancement	Active	Active	1. Improved groundwater recharge

Tier	Title	Description	Lead Agency	Category	Status	Anticipated Timeframe	Targeted Sustainability Indicator(s) / Benefits
							2. Raise groundwater elevations 3. Improved habitat
I	Watermaster Butte Creek Flow Management	A Watermaster manages flow of Butte Creek into Butte Valley.	GSA/ USFS	Supply Enhancement	Active	Active	1. Groundwater Recharge Flood control
Tier II PMAs							
II	Well inventory and Mitigation Program	Development and implementation of a program to address well outage issues due to groundwater level declines for domestic well owners.	GSA	Supply Enhancement	Active	Active	GSA Implementation
II	Preliminary Groundwater Allocation Program	Development of a draft program for groundwater allocation as a potential management action.	GSA	Demand Management	Active	Conceptual phase	Groundwater Levels, groundwater storage
II	City of Dorris Well Deepening and Pipeline Replacement Project	Replace or repair water distribution system, City well and up to 4 Butte Valley wells.	GSA	Supply Enhancement	Active	Active	GSA implementation
II	Avoiding Increase of Total Net Groundwater	Avoid significant future expansion of total net consumptive water use within the Basin and its surrounding	GSA, County of	Demand Management	Planning Phase	No later than January 31, 2024	Groundwater levels

Tier	Title	Description	Lead Agency	Category	Status	Anticipated Timeframe	Targeted Sustainability Indicator(s) / Benefits
	Use Above Sustainable Yield	watershed through planning and coordination	Siskiyou, local land use zoning agencies				
II	Dorris Water Meter Installation Project	The City of Dorris is upgrading their water system by installing water meters and replacing old pipelines.	City of Dorris	Demand Management	Invitation for Bids sent out Feb 2021. Contractor proposals due March 18, 2021	Planning Phase	Groundwater levels
II	Irrigation Efficiency Improvements	Increase irrigation efficiency (and in some cases, yields) through infrastructure or equipment improvements. This PMA will focus on low efficiency practices. Exceptions may include landowners that have already implemented irrigation efficiency improvements and best management practices.	GSA	Demand Management	Planning Phase	Planning Phase	Groundwater levels
II	Public Outreach	Public outreach and education for GSA stakeholders.	GSA	GSA Implementation	Planning Phase	Implementation	GSA Implementation
II	Voluntary Managed Land Repurposing	Reduce water use through other voluntary managed land repurposing activities including term contracts, crop rotation, irrigated margin reduction,	GSA, TBD	Demand Management	Conceptual Phase	Conceptual phase	Groundwater levels

Tier	Title	Description	Lead Agency	Category	Status	Anticipated Timeframe	Targeted Sustainability Indicator(s) / Benefits
		conservation easements, and other uses					
Tier III PMAs							
III	Alternative, lower ET crops	Pilot programs on introducing alternative crops with lower ET but sufficient economic value. Incentivize and provide extension on long-term shift to lower ET crops.	GSA, UCCE, TBD	Demand Management	Conceptual Phase	Conceptual Phase	Groundwater levels
III	Butte Creek Diversion Relocation	Move the diversion of Butte Creek to Cedar Lake/Dry Lake	GSA/ USFS	Supply Enhancement	Conceptual Phase	Conceptual Phase	Groundwater levels
III	Butte Valley National Grassland Groundwater Recharge Project	Explore recharge benefits in National Grasslands from Meiss Lake overflow.	GSA/ USFS	Recharge	Conceptual Phase	Conceptual Phase	Groundwater levels
III	Strategic Groundwater Pumping Restriction	Strategic timing of groundwater pumping curtailments. This management action would only be developed if Tier I and Tier II PMAs are insufficient. It would be an alternative for the GSA in support of the groundwater level SMC.	GSA	Demand Management	Conceptual Phase	Conceptual Phase	Groundwater levels

4.2 TIER I: EXISTING OR ONGOING PROJECTS AND MANAGEMENT ACTIONS

As shown in Table 4.1 there are multiple existing and ongoing PMAs in the Basin (Tier I). The Basin has a range of existing PMAs in place to provide demand management, mitigation of outages for shallow wells, and supply augmentation.

Abandonment of Sam's Neck Flood Control Facility

Historically the Sam's Neck Flood Control Facility has pumped flood waters of Meiss Lake to the Klamath River. The long-term goal of the Butte Valley Wildlife Area (BVWA) and County is to eliminate the need for the Sam's Neck pumping project and instead use the flood waters to create and maintain wetland habitat. BVWA had a memorandum of understanding with Siskiyou County to utilize as much creek and lake water as possible for wetlands to minimize pumping to the Klamath River. In 2017, the County sent a formal request to the United States Army Corps of Engineers to abandon the Sam's Neck Flood Control Facility (Kit Novick 1996; County of Siskiyou 2017).

Benefits of this project include:

- Meiss Lake flood waters are kept within the Basin for groundwater recharge instead of being pumped to the Klamath River.
- Increased habitat for wildlife.
- New flood control mechanism for Butte Valley.

City of Dorris Water Conservation

The City of Dorris Municipal Code (Title 13, Chapter 5) outlines water conservation regulations. The City's Public Works Director (Director) determines the extent of conservation required based on the projected supply and demand of customers. Through a public announcement and notice, the Director orders the implementation or termination of water conservation stages. These stages range from "voluntary compliance" to "mandatory compliance – water emergency" and restricts activities such as lawn watering, landscape irrigation, mobile washing (cars, boats, airplanes), non-emergency fire hydrant use, pavement washing, serving water in restaurants, and ornamental fountains. More severe stages restrict new permits for unmetered water service, limited water for construction, no water for air conditioning purposes, and water for commercial, manufacturing, and processing purposes cut 50% by volume.

Well Drilling Permits and County of Siskiyou Groundwater Use Restrictions

There are several existing regulations that are included in the demand management category of PMAs. These include the permitting requirements for new wells, as detailed in Title 5, Chapter 8 of the Siskiyou County Code of Ordinances. Siskiyou County also has ordinances that require permitting for extraction of groundwater underlying the Basin for use outside the Basin (per Title 3, Chapter 13) and a prohibition on wasting groundwater with underlying Siskiyou County for use cannabis cultivation (Article 7, Chapter 13, Title 3 of Siskiyou County Code of Ordinances). Providing demand management, this management action (MA) benefits sustainability multiple indicators, including declining groundwater levels, groundwater storage, and depletion of interconnected surface waters (ISWs). To comply with the recent Executive Orders N-7-22[1] and N-3-23[2] regarding drilling of new wells, the County and the GSA developed new guidelines that were approved by the Board of Supervisors at the May 21, 2024 meeting.[3] Specifically for

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[1] Executive Order N-7-22: https://www.gov.ca.gov/wp-content/uploads/2022/03/March-2022-Drought-EO.pdf 2

[2] Executive Order N-3-23: https://www.gov.ca.gov/wp-content/uploads/2023/02/Feb-13-2023-Executive-Order.pdf?emrc=b12708

[3] https://bosagenda.co.siskiyou.ca.us/467860/467869/480054/Documents.htm

Butte Valley, a preliminary tool has been developed to simulate the impact of potential new wells on existing wells. This tool will be used by the County to define preliminary criteria to be used in the process of approval/denial of new wells.

Kegg Meadow Enhancement and Butte Creek Channel Restoration

This project is an example of wetland reconstruction and groundwater recharge using Butte Creek surface waters. The location of the project is outside the Basin along Butte Creek between Mt Hebron and Orr Mountain. The project returns streamflow to the original Butte Creek channel to rewet Kegg Meadow, restore riparian habitat, and locally raise groundwater levels. Kegg Meadow was damaged by channel diversion of Butte Creek to new stream channels in the 1930s. Construction returned streamflow to 2,000 feet of historical channel and 1,400 of prior channel was abandoned and converted into a permanent wetland feature. Willow cuttings were planted along the rewetted historic channel to increase habitat and utilize the raised groundwater levels. Construction was completed in 2013 (Bell and Harrington 2011; NCRWQCB 2013).

Permit required for groundwater extraction for use outside the basin from which it was extracted (Siskiyou County Code of Ordinances)

Permit requirement for extraction of groundwater underlying the Basin for use outside the Basin (Article 1, Chapter 13, Title 3 of Siskiyou County Code of Ordinances):[12]

It is unlawful for any person, firm, corporation, or governmental agency (except an agency of the United States, to the extent, if any, that federal law preempts this chapter) to extract groundwater by any artificial means from any of the groundwater basins underlying the County, directly or indirectly, for use outside the basin from which it was extracted, without first obtaining a written permit as provided in this chapter.

Upland Management

Upland management includes removal of excess vegetation, to reduce evapotranspiration and increase rainfall percolation to groundwater. This can occur on USFS, Bureau of Land Management (BLM), or private land.

The USFS regularly manages sections of USFS land and current active projects within the Butte Valley watershed (Watershed) includes the Harlan Project, through the Klamath National Forest Goosenest Ranger District (USFS 2021). The project will complete vegetation management and fuel reduction with an emphasis on improving forest resilience to wildfire, insects and disease, while improving mule deer habitat. The project will treat 21,000 acres in an area five miles northwest of Tennant. Implementation of the Harlan Project was given permission to proceed on Feb 9, 2021.

Watermaster Butte Creek Flow Management

A watermaster manages flow of Butte Creek into Butte Valley and the Butte Creek diversion of flood waters to Cedar Lake / Dry Lake, a bedrock fracture that recharges the Butte Valley Basalt aquifer (County of Siskiyou 1996). The diversion of Butte Creek restricts stream flow to less than 25 cubic feet per second (cfs), with excess water diverted to a Cedar Lake / Dry Lake. Streamflow of Butte Creek is a data gap so the frequency of diversion use is unknown. Two flood events have occurred recently that exceeded several hundred cfs (Todd Sloat Biological Consulting 2012). After diverted Butte Creek water is recharged into groundwater at Cedar Lake/Dry Lake, the direction of this groundwater recharge is unknown and a data

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[1] https://library.municode.com/ca/siskiyou_county/codes/code_of_ordinances

gap (ie., Butte Valley or Red Rock groundwater basins). See section “Tier III - Butte Creek Diversion Relocation” for more information on the Butte Creek diversion.

4.3 TIER II: NEAR-TERM PROJECTS AND MANAGEMENT ACTIONS (2022-2027)

Tier II PMAs, with near-term initiation and implementation (2022 to 2027) by individual agencies, exist at varying stages in their development. Project descriptions are provided below for each of the identified Tier II PMAs. The level of detail provided for the eight PMAs described below depends on the status of the PMA; where possible the project descriptions include information relevant to §354.42 and §354.44 of the SGMA regulations:

1. Well Inventory and Mitigation Program
2. Preliminary Groundwater Allocation Program
3. Groundwater Demand Management
4. City of Dorris Well Deepening and Pipeline Replacement Project
5. High Priority PMAs - Data Gaps and Data Collection
    a. Butte Valley Integrated Hydrologic Model (BVIHM) Update (High Priority)
    b. Drought Year Analysis (High Priority)
    c. Expand Monitoring Networks (High Priority)
    d. General Data Gaps (High Priority)
    e. Groundwater Dependent Ecosystem Data Gaps (High Priority) • Interconnected Surface Water Data Gaps (High Priority)
6. Avoiding Increase of Total Net Groundwater Use Above Sustainable Yield
7. Management of Groundwater Use and Recharge iv. Conservation Easements
8. Dorris Water Meter Installation Project
9. Irrigation Efficiency Improvements
10. Public Outreach
11. Voluntary Managed Land Repurposing (not including Conservation Easements)

Well Inventory and Mitigation Program

Project Description

A detailed well inventory will be developed to improve the understanding of the Basin conditions and to improve model performance. An improved inventory of domestic wells and other drinking water wells will assist the GSA in protecting beneficial users in times of drought and other critical times. It will also help solve ongoing issues with the identification of *de-minimus* users and their proper inclusion in BVIHM.

A Well Mitigation Program (Program) will be developed and implemented concurrently with the well inventory. This program is intended to gain information on well issues effecting domestic well owners due to groundwater level declines since 2015. This Program includes both an expansion in groundwater level monitoring, specifically to support domestic well-owners, as well as development and implementation of measures to mitigate the identified well issues.

The GSA recognizes the importance of protecting the interests of all beneficial uses and users of groundwater, including domestic well-owners and especially those in Disadvantaged Communities (DACs). To support this effort, the GSA is in the process of developing a Domestic Well Advisory Group (DWAG) to include diverse domestic well owner perspectives and input to guide development of the Well Mitigation Program. The DWAG will provide important input to the GSA to aid in the development of the well inventory and mitigation program. Additionally, the DWAG will assist with community outreach and support implementation of both expanded groundwater level monitoring and implementation of the well mitigation program, to best support domestic well-owners.

Circumstances for Implementation

The Program will address well issues caused by groundwater level declines from 2015 and resulting from groundwater management on a basin-wide scale. Eligibility for support under this program will likely be determined through review of information from well-owners and physical inspection of candidate wells. The procedure and criteria for determining eligibility will be developed as an element of the Program.

Public Noticing, Permitting, and Regulatory Processes

The GSA will provide information related to this project, and updates on its progress through quarterly Advisory Committee meetings. The GSA also plans to coordinate with the County of Siskiyou Department of Environmental Health and Board of Supervisors on project progress and the implementation timeline.

This Program is not anticipated to require significant permitting in its development or implementation. Any permitting that may be required for potential mitigation actions, such as well deepening, will be completed with support of the GSA and in coordination with the County of Siskiyou Department of Environmental Health.

Project Status and Timeline for Implementation

Expected timelines for major milestones associated with this project include:

- Development of the DWAG by December 2024
- Development of a preliminary assessment of well conditions as results of the well inventory PMA (the well inventory PMA is already active and has been funded through DWR GSP implementation grant) by March 2025
- Development of the draft well mitigation program by June 2025
- Development of the final well mitigation program by September 2025 (including opportunity for public review and comment)

Expected Benefits and Evaluation of Benefits

It is expected that benefits to well-owners through implementation of the well mitigation program will begin after the well mitigation program is finalized in September of 2025. Benefits from this program are expected to be primarily realized through well diagnostics and improvements, and well deepening. The GSA will also coordinate with Office of Emergency Services, as and the County of Siskiyou Environmental Health Department, as needed. The benefits and overall success of the program are anticipated to be tracked through the number of well outages reported, the number of applications under the Well Mitigation Program, the number of eligible wells under the Program and the number of wells that have received support.

Legal Authority

This project will be implemented under the authority of the GSA but will closely coordinate with all relevant local, state, and federal agencies depending on the situation.

Estimated Cost

The estimated cost of the well inventory is anticipated to be from $50,000 to $80,00. The well mitigation program development is estimated to be $50,000 to $70,000. The cost of program implementation is estimated to be $50,000 to $100,000 per year, dependent upon the groundwater conditions and well outages reported. Program implementation will be funded through a combination of GSA funding. Grant funding (if available) will be coordinated with the office of Emergency Services.

The well inventory and the development of the Well Mitigation Program will be funded through the Butte Valley GSP Implementation Funding obtained through the Department of Water Resources' Sustainable Groundwater Management Grant Program Round 2 Implementation Funding. The Well Mitigation Program was included under the Well Inventory Component. The implementation of the program, and well mitigation actions, will be covered by the GSA, with support from other sources of funding including state and federal grant programs, as available. To ensure the avoidance of significant impacts (i.e. domestic wells outages that would cause failure to provide for human right to water), the GSA has committed to mitigating up to 20% of domestic wells in the Butte Basin (a total of up to 48 wells) over the GSP implementation period, as needed. The GSA will coordinate with the Office of Emergency Services (OES), and County of Siskiyou Department of Environmental Health, to evaluate the best pathway to fund the replacement of these wells.

This program is recognized as a critical implementation action and the GSA recognizes the necessity of a secure, on-going funding mechanism. This will be included as part of the Fee Study development, as a necessary item to fund throughout the GSP implementation period. The GSA will also explore alternative funding sources including investigating grant opportunities and collaborating with other agencies.

Relevant Measurable Objectives

The Well Mitigation Program benefits the groundwater elevation measurable objective by protecting domestic well beneficial users and avoiding impacts to domestic well owners from wells going dry, a part of the Basin's sustainability goal.

Preliminary Groundwater Allocation Program

Project Description

The GSA plans to develop a preliminary Groundwater Allocation Program (Program) as a management action to create a tool for implementation, as necessary. This Program will be developed through a stakeholder-driven process as a management tool to be used in the case of necessary, immediate, demand reductions. Elements of this program include the allocation, groundwater usage measurement and reporting, and implementation. This project is still in the conceptual phase. It is anticipated that a GSA-supported working group will spearhead this effort.

Circumstances for Implementation

This Program is anticipated as a measure to be implemented in circumstances where rapid action is required to address declining groundwater levels, and to fulfill the requirement of 10-15% reduction of groundwater pumping (which corresponds to the 65,000 acre-ft /year of sustainable yield). The GSA intends to develop this Program as a potential tool to be used in the event circumstances require demand reduction quickly and the GSA has exhausted ongoing PMA's. Exact circumstances for implementation will be discussed and assessed by the Advisory Committee and stakeholders.

Public Noticing, Permitting, and Regulatory Processes

This project is currently in the conceptual phase. The GSA plans to coordinate with the advisory committee and local stakeholders in its development. This Program is not anticipated to require significant permitting in development or implementation.

Project Status and Timeline for Implementation

Expected timelines for major milestones associated with this project include:

- Development of the Program Working Group by December 2024
- Development of the draft water allocation program by December 2025
- Development of the final water allocation program by December 2026 (including opportunity for public review and comment, and expecting the need to evaluate different practical options in 2025 and 2026)
- The sustainable yield of 65,000 AF will be achieved by 2027

Expected Benefits and Evaluation of Benefits

It is expected that benefits resulting from Program implementation will be realized by mitigating groundwater declines. The Program will include metrics to evaluate benefits and to assess whether the Program's objectives are being achieved. This will include tracking changes in groundwater levels with Program implementation, and measurements of groundwater demands, among others.

Legal Authority

This project will be implemented under the authority of the GSA.

Estimated Cost

The estimated cost of program development is $65,000. The cost of program development is anticipated to be funded through the Butte Valley GSP Implementation Funding obtained through the Department of Water Resources' Sustainable Groundwater Management Grant Program Round 2 Implementation Funding (specifically funding related to a water market analysis under Component 3d, Task 5).

Relevant Measurable Objectives

The Program benefits the groundwater elevation measurable objective through a reduction of the demand for groundwater, and the potential slowing or reversal of groundwater level decline.

Groundwater Demand Management

Project Description

The objective of this project is to manage groundwater use to achieve the sustainable yield. The goal of this management action is to ensure groundwater extraction is not exceeding a value that is sustainable for the Basin. The Basin's sustainable yield has been determined as the average of the baseline period between 1990 and 2014, a value of 65,000 acre-feet (AF). This value is also consistent with estimates reported in the 1970s. Capping groundwater extraction at this value would require a 10-15% reduction from present groundwater use. This will be achieved through a combination of irrigation efficiency improvements, better assessments of crop needs, and implementation of water allocations, if needed.

A key component of this action is the additional monitoring that is required, including estimates of evapotranspiration (from satellite and in-field data), flowmeters on representative wells to provide groundwater extraction data, and soil moisture data collection. This information will support improvements in irrigation efficiency methods and will increase water use efficiency.

Circumstances for Implementation

This effort is already underway and will continue to be implemented by the GSA.

Public Noticing, Permitting, and Regulatory Processes

No public noticing, permitting, or regulatory processes are anticipated to be required as part of this Program.

Project Status and Timeline for Implementation

Expected timelines for major milestones associated with this project include:

- Development of draft monitoring site list by March 2025
- Instrumentation and monitoring installations on all selected sites by March 2026

Data collection is anticipated to occur throughout the entirety of the GSP implementation period.

Expected Benefits and Evaluation of Benefits

It is expected that benefits resulting from Program implementation will be realized by reducing groundwater declines. The Program will include monitoring to confirm increased efficiencies in irrigation and water use.

Legal Authority

This project will be implemented under the authority of the GSA.

Estimated Cost

The estimated cost of program development is $60,000. The cost of program development is anticipated to be funded through the Butte Valley GSP Implementation Funding obtained through the Department of Water Resources' Sustainable Groundwater Management Grant Program Round 2 Implementation Funding. Specifically, land use and irrigation efficiency are included under Component 2d, Task 6 and well metering is funded under Component 5d, Task 1.

Relevant Measurable Objectives

The Program benefits the groundwater elevation measurable objective through reduction of demand for groundwater, and potential slowing or reverse of groundwater level decline.

City of Dorris Well Deepening and Pipeline Replacement Project

Project Description

This project is to 1) replace or repair water distribution infrastructure in the City of Dorris and add a new municipal well and, 2) identify wells in Butte Valley needing repair or replacement and the repair or replacement of up to 4 wells. Initial outreach was conducted to identify priority water users and to coordinate efforts with other County agencies and community groups. Mailing lists of local addresses were developed to distribute the well outage surveys. The well outage survey was developed and was translated into Spanish and Hmong. The survey was mailed to approximately 400 local addresses, posted on the City of Dorris' website and posted at the Macdoel and Dorris post offices. In addition, well surveys were distributed during public meetings in Butte Valley. Of the 20 survey responses that were received, 10 reported wells needing repair or replacement.

Responses to the well outage survey were summarized and mapped to identify locations and to characterize reported issues with the wells. Additional surveys were mailed to property owners not previously contacted (i.e. Butte Valley property owners with non-local addresses). Site visits were conducted in June 2023 and 5 wells were identified as needing repairs or replacement. Additional site visits were conducted in the September 2023 to further evaluate the repairs needed. In addition, information was collected regarding shallow sediment and geology to determine well depths needed for long-term water security.

Based on this review and follow up with the well owners, 4 wells were identified to be replaced. Repairs for other wells that were evaluated will be done if funding is available after the completion of the 4 well replacements.

Circumstances for Implementation

This effort is already underway and will continue to be implemented by the city of Dorris, with support from the GSA.

Public Noticing, Permitting, and Regulatory Processes

Permits have been obtained for drilling the new municipal well for the City of Dorris and for well-deepening. No public noticing, or regulatory processes have been required as part of this project.

Project Status and Timeline for Implementation

The timeline for this project is December 2021 through June 2025, expected timelines for major milestones associated with this project include:

- Improvement of water distribution system by June 30, 2024
- Well Deepening Program by June 30, 2025

Expected Benefits and Evaluation of Benefits

Expected benefits from this project include ensuring reliable water supply and distribution for City of Dorris residents and repairing or replacing an additional four wells in Butte Valley. Benefits will be measured through tracking benefits associated with well repair or replacement, and improvements to the water distribution system.

Legal Authority

This project will be implemented under the authority of the GSA.

Estimated Cost

The total cost of this project is $3,762,436, and it is being funded through the Department of Water Resources' Small Community Drought Relief Program.

Relevant Measurable Objectives

The Program benefits the groundwater elevation measurable objective through a reduction of demand for groundwater, and potential slowing or reversal of the groundwater level decline.

Butte Valley Integrated Hydrologic Model (BVIHM) (High Priority)

Project Description

Planned futures updates to the Butte Valley Integrated Hydrologic Model (BVIHM) include:

- After the PMA "Interconnected Surface Water Data Gaps" has been addressed, the GSA will update BVIHM to include surface water, including irrigation canals.
- Update with more new data and extend the model to more recent years to capture additional climate and pumping patterns, particularly the last drought. Continuous groundwater level data will aid the calibration of the BVIHM by providing insight on seasonal groundwater level and storage fluctuations.

This PMA depends on expansion of current monitoring network and data collection, as outlined in other PMAs.

Drought Year Analysis (High Priority)

Project Description

The year 2021 was faced with an unprecedented drought. The GSA will analyze all data collected within the 2021 water year to study how the Butte Valley groundwater basin responded to an exceptional drought year.

Expand Monitoring Networks (High Priority)

Project Description

The GSA will expand the current monitoring networks to address identified data gaps, as defined in Appendix 3-A with implementation details in Chapter 5. This includes:

- Expansion of the groundwater level monitoring network to areas of interest, with an emphasis on continuous monitoring data. Expansion of the groundwater level monitoring network to areas of interest such as Sam's Neck, Meiss Lake, Butte, Prather, Ikes, Harris, and Muskgrave Creeks, and Butte Valley National Grasslands (see Section 3.3). Monitoring wells near surface water and potential groundwater dependent ecosystems (GDEs) are needed. Additional monitoring of domestic wells is needed.
- Expansion of the water quality monitoring network is needed to cover multiple needs such as:
    - Coverage of all beneficial users such as domestic, agriculture, and environmental users. – Improved spatial coverage of the Basin.
    - Representation of all major water bearing formations in the Basin, such as shallow units that primarily supply domestic wells and deep units that supply agricultural and municipal wells.

Completion of this project during the implementation process will depend on funding availability and cooperation of partner agencies and stakeholders (see Chapter 5).

General Data Gaps (High Priority)

Project Description

The GSA will aim to fill all data gaps described in the GSP and Appendix 3-A. Data gaps regarding the monitoring networks, GDEs, and ISWs are already addressed in separate PMAs. Additional data gaps that this PMA will address include:

- Increasing the current frequency of water quality sampling.
- Add continuous groundwater level monitoring to the groundwater level network.
- Add snow and weather stations to the Watershed.

Completion of this project during the implementation process will depend on funding availability and cooperation of partner agencies and stakeholders (see Chapter 5). This work is ongoing, and progress made towards filling the identified data gaps are reported each year with the annual report.

Groundwater Dependent Ecosystem Data Gaps (High Priority)

Project Description

The GSA will work with the California Department of Fish and Wildlife (CDFW) and other interested stakeholders to address the data gaps related to GDEs in the Basin (Appendix 3-A). This includes:

- Habitat maps of species that depend on GDEs based on local knowledge and surveys.
- Ad-hoc committee review of species lists, habitat maps, and GDE maps.
- Review species that depend on GDEs with a biologist or related expert.
- Extend the groundwater level monitoring network to areas with potential GDEs.
- Reanalyze potential GDEs after additional data is collected.
- Develop a biological monitoring methodology to monitor GDEs for unreasonable impacts due to groundwater conditions, such as through satellite images.
- Analyze if Meiss Lake and areas within the Butte Wildlife Area (BVWA) should be considered GDEs.

Completion of this project during the implementation process will depend on funding availability and cooperation of partner agencies and stakeholders (See Chapter 5). Completion of this PMA would enable setting sustainable management criteria (SMCs) to protect GDEs in the next five-year GSP update.

Interconnected Surface Water Data Gaps (High Priority)

Project Description

The GSA will work with the CDFW and other interested stakeholders to address the data gaps related to ISWs in the Basin (Appendix 3-A). This includes:

- Installing stream gages to record seasonal flow.
- Adjacent to surface water, including Meiss Lake and all other creeks that enter the Basin:
    - Butte, Prather, Ikes, Harris, and Muskgrave (Chapter 2).

- Conduct a pilot study of shallow monitoring wells or alternative options to analyze if surface water bodies are connected or disconnected to groundwater.
- Collect surface water data for BVIHM such as surface water diversions, canal seepage, streamflow losses, and percolation from wetlands and Meiss Lake.
- Reanalyze potential ISWs after additional data is collected and surface water has been incorporated into the numerical model.
- If ISWs are found to be present in the Basin, create ISWs SMCs as needed and define undesirable results for a future GSP update.

Completion of this project during the implementation process will depend on funding availability and cooperation of partner agencies and stakeholders (see Chapter 5).

Avoiding Increase of Total Net Groundwater Use Above Sustainable Yield

Project Description

The goal of this MA is to avoid water level declines in Butte Valley that would result from increases of total net groundwater use over the sustainable yield of 65,000 acre-feet (AF). This MA is intended to avoid future sustained increases of total net groundwater use through a selection of planning and management actions. Net groundwater use is defined as the difference between groundwater pumping and groundwater recharge in the Basin. Under conditions of long-term stable recharge (from precipitation, irrigation, streams, floods) and long-term stable surface water supplies in the Basin, significant increases in long-term average evapotranspiration (ET; or other consumptive uses) in the Basin lead to significant increases in long-term average net groundwater use. Such expansion of net groundwater use would result in a new dynamic equilibrium of water levels in the Basin, bringing water levels in the Basin or portions of the Basin to levels lower than the minimum threshold (MT) for significant periods of time. This would then set in motion basin-wide reductions in groundwater pumping (see MA “Strategic Groundwater Pumping Restrictions”).

The MA sets a framework to develop a process for avoiding significant long-term increases in net groundwater use in the Basin, while protecting current groundwater and surface water users. By preventing groundwater extraction above the sustainable yield, the MA will help the GSA achieve the measurable objectives (MO) of several sustainability indicators: groundwater levels, groundwater storage, and subsidence.

Implementation of the MA is measured by comparing the most recent 5 and 10-year running averages of agricultural and urban ET over both the Basin and Watershed, to the average value of Basin ET measured in the 2010 to 2020 period, within the limits of measurement uncertainty. Basin ET from anthropogenic activities in the Basin and surrounding Watershed cannot increase significantly in the future without impacting sustainable yield. This design is intended to achieve the following:

- To avoid disruption of existing urban and agricultural activities.
- To provide an efficient, effective, and transparent planning tool that allows for new urban, domestic, and agricultural groundwater extraction without expansion of total net groundwater use through exchanges, conservation easements, and other voluntary market mechanisms while also meeting current zoning restrictions for open space, agricultural conservation, etc (see Chapter 2).

  To be flexible in adjusting the limit on total net groundwater extraction if and where additional groundwater resources become available.

Critical tools of the MA will be monitoring and assessment of long-term changes in Basin and surrounding watershed hydrology (ET, precipitation, streamflow, groundwater levels, see Chapter 3), outreach and communication with stakeholders, well permitting, collaboration with land use planning and zoning agencies, and limiting groundwater extraction to not exceed the sustainable yield.

Measurable Objectives Expected to Benefit

This MA directly benefits the measurable objectives of the following sustainability indicators:

- Groundwater levels – Stabilizing declining water levels at depths not to exceed those corresponding to the most recent 10-year period.
- Groundwater storage – Stabilizing declining storage levels at depths not to exceed those corresponding to the most recent 10-year period.
- Subsidence – Stabilization of water levels will reduce the risk of compaction in fine-grained aquifer materials and associated land subsidence.

Circumstances for Implementation

This MA is appropriate because the threat of declining water levels in Butte Valley is not due to overdraft conditions. Future threats to groundwater levels fall into two categories, further explained below:

- Sustained, increased Basin net groundwater use above the sustainable yield (Basin net groundwater use: difference between Basin recharge and Basin pumping).
- Reduced subsurface inflows from the volcanic aquifer system underlying the watershed surrounding the Basin, which would be the result of:
  - Reduced recharge across the upland watershed; or
  - Increased pumping in the watershed surrounding the Basin.

This MA ensures that future declining water levels are not the result of significant expansion of groundwater pumping in the Basin (first category), which would lead to new, lower dynamic groundwater level equilibrium conditions possibly exceeding the MT.

Increasing Basin Net Groundwater Use

Groundwater levels in the basin are fundamentally controlled by:

- The elevation of water levels in groundwater basins to the northeast and east of Butte Valley.
- The amount of groundwater outflow through the volcanic bedrocks to the northeast and east of the Watershed.
- The amount of recharge in the Watershed, especially to the south and west of Butte Valley
- The amount of recharge from the Butte Valley landscape due to precipitation, irrigation return flows, flooding, and managed aquifer recharge (MAR).
- The amount of groundwater pumping for irrigation (Note: the net consumptive groundwater use by domestic and public users is relatively small after accounting for return flows from septic systems and wastewater treatment plants to either groundwater or streams).

Groundwater flow is generally from the south and west to the northeast and east, through the Basin itself, with some local, stable pumping depressions in the Basin. A dynamic equilibrium exists between the recharge into the volcanic uplands south and west of the Basin, groundwater pumping, and groundwater discharge through the volcanic bedrock to the northeast and east of Butte Valley.

Continued or renewed increase in groundwater pumping within the Basin leads to a continued or renewed lowering of the water table in the Basin due to lower total groundwater outflow to the northeast and east of the Basin and, hence, flattened groundwater gradients toward the neighboring, downgradient groundwater basins. By halting or preventing a long-term increase in net groundwater uses through keeping total net groundwater uses at current conditions, a groundwater basin that is not in overdraft remains at a dynamic equilibrium in water level conditions if groundwater inflows and outflows to and from the Basin remain stable. The impact of drought conditions and increased pumping in neighboring groundwater basins is currently a data gap.

Decreasing Recharge or Runoff, or Increasing Pumping in the Surrounding Watershed

Butte Valley is a groundwater basin that is receiving significant groundwater inflow from surrounding groundwater areas and is contributing significant groundwater outflow to downgradient groundwater areas. Hence, water levels within the groundwater basin are affected by recharge and pumping not only inside, but also outside the GSA.

The Basin is part of the much larger Butte Valley watershed, in the southwest portion of the Upper Klamath watershed (Gannett 2010; Gannett, Wagner, and Lite 2012). Much of the watershed outside of the predominantly alluvial groundwater basin consists of volcanic rocks of varying hydraulic conductivity. Much of the precipitation over the Watershed percolates into the volcanic groundwater system surrounding the alluvial basin and flows into and out of the alluvial basin as subsurface flow. Butte Creek is the major surface water feature (see Chapter 2). All Butte Creek flows are recharged to groundwater or diverted for irrigation. For all surface water, the Basin is a terminal, closed basin: all surface inflows are recharging to groundwater or subject to ET.

Due to this immediate connectivity of the alluvial groundwater basin that constitutes the Butte Valley GSA with its surrounding volcanic (and partially alluvial) groundwater, water levels in the GSA can be affected by changes in recharge and groundwater uses occurring outside its boundaries, within the larger Watershed.

Historic Trends of Basin Net Extraction and of External Watershed Pumping and Recharge

In Butte Valley, Basin net groundwater use, estimated as the total amount of annual agricultural evapotranspiration in the Basin over the past 25 years, has generally been increasing as evidenced by the increase in ET from applied water in the Basin (Figure 4.2). Between the early 1990s and the 2010s, the total increase has been on the order of 40% (see Appendix 2-E).

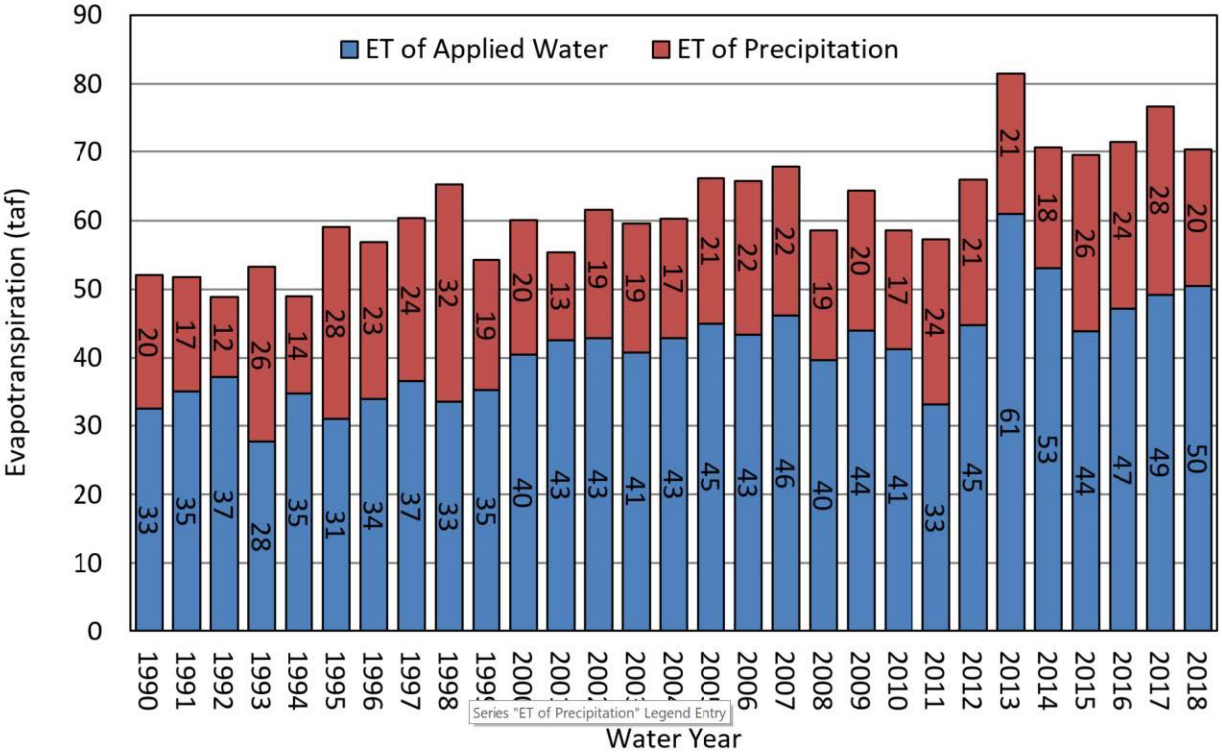


Figure 4.2: ET from applied water (blue) and from precipitation (red) on irrigated lands within the Butte Valley GSA (see Appendix 2-E).

For the 8-year period from 1990 to 1997, agricultural ET varied from 28 to 37 thousand acre-feet per year, averaging 34 thousand acre-feet. For the 8-year period from 2011 to 2018, agricultural ET varied from 33 to 61 thousand acre-feet per year, averaging 48 thousand acre-feet (see Appendix 2-E).

Over the same period, precipitation trends have been decreasing (Figure 4.3). The 10-year rolling average precipitation remained well above the 1941 to 2020 mean precipitation until 1980, but has since been below the long-term mean precipitation except during the wet years of the late 1990s.

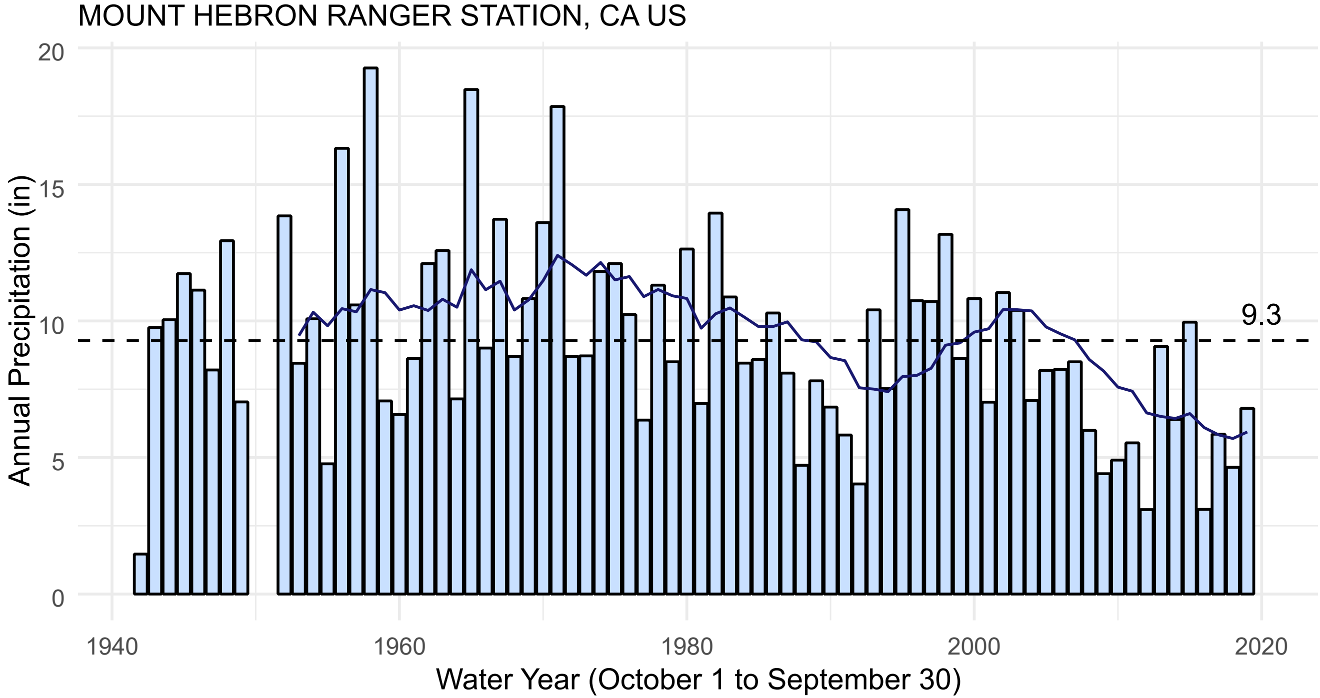
Water levels in areas south (upgradient) and east-northeast (downgradient) have been declining. Chapter 2 describes the Butte Valley Integrated Hydrologic Model (BVIHM). The model can be used to determine whether potentially decreased recharge into surrounding volcanic aquifer units and a commensurate decrease in groundwater inflow to the Basin may have contributed to recent groundwater level declines.

Groundwater levels over the past 30 years have generally been observed to be declining at a rate of about 0.25 to 1 feet per year, depending on location, reflecting adjustments of the groundwater system to declining recharge and increased pumping. From a water budget perspective, the increased pumping is matched by increased groundwater inflow from outside the Basin, particularly from the south and southwest. With this increased inflow, a new dynamic water table equilibrium is achieved as groundwater use has stabilized at recent conditions while precipitation rates have not been further declining over the past half decade. It remained relatively steady albeit at low levels.

Based on current conditions in the Basin, this MA will be implemented immediately upon approval of the GSP in partnership with other relevant agencies. During MA implementation, if groundwater levels stabilize at higher elevations due to GSA activities or climate change, the groundwater use cap and the sustainable yield may be adjusted or removed altogether. The mechanism for off-ramping the MA is described in the implementation section below.

Annual water year precipitation with 10−year rolling and long−term means

Figure 4.3: Annual water year precipitation with 10-year rolling and long-term means for water year 1941 through 2020 as measured at the Mount Hebron weather station (USC00045941).



Public Noticing

The GSA will implement the following education and outreach actions regarding the MA:

- Post and advertise the progress of MA implementation through the submittal of annual progress reports to the California Department of Water Resources (DWR).

Implementation: Collaboration with Permitting and Regulatory Agencies

Implementation of the MA is focused on developing active coordination between the GSA with other planning, permitting, and regulatory entities within the Basin, including the Siskiyou County Department of Environmental Health and local land use zoning agencies (see below).

Siskiyou County Department of Environmental Health

The GSA will develop a formal partnership with the well construction permitting agency that operates within the Basin, the Siskiyou County Department of Environmental Health. The objective of the partnership is to develop a well permitting program for agricultural, urban, and large domestic wells that is supportive of and consistent with the GSA's goal not to expand total net groundwater use in the Butte Valley watershed surrounding the Basin and in the Basin itself. The permitting program would ensure that construction of new extraction wells does not expand current total net groundwater use in the Basin itself and across the Watershed as a whole (to the degree that such expansion may cause the occurrence of undesirable results). This can be achieved through well retirements and through voluntary water market instruments.

Technical Example (Not a PMA)

Well replacement may not require that the new well has the same construction design as the old well, including well capacity. Here are two illustrative examples of an appropriate use of well replacement:

Example 1: Replacement of a 1,000-gpm agricultural well that will be properly decommissioned with a new 1,000-gpm agricultural well is permissible.

Example 2: Replacement of a 1,000-gpm agricultural well that will be properly decommissioned with a new 2,000-gpm capacity agricultural well is permissible with the explicit condition that the 10-year average total net groundwater extraction within the combined area serviced by the old and the new well does not exceed the average groundwater extraction over the most recent 10-years.

Land Use Zoning Agencies

The GSA will develop a partnership with all relevant land use zoning agencies in the Watershed. Land use zoning agencies and relevant stakeholders in the Butte Valley watershed include:

- Siskiyou County
- City of Dorris
- Macdoel (census-designated place)
- Mount Hebron (census-designated place)
- Tennant (census-designated place)
- Red Rock Valley Groundwater Basin
- Bray Town Area Groundwater Basin
- Lower Klamath Groundwater Basin (outside watershed)
- Tulelake Groundwater Basin (outside watershed)

The objective of the partnership is for those agencies to inform land use zoning and land use permitting programs to ensure that zoning decisions are based on a full understanding of groundwater conditions in the Watershed and Basin and that such decisions are supportive of and consistent with the GSA’s goal not to expand total net groundwater use in the Butte Valley watershed. Developing close partnerships and timely transfer of information will best prevent an expansion of total anthropogenic consumptive water use in the Watershed.

Preventing an expansion of total net groundwater use in the Basin and surrounding areas still allows for both urban and agricultural growth.

Urban expansion is made possible primarily by expansion into agricultural or rangeland that will be retired. Agriculture-to-urban land use conversion does not increase net groundwater use within the footprint of that conversion. Sometimes the net groundwater use may be lower after conversion (due to lower evapotranspiration). The total annual volume of net groundwater use reduction can be made available for net groundwater use increase elsewhere in the Basin through designing appropriate land use zoning and permitting processes, and after considering ecological, public interest, and any hydrologic or hydrogeologic constraints to such exchanges.

Agricultural expansion, where permissible under zoning regulations, is similarly made possible, e.g., primarily by voluntary managed land repurposing of existing agricultural activities in the same location or elsewhere within the Basin and ensuring that there is no increase in net groundwater extraction between the expansion on one hand and land repurposing on the other. This may be achieved through land purchasing or trade of net groundwater extraction rights (water markets) or through contractual arrangements for land repurposing (e.g., conservation easements) to balance expansion and reduction of net groundwater use. If additional Basin total net groundwater extraction capacity becomes available (after a pro-longed period of water level increase), the GSA will work with the land use zoning agencies to ensure land use zoning and permitting is adjusted accordingly, following a hydrologic assessment.

Technical Example (Not a PMA)

Market instruments encompass a wide range of management tools that rely on monetary transactions to efficiently and effectively trade water uses in ways that do not affect the overall water balance of a basin. The following are two hypothetical examples of water market transactions to illustrate how such instruments may be applied, if circumstances and zoning regulations are appropriate:

Example 1: Expansion of urban groundwater use into agricultural lands, where consistent with zoning and land use planning - Net groundwater use per acre of urban land is generally similar to or lower than under agricultural land use (this accounts for the fact that wastewater is recharged to groundwater and that the largest consumptive use in urban settings is ET from green landscapes). A hypothetical example: lets assume that urban net groundwater use is 1.5 acre-feet per acre, whereas it is 3 acre-feet per acre on agricultural land. Net water use is the difference between groundwater pumping and groundwater recharge over the area in question. Let’s further assume that an urban expansion occurs into 500 acres of agricultural land. Prior to the land use conversion, net water use was 3 x 500 = 1,500 acre-feet. After the land use conversion, net water use is 1.5 x 500 = 750 acre-feet. The land use conversion makes 750 acre-feet available for additional annual groundwater pumping elsewhere in the Basin.

Example 2: Expansion of urban groundwater use into natural lands, where consistent with zoning and land use planning - Net groundwater use of urban land is generally larger than under natural land use. A hypothetical example: urban net groundwater use is 1.5 acre-feet per acre, whereas it is 0.5 acre-feet per acre prior to the land-use conversion. Let’s again assume that the urban expansion is 500 acres. Prior to the land use conversion, water use on the 500 acres was 0.5 x 500 = 250 acre-feet. After land use conversion, the net water use is 1.5 * 500 = 750 acre-feet. The land use conversion therefore requires an additional 500 acre-feet of water.

If the city also purchases 500 acres of agricultural land for urban development, as in example 1, it already has a credit of 750 acre-feet, of which it may apply 500 acre-feet toward this additional 500 acre expansion into natural land.

Alternatively, the city would need to purchase a conservation easement on 200 acres of agricultural land elsewhere in the groundwater basin (net groundwater use: 3 acre-feet per acre, or 3 x 200 = 600 acre-feet) that converts that agricultural land to natural land (net groundwater use: 0.5 acre-feet per acre, or 0.5 x 200 = 100 acre-feet). The net groundwater use on the easement would be reduced from 600 acre-feet to 100 acre-feet, a 500 acre-feet gain to balance the city’s development into natural lands, above. Costs for the easement may include costs for purchasing or leasing that land and the cost for maintaining the conservation easement. We note that conversion to natural land may require significant and habitat development and management as appropriate.

> The above examples do not account for possible water rights issues that will also need to be considered. In California, urban groundwater rights are generally appropriative, while agricultural water rights are overlying, correlative rights.

De minimis exceptions to net groundwater use expansion: domestic water use, up to 2 acre-feet per household, contributes minimally to net groundwater extraction of a basin. Nearly all household water use other than irrigation is returned to groundwater via septic systems leachate. Larger household water use, above *de minimis* levels is typically due to irrigation of pasture or lawn and therefore, will be considered a net groundwater extraction.

If additional net groundwater extraction becomes available (after a prolonged period of water level increase), the partnership will ensure that well permitting is adjusted accordingly.

Status

The schedule for implementing the MA is as follows:

- The GSA will create partnerships within the first year of the GSP, by January 31, 2023.
- The partnerships will have the MA program in place no later than January 31, 2024.
- Benefits are to be seen immediately; that is, net groundwater use during the 2020 to 2030 decade will not exceed net groundwater use during the 2010 to 2020 baseline period.

Expected Benefits

Benefits generated by the MA will include:

- Security of groundwater pumping for existing groundwater users.
- Efficient, effective, and transparent planning tools available for new groundwater uses through market instruments involving the retirement of existing groundwater uses.

Implementation: Monitoring

In a groundwater basin where agricultural pumping exceeds 95% of applied groundwater use, the total long-term change in the amount of net groundwater use (groundwater pumping minus irrigation return flows to groundwater) can be estimated by quantifying the long-term changes in the Basin's ET from irrigated landscapes. This assumes that long-term trends in precipitation and applied surface water are sufficiently negligible such that only a significant increase in Basin ET leads to changes in the long-term groundwater balance or that their impacts are separately assessed using a model (Section 2.2.4).

Butte Valley is a closed surface water basin. All surface water inflows captured for irrigation represent flows that would otherwise be subject to groundwater recharge. Hence, surface water irrigation is an indirect form of groundwater pumping (a kind of "in lieu pumping"). Therefore, from a hydrological perspective, the net agricultural groundwater use in Butte Valley is effectively equal to the amount of agricultural ET.

In Butte Valley, the net groundwater use in urban areas is largely due to ET from lawn areas and suburban pasture. Most household water use other than irrigation is subject to recharge back to groundwater via septic systems or recharge of treated wastewater. For the Basin, DWR will provide estimates of annual agricultural ET and ET from urban lawn and suburban pasture areas. Spatially distributed ET rates are obtained through use of remote sensing data. The accuracy of a basin-total annual agricultural and urban ET value is on the order of +/-10% (Medellin-Azuara et al. 2018). DWR estimates of ET provide an inexpensive, readily available data source to estimate net annual groundwater use from individual fields, and from the Basin as a whole.

Groundwater storage will be evaluated continually to assess the effectiveness of the avoiding the expansion of total net groundwater use. If a sustained long-term (5 to 10 year) increase in groundwater levels is observed in the representative monitoring network (or an expanded version of that network, which may include wells outside the GSA boundary but within the watershed), appropriate scientific-technical assessments, including groundwater modeling, will be used to determine the amount of expanded total net groundwater use capacity available. If groundwater levels have increased due to long-term increase in recharge in the surrounding Watershed, the GSA may work with land use zoning agencies to allow for a gradual expansion of total net groundwater use that will allow water levels to remain within the measurable objective (MO).

Legal Authority

The GSA only has authority for groundwater within the Butte Valley groundwater basin. The GSA has no land use zoning authority. The GSA will work collaboratively with the County of Siskiyou, other land use zoning agencies, and stakeholders within the Basin to implement this MA.

Estimated Costs and Funding Plan

An economic analysis contractor will complete a description of the estimated cost for each project or management action and a description of how the Agency plans to meet those costs will be provided in the GSP update when the planning phase has been completed for a majority of PMAs.

Management of Groundwater Use and Recharge

Management of groundwater uses and recharge will be evaluated to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods. Assumptions that will be used to evaluate management of groundwater use and recharge include:

- There is currently no overdraft in the Basin.
- The goal of this MA is to avoid renewed water level declines in Butte Valley that are due to further expansion of net groundwater use.
- The MA sets a framework to develop a process for avoiding significant long-term increases in net groundwater use in the Butte Valley GSA as well as in the surrounding watershed, while allowing basin and watershed total groundwater use to remain at levels that have occurred over the most recent ten-year period (2010 to 2020).
- Monitoring: Compliance with the MA is measured by determining whether the most recent ten year running average Basin/Watershed sum of agricultural and urban ET remains at or below levels measured for the 2010 to 2020 period, within the limits of measurement uncertainty.

Dorris Water Meter Installation Project

Project Description

To improve water conservation, the City of Dorris is in the process of adopting a metered water rate structure by installing water meters. The project is also replacing old pipelines. Following the installation of meters, water consumption can be tracked and water rates adjusted based on actual water volume used. This project will begin in 2021. This project is fully funded through grants from the Department of Public Health Safe Drinking Water State Revolving Fund and State Revolving Fund.

Irrigation Efficiency Improvement

Project Description

Achieving increases in irrigation efficiency through equipment improvements are anticipated to reduce overall water demand with the potential to decrease overall consumptive water use, predominantly through a reduction in evaporation. This is expected to support stable water level conditions.

Currently, this project is in the planning phase and funding options will be explored during the first five years of GSP implementation. This project involves an exploration of options to improve irrigation efficiency, assessment of irrigator willingness, outreach and extension activities, and development of funding options, primarily by cooperators, possibly in cooperation with NRCS. This PMA is likely to be accomplished through a voluntary, incentive-based program. Cost estimates have not yet been completed for this PMA.

Monitoring data collected in this irrigation efficiency improvement program include, but are not limited to:

- Total acreage with improved irrigation efficiency equipment.
- Location of fields under improved irrigation efficiency equipment.
- Assessment of the increase in irrigation efficiency, with particular emphasis on assessing the reduction or changes in consumptive water use (evaporation, evapotranspiration) based on equipment specification, scientific literature, or field experiments.
- Cropping systems in fields with improved irrigation efficiency equipment.

Public Outreach

This general PMA emphasizes the GSA’s goal for public outreach and education among stakeholders to implement the spirit of the PMA and achieve groundwater sustainability within the Shasta Valley groundwater basin. This includes outreach related to other PMAs and filling data gaps, as well as coordinated, widespread, voluntary conservation efforts and grassroots stewardship. The GSA will also work with municipal water agencies and other relevant organizations to coordinate residential, municipal, and small agricultural water conservation education, particularly in times of drought or critical times of the year. This outreach will help engage the public and create more meaningful opportunities for public interest representation within the GSA.

Voluntary Managed Land Repurposing

Project Description

Voluntary managed land repurposing programs include a wide range of voluntary activities that make dedicated, managed changes to land use (including crop type) on specific parcels in an effort to reduce consumptive water use in the Basin to improve and increase groundwater levels This voluntary land repurposing program will encourage a range of activities that would reduce water use in the Basin. These activities may include any of the following:

Term Contracts: In some circumstances, programs like the Conservation Reserve Program (CRP) could provide a means of limiting irrigation on a given area for a term of years. Because of low rates, the CRP has not been utilized much in California, but this could change in the future. In addition, other term agreements may be developed at the state or local level.

Crop Rotation: Landowners may agree to include a limited portion of their irrigated acreage in crops that require only early season irrigation. For example, a farmer may agree to include 10% of their land in grain crops that will not be irrigated after June 30.

Irrigated Margin Reduction: Farmers could be encouraged to reduce irrigated acreage by ceasing irrigation of field margins where the incentives are sufficient to offset production losses. For corners, irregular margins, and pivot end guns, this could include ceasing irrigation after a certain date or even ceasing irrigation entirely in some instances.

Crop Support: To support crop rotation, particularly for grain crops, access to crop support programs may be important to ensure that this option is economically viable. Some type of crop insurance and prevented planting payment programs could provide financial assurances to farmers interested in planting grain crops.

Other Uses: In some circumstances, portions of a farm that are currently irrigated may be well suited for other uses that do not consume water. For example, a corner of a field may be well suited for wildlife habitat or solar panel, subject to appropriate zoning requirements to avoid undesirable outcomes. Depending on the circumstances of an individual project, conservation easements may include habitat conservation easements, wetland reserve easements, or other easements that limit irrigation with surface water or groundwater on a certain area of land. It may be established that certain portions of a property may be suitable for an easement, while the rest of the property remains in irrigated agriculture. Many form of such temporary, seasonal, or permanent easements are possible. They may additionally specify restrictions or requirements on the repurposed use, e.g., to ensure appropriate habitat management.

Currently in the planning phase, this project type is to be developed throughout the next five years.

Implementation of this project type includes consideration of the following elements:

- Role of the GSA versus other agencies, local organizations, and NGOs.
- Development of education and outreach programs in collaboration with local organizations.
- Exploration of program structure.
- Contracting options.
- Exploration and securing of funding source(s).
- Identification of areas and options for easements or other contractual instruments.

Monitoring data collected in this voluntary managed land repurposing program include, but are not limited to:

- Total acreage and timing of land repurposing.
- Location of parcels with land repurposing.
- Assessment of the effective decrease in evapotranspiration (consumptive water use) and applied water use.
- Description of the alternative management on repurposed land with:
  - Quantification and timeline of groundwater pumping restrictions, including water year type or similar rule to be applied and specified in the easement.

4.4 TIER III: POTENTIAL FUTURE PROJECT AND MANAGEMENT ACTIONS

Alternative, Lower ET Crops

Project Description

The “alternative, lower ET crop” PMA is a pilot program to develop and introduce alternative crops with lower ET but sufficient economic value to the Basin’s agricultural landscape. The implementation of such crop changes would occur as part of the Tier II Voluntary Managed Land Repurposing PMA. The objective of this PMA is to develop capacity in the basin to facilitate crop conversion in some of the agricultural landscape that would reduce total crop consumptive use (ET) of water in the Basin as needed. The MA is to develop a program to develop and implement pilot studies with alternative crops that have a lower net water consumption for ET, and to provide extension assistance and outreach to growers to facilitate and potentially incentivize the crop conversion process. This PMA will be implemented jointly with University of California Cooperative Extension, the Siskiyou County Farm Bureau, the Siskiyou County Resources Conservation District, and/or other partners. Currently in the conceptual phase, this project involves:

- Scoping of potential crops.
- Pilot research and demonstrations.
- Defining project plan.
- Exploration of funding options.
- Securing funding.
- Development of an incentives program.
- Implementation of education and outreach.

Anticipated benefits from this project include introduction of lower consumptive water use crops and either an increase in recharge (on surface water irrigated crops) or a reduction in the amount of irrigation or both. As a result, water levels in the aquifer system will rise. Implementation of this project is contingent on the evaluation of alternative, lower ET crops that provide sufficient economic value. Future benefits of actual implementation status will be evaluated and assessed with BVIHM using monitoring data describing the implementation of the alternative, lower ET program.

Monitoring data collected in this alternative, lower ET program include, but are not limited to:

- Total acreage with alternative, lower ET crops.
- Location of fields with alternative, lower ET crops.
- Assessment of the effective decrease in ET.
- Cropping systems used as alternative, lower ET crops.

Butte Creek Diversion Relocation

Project Description

For emergency flood control, the Army Corps of Engineers created two Butte Creek diversions in 1965 into storage reservoirs for groundwater recharge. One diverts to Dry Lake and the second east of Orr Mountain, where the Butte Valley Irrigation District (BVID) later constructed a dam and canal for the diversion (Bell and Harrington 2011). The impact of the groundwater recharge due to the creek diversion is unknown due to the lack of stream flow data, diversion flow data, and the direction of recharged groundwater (ie., Butte Valley or Red Rock groundwater basins).

This PMA is broken into two steps:

- Firstly, to fill data gaps related to streamflow and groundwater levels and recharge at the creek diversions. This will also increase the GSA's understanding of groundwater inflows into the Basin.
- Secondly, investigate if moving or altering the Butte Creek diversion would increase groundwater flows in the Basin. A complication is the need to avoid harming the Red Rock groundwater basin if the Butte Creek diversion is providing recharge.

Butte Valley National Grassland Groundwater Recharge Project

Project Description

The Butte Valley National Grasslands may be developed to store Meiss Lake floodwaters for groundwater recharge. This project could be tied with other PMAs to prevent flooding of populated and agriculture lands by Butte Creek winter flows if the current diversion is moved. This project will require infrastructure development to divert excess floodwaters from Butte Creek to Meiss Lake and the National Grasslands.

Strategic Groundwater Pumping Restriction

Through SGMA, the GSA has the ability to implement groundwater pumping restrictions within locations of the GSA's jurisdiction. Although the GSA has the ability to implement pumping restrictions, the development and implementation of Tier I, Tier II, and other Tier III PMAs are designed to maintain sustainability within the Basin, making pumping restrictions a last resort under this GSP.

Considerably more work, data collection and discussion would need to be done to define the policies and procedures for pumping restrictions, and the GSA would first determine, using the BVIHM, and other hydrologic assessment tools, the amount of water that affected pumpers could take sustainably prior to determining what may need to be restricted. Restrictions may be temporary, seasonal, or permanent.

4.5 OTHER MANAGEMENT ACTIONS

Monitoring Activities

Chapter 3 and the data gap Appendix 3-A clearly describe the importance of establishing an extensive monitoring network which will be used to support future GSP updates. A summary of the proposed monitoring activities includes, but is not limited to:

- Development of new RMPs (Representative Monitoring Points) to support the groundwater quality SMC.
- Development of new RMPs to support groundwater level SMC.
- New stream gauges in Butte Creek.
- Use of satellite images, twice per year, to evaluate status of GDEs.

Voluntary Well Metering

This project would facilitate the collection and reporting of groundwater extraction data. Accurate groundwater extraction data improves the quality of information used in modeling, and in decision making. Additionally, collection of pumping data is useful for tracking the effectiveness of the proposed demand reduction PMAs.

Future of the Basin

This project would entail developing a study of the economic impacts of the projects and management actions included in the GSP. This would include an evaluation of how implementation of the project could affect the economic health of the region and on local agricultural industry. It would also consider the projected changes to the region’s land uses and population and whether implementation of these projects would support projected and planned growth. While an agricultural economic analysis considering groundwater regulation has been completed (see Appendix 5-D) and provides a good starting point, additional work is needed.

Chapter 5

IMPLEMENTATION

Groundwater management has been conducted in the Butte Valley groundwater basin (Basin) for decades. As described in prior sections, a variety of project and management actions (PMAs) are currently, or have previously been, implemented, that support groundwater levels, groundwater storage and interconnected surface waters (ISW). Existing and planned PMAs will contribute to the attainment of the groundwater sustainability goal in the Basin over the planning horizon of this Groundwater Sustainability Plan (GSP). These PMAs, as described in Chapter 4, enable the continued use of groundwater and protection of groundwater uses and users into the future.

In this section, the GSP implementation plan for the Basin is defined. Elements of this plan include:

1) **Management and Administration**
    a. GSA management, administration, legal and day-to-day operations.
    b. Reporting, including preparation of annual reports and five-year evaluations and updates.
2) **Implementation**
    a. Implementation of the GSP monitoring program activities described in Chapter 3.
    b. Technical support, including model updates, data collection and other technical analysis.
    c. PMAs as described in Chapter 4.
3) **Outreach and Education**
    a. Coordination activities with stakeholders and entities in the Basin.
    b. Ongoing outreach activities to stakeholders.

Cost estimates and funding methods for GSP implementation are also presented in this section.

5.1. DESCRIPTION OF GSP IMPLEMENTATION ELEMENTS

The following tasks and functions will be required for implementation of this GSP:

5.1.1 Management and Administration

GSA Management, Administration, Legal and Day-to-Day Operations

GSA functions associated with the management and administration of the GSP implementation activities are covered under this category, which includes the administrative, technical and finance staff support and related expenses, office supplies and materials, insurance, and grant writing to support funding for specific projects and/or management actions. GSA staff will provide work products, administrative support, staff leadership, and management for the GSA.

As the GSP implementation begins in February 2022, staffing support and ongoing administrative and management needs will be further evaluated so that the budget can be refined, as necessary. Staffing needs will be reevaluated annually during the early years of GSP implementation to gain a better understanding of the support required and associated costs.

GSA administration activities include coordination meetings with other organizations on projects or studies, email communications for updating GSA stakeholders about ongoing activities within the Basin, administration of projects implemented by the GSA, and general oversight and coordination. Other oversight and administrative activities will occur on an as-needed basis.

The GSA is responsible for, and authorized to take, appropriate action to achieve sustainable management of groundwater within the Basin based on the authority granted under Section 6 of the California Water Code. On an as-needed basis, the GSA may seek legal services to assist in the interpretation of legal requirements and provide legal advice during GSP implementation.