Tule Lake Subbasin

Groundwater Sustainability Plan

Amendment 1

DRAFT

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Only updated appendices have been included in the public redline draft

List of Acronyms and Abbreviations

1902 Act	1902 Reclamation Act	MTMOU	Minimum ThresholdMemorandum of Understanding
2017 Standard Criteria	Water Management Plan 2017 Standard Criteria	NCCAGMT	Natural Communities Commonly Associated with GroundwaterMinimum Threshold
AB	Assembly Bill	NGSNCCAG	National Geodetic SurveyNatural Communities Commonly Associated with Groundwater
AEM	Airborne Electromagnetic	NOINGS	Notice of IntentNational Geodetic Survey
BMP	Best Management Practices	PWSNOI	Public Water SystemNotice of Intent
CASGEM	California Statewide Groundwater Elevation Monitoring	ReclamationPWS	U.S. Bureau of Reclamation Public Water System
CDFW	California Department of Fish and Wildlife	SBReclamation	Senate BillU.S. Bureau of Reclamation
Core Team	Tule Llake Subbasin GSP Core Team	SDACSB	Severely Disadvantaged CommunitySenate Bill
DAC	Disadvantaged Community	SGMA	Sustainable Groundwater Management Act
DEW	Drier Extreme Warming	SMC	Sustainable Management Criteria
DWR	California Department of Water Resources	SMCLSGMA	Secondary Maximum Containment LevelSustainable Groundwater Management Act
ESA	Endangered Species Act	SNMPSMC	Salt and Nutrient Management PlansSustainable Management Criteria
GAMA	Groundwater Ambient Monitoring and Assessment Program	SWNSMCL	State Well NumberSecondary Maximum Containment Level
GDE	Groundwater Dependent Ecosystems	SWRCBSNMP	State Water Resources Control BoardSalt and Nutrient Management Plans
GPS	Global Positioning System	TAFSWN	Thousand Acre FeetState Well Number
GSA	Groundwater Sustainability Agency	TDSSWRCB	Total Dissolved SolidsState Water Resources Control Board
GSP or Plan	Groundwater Sustainability Plan	TIDTDS	Tulelake Irrigation DistrictTotal Dissolved Solids
GWMP	Groundwater Management Plan	TLNWRTID	Tule Lake National Wildlife RefugeTulelake Irrigation District
HCM	Hydrogeologic Conceptual Model	TNCTLNWR	The Nature ConservancyTule Lake National Wildlife Refuge
ILRP	Irrigated Land Regulatory Program	TSSTNC	Technical Support ServicesThe Nature Conservancy
InSAR	Interferometric Synthetic Aperture Radar	UKLTSS	Upper Klamath LakeTechnical Support Services
KBNWR	Klamath Basin National Wildlife Refuge	USFWS	U.S. Fish and Wildlife Service
KID	Klamath Irrigation District	USGSUKL	U.S. Geological SurveyUpper Klamath Lake

KPDRA	Klamath Project Drought Response Agency	UTM~~USGS~~	Universal Transverse Mercator~~U.S. Geological Survey~~
KWAPA	Klamath Water and Power Agency	VOC~~UTM~~	Volatile Organic Compounds~~Universal Transverse Mercator~~
LKNWR	Lower Klamath National Wildlife Refuge	WCR~~VOC~~	~~Volatile O~~Well Completion Report~~rganic Compounds~~
LRDC	Lost River Diversion Channel	WDL~~WDL~~	Water Data Library~~Water Data Library~~
MCL	Maximum Containment Level	WMP~~WMP~~	Water Management Plan~~Water Management Plan~~
MCLG	Maximum Containment Level Goal	WQ~~WUMP~~	Water Quality~~Water User Mitigation Program~~
M&I	Municipal & Industrial	WUMP	Water User Mitigation Program
MO	Measurable Objective	Zoning Plan	Siskiyou County Zoning Plan
MOU	Memorandum of Understanding		

Executive Summary

Introduction

On September 16, 2014, Governor Jerry Brown signed into law a three-bill legislative package, composed of Assembly Bill (AB) 1739 (Dickinson)~~;~~, Senate Bill (SB) 1168 (Pavley)~~;~~ and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA), which is codified in Section 10720 et seq. of the California Water Code. The purpose of this Groundwater Sustainability Plan (GSP or Plan) is to bring the Klamath River Valley – Tule Lake Subbasin (Tule Lake Subbasin or Subbasin), a medium priority basin, into sustainable groundwater management by 2042, which would meet the requirements of SGMA.

Sustainability Goal and Agency Information

The sustainability goal for the Tule Lake Subbasin is to ensure that by 2042 the Subbasin is being locally managed and operated in order to maintain a reliable water supply for current and future beneficial uses, without causing undesirable results.

There are four Groundwater Sustainability Agencies (GSAs) in the Tule Lake Subbasin: the Tulelake Irrigation District (TID) GSA, the Modoc County GSA, the Siskiyou County GSA, and the City of Tulelake GSA. Collectively, these four GSAs will be referred to as “GSAs”. Figure ES-1Figure 1-1 shows the location of the Tule Lake Subbasin and the GSAs.

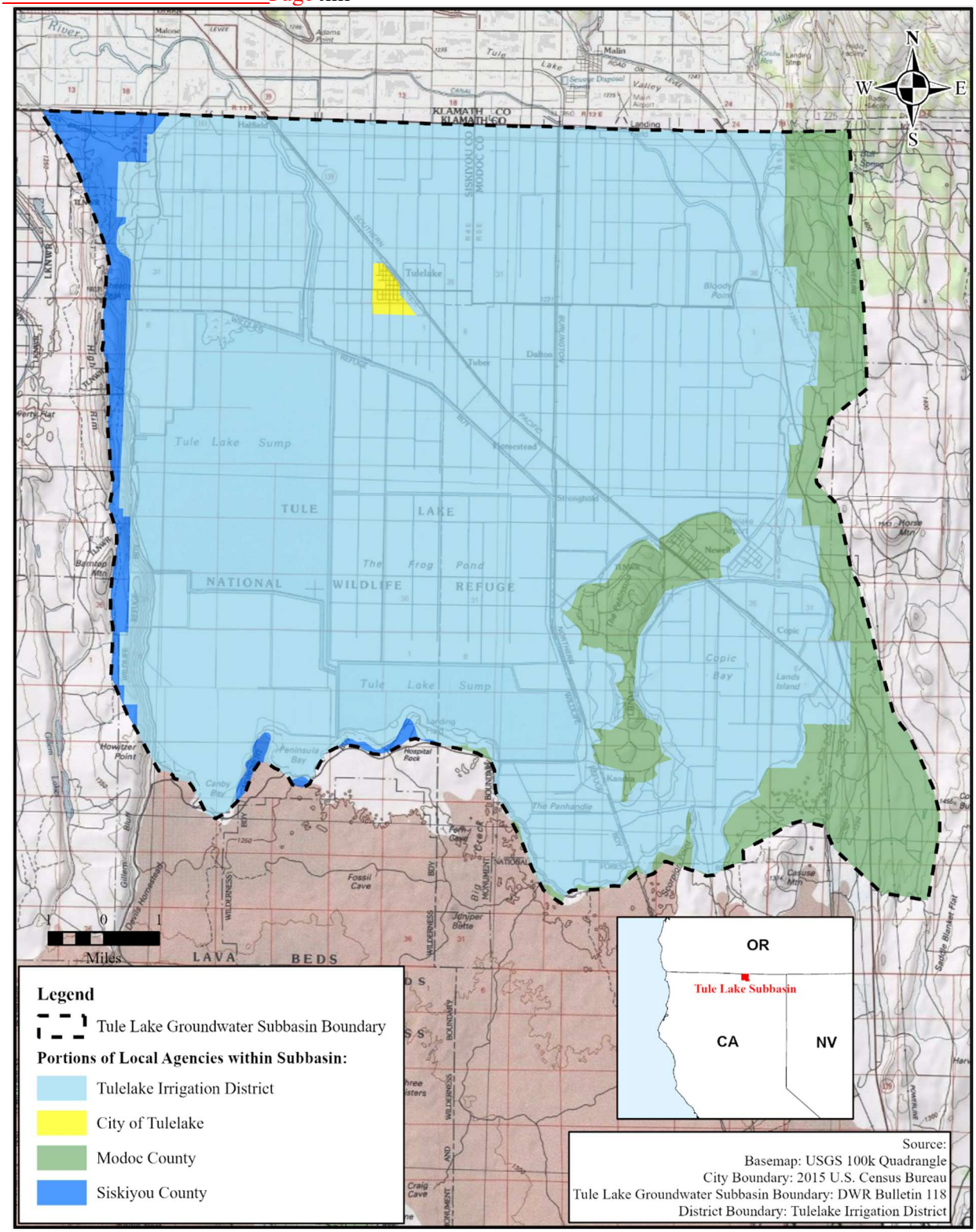


Figure ES-1. Location of the Groundwater Sustainability Agencies within the Tule Lake Subbasin

Plan Area

This GSP covers the entire Tule Lake Subbasin, which comprises approximately 64,000 acres of irrigated land near the California-Oregon border. The Subbasin is part of the larger Upper Klamath Basin, which extends into Oregon, and is located within the North Coast Hydrologic Region. The Subbasin is within Modoc County and Siskiyou County, which have been respectively identified as "Sseverely Ddisadvantaged Communities" and "dDisadvantaged" Ceommunities". The majority of land in the Subbasin is also in TID, which covers approximately 84% of the Subbasin. As the most prominent public agency within the Subbasin, TID has been the primary GSA responsible for recent planning activities.

TID provides surface water to its customers; however, both TID and many a lot of the landowners also have private irrigation wells, which are used when surface water is limited. The City of TulelakeTulelake and the Town of Newell (served by the Newell County Water District) rely exclusively upon groundwater to serve their customers, while residents outside of the City of Tulelake and Newell County Water District service areas rely upon domestic wells for their water supply. Therefore, the entire population of approximately 2,400 people are dependent on groundwater for domestic purposes.

Hydrogeologic Conceptual Model

The Tule Lake Subbasin is located within the Upper Klamath Groundwater Basin, which is approximately 8,000 square miles, and is located in South Central Oregon and northeastern California on the east side of the Cascade Mountain Range. The Subbasin is bounded to the east and west by fault zones, to south by low-lying volcanic fields, and to the north by faults along a mountain block. For the purposes of SGMA and this GSP, the Subbasin is bounded to the north by the state boundary of Oregon and California, as shown in Figure 2-11.

In general, two aquifer principal aquifer systems have been identified in the Subbasin – the alluvial aquifer system, or shallow aquifer, and the volcanic aquifer system, or deep aquifer. The alluvial aquifer system (primary aquifer) consists of surficial deposits. that extend to over 1,000 feet deep in the center of the basin. The volcanic aquifer system consists of the Upper, Intermediate, and Lower basalt units, as well as pyroclastic and tuffaceous deposits. The volcanic units of the Subbasin comprise the bedrock and produce groundwater through fractures and voids. In locations throughout the Subbasin, the volcanic units may be interbedded with basin fill deposits (DWR, 2002).

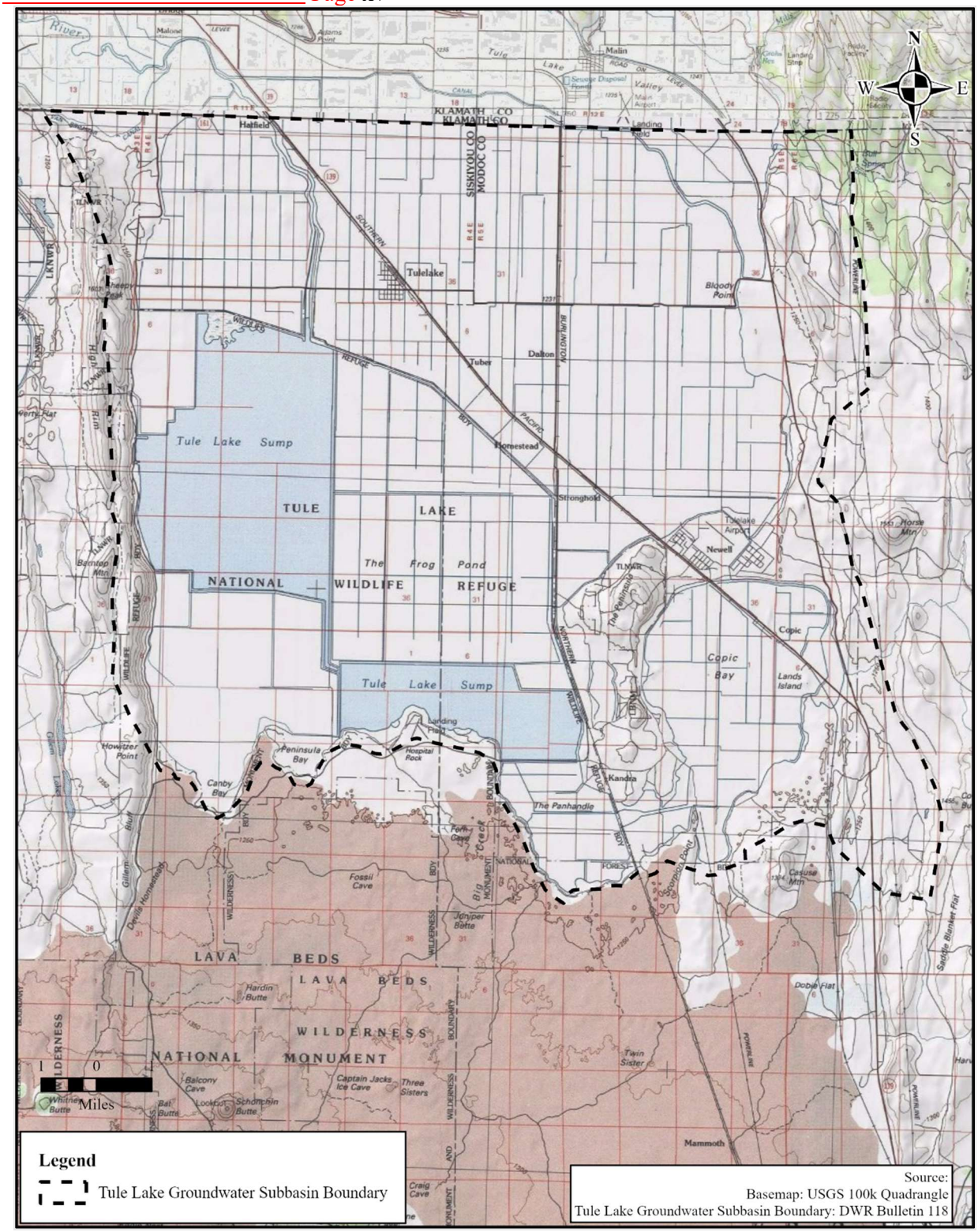


Figure ES-2. Tule Lake Subbasin Boundary

Groundwater Conditions

The main source of water within the Subbasin is surface water from the Klamath River. The water is made available to TID from the Klamath Reclamation Project for irrigation purposes through an intertie between the Klamath River and the Lost River. TID also receives tailwater from Klamath River water users located north of the California-Oregon Stateline. At times, the Lost River provides some surface water to TID. Groundwater is pumped for uses other than irrigation, and to meet irrigation demands when not enough surface water supply is available. Groundwater levels within the Subbasin partially fluctuate, ~~partially~~ as a result of the amount of surface water delivered to TID. Since 2001, the reduction in available surface water supplies has resulted in an increase in groundwater extraction within the Klamath Reclamation Project, including the GSP area. As a result, recent trends in groundwater elevation are reflective of not only climatic conditions and surface water recharge, but also the generally increased (although varying) levels of annual groundwater extraction.

The quality of groundwater in the Subbasin is suitable for current uses. Public Water Suppliers rely on groundwater ~~as~~ because it is their water source in the Subbasin. Therefore, it is important to note that the groundwater supply meets drinking water standards without treatment.

There has been no documented inelastic subsidence within the Subbasin to date. However, some elastic subsidence is noted annually in response to seasonal groundwater level fluctuations.

Surface water presence in the Subbasin is dependent upon deliveries of water by the U. S. Bureau of Reclamation (Reclamation) from the Klamath Project. Within the Subbasin, surface water systems include the small reach of the Lost River ~~which~~ that extends into the Tule L~~l~~ake area and the “Sumps”. As part of Reclamation’s Klamath Project this system is highly regulated, and flows in the Lost River and water levels within the Sumps are dependent on surface water deliveries made available by Reclamation from the Klamath Project. The section of the Lost River within the Subbasin is referred to as the lower Lost River Improved Channel. Flow in this section is dependent on spill of Klamath Project water at the Anderson-Rose Dam during the irrigation season. Therefore, it is generally considered an irrigation channel and not a natural river channel.

The Natural Communities Commonly Associated with Groundwater (NCCAG) database was used to identify plants commonly associated with groundwater use and to determine potential groundwater dependent ecosystems (GDE). Most NCCAGs are located adjacent to canals or other water delivery facilities, and are assumed to be dependent on surface water; however, remaining assumed GDEs will be verified through field investigations.

Monitoring Networks

Groundwater levels and water quality in the Subbasin have been monitored by the GSAs and other local, state, and federal agencies. Beginning in the 1980s, groundwater elevation data have been collected by the California Department of Water Resources (DWR) and the U.S. Geological Survey (USGS) within the GSP area. Prior to 1999, DWR monitored groundwater elevations in five wells twice each year (spring and fall). In 1999, an expanded groundwater monitoring program was developed through a contract

with Reclamation to increase the monitoring well network from five wells to thirty-five (35) wells. By the mid-2000s, the monitoring well network had expanded to an average of seventy (70) wells, monitored on a monthly basis within the Subbasin, and an adjacent nearby subbasin (the Lower Klamath Subbasin).

A total of 1315 wells were selected for the representative groundwater level monitoring network, based on their spatial distribution throughout the Subbasin and their construction/screening details. The representative groundwater level monitoring network is the network that is used to monitor chronic lowering of groundwater levels, and changes in storage, and land subsidence. Appendix N outlines four open GeoTracker sites that are currently being monitored by the State Water Resources Control Board (SWRCB). Because Outside of these areas there are no known areas of degraded water quality or contaminant plumes which need to be actively monitored., The water quality monitoring network relies on existing wells used for monitoring water quality within the Subbasin, which are public water supply wells.

The data from the wells within the monitoring networks will continue to build on existing data to track short-term, seasonal, and long-term trends in groundwater and related surface conditions. The monitoring network, through evaluation of changes in groundwater levels, will support estimates of annual changes in water budget components.

Water Budget Information

To prepare water budgets for the Subbasin, an integrated groundwater/surface water flow model of the area encompassing the Subbasin in portions of Siskiyou and Modoc counties in California, andwhich extendsing to the north of the Subbasin within Klamath County, Oregon, was developed. The model integrates the threethree-dimensional groundwater and surface-water systems, land surface processes, and water management operations. Development of this model included the assimilation of information on land use, water infrastructure, hydrogeologic conditions, and agricultural water demands and supplies.

Table ES-1 presents the groundwater budget for the historical, current, projected baseline, and projected with--climate -change scenarios. Based on information from the historical water budget, the sustainable yield of the Subbasin is estimated to be approximately 48,00057,000 acre-feet. The Subbasin is known to experience annual fluctuations in groundwater levels, which generally depends on hydrology and surface water supply available from the Klamath Project. These fluctuationsis will continue into the future; however, current projections indicate that the Subbasin will remain sustainable.

Table ES-1. Water Budget Summary

Groundwater Budget Term	Historical	Current	Projected Baseline	Projected w/ Climate Change
	2000 - 2018 2025 Avg (TAF)	2018 - 2025 (TAF)	2019 2026 - 2071 Avg (TAF)	2019 2026 - 2071 Avg (TAF)
Groundwater Recharge from Precipitation & Applied WaterGroundwater Recharge from Precipitation & Applied Water	5859	5280	5659	5363
Groundwater Recharge from Canal Laterals	47	49	44	44
Groundwater Recharge from Tulelake Sumps	10	9	11	12
Groundwater Recharge from Main CanalsCanal Laterals Leakage	6492	6693	6493	6493
Groundwater Recharge from Lost RiverTulelake Sumps Leakage	75	57	96	96
Subsurface Inflow from Surrounding AreaMain Canals and Lost River Leakage	1763	1772	1766	1666
Total Inflow Subsurface Flow Into Subbasin	**20317**	**19817**	**20115**	**19814**
Irrigation & M&I Groundwater Pumping**Total Inflow**	8236	11268	8238	8242
Private Agricultural PumpingIrrigation & M&I Groundwater Pumping	5042	5727	6342	7242
Groundwater Discharge to DrainsPrivate Groundwater Pumping	1376	1205	1176	1026
Shallow Groundwater EvapotranspirationGroundwater Discharge to Drains	2171	1192	1165	1165
Groundwater Discharge to Tulelake SumpsShallow Groundwater Evapotranspiration	05	04	05	05
Groundwater Discharge to Main CanalsGroundwater Discharge to Tulelake Sumps	00	00	00	00
Groundwater Discharge to Lost RiverGroundwater Discharge to Main Canals and Lost Rivers	02	02	01	01
Subsurface Outflow to Surrounding AreaSubsurface Flow Out of Subbasin	1014	1321	1220	1822
Total Outflow**Total Outflow**	**207240**	**202251**	**201238**	**201242**
Change in StorageChange in Storage	-4-4	-417	00	-30

Sustainable Management Criteria and Sustainability Goal

The GSPs sustainable management criteria isare used to define conditions that constitute sustainable groundwater management for the Subbasin, which includes the sustainability goal;, undesirable results;, and the minimum thresholds for each applicable sustainability indicator. The entirety of the Subbasin is identified as either a Disadvantaged Community or a Severely Disadvantaged Community, and the primary use of water in the Subbasin is for agricultural purposes. Therefore, the sustainability goal for the Tule Lake Subbasin is to maintain a locally governed, economically viable, reliable, and sustainable groundwater subbasin for current and future beneficial uses, without causing undesirable results.

Undesirable Results, Measurable Objectives, and Minimum Thresholds were defined for each of the Sustainability Indicators, which includes:

- Chronic Lowering of Groundwater Levels
- Depletion of Interconnected Surface Water
- Degraded Water Quality
- Land Subsidence
- Seawater Intrusion (not applicable to Tule Lake Subbasin)
- Reduction in Groundwater Storage

Sustainable Management Criteria established for chronic lowering of groundwater levels will be used as a proxy for depletion of interconnected surface water, land subsidence, and for the reduction in groundwater storage.

Projects and Management Actions

The Tule Lake Subbasin is currently being sustainably managed. Therefore, no projects or management actions are required to achieve sustainability; however, the Tule Lake Subbasin GSAs have identified projects and management actions that can improve their understanding of the groundwater subbasin. Due to the standing of the subbasin, these projects and management actions are intended to help reduce or eliminate data gaps identified throughout this GSP and will be implemented based on the availability of resources and funding.

Projects and management actions that have currently been proposed include the development of a well inventory, construction of dedicated groundwater monitoring wells, expansion of the water quality monitoring network to include additional wells, potential groundwater dependent ecosystems field investigations, groundwater recharge, domestic well assistance program, and an adaptive management strategy.

Plan Implementation

Implementation of this GSP includes consideration of the implementation costs, the schedule of implementation, reporting, and periodic evaluations. These considerations cover both the projects and

the management actions, as well as non-project and non-management actions that are required in order to successfully implement the Plan. The amendedfinal Plan and Periodic Evaluation will be submitted to DWR no later than January 31, 2027. Following the submittal, there are reporting and periodic evaluation requirements. On at least a quarterly basis, the GSAs plan to hold public meetings in order to discuss the status of the reporting requirements, and the projects and management actions. These meetings will help to ensure that the GSP is implemented, and that the sustainability goal is maintained.

1 Introduction

1.1 Purpose of the Groundwater Sustainability Plan

On September 16, 2014, Governor Jerry Brown signed into law a three-bill legislative package, composed of Assembly Bill (AB) 1739 (Dickinson), Senate Bill (SB) 1168 (Pavley), and SB 1319 (Pavley), collectively known as the Sustainable Groundwater Management Act (SGMA), which is codified in Section 10720 et seq. of the California Water Code. The purpose of this Groundwater Sustainability Plan (GSP or Plan) is to bring the Klamath River Valley – Tule Lake Subbasin (Tule Lake Subbasin or Subbasin), a medium priority basin, into sustainable groundwater management by 2042, which would meet the requirements of SGMA. A GSP wa~~i~~s required to be prepared in order to manage a medium-priority basin by January 31, 2022, and to achieve sustainable groundwater management within the subbasin by 2042. Under SGMA, a GSP is prepared and implemented by a Groundwater Sustainability Agency (GSA).

In the SGMA, sustainable groundwater management is defined as management of groundwater supplies in a manner that can be maintained in planning and implementation phases without causing undesirable results. Undesirable results include significant and unreasonable chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface waters.

1.2 Sustainability Goal

The sustainability goal for the Tule Lake Subbasin is to ensure that by 2042 the Subbasin is being locally managed and operated to maintain a reliable water supply for current and future beneficial uses, without causing undesirable results. More information regarding the Sustainability Goal and the Quantitative Sustainable Management Criteria (SMC) for the Subbasin is in Section 5.

1.3 Agency Information (Reg. § 354.6)

There are four Groundwater Sustainability Agencies (GSAs) in the Tule Lake Subbasin: the Tulelake Irrigation District (TID) GSA, the Modoc County GSA, the Siskiyou County GSA, and the City of Tulelake GSA. Collectively, these four GSAs will be referred to as “GSAs”, all of which are shown in Figure 1-1.

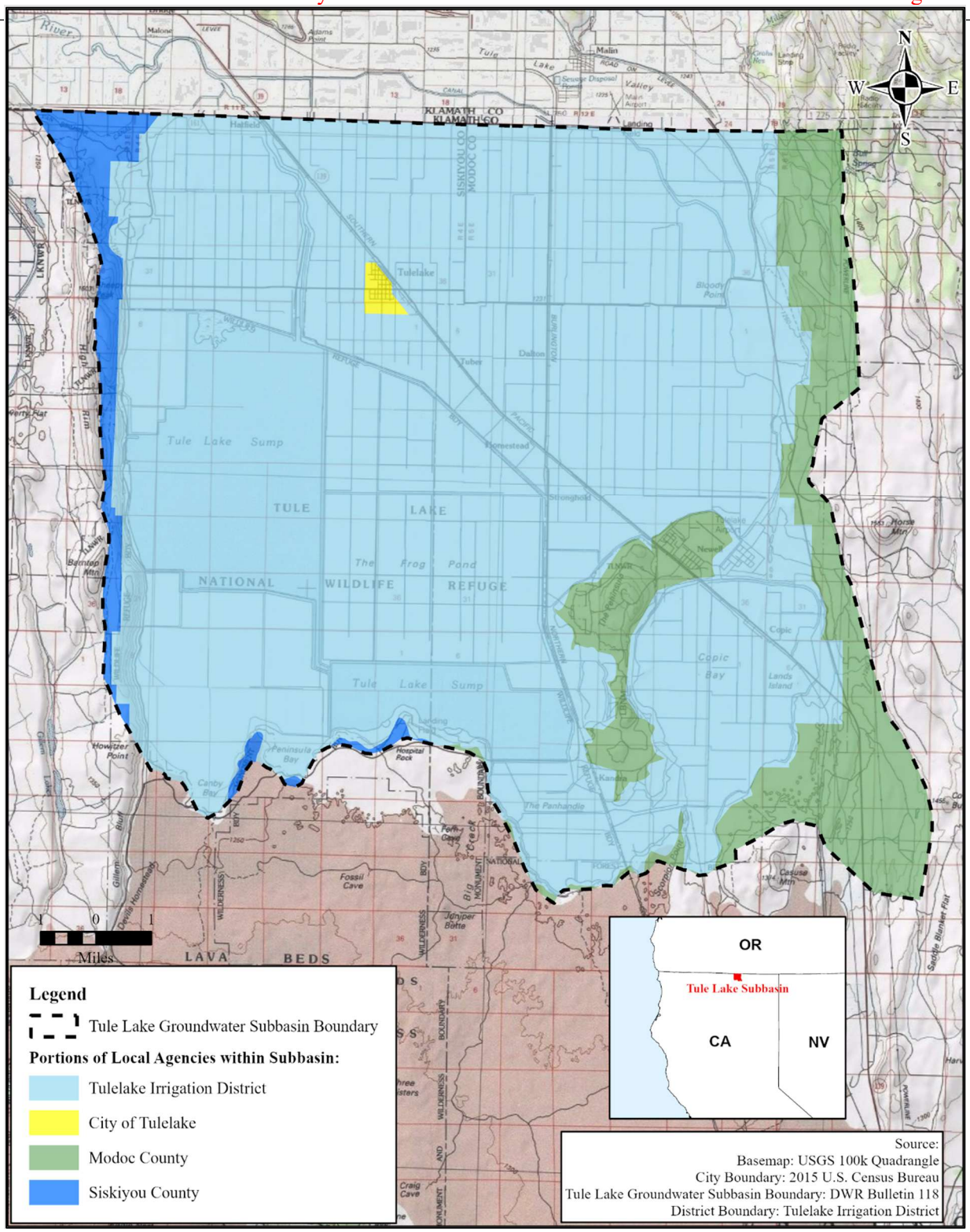


Figure 1-~~1~~1. Location of the Groundwater Sustainability Agencies within the Tule Lake Subbasin~~Tule Lake Subbasin~~

~~A copy of the Initial Notification to develop a Groundwater Sustainability Plan filed by the TID GSA on~~ behalf of the Tule Lake Subbasin is included in Appendix A. Similarly, the Notices of Intent (NOIs) filed by the GSAs to adopt the GSP ~~a~~; the~~,~~ ~~nd the~~ revised GSP~~;~~ and the GSP Amendment 1 are included in Appendix A.

The contact information for each of the GSAs and the GSP Plan Manager is listed below:

Tulelake Irrigation District GSA

The Tulelake Irrigation District GSA consists of the portion of the Subbasin within the boundary of Tulelake Irrigation District. The mailing address for the Tulelake Irrigation District GSA is:

Tulelake Irrigation District GSA
P.O. Box 699
Tulelake, CA 96134

Modoc County GSA

The Modoc County GSA consists of the portion of the Subbasin within the jurisdictional boundary of Modoc County, and outside the boundary of TID. Modoc County meets the requirements of a S~~s~~everely ~~d~~Disadvantaged C~~c~~ommunity (SDAC). The mailing address for the Modoc County GSA is:

Clerk of the Board
204 S. Court Street
Alturas, CA 96101

Siskiyou County

The Siskiyou County GSA consists of the portion of the Subbasin within the jurisdictional boundary of Siskiyou County, and outside the boundary of TID. Siskiyou County meets the requirements of a D~~d~~isadvantaged ~~c~~Community (DAC). The mailing address for the Siskiyou County GSA is:

County Clerk
510 North Main St.
Yreka, CA 96097

City of Tulelake

The City of Tulelake GSA consists of the portion of the Subbasin within the jurisdictional boundary of the City of Tulelake. The mailing address for the City of Tulelake GSA is:

City Clerk
P.O. Box 847
Tulelake, CA 96134

Tule Lake Subbasin GSP Plan Manager

SGMA Regulation § 354.6(c) requires that the GSP provide the contact information for the Plan Manager. The contact information for the Tule Lake Subbasin GSP is:

~~Brad Kirby~~Kraig Beasly
Tulelake Irrigation District GSA
P.O. Box 699
Tulelake, CA 96134
Phone: (530) 667-2249
Email: kbeasly~~bkirby~~@tulelakeid.com

1.3.1 Organization & Management Structure of the Groundwater Sustainability Agency (GSA or Agency)

During August 2017~~,~~ the GSAs executed a "Memorandum of Understanding Regarding Development and Implementation of a Groundwater Sustainability Plan for the Tule L~~l~~ake Groundwater Subbasin" (MOU). The MOU is provided as Appendix B to this document. The MOU established the Tule Lake Subbasin GSP's Core Team (Core Team), comprised of representatives from each GSA, and responsible for directing and coordinating the development~~,~~; financing~~,~~; and implementation of the GSP, and satisfying the requirements of SGMA. In addition, a diverse group of advisory members, who were selected through an application process, informed the Core Team during GSP development and implementation. The advisory members consist of an environmental conservation water user, a residential domestic water user, an agricultural groundwater/surface water user, and an Oregon groundwater/surface water user. The Core Team holds quarterly public meetings to coordinate on Subbasin activities~~,~~ and conditions, and to discuss items, such as Annual Reports;~~,~~ GSP Amendments;~~,~~ Periodic Evaluations;~~,~~ and implementation of projects and management actions. See Appendix C for a list of the advisory members.

1.3.2 Legal Authority of the GSA

Tulelake Irrigation District, Modoc County, Siskiyou County, and the City of Tulelake are local public agencies with existing statutory authorities that each decided to form a GSA. The MOU (Appendix B) between the four GSAs describes the additional authorities provided to the GSAs by SGMA. In addition, the MOU memorialized the GSAs~~'~~ intent to exercise their existing authorities, and those provided by SGMA, in order to develop and implement this GSP.

1.3.3 Estimated Cost of Implementing the GSP and the GSA's Approach to Meet Costs

Development of this GSP was substantially funded through a Proposition 1 Sustainable Groundwater Planning Grant. The implementation of the GSP and future SGMA compliance will be highly dependent upon management actions, if necessary. Costs for management actions will be shared by the GSAs based on action beneficiaries. The primary ongoing cost will be for GSP administration, which includes the development of annual reports and 5-year updates. These costs will be shared by the GSAs in accordance with the budget proportions outlined in the MOU. Implementation of the GSP is estimated

~~to cost from $50,000 to greater than $150,000 per year, depending on the need for projects and~~ management actions.

1.4 GSP Organization

This GSP is organized in a manner consistent with the California Department of Water Resources' (DWR) "Groundwater Sustainability Plan ~~(GSP)~~ Annotated Outline". In addition, during the preparation of this GSP, DWR's "Preparation Checklist for GSP Submittal" was utilized. A completed checklist is provided as Appendix D.

2 Plan Area

2.1 Description of the Plan Area (Reg. § 354.8)

This GSP covers the entire Tule Lake Subbasin, which comprises approximately 64,000 acres of irrigated land near the California-Oregon border. The Subbasin is part of the larger Upper Klamath Basin, which extends into Oregon, and is located within the North Coast Hydrologic Region. The Subbasin is within Modoc County and Siskiyou County. The region is similar to much of the northeastern Plateau area of ~~the State~~California, which is characterized by sparsely populated towns and little industry other than those related to forestry and agriculture. The majority of land in the Subbasin is also in TID, which covers approximately 84% of the Subbasin. As the most prominent public agency within the Subbasin, TID has been the primary GSA responsible for recent planning activities as ~~further~~ described ~~below~~in the following sections. Figure 1-1 shows the location of the GSAs within the Subbasin.

2.1.1 Summary of Jurisdictional Areas and Other Features (Reg. § 354.8b)

Jurisdictional areas and other features, with the exception of the GSAs, include an agricultural water purveyor; a city; an unincorporated town; and public lands. There are no areas within the Subbasin covered by an Alternative Plan.

2.1.1.1 Adjudicated Areas

The Subbasin is located within the southeastern region of the Upper Klamath Basin hydrogeologic region (see Figure 2-1). Currently, the Klamath River water rights for the Klamath Project are being adjudicated by the State of Oregon.

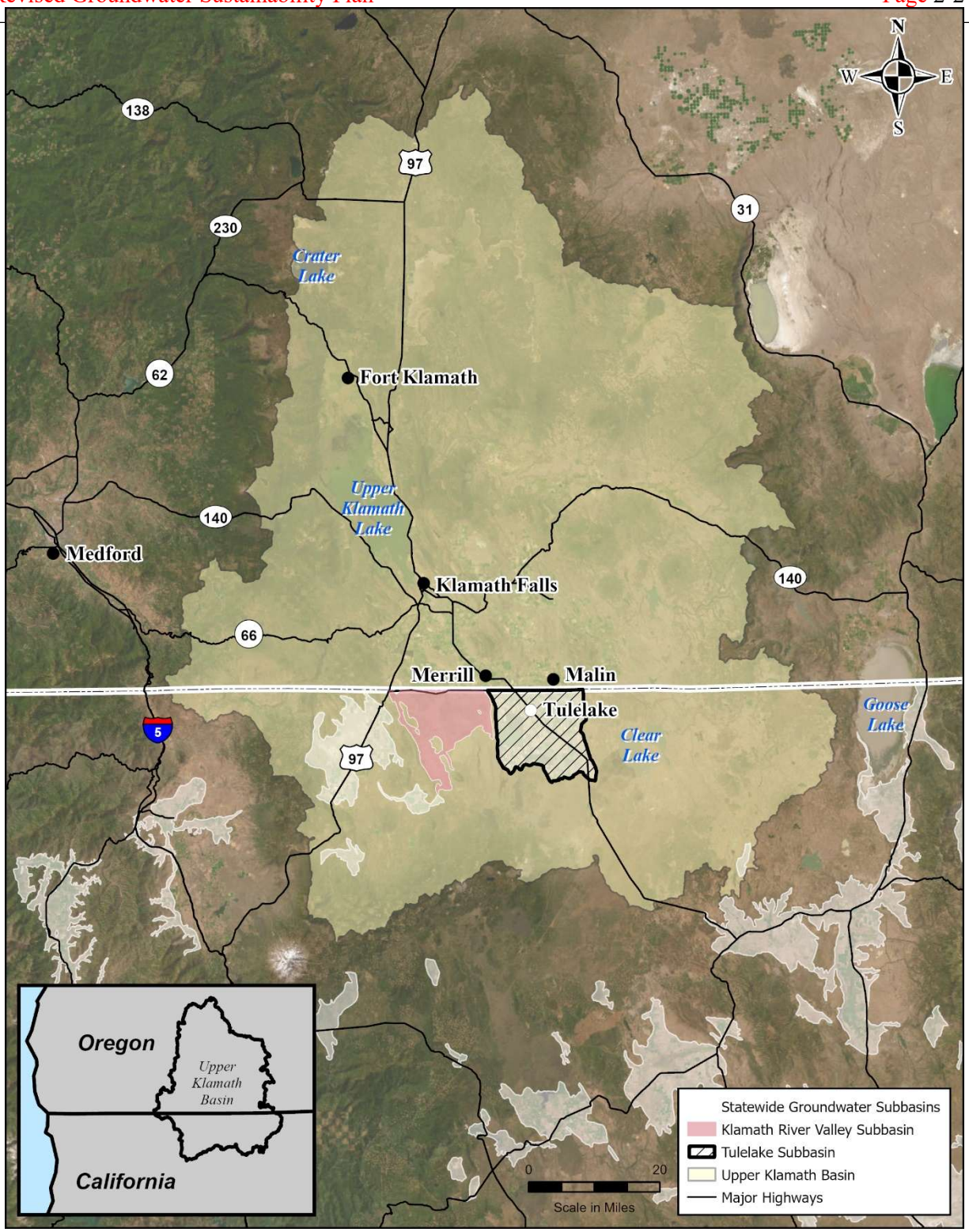


Figure 2-1. Upper Klamath Basin Boundary and Tule Lake Subbasin Boundary

In 1902, Congress enacted the Reclamation Act (1902 Act). Construction of the Klamath Reclamation Project began in 1906. Prior to construction of the Klamath Project, most of the lands located within the

~~current boundary of the TID were submerged during certain times of the year, depending upon~~ hydrologic conditions. The submergence of this land created a body of water known as Tule Lake. In October 1909~~,~~ two outlets were constructed at the southern end of Tule Lake, and the reclamation of lands submerged by Tule Lake began. The draining of Tule Lake continued until 1912, when the level of the lake became too low to continue utilizing the outlets.

Construction of the Klamath Basin Project continued during the early 1900s, and by 1910, Clear Lake Dam was completed. By the spring of 1912, the Lost River Diversion Dam and Channel were complete. These facilities diverted water from the Lost River to the Klamath River and reduced flows into Tule Lake. In 1916, work began on the Tule Lake unit with the construction of distribution and drainage systems for exposed lands along the northern portion of Tule Lake. By 1916, approximately 5,900 acres within the previously submerged region of Tule Lake had been exposed. In 1917, the first Tule Lake lands opened to homestead entry. In 1920, Anderson-Rose Dam was constructed. Work also began on the J-Canal, which was completed in 1923. During the 1920s and 1930s, work on the distribution and drainage systems continued within the Tule Lake area. By 1923, the continued diversion of Lost River water into the Klamath River and diversion for irrigation resulted in approximately 85,000 acres of the previously submerged 90,000 acres of Tule Lake being made available for farming. During the late 1920s, as much as 50,000 acres were being farmed.

Reclaimed lands were made available to settlers and homesteaded under public notices issued from the 1920s to 1940s. Lands were typically leased to private individuals, prior to homestead entry. In 1940, work began on the D-Pumping Plant. This pumping plant and the Tule Lake Tunnel were completed in November 1941. During World War II, about 44,000 acres owned by the United States within Tulelake were leased for farming. The Copic Bay region of Tulelake was opened to homesteading in 1947, and 1948. By the 1950s, about 44,000 acres had been homesteaded.

In 1950, the U.S. Bureau of Reclamation (Reclamation) required the organization of an irrigation district in the Tulelake area. By 1952, Tulelake Irrigation District had been formed and was holding regular meetings. On September 10, 1956, TID entered into a contract with Reclamation for repayment of the construction charges, and to transfer to TID the operation and maintenance of the facilities used to deliver water to lands within the irrigation district. Following the formation of TID and the execution of Contract No. 14-06-200-5954 between TID and the United States, the Tulelake Irrigation District began providing water service to lands within its boundary. Contractually, Reclamation recognizes certain lands within TID as having a higher priority to Klamath Project supplies than other lands. The Tulelake Irrigation District is an active participant in the ongoing Klamath River Adjudication.

Two contracts with irrigation districts in the Klamath Project were made, pursuant to the 1902 Act, and related authority to serve lands in the “Main Division” and “Modoc Division” of the Klamath Project. The “Modoc Division” is in the Tulelake Division, and the contract with TID was made pursuant to the 1902 Act and Section 9(d) of the Reclamation Project Act of 1939, and other legislation. TID’s contract does not specify a duty or rate of diversion. Rather, it provides for the repayment of the construction costs of the Klamath Project by TID, in consideration for the right to divert and deliver to their members that amount of water which can be applied to the crops beneficially and without waste.

The State of Oregon’s water rights were issued through the Final Order of Determination of the Klamath Adjudication. The Final Order of Determination was issued in 2013, with amendments and corrections

~~incorporated during 2014. Following the release of the Final Order of Determination, the adjudicatory~~ judicial process will continue with an uncertain end date. The Tulelake Irrigation District was associated with the consolidated claim (Claim Nos. 321-17, 293, 323-3~~), and~~) and Claims 312 and 317. The claim numbers, description, and associated acreages are summarized in Table 2-1.

Table 2-1. Claims Associated with the Final Order of Determination of the Klamath Adjudication

Claim #	Description/Acres
293	215,559.4 acres agriculture & refuge lands + 15,659.00 acres of inchoate lands
312	35,000 acre-feet of water per year for irrigation of up to a maximum of 10,000 acres per year within a place of use totaling 25,881.7 acres within Lower Klamath National Wildlife Refuge
317	49,902.3 acre-feet of water per year for irrigation of up to a maximum of 16,000 acres per year within a place of use totaling 17,967.3 acres within Tule Lake National Wildlife Refuge (TLNWR)
321-17	178,857.81 acres 3280 cfs from Upper Klamath Lake (UKL), Lake Ewauna, Link River, & Klamath River including the Lost River Diversion Channel (LRDC) & all tributaries to Klamath River
323-3	735,500 acre-feet of storage in UKL, Agency Lake, & Lake Ewauna 18,500 acre-feet

The water rights acquired for the Klamath Project are for the benefit of all Klamath Project lands, including those lands within the Tulelake Irrigation District and the other entities served by the Klamath Project canal system, which are operated and maintained by Klamath Project districts.

As part of the Final Order of Determination, the total amount of water that could be diverted by the combined irrigation system of the Klamath Irrigation District (KID) and the TID was estimated based on the history of the use of water from the combined KID/TID system between 1961 and 2000. The total quantity of water for the KID/TID system includes water delivered to federal lands, namely Tule Lake National Wildlife Refuge, under Claim 317. This estimate includes the March 1 through October 31 season, and the February 15 through November 15 season, recognized for use of water from Station 48 and the No. 1 Drain Gate.

2.1.1.2 Other Agencies Within the Basin and Areas Covered by an Alternative Plan (Reg. § 354.8a)

This GSP, prepared with input from all GSAs within the Subbasin, covers the entirety of the Subbasin. The Subbasin is hydrologically isolated and-, ~~an isolated basin,~~ not immediately adjoined to any other subbasins in California; therefore, no alternative plans have been submitted for any part of the Subbasin or any immediately surrounding subbasin. The Lower Klamath Subbasin is located directly west of the Tule Lłake Subbasin, separated by the Gillems Bluff Fault forming the steep eastern escarpment of Sheepy Ridge (see Figure ~~X-X~~2-1 for Subbasin location).~~A map is not included with this section because there are not any other Agencies or alternative plans within the Subbasin.~~

2.1.1.3 Jurisdictional Boundaries of Federal or State Land (Reg. § 354.8a)

Figure 2-2 shows jurisdictional boundaries of Modoc County, Siskiyou County, the City of Tulelake, and the Unincorporated Community of Newell within the Subbasin. In addition, Westside Irrigation District is identified, which receives delivered water via TID conveyance facilities.

Figure 2-2 also shows the Tule L~~l~~ake National Wildlife Refuge (TLNWR) within the Subbasin. The TLNWR is located within the southwest portion of the TID boundary and totals approximately 40,000 acres, of which approximately 17,300 acres are leased to farmers or farmed by refuge permit holders. Grain, row crop, and alfalfa are typically produced on these lands. These crops, together with the waste grain from the lease program, are a major food source for migrating and wintering waterfowl. The remaining acreage is open water in Sumps 1A and 1B, or permanent or seasonal wetlands~~;~~, or areas of emergent vegetation. The refuge, along with the Lower Klamath National Wildlife Refuge (LKNWR), is located at the downgradient end of Reclamation's Klamath Project. Excess water not used on the refuges is ultimately pumped back into the Klamath River through the Klamath Straights Drain.

Management of the TLNWR is guided by f~~F~~ederal legislation, which requires a coexistence of wetland wildlife habitat and commercial agriculture (USFW, 2013). Klamath Project and other facilities are used to deliver water to ~~Lower Klamath National Wildlife Refuge (~~LKNWR~~)'s~~ and TLNWR's wetlands (including seasonal wetlands, permanent vegetation, and open water areas), sumps, cooperative farming lands, ~~and~~ lease lands, and to walking wetlands within the Klamath Reclamation Project. Walking wetlands are part of a Refuge-approved program that incorporates managed wetlands into agricultural crop rotations on the TLNWR (KBRA, 2010). This program is designed to facilitate mutual benefit between wildlife and agriculture by providing habitat for wildlife during wet years, which also improves soil conditions for cropping years.

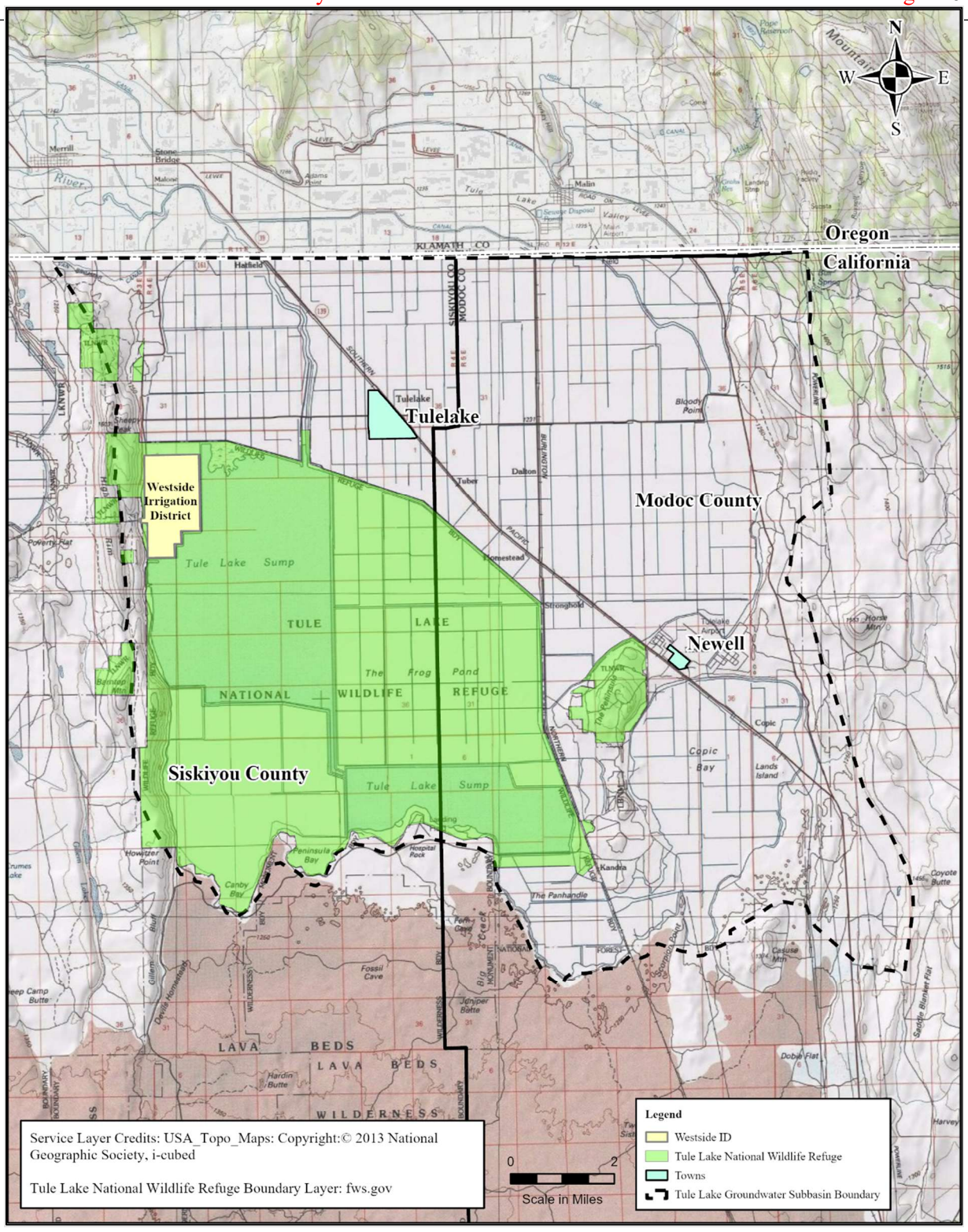


Figure 2-2. Jurisdictional Bboundaries within the Tule Lake Subbasin

2.1.1.4 Existing Land Use Designations (Reg. § 354.8a)

In 2014, DWR contracted with Land IQ to conduct statewide land use surveys using satellite imagery. Based on these data, the Subbasin was approximately 58% agriculture, 12% managed wetlands, and less than 1% urban (Land IQ, 2014). An additional 29% of the land was unclassified, which includes the eastward slopes of Sheepy Ridge, the TLNWR, the Lava Beds National Monument, the area surrounding the Tulelake Municipal Airport, Little Horse Mountain, the mountains on the eastern edge of the Subbasin, and the southeast portion of the Subbasin. All of these areas appear to be undeveloped. The acreage associated with each land use category is shown in Table 2-2.

Table 2-2. Land Use Summary for 2014

Land Use	Acres
Urban	**627**
Urban	627
Managed Wetland	**13,607**
Managed Wetland	13,607
Agriculture	**64,287**
Alfalfa and Alfalfa Mixtures	20,725
Idle	4,035
Miscellaneous Grain and Hay	24,143
Miscellaneous Grasses	430
Miscellaneous Truck Crops	2,244
Mixed Pasture	1,185
Onions and Garlic	2,632
Potatoes and Sweet Potatoes	8,793
Strawberries	101
Unclassified Areas	**32,000**
Sub-basin Acres	**110,521**

The population within the Subbasin is projected to increase by 1% from 2,407 people in 2010 to 2,434 people in 2030 (DWR, 2020a). This minimal increase in population will not result in an appreciable change in urban/domestic water demand in the area.

The plan area consists of approximately 64,000 acres of irrigated land. Crop types within the Subbasin are relatively consistent on a year-to-year basis and include alfalfa, cereal grains, mint, onions, pasture, potatoes, and other miscellaneous crops. Figure 2-3 identifies the cropping pattern from these surveys within the plan area, which provides a general idea of existing land use. These categorizations were

~~focused on distinguishing cropland from other land uses, with less focus on specific subcategories for~~ managed wetlands or other habitats. More information on groundwater dependent ecosystems can be found in Section 2.2.2.9.

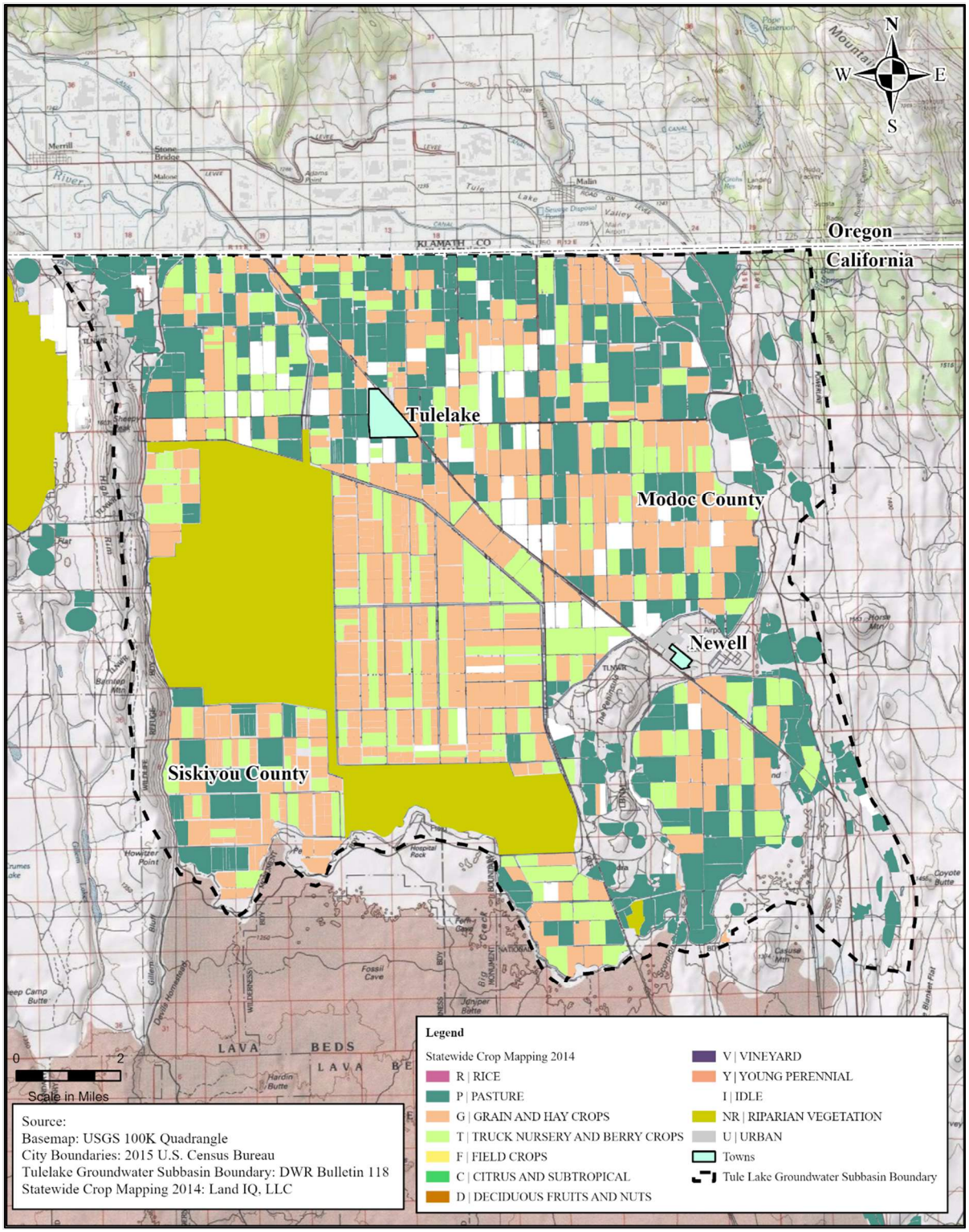


Figure 2-3. Tule Lake Subbasin 2014 Crop Map

2.1.1.5 Identification of Water Use Sector and Water Source Type (Reg. § 354.8a)

As previously stated, the majority of the Subbasin is also located within TID. TID provides surface water to its customers; however, many landowners also have private irrigation wells ~~which~~ that are used when surface water is limited. Both the City of Tulelake and the Town of Newell (served by the Newell County Water District) rely exclusively upon groundwater to serve their customers. In addition, residents outside the City of Tulelake and Newell County Water District service areas rely upon domestic wells for their water supply. Figure 2-4 shows the areas and water source types within the Subbasin.

As mentioned in Section 1.3, the portion of the Subbasin within Modoc County is identified as a S~~s~~severely D~~d~~isadvantaged C~~c~~ommunity and the portion within Siskiyou County is identified as a ~~d~~Disadvantaged C~~c~~ommunity. Therefore, the entire population of approximately 2,400 people within the Subbasin are located within these designations. Figure 2-5 shows the D~~d~~isadvantaged C~~c~~ommunity areas.

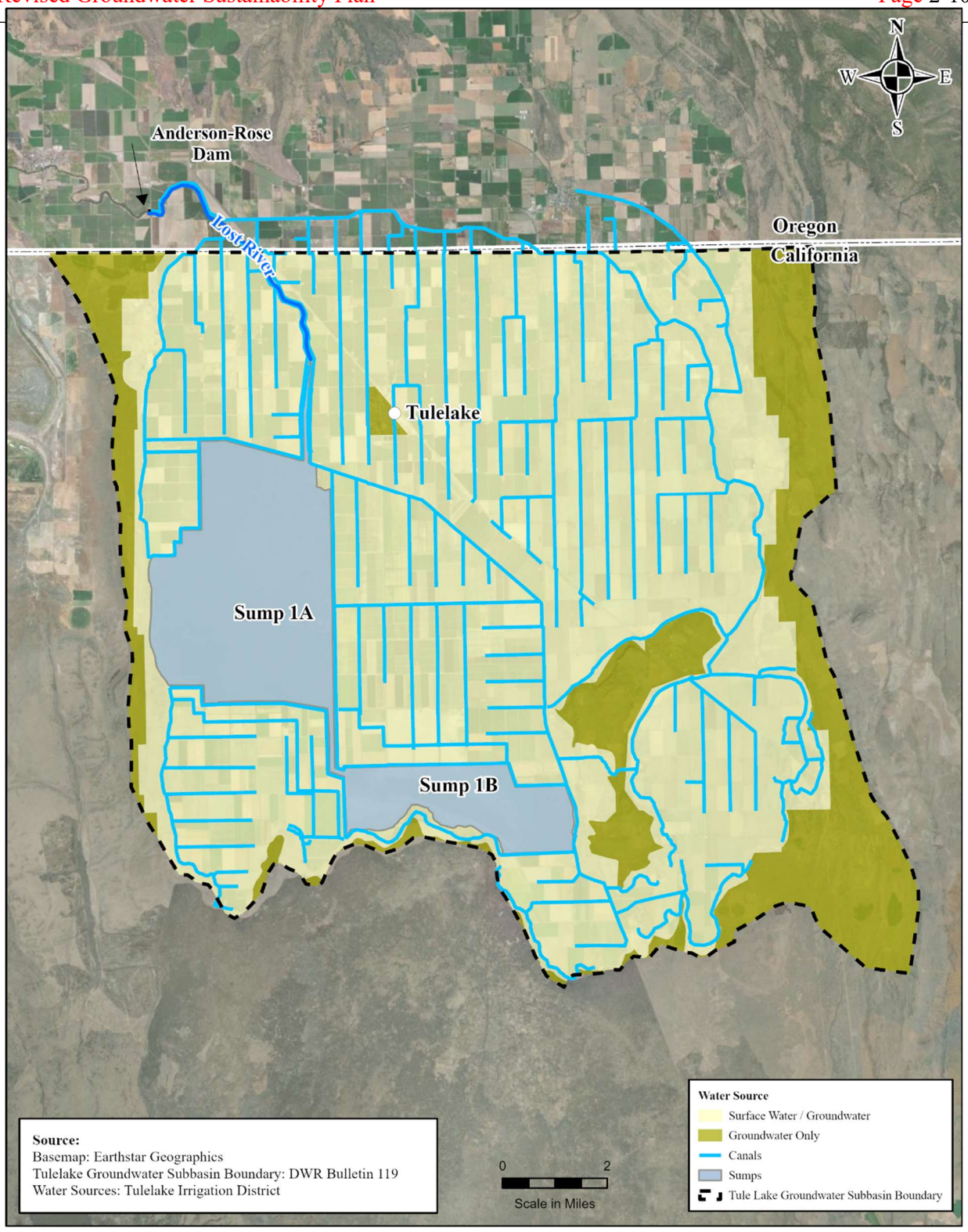


Figure 2-4. Water Source Types

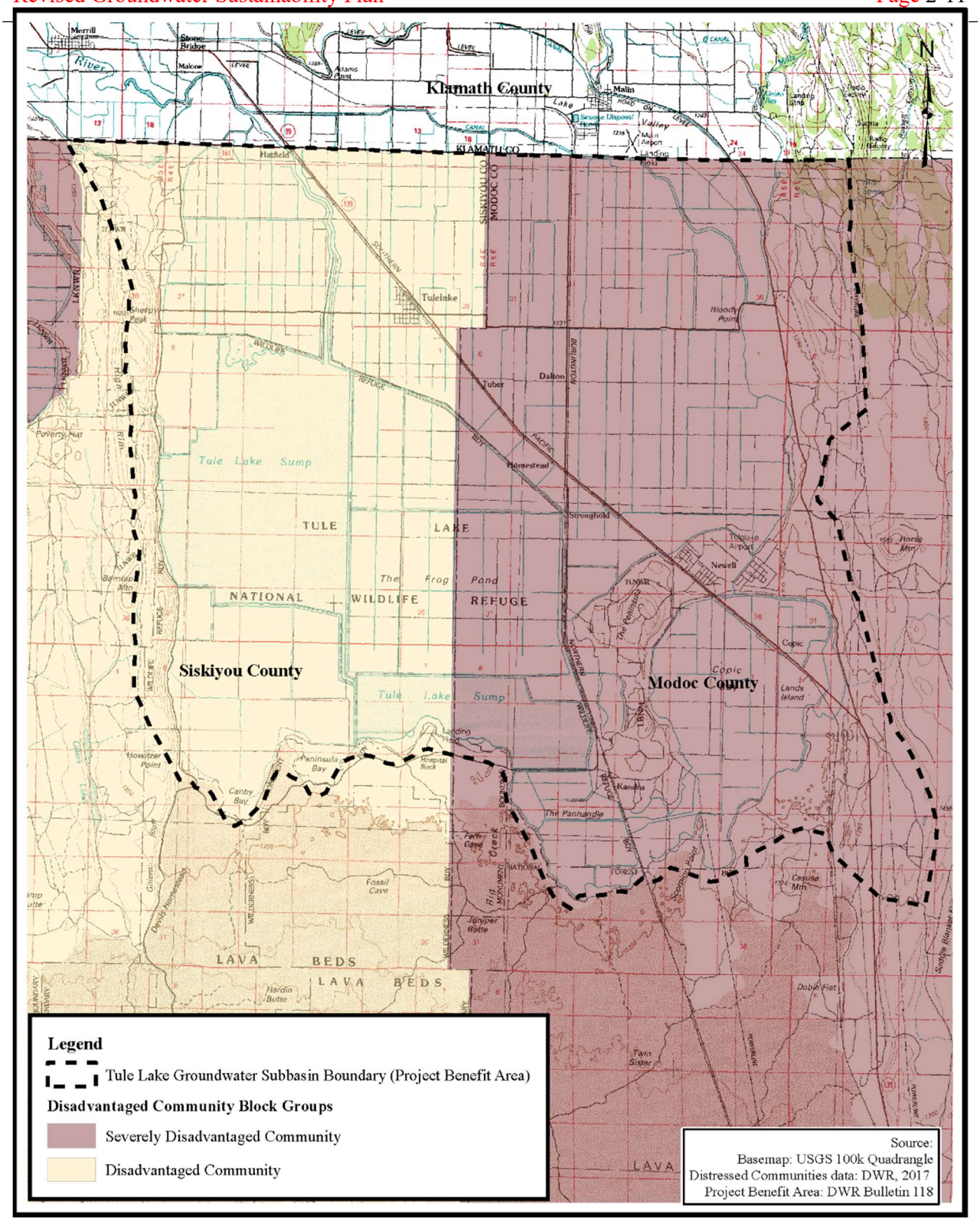


Figure 2-5. Disadvantaged Communities within Tule Lake Subbasin

~~The majority of Tulelake Irrigation District's surface water supply is from the Klamath River, and~~River and is directed to the District through an intertie between the Klamath River and the Lost River, known as the Lost River Diversion Channel ~~(LRDC)~~. Klamath River water is diverted at locations on the LRDC known as Station 48 and the No. 1 Drain during the irrigation season. These diversions provide Klamath River flows to the TID and other water users. TID also receives tailwater from Klamath River water users located north of the California-Oregon State Line, including lands within the Klamath Irrigation District. At times, the Lost River provides some surface water supply during the irrigation season to the TID. The Lost River supply is infrequent and unreliable for irrigation needs.

The Tulelake Irrigation District operates and maintains a diversion dam on the lower Lost River Improved Channel, known as the Anderson-Rose Dam, located less than one-mile north of the California-Oregon State Line. The Anderson-Rose Dam is operated to deliver surface water into the TID's J-Canal, which distributes water to more than one-half of the TID's irrigated lands through turnouts and lateral canals. The J-Canal also conveys water to other canal systems for delivery to additional lands within the TID. Water that is not diverted by TID at Anderson-Rose Dam flows through the lower Lost River Improved Channel and into the Tule Lake Sumps. Water regulated and stored within the Tule Lake Sumps may be diverted or re-diverted for irrigation within TID or discharged by TID's D-Pumping Plant to the P-Canal. This water then becomes available to the ~~Lower Klamath National Wildlife Refuge (~~LKNWR~~)~~ and the water users on the P-Canal system of the Klamath Project. The operational spills and tailwater resulting from irrigation within the Tulelake Irrigation District are conveyed through the TID's extensive drainage system, which utilizes gravity and pumped discharge into portions of the canal system or into the Tule Lake Sumps.

Figure 2-6 identifies the major water conveyance system facilities within the Klamath Project.

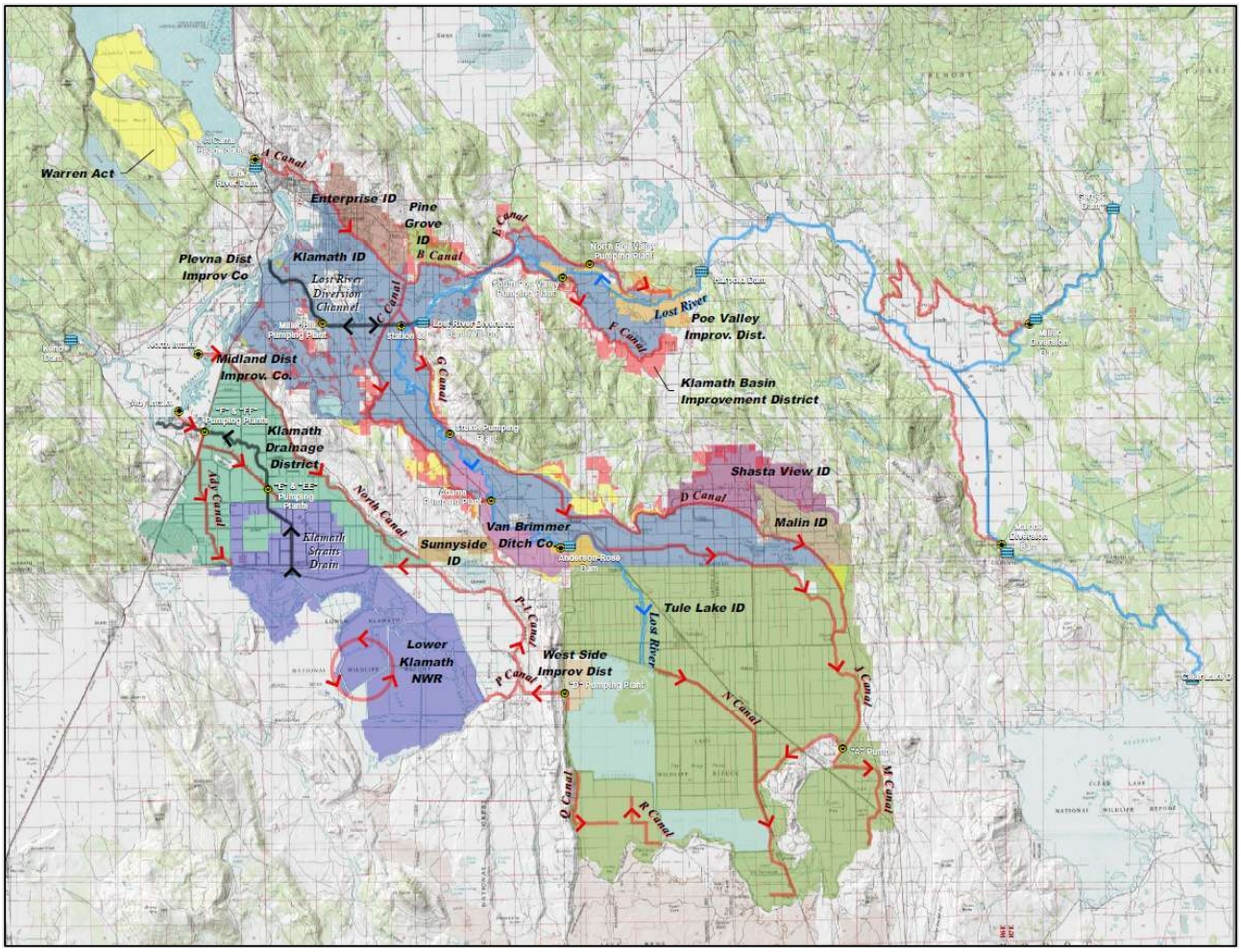


Figure 2-6. Klamath Project Conveyance Facilities

Figure 2-7 identifies the major facilities within the Tulelake Irrigation District, including the conveyance and drainage system.

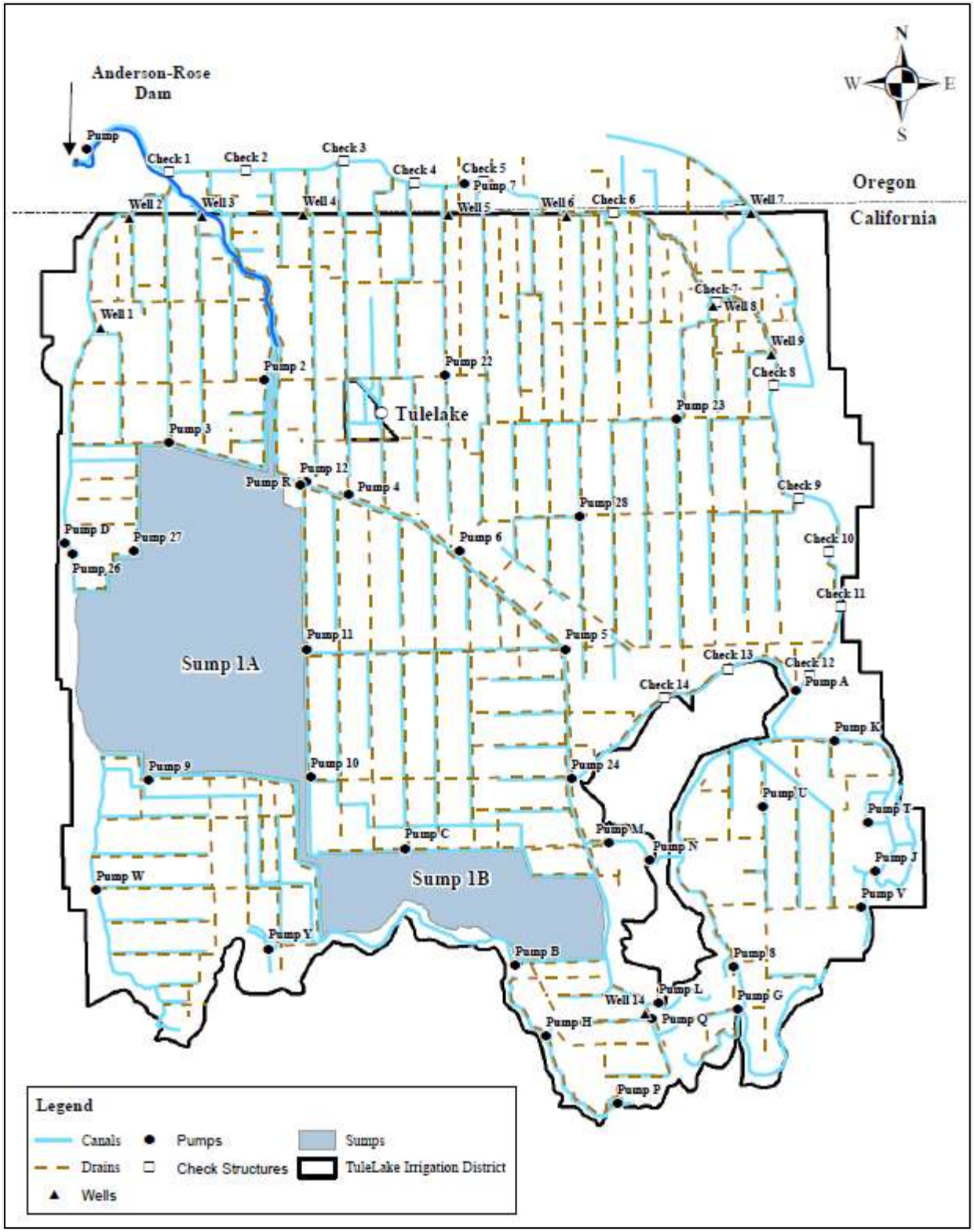


Figure 2-7. District Conveyance and Drainage Facilities

Most of the areas of TID conjunctively use surface water and groundwater. Therefore, in addition to the surface water supply discussed previously, many private landowners within TID own and operate private groundwater wells. In addition, in 2001, TID constructed 10 groundwater wells to provide supplemental water supplies during drier years. Typically, groundwater is only utilized within TID during years where surface water supplies do not meet agricultural demands and represents a small portion of the total water supplies available in any given year.

2.1.1.6 Inventory and Density of Wells per Square Mile (Reg. § 354.8a)

Table 2-3 ~~below~~ provides an inventory of wells within the Tule Lake Subbasin by county and type. DWR maintains a well completion report database, which was utilized to prepare this table.

Table 2-3. Well Inventory

Type of Well	Modoc County Total Wells	Siskiyou County Total Wells
Agricultural	974	196
Industrial	1	4
Monitoring	13	58
Miscellaneous[1]	171	386
Domestic & Public Supply	1098	431
Total	23727	155162

Source: DWR Well Completion Report Database, downloaded ~~January~~ September 2021

[1] This category includes the following planned uses identified in the DWR Well Completion Report Database: Other, Other Destroyed, Other Not Specified, Other Unknown, Injection, Sparging, Test Well, Vapor Extraction

Based on the data from the DWR Well Completion Report Database, there are 39982 wells in the Subbasin, and ~~311~~ 328 of those are assumed to be production wells (i.e., not monitoring wells). It is unknown how many of these wells are actively used or how many of these wells have been abandoned and/or destroyed, as this information is not always reported.

~~I~~Using the information from Table 2-3 was used in ~~,~~ Figure 2-8~~;~~, Figure 2-9~~;~~, and Figure 2-10 identify the density of wells per square mile for agricultural wells~~,~~; industrial/monitoring/miscellaneous wells~~,~~; and domestic wells, respectively. Each of the squares on the figures represent approximately one square mile of land. The color of each square indicates the number of wells within the square.

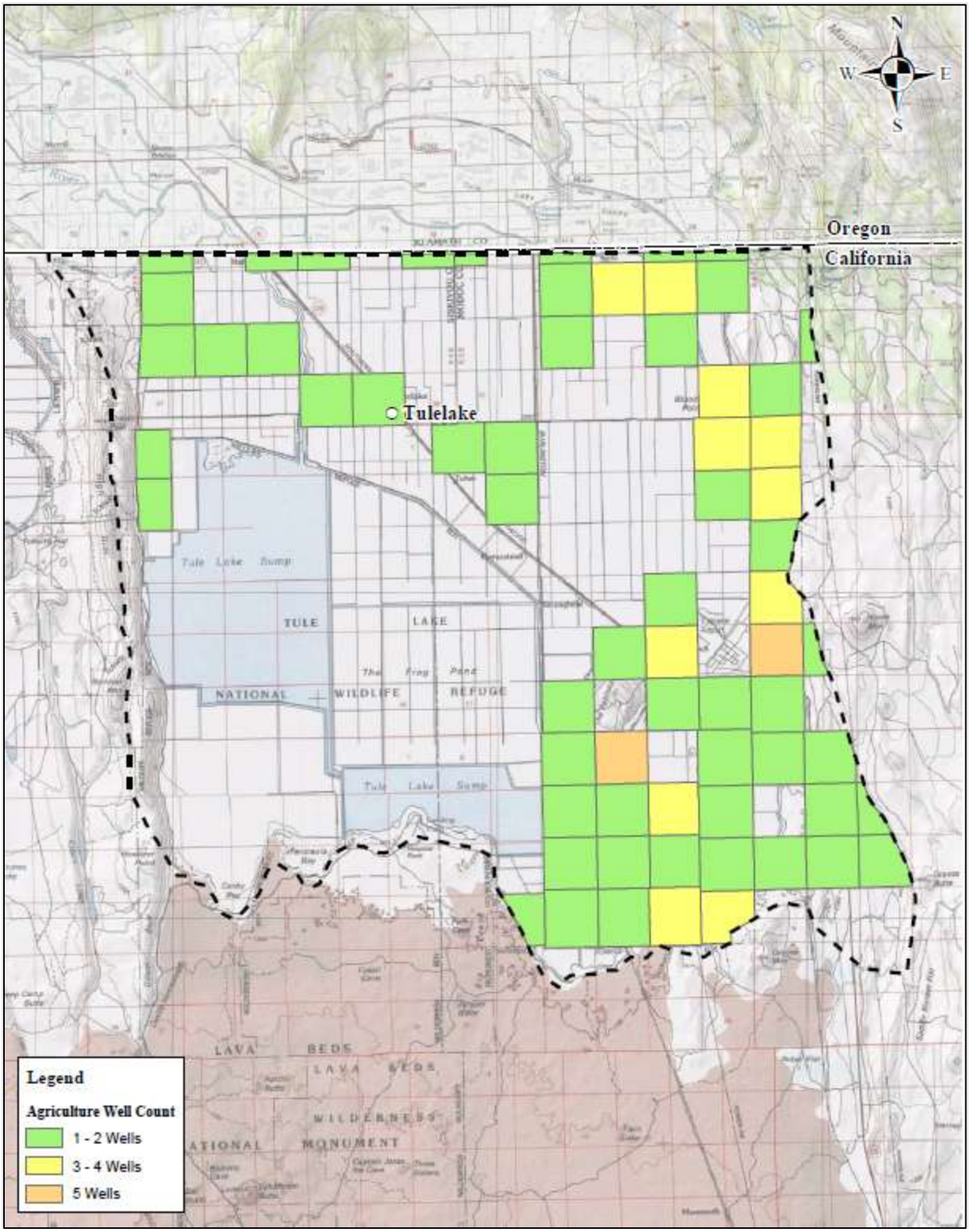


Figure 2-8. Density of Agricultural Wells per Square Mile

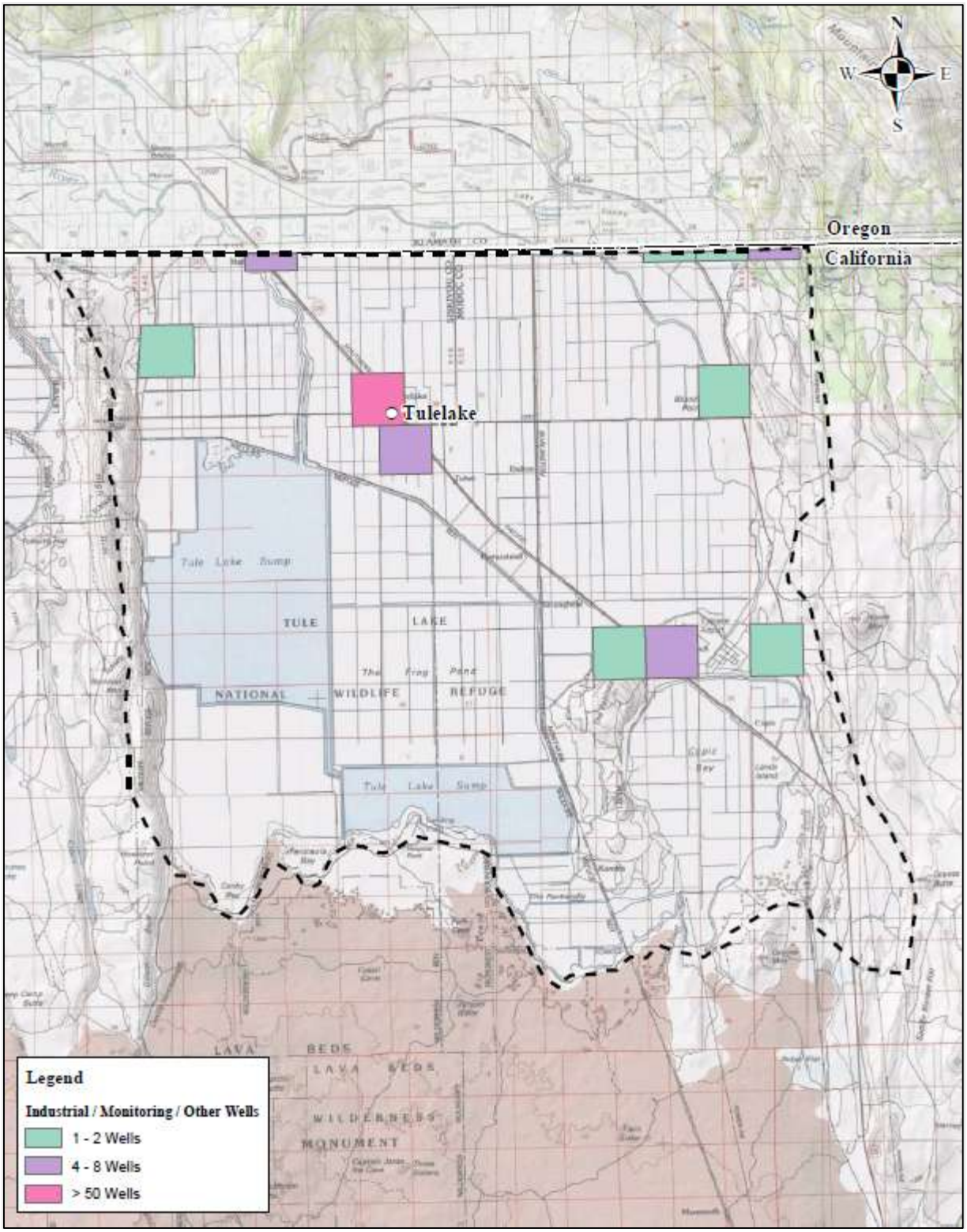


Figure 2-9. Density of Industrial/Monitoring/Miscellaneous Wells per Square Mile

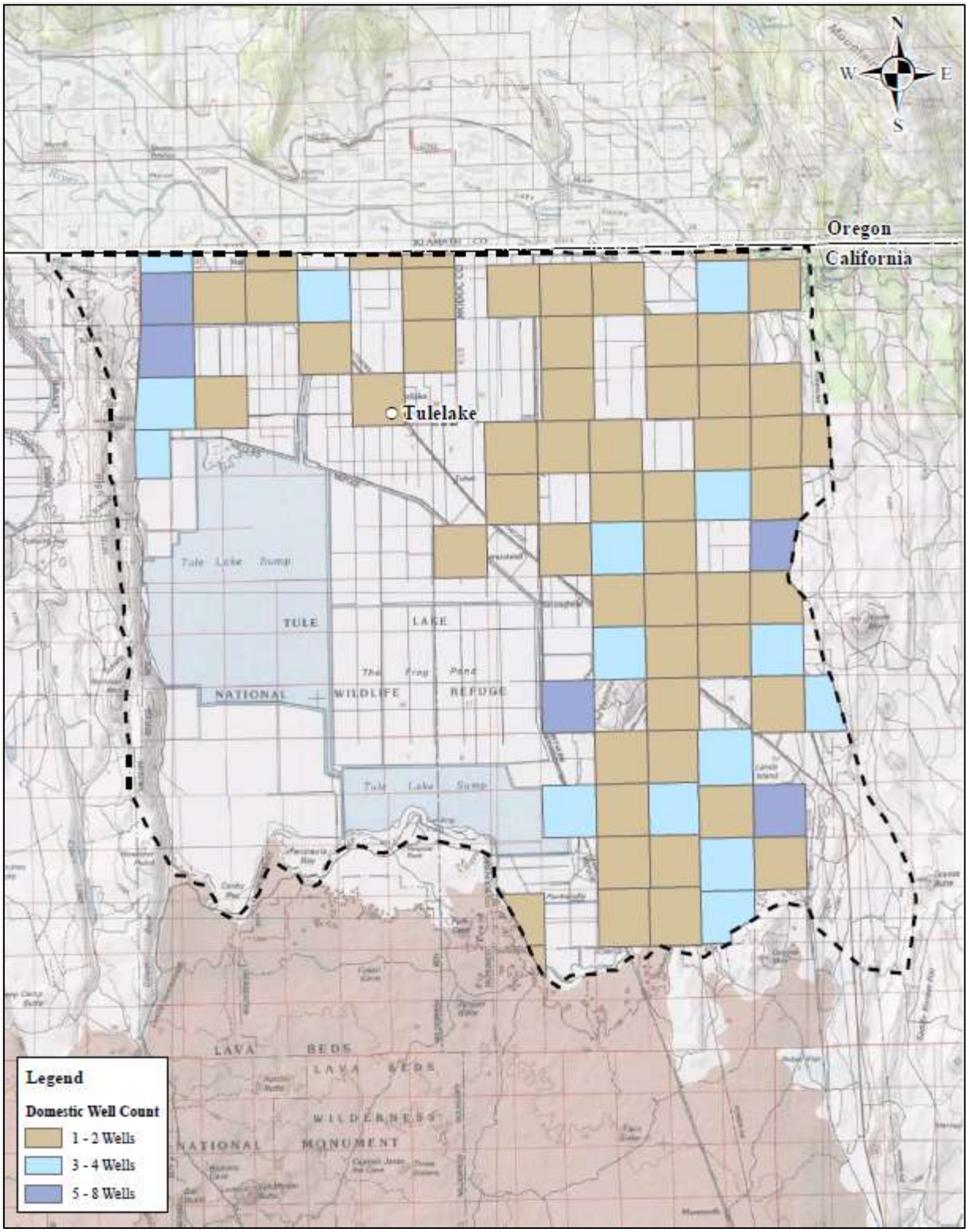


Figure 2-10. Density of Domestic and Public Supply Wells per Square Mile

2.1.2 Water Resources Monitoring and Management Programs (Reg. § 354.8 c, d, e)

The following section provides information, relative to various water resources monitoring and management programs, within the Subbasin. These programs provide valuable information that assisted with the development of this GSP and will also help with implementation of the GSP. These existing programs support water management in the Subbasin and do not limit operational flexibility.

2.1.2.1 Groundwater Management Plan (2013)

In 2013, TID prepared and adopted a Groundwater Management Plan (GWMP), as authorized by sections 10753 – 10753.11 of the California Water Code. The preparation of the GWMP included the development of appropriate groundwater "Management Objectives" within the GWMP area (District boundary), and the corresponding monitoring to ensure that the Management Objectives are being met. The primary goal in developing the GWMP was to work cooperatively with landowners within TID to more efficiently monitor the groundwater resources, and to continue with an efficient and effective conjunctive use operation during years where surface water supplies are limited or not available.

The 2013 GWMP provides valuable information and a framework of management objectives that align with the goals of this GSP.

2.1.2.2 Water Management Plan (2017)

In 2017, TID prepared and adopted a Water Management Plan (WMP) in compliance with U.S. Bureau of Reclamation's Water Management Plan 2017 Standard Criteria (2017 Standard Criteria). As part of the WMP preparation process, implementation of Critical Best Management Practices (~~Critical~~ BMPs) was required. The WMP helped ensure TID practices efficient water management practices, which in this case are identified as Critical BMPs. The Critical BMPs include:

- Measure the volume of water delivered by TID to each turnout with devices that are operated and maintained to a reasonable degree of accuracy, under most conditions, to ± 6%
- Designate a water conservation coordinator to develop and implement the Plan and develop progress reports
- Provide or support the availability of water management services to water users
- Pricing structure – based at least in part on quantity delivered
- Evaluate and improve efficiencies of TID pumps

In addition to the aforementioned Critical BMPs, the 2017 Standard Criteria identified Exemptible BMPs which are required, unless an exemption from Reclamation is approved. The Exemptible BMPs include:

- Facilitate alternative land use
- Facilitate use of available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not cause harm to crops or soils
- Facilitate the financing of capital improvements for on-farm irrigation systems

- Incentive pricing
- Canal lining/piping and regulatory reservoirs
- Increase flexibility in water ordering by, and delivery to, water users (within operational limits)
- Construct and operate contractor spill and tailwater recovery systems
- Plan to measure outflow
- Optimize conjunctive use
- Automate distribution and/or drainage system structures
- Facilitate or promote water user pump testing and evaluation
- Mapping

The 2017 WMP provides valuable information and a framework of best management practices that align with the goals of this GSP.

2.1.2.3 CASGEM Monitoring/SGMA Portal's Monitoring Network Module

The California Statewide Groundwater Elevation Monitoring program (CASGEM) ~~is~~ was a statewide initiative to collect groundwater elevations and facilitate collaboration between local monitoring entities and DWR. TID enrolled in the CASGEM program on behalf of its landowners in 2010. Participation by TID include~~s~~ working cooperatively with DWR in order to monitor groundwater elevations within the groundwater well monitoring network. On July 1, 2026, the ~~California Statewide Groundwater Elevation Monitoring (~~CASGEM~~)~~ Program's Online System became fully integrated with the SGMA Portal's Monitoring Network Module (MNM) and the existing CASGEM Online System ~~has been~~was closed down. The GSAs~~ID plans to~~ imported the wells identified in Section 3~~3~~ into DWR's GSP Reporting System and Monitoring Network Module, which along with TID's internal data management system, ~~will~~ serve as the GSAs Data Management System. This centralized groundwater level data storage platform ~~will~~ assists with collection, reporting, and sharing with DWR.

2.1.2.4 Groundwater Extraction Monitoring

TID monitors groundwater extractions from TID-operated wells on a monthly basis while the wells are in operation. These records are maintained by TID, and the City of Tulelake monitors groundwater extractions from its wells. During the water bank programs discussed in Section 2.1.2.10, participating wells, which include both TID-operated wells and private wells, are monitored on a monthly basis. The data collected as part of these monitoring efforts was utilized in the development of this GSP. Similarly, future data collected as part of these monitoring efforts will be utilized for updates to this GSP.

2.1.2.5 Groundwater Quality Monitoring

The State Water Resource Control Board's (SWRCB) 2009 Recycled Water Policy (amended in 2013) required that local water and wastewater entities in priority basins develop Salt and Nutrient Management Plans (SNMPs). The Tule Lake Subbasin was classified as a "Low Use" basin under this policy, and therefore did not have to prepare a plan.

The U.S. Geological Survey (USGS) collects groundwater quality data on a regular basis under the Groundwater Ambient Monitoring and Assessment Program (GAMA). These data are stored in the GAMA online database.

The data collected as part of these monitoring efforts was utilized in the development of this GSP. Similarly, future data collected as part of these monitoring efforts will be utilized for updates to this GSP.

The GSAs reviewed and compiled GeoTracker data, which is included in Appendix N. ~~are not aware of any contaminated groundwater in the Subbasin. Therefore, migration of contaminated groundwater is not an issue in the Subbasin.~~

2.1.2.6 Irrigated Lands Regulatory Program

The Irrigated Land Regulatory Program (ILRP) was initiated in 2003, to regulate agricultural runoff to surface waters and groundwater. The North Coast Regional Water Quality Control Board is currently working on an approach to address discharges of waste associated with agricultural lands in the Tule Lake Subbasin.

2.1.2.7 Land Subsidence Monitoring

Monitoring of land subsidence within the Upper Klamath Basin and the Tule Lake Subbasin has been limited. Historically, land subsidence was monitored along transects by comparing periodic spirit level surveys conducted by the USGS and the National Geodetic Survey (NGS). In the mid-1980s, a transition was made from the spirit level surveys to global positioning system (GPS) surveys. Like spirit level transects, GPS monitoring of subsidence relies on periodic resurveying of a network of monuments. In 2001, DWR defined a network of 23 stations. In 2011, DWR re-surveyed 6 of the 23 monuments along the east and southeast portion of the Subbasin to identify any potential land subsidence. Results from the 2011 survey indicate that there has been no noticeable subsidence on the east side of the Subbasin. Most recently, as part of DWR's SGMA technical assistance, a statewide Interferometric Synthetic Aperture Radar (InSAR) dataset was acquired which currently provides data for 2015 through 2025~~19~~.

2.1.2.8 Surface Water Diversion Monitoring

TID, along with other water users in the Klamath Project, and in coordination with Reclamation, monitors surface water diversions within the Klamath Project. Reclamation maintains historical diversion information for the Klamath Project. In addition, the TID maintains similar records for its diversions. The data collected as part of these monitoring efforts was utilized in the development of this GSP. Similarly, future data collected as part of these monitoring efforts will be utilized for updates to this GSP.

2.1.2.9 County Ordinances and Permitting

Siskiyou and Modoc counties have provisions in their ordinances for groundwater management and use. In general, these county ordinances which outline a permit process for groundwater extraction for use outside of each respective county do not apply to TID and the GSP area. There are specific provisions in each county ordinance that allow for the use of water within the boundaries of a district, which is ~~in~~

partly located within one county and ~~in~~ partly in another county (or counties), where such extraction quantities and use are consistent with the historical practices of a district. These provisions are consistent with current TID operations.

Well construction permitting within the Subbasin is administered by the Modoc County and ~~Siskiyou county~~Siskiyou County health departments, which effectively implemented the California Well Standards for water wells and monitoring wells. Permitting of municipal supply wells is also within the purview of the State Department of Public Health. *DWR Bulletin 74: California Well Standards* (Bulletin 74), establishes the minimum standards for groundwater well construction with the purpose of protecting groundwater quality. Bulletin 74 includes requirements for well construction (surface seals and construction, well development, rehabilitation, and deepening) and destruction of wells, among other things.

2.1.2.10 Water Bank Programs

Water banks were initiated in the Klamath Project based on a variety of needs. Reclamation was the original facilitating entity for the water bank programs. Following the formation of the Klamath Water and Power Agency (KWAPA) in 2008, a cooperative agreement between Reclamation and KWAPA was initiated, resulting in the Water User Mitigation Program (WUMP). KWAPA dissolved in 2016, and the Klamath Project Drought Response Agency (KPDRA) was formed in 2018, by water districts in the Klamath Project~~,~~ (including TID)~~,~~ to facilitate future programs. The goal of the implementation of the water bank programs was to develop a market-based approach wherein which water was purchased by a single buyer (Reclamation/KWAPA/KPDRA) from multiple sellers for Endangered Species Act (ESA) needs in the Klamath River. The amount of water acquired during each water bank program was based on the estimate of the water demand reduction needed in order to meet delivery objectives and ESA requirements.

During the water bank programs, up to three water management strategies were utilized to decrease Project demand and provide additional water supplies: ~~1)~~ cropland idling/dryland farming~~,~~; ~~2)~~ groundwater substitution (direct and indirect)~~;~~ and ~~3)~~ storage. In addition, domestic well mitigation programs were offered during several years. Water bank programs changed from year to year based on demand and lessons learned through the implementation of water management strategies. Beginning in 2026, a demand reduction program was introduced that allows producers to idle areas for five years.

The official name of each water bank program for a specific year, along with the facilitating entity are identified in Table 2-4. Years during which a domestic well mitigation program was offered are also indicated.

Table 2-4. Water Bank Programs

Year	Official Name of the Water Bank Program	Facilitating Entity
2001	Pilot Irrigation Demand Reduction Program (Cropland Idling) Groundwater Acquisition Program (Groundwater Substitution)	Reclamation
2002	No Program	Reclamation
2003	Klamath Basin Pilot Water Bank	Reclamation

Year	Official Name of the Water Bank Program	Facilitating Entity
2004	Klamath Basin Pilot Water Bank	Reclamation
2005	Klamath Basin Pilot Water Bank	Reclamation
2006	Klamath Basin Pilot Water Bank	Reclamation
2007	Water Supply Enhancement Study	Reclamation
2008	No Program	KWAPA
2009	No Program	KWAPA
2010	Water User Mitigation Program (WUMP)*	KWAPA
2011	No Program	KWAPA
2012	Water User Mitigation Program (WUMP)	KWAPA
2013	Water User Mitigation Program (WUMP)*	KWAPA
2014	Water User Mitigation Program (WUMP)*	KWAPA
2015	Water User Mitigation Program (WUMP)*	KWAPA
2016	No Program	KWAPA
2017	No Program	N/A
2018	Groundwater Program & Land Idling Program	KPDRA
2019	No Program	KPDRA
2020	Groundwater Program & Land Idling Program*	KPDRA
2021	Land Idling Program	KPDRA
2022	Land Idling Program	KPDRA
2023	Land Idling Program	KPDRA
2024	Land Idling Program	KPDRA
2025	No Program	KPDRA

* Domestic Well Mitigation Program offered.

~~* Domestic Well Mitigation Program offered.~~ ~~Below is a~~The following table ~~that~~ outlines the number of acres idled in TID during the KPDRA programs from 2018 to 2026. The KPDRA, including TID, continues to work with USBR to fund future similar land idling programs.

Table 2-5. Number of Acres Idled in TID during KPDRA from 2018 to 2026

Year	TID Idled Acres in a KPDRA Program
2018	5,156
2019[1]	N/A
2020	8,997
2021	13,180
2022	10,587
2023	4,846
2024	6,671
2025[1]	N/A
[1] No Program due to sufficient surface water supply.	

2.1.3 Land Use Elements or Topic Categories of Applicable General Plans (Reg. § 354.8 f)

The Subbasin is located within Modoc County and Siskiyou County, both of which have jurisdiction over land use planning. All long-term land use planning decisions that would affect the Subbasin are also under the jurisdiction of Modoc County and Siskiyou County. Therefore, any implementation of the GSP will be affected by the policies and regulations outlined by Modoc County and Siskiyou County's respective General Plans. In addition, implementation of these plans may change water demands in the Subbasin or could influence the GSP's ability to achieve sustainable groundwater use. Conversely, the GSP may affect implementation of the land use policies outlined in these plans.

2.1.3.1 Modoc County General Plan

The Land Use Element of the General Plan prepared by Modoc County identifies policies and an action program to meet the primary goal of protecting and supporting the agricultural economy of Modoc County.

2.1.3.2 Siskiyou County General Plan

Siskiyou County's General Plan serves as a guide for land use decisions within their 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 the 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.

Siskiyou ~~The~~ County is currently undertaking the Siskiyou 2050 General Plan Update. The General Plan Update is intended to establish an updated, long-term framework for land use, growth, and resource

management within the c~~C~~ounty. Until the General Plan Update is adopted, the existing General Plan remains the applicable land use policy framework. Accordingly, the following policies ~~described below~~ reflect the currently adopted General Plan and may be modified as part of the ongoing General Plan Update.

The *Conservation Element of the General Plan* (County of Siskiyou, 1973) recognizes the importance of water resources in Siskiyou County, and outlines objectives for the conservation and protection of these resources to ensure continued 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 section G, Paragraph 1 where it states,~~:~~ "Groundwater resources, water quality and flood control remain the most important land use determinants within the county…" (County of Siskiyou, 1973). Specific topics addressed in the Conservation Element section include preventing pollution from industrial and agricultural waste, maintaining water supply and planning for future expansion, reclaiming and recycling wastewater, and protecting watershed or 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 land; and prevention of degradation of water quality.

The Open Space Element of the General Plan includes, in its definition of open space, watershed and groundwater recharge land (County of Siskiyou, 1972). 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 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.

The General Plan Update provides an opportunity to evaluate and update these existing policies in consideration of current conditions, community priorities, and applicable regulatory requirements. The GSP will continue to be considered in conjunction with the County's land use planning efforts as the General Plan Update proceeds.

2.1.3.3 Siskiyou County Zoning Plan

The Siskiyou County Zoning Plan (Zoning Plan) is codified in Title 10 (DWR, n.d.) Chapter 6 of the County Code. The Siskiyou County 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, requirements and stipulations for land use and development.

Siskiyou -County is currently undertaking an update to its zoning regulations in conjunction with the Siskiyou 2050 General Plan Update. The zoning update is intended to modernize and reorganize the c~~C~~ounty's development regulations and establish updated standards consistent with the c~~C~~ounty's long-

term land use framework. Until the updated zoning regulations are adopted, the existing zoning ordinance remains the applicable regulatory framework. Accordingly, the provisions described above reflect the existing zoning framework and may be modified through the ongoing zoning update.

The existing and updated zoning regulations will continue to provide mechanisms for implementing Siskiyou ~~the~~ County's land use policies, including through permitted and restricted uses, development standards, and other requirements applicable to land use and development. These regulatory mechanisms are relevant to the implementation of the GSP because land use regulations can influence the location and intensity of development and, consequently, potential demands on groundwater resources.

2.1.3.4 Land Use Plans Outside the Subbasin

As identified in Section 2.1.1.1, the Subbasin is located within the southeastern region of the Upper Klamath Basin. Adjacent to the northern boundary of the Subbasin is Klamath County. A comprehensive plan for Klamath County was prepared, and ~~identifies~~identified an agricultural land primary objective of economically stabilizing the agricultural community in Klamath County. Land use decisions in Klamath County are likely to affect groundwater conditions in the Subbasin, which is why the GSAs included a Core Team Advisory Member from Klamath County.

2.1.3.5 Groundwater Sustainability Plan Implementation

Because the Subbasin is already operated sustainably, implementation of this GSP will not change the water demands nor the water supply assumptions of the previously identified land use plans.

2.1.4 Additional GSP Elements (Reg. § 354.8 g)

The following topics are required to be addressed in the GSP. The references for each topic have also been included.

- Control of saline water intrusion
  - See Section 5.2.6 "Seawater Intrusion" for an explanation as to why the saline water intrusion sustainability indicator does not apply to the Subbasin.
- Wellhead protection
  - See information provided under Section 2.1.2.9 "County Ordinances and Permitting"
- Migration of contaminated groundwater
  - See Section 2.1.2.5 "Groundwater Quality Monitoring" for details on migration of contaminated groundwater
- Well abandonment and well destruction program
  - See information provided under Section 2.1.2.9 "County Ordinances and Permitting"

- Replenishment of groundwater extractions
    - See Section 2.1.2.4 “Groundwater Extraction Monitoring” for details on groundwater extractions
- Conjunctive use and underground storage
    - See Section 4 for details on conjunctive use and underground storage, and see information provided under Section 2.1.2.1 “Groundwater Management Plan, (MBK, 2013)”
- Well construction policies
    - See information provided under Section 2.1.2.9 “County Ordinances and Permitting”
- Groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects
    - There are no active or planned projects of this nature in the Tule Lake Subbasin. Therefore, a section covering these types of projects has not been included.
- Efficient water management practices
    - See information provided under Section 2.1.2.2 “Agricultural Water Management Plan (DWR, 2017)”
- Relationships with state and federal regulatory agencies
    - See Section 2.1.1.1 for details on relationships with state and federal regulatory agencies
- Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity
    - See information provided under Section 2.1.3
- Impacts on groundwater dependent ecosystems
    - See Section 2.2.2.9 “Identification of Groundwater-Dependent Ecosystems” for details on groundwater dependent ecosystems

2.1.5 Notice and Communication (Reg. § 354.10)

Development and implementation of the GSP takes beneficial uses and users of groundwater into consideration, including agricultural water users, ~~SDAC~~ Severely Disadvantaged Community and ~~DAC~~ Disadvantaged Community users, public water suppliers, groundwater dependent ecosystems and other environmental uses, and other stakeholders. A list of beneficial users is included in Appendix C.

See Appendix C for the GSAs Communications and Engagement Plan, which includes details on the GSAs decision making process, goals, stakeholder identification process, venues for engagement, and implementation timeline. Appendix C also includes comments received regarding the GSP, a list of the meetings held to date, a list of the advisory team members, and a list of the interested persons.

2.2 Basin Setting

The following section provides a brief background of the geology and hydrology of the Upper Klamath Basin and the portion of the Upper Klamath Basin that is covered by the GSP area (Tule Lake Subbasin).

2.2.1 Hydrogeologic Conceptual Model (Reg. § 354.14)

This Hydrogeologic Conceptual Model (HCM) is prepared, pursuant to California Code of Regulations Section 344.12. In general, this follows the description of the Tule Lake Subbasin prepared by DWR for the 2003 update to Bulletin 118, and the changes which were made through the 2016 Basin Boundary Modification.

2.2.1.1 Basin Boundaries and Hydrology

The Upper Klamath Groundwater Basin is approximately 8,000 square miles and is located in south central Oregon and northeastern California on the east side of the Cascade Mountain Range. Figure 2-1 identifies the location of the Upper Klamath Groundwater Basin. As further described in this section, the Tule Lake Subbasin is located in the southeastern portion of the Upper Klamath Basin.

The Subbasin is bounded to the west by the Gillems Bluff Fault, which extends beneath and is a major structural feature of the Medicine Lake volcanic highlands (Lavine, 1994). The fault forms the steep eastern escarpment of Sheepy Ridge, which separates the Tule Lake and Lower Klamath subbasins (DWR, 2003). The basin boundary extends to the fault-controlled drainage divide between the Tule Lake and Lower Klamath Lake subbasins (the crest of Sheepy Ridge). Volcanic deposits extend eastward from the crest beneath the Quaternary sediment, and are penetrated by wells, which are producing from the volcanic deposits on the west margin of the basin (Gannett, 2016).

The Subbasin is bounded to the east by the Saddle Blanket Fault Zone, a north-trending normal fault, which forms the western edge of the block faulted mountains between Tule Lake and Clear Lake Reservoir. The Subbasin extends to a portion of the Quaternary volcanic deposits, which includes irrigation wells (Gannett et al., 2010). Clear Lake Reservoir is the headwaters of Lost River. Lost River flows north into Oregon, and meanders through the Poe and Langell valleys before it flows south into California, and ends at the Tule Lake Sump (DWR, 2003).

The Subbasin is bounded to the south by the low-lying volcanic fields on the north slope of the Medicine Lake Highlands. Medicine Lake occupies the crater at the peak of this large, relatively young shield volcano. The Subbasin includes the Peninsula and extends to the east to the Saddle Blanket Fault Zone. Wells in these areas where the volcanics are exposed mostly produce from the surficial volcanic deposits, but some wells penetrate through the surficial deposits and underlying basin-filling sediments to the underlying volcanic strata (Gannett, 2016).

To the north, the basin extends into Oregon and is bounded by northwest trending normal faults on the south side of the mountain block dividing Poe Valley from the Tule Lake Subbasin. Approximately two-thirds of the Subbasin are in California. For the purposes of SGMA, the Subbasin is bounded to the north by the state boundary of Oregon and California.

A map of the Tule Lake Subbasin is provided as Figure 2-11.

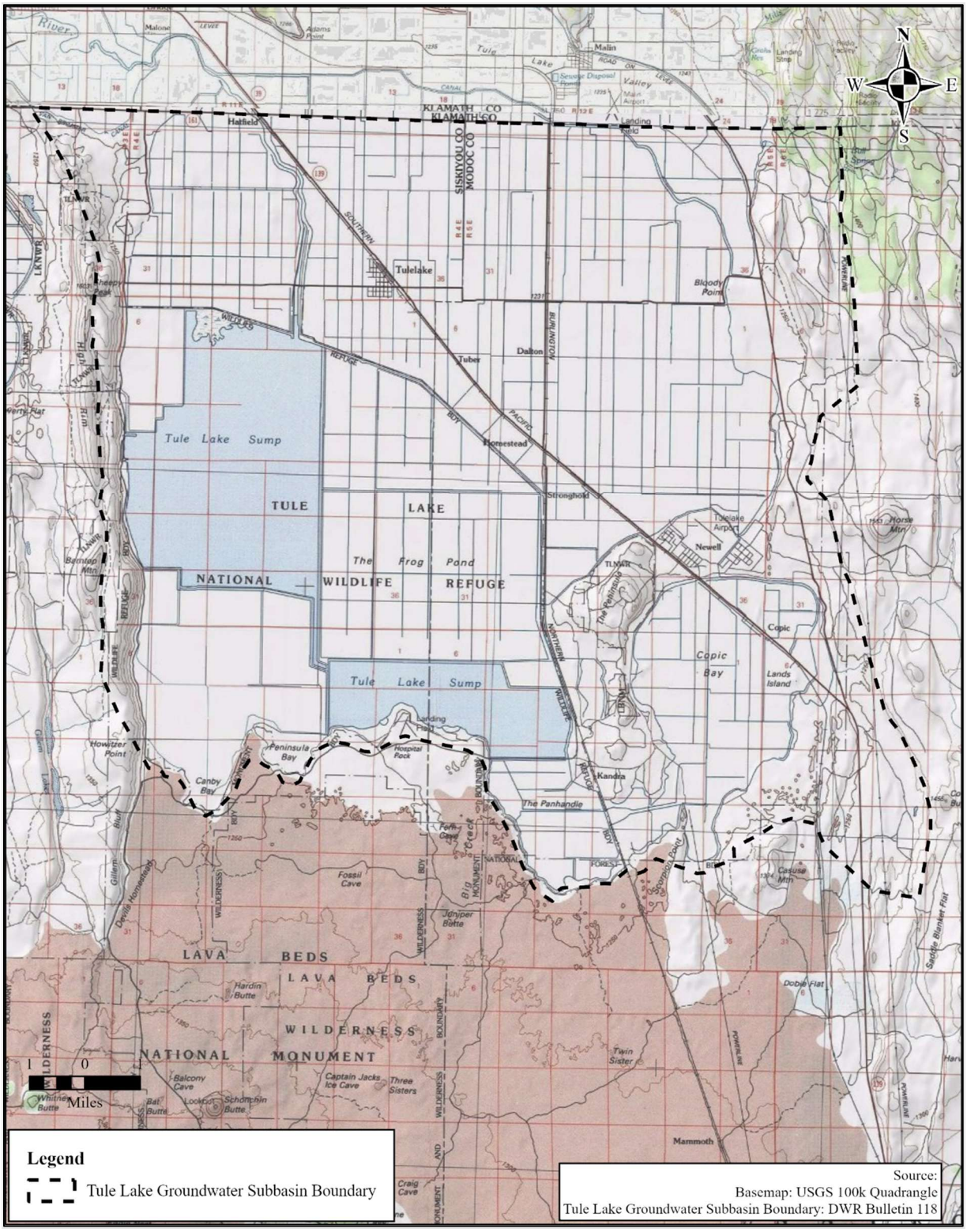


Figure 2-11. Tule Lake Subbasin Boundary

Figure 2-6 identifies the Klamath Project surface water bodies and conveyance facilities that are significant to the management of the Subbasin. Figure 2-7 identifies surface water bodies and conveyance facilities within TID, which are significant to the management of the Subbasin.

A map identifying the soil characteristics of the Tule Lake Subbasin is provided as Figure 2-12.

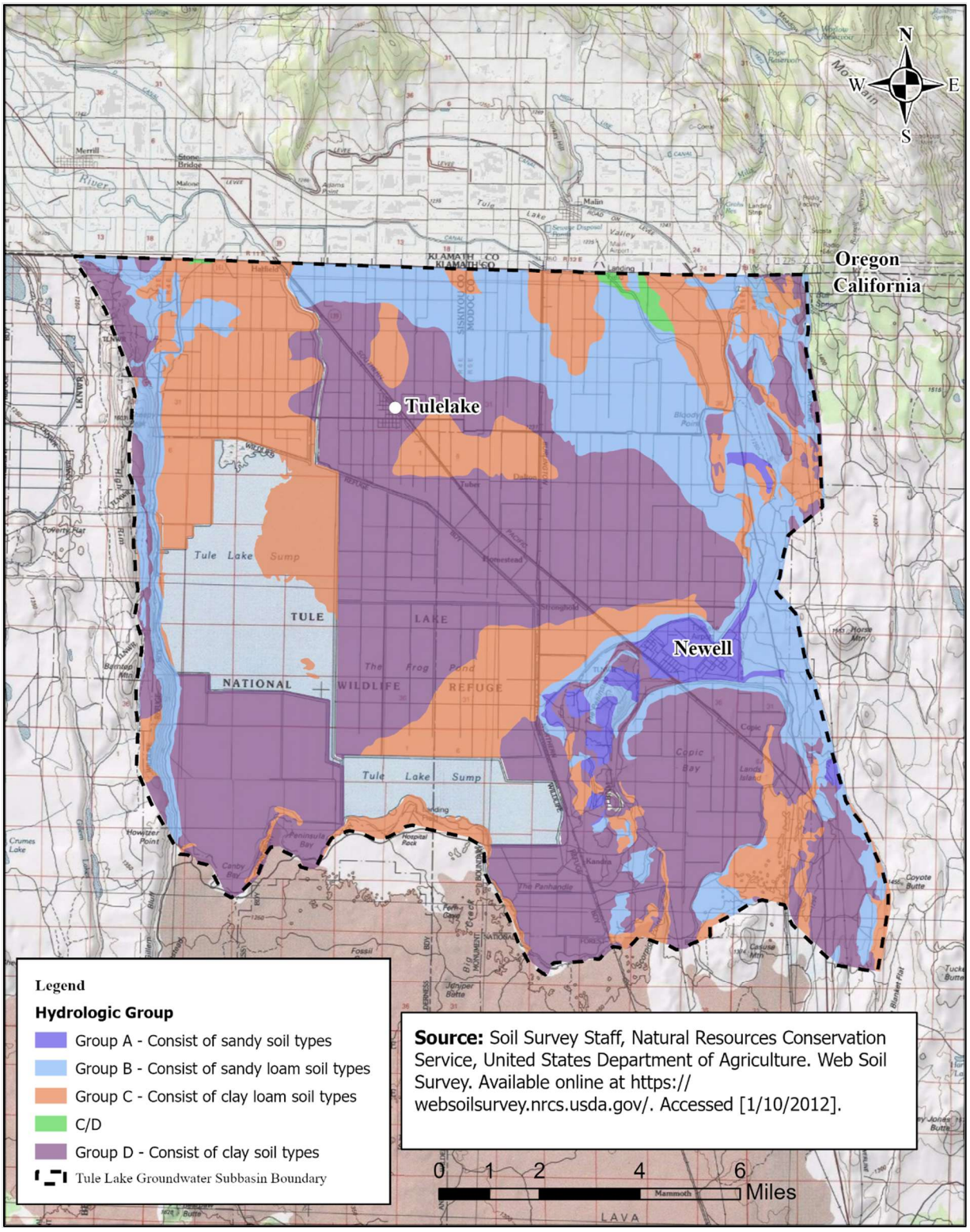


Figure 2-12. Tule Lake Subbasin Soil Characteristics

A topographic map using scanned images of USGS paper topographic maps of the Tule Lake Subbasin is provided as Figure 2-13.

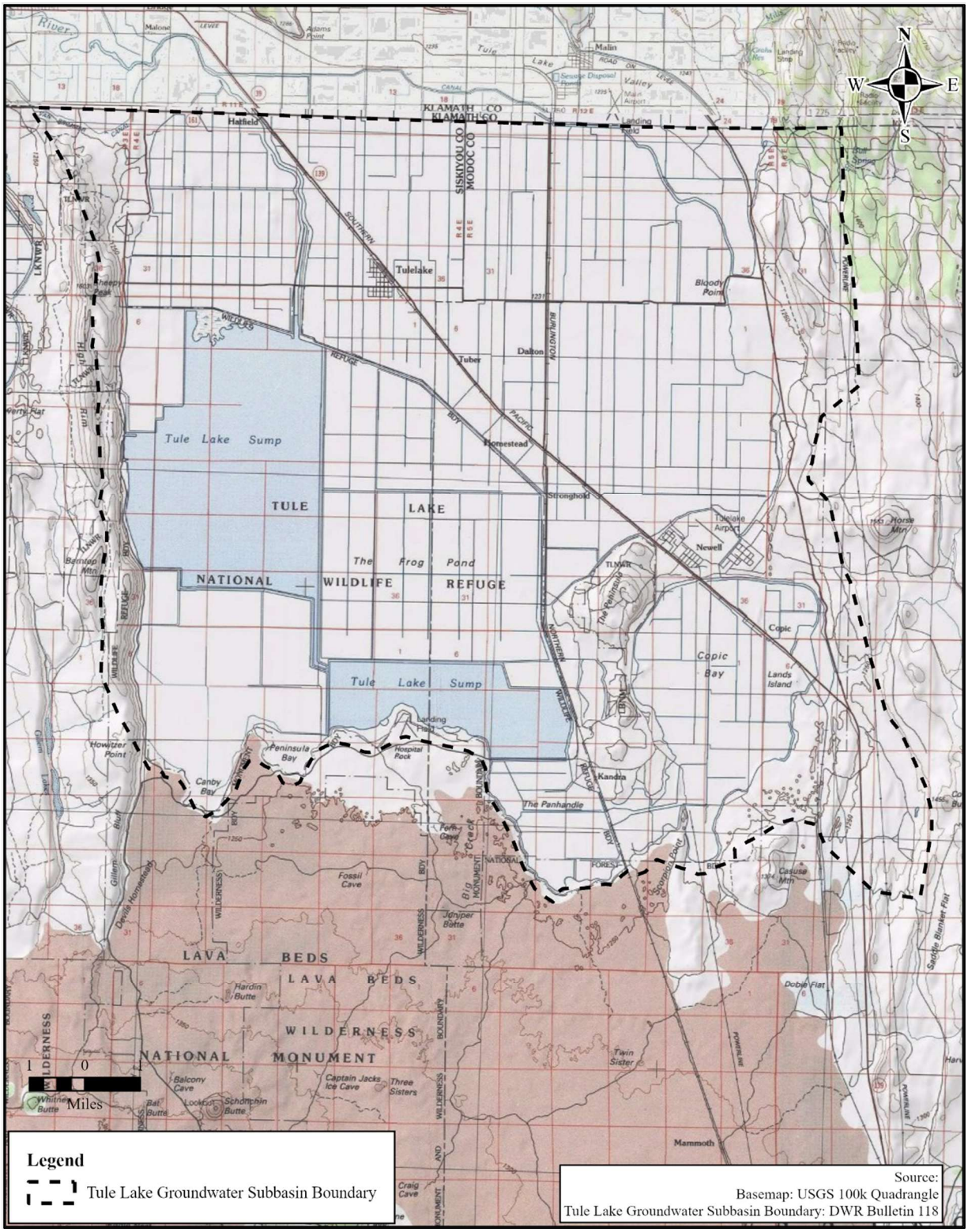


Figure 2-13. Tule Lake Subbasin Topography

2.2.1.2 Hydrogeologic Information

Water-Bearing Formations. The principal water-bearing formations in the subbasin include Tertiary to Quaternary lake deposits and volcanics. In general, two systems have been identified in the Subbasin ~~,~~ the alluvial aquifer system ~~(primary aquifer)~~ and the volcanic aquifer system. The alluvial aquifer system consists of the surficial deposits ~~that extend to over 1,000 feet deep in the center of the basin~~. The volcanic aquifer system consists of the Upper, Intermediate, and Lower basalt units, as well as pyroclastic and tuffaceous deposits. Groundwater in the surficial deposits and Upper Basalt is unconfined. The Intermediate Basalt and scoraceous deposits are predominantly unconfined in the southern portion of the basin where they exist at or near the surface and become confined as they deepen beneath the lake sediments in a northward direction. The Lower Basalt is confined in the center of the basin where it underlies surficial deposits, but is unconfined or semi-confined where it crops out at the edges of the basin. The tuffaceous deposits are predominantly confined except where they crop out on the west side of the Subbasin and on portions of the Peninsula (DWR, 2002).

Pliocene to Miocene Lower Basalt. This Lower Basalt is a primary water-bearing deposit for irrigation, public, and municipal wells. The older basalt ranges from green-black ophitic olivine basalt to a gray-black porphyritic basalt. It often exhibits weak columnar jointing and fracturing in surface exposures. This is typically a highly permeable aquifer that is commonly confined within the Subbasin where it underlies lake sediments (DWR, 2003). At the edges of the basin at the north, east, and west, the Lower Basalt acts more unconfined or semi-confined (DWR, 2002). Where volcanic rocks are exposed at the surface, the area is likely underlain by an unconfined aquifer body (Hotchkiss, 1968). Surface exposure of the unit occurs east and west of the Subbasin. For the purposes of sustainable groundwater management and based on known areas of groundwater use, the unconfined aquifer of the Lower Basalt is assumed to extend to the east where surface exposure occurs. Review of hydrographs show that these wells reflect similar stresses to wells located throughout the Tule Lake Subbasin, which indicates a hydrogeologic connection and possible interbedding of basalt layers with lake deposits (Gannett, 2016; DWR, 2002). Where exposed in the uplands surrounding the basin, the unit is an important source of recharge.

The depth of the older basalt beneath the lake sediments varies due to the region's extensive block faulting. New deep irrigation wells drilled in 2001, on the California/Oregon border show that the basalt is encountered at depths ranging from 810 feet on the east side of the basin, to 1,190 feet several miles to the west, and to 190 feet on the far west side. These differing depths likely represent individual blocks offset by steep, normal faults. The Lower Basalt can yield large quantities of water suitable for irrigation purposes (DWR, 2002). The depth to good production zones in these wells varies from 800 feet to 1,200 feet to 245 feet in the same east to west order. On the east side of the Subbasin well yields range from 4,000- to 7,000-gpm, whereas yields mid-basin and on the west side range from 9,000- to 12,000-gpm (DWR, 2003).

Pleistocene Intermediate Basalt. This unit is a series of reddish-brown to black, thin bedded flows of Pleistocene diabasic olivine basalt. These rocks border the surficial alluvium to the south and east and interfinger with lakebed deposits at the edge of the basin. These rocks are generally highly permeable due to well-developed columnar jointing and the abundance of bedding planes. Wells developed in these rocks will often yield moderate to large quantities of water ranging from 2,000- to 4,000-gpm with

specific capacities of 50- to 250-gpm per foot of drawdown if sufficient fractures, fracture interconnections, and saturated depths are encountered (Hotchkiss, 1968).

This unit is exposed at the surface in the southern portion of the Subbasin and crops out on the eastern and western ridges (DWR, 2002). Along the southern edge, this Quaternary basalt overlies and is interbedded with basin-filling sediments (Gannett et al., 2012). This is evidenced in the Peninsula region and southeast of Copic Bay where groundwater pumping occurs for irrigation. Analysis of available hydrographs indicates that groundwater levels in this area reflect similar stresses as those seen elsewhere in the basin, suggesting that the surficial basalt and deeper volcanics are in hydraulic connection (Gannett, 2016).

Some well yields in this unit are low where extensive cross faulting has created barriers to groundwater recharge and flow. In the Panhandle region, the thickness of the unit is greater than 400 feet, with well yields ranging up to 9,500 gpm with a specific capacity of up to 395 gpm per foot of drawdown. In the vicinity of Prisoners Rock and the Peninsula, the unit reaches a thickness of at least 400 feet with estimated well yields of 500- to 3,100-gpm (DWR, 2003).

Pleistocene Upper Basalt. This unit is an unweathered, vesicular, olivine basalt that is generally highly permeable due to extensive fracturing. The basalt flows of this unit are generally above the saturated zone in upland ~~areas, but~~areas, but serve as recharge areas where fractured. Some areas have exposures of massive, unfractured flows. The fractured flows readily yield water to wells. These flows border the Subbasin on the south (to the west of the Peninsula), and outcrop as a Subbasin boundary to the southeast of Copic Bay along the north flank of the Medicine Lake Highlands (DWR, 2003).

Pliocene to Holocene Lake Deposits. The surficial deposits, consisting mostly of fluvial and lacustrine sediments are unconsolidated to semi-consolidated (DWR, 2002). The lake deposits consist of sand, silt, clay, ash, lenses of diatomaceous earth, and semi-consolidated shale. Poorly sorted deposits that have very low permeability and may act as a confining layer ~~where~~were interfingered with basalts. Wells developed in the sedimentary deposits are usually less than 150 feet deep and yield only small quantities of water in the range of 30 gpm (Hotchkiss, 1968). Isotopic analysis of groundwater in aquifers supplying deep irrigation wells in the Subbasin suggests a hydraulic connection between the shallow (alluvial) aquifer and deep (volcanic) aquifer (Pischel and Gannett, 2015).

2.2.1.3 Restrictive Structures

The western boundary of Tule Lake is marked by a prominent north-south trending normal fault, downthrown to the east. The displacement is unknown, but is ~~probably~~ likely ~~in~~to be in the range of several hundred feet. The east side of the Tule Lake Subbasin is bounded by a normal fault downthrown to the west. Subsurface block faulting can also cause boundaries or conduits to groundwater flow. It is assumed a buried horst may exist, extending from Turkey Hill in the north to the Peninsula to the south (DWR, 2002).

The water-transmitting properties of these faults are not fully understood.

2.2.1.4 Bottom of Subbasin

The volcanic units of the Subbasin comprise the bedrock and produce groundwater through fractures and voids. In locations throughout the Subbasin, the volcanic units may be interbedded with basin fill

deposits (DWR, 2002). Due to the interaction between the volcanic aquifer and alluvial aquifer, it is difficult to define the bottom of the Subbasin.

A review of cross sections incorporated into USGS models identifies the bottom of the basin at approximately 1,500 – 2,000 feet above mean sea level (Gannett et al., 2012; Wagner and Gannett, 2014). This corresponds to the assumed location of contact between the regional groundwater flow system and underlying rock with very low permeability (Gannett et al., 2012). Figure 2-14 identifies the location of the cross sections and Figure 2-15 provides the cross sections.

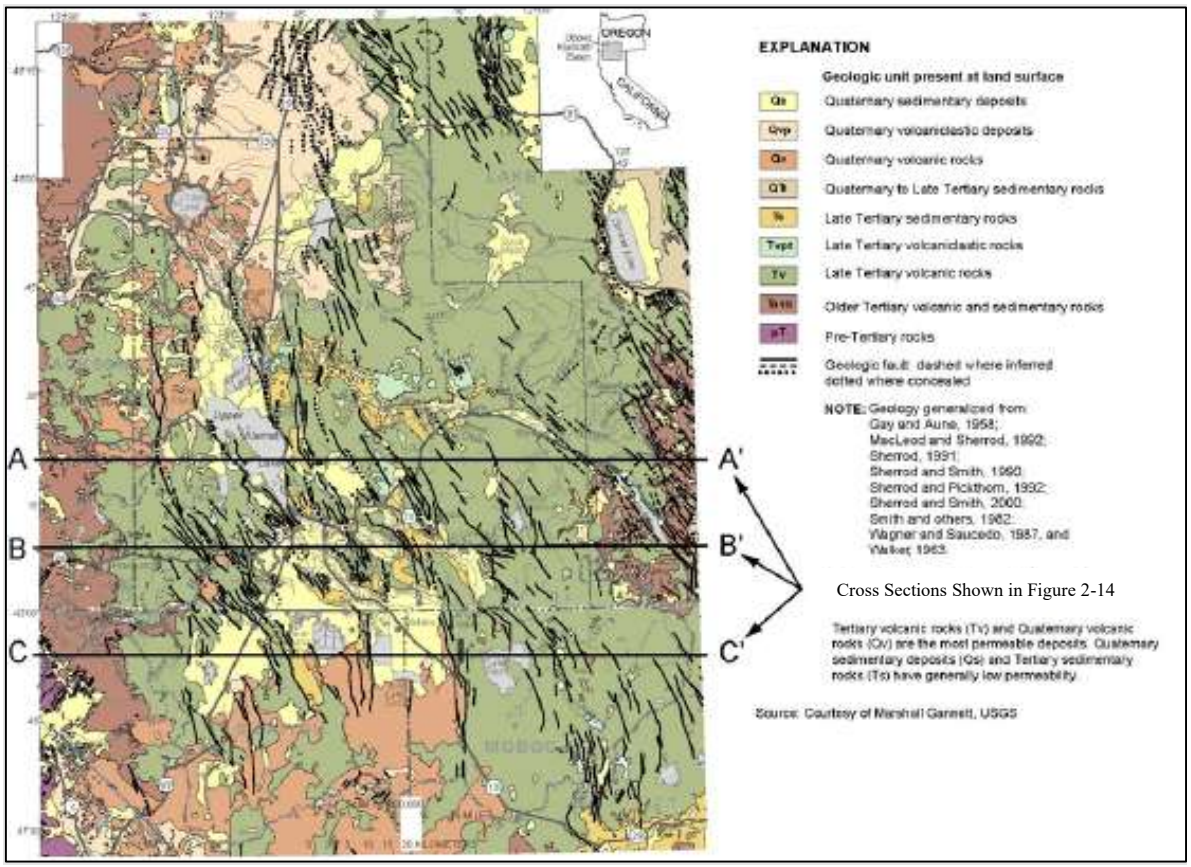


Figure 2-14. Hydrologic Units of the Upper Klamath Basin, Oregon, and California

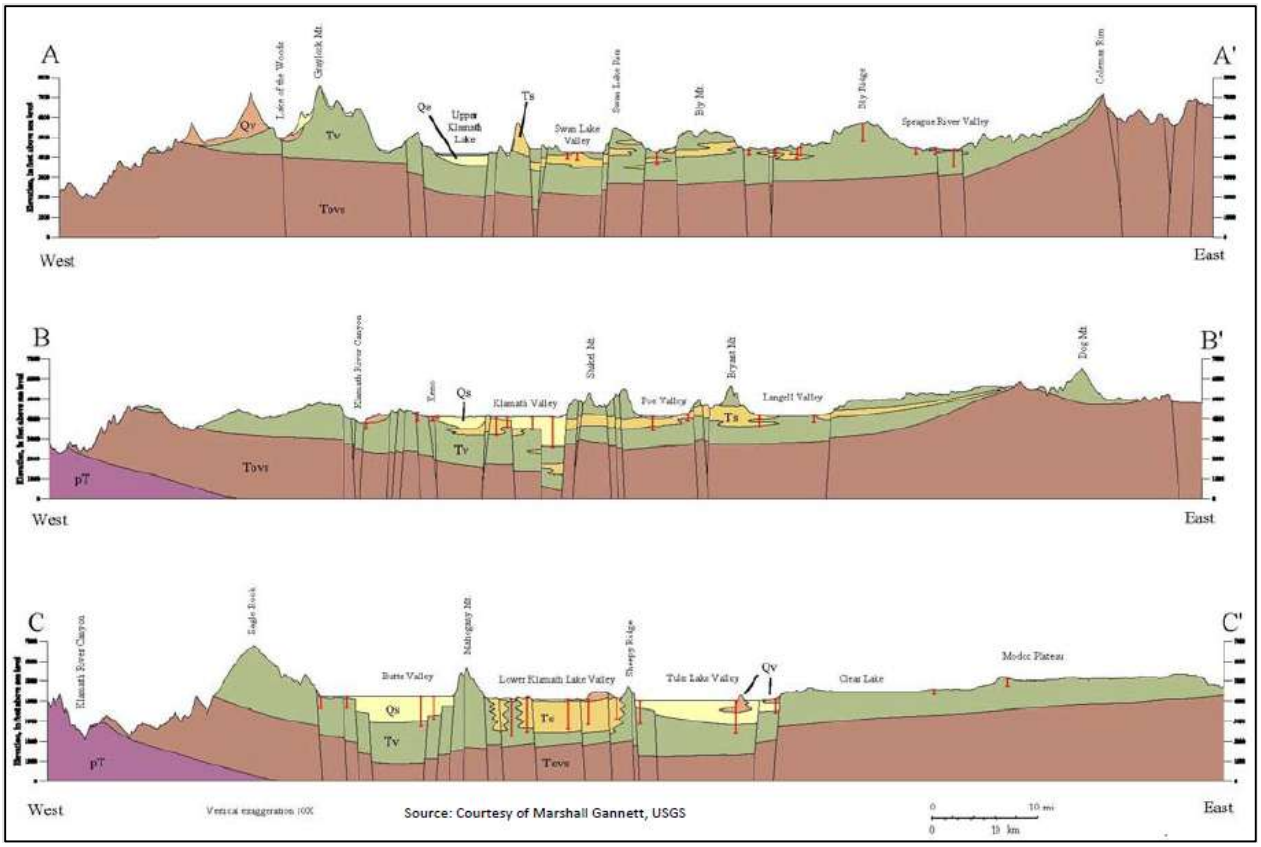


Figure 2-15. Series of West-to-East Geologic Cross Sections through the Central Part of the Upper Klamath Basin

The findings by the USGS correlate to cross sections developed by DWR, which identify interbedded volcanics, and fill deposits occurring at varying depths (DWR, 2002). Appendix E provides the plate showing locations of the DWR cross sections and the plate of the DWR cross sections.

The location and quantity of groundwater movement, including migration and recharge within any groundwater basin, is difficult to quantify. This is because there are various factors that affect each of the components. In many cases, limited data regarding one aspect of the movement of groundwater can make it difficult to develop a comprehensive understanding of the groundwater basin. In order to better understand groundwater in the Upper Klamath Basin, a groundwater simulation and management model (Model) was developed by the USGS, in collaboration with Oregon Water Resources Department and Reclamation. This Model provides improved understanding of how the groundwater and surface-water system responds to varying hydrologic conditions and groundwater pumping within the Upper Klamath Basin. In order to develop this Model, the USGS relied on countless reports compiled within the Upper Klamath Basin relative to surface and groundwater. One of these reports, *Ground-water Hydrology of the Upper Klamath Basin, Oregon and California (*Gannett et al., 2010), states that groundwater flow in the Upper Klamath Basin is influenced by topography, geologic composition, stream system geometry, recharge of precipitation and applied water, and groundwater production from wells. The groundwater flow system receives large amounts of recharge from deep percolation of precipitation, snowmelt in the Cascades Range, and upland areas within and on the eastern margins of

the basin. The primary components of groundwater discharge include discharge to streams through a complex of springs within the Upper Klamath Basin interior, and discharge to wells at various locations and depths. Groundwater in the Upper Klamath Basin generally flows toward Upper Klamath Lake, the Klamath River Canyon, and the Tule Lake Subbasin (see Figure 2-16; Gannett et al., 2010).

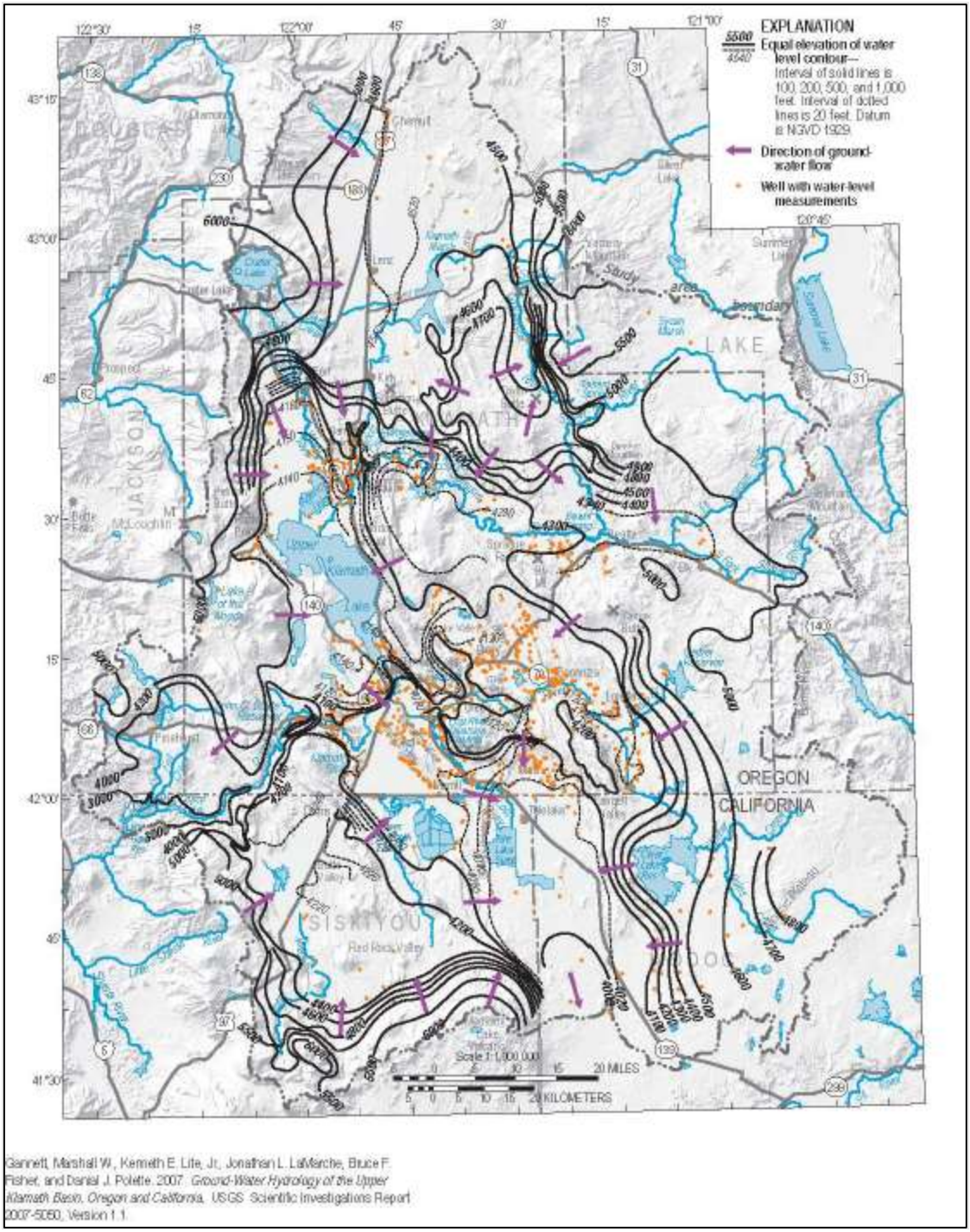


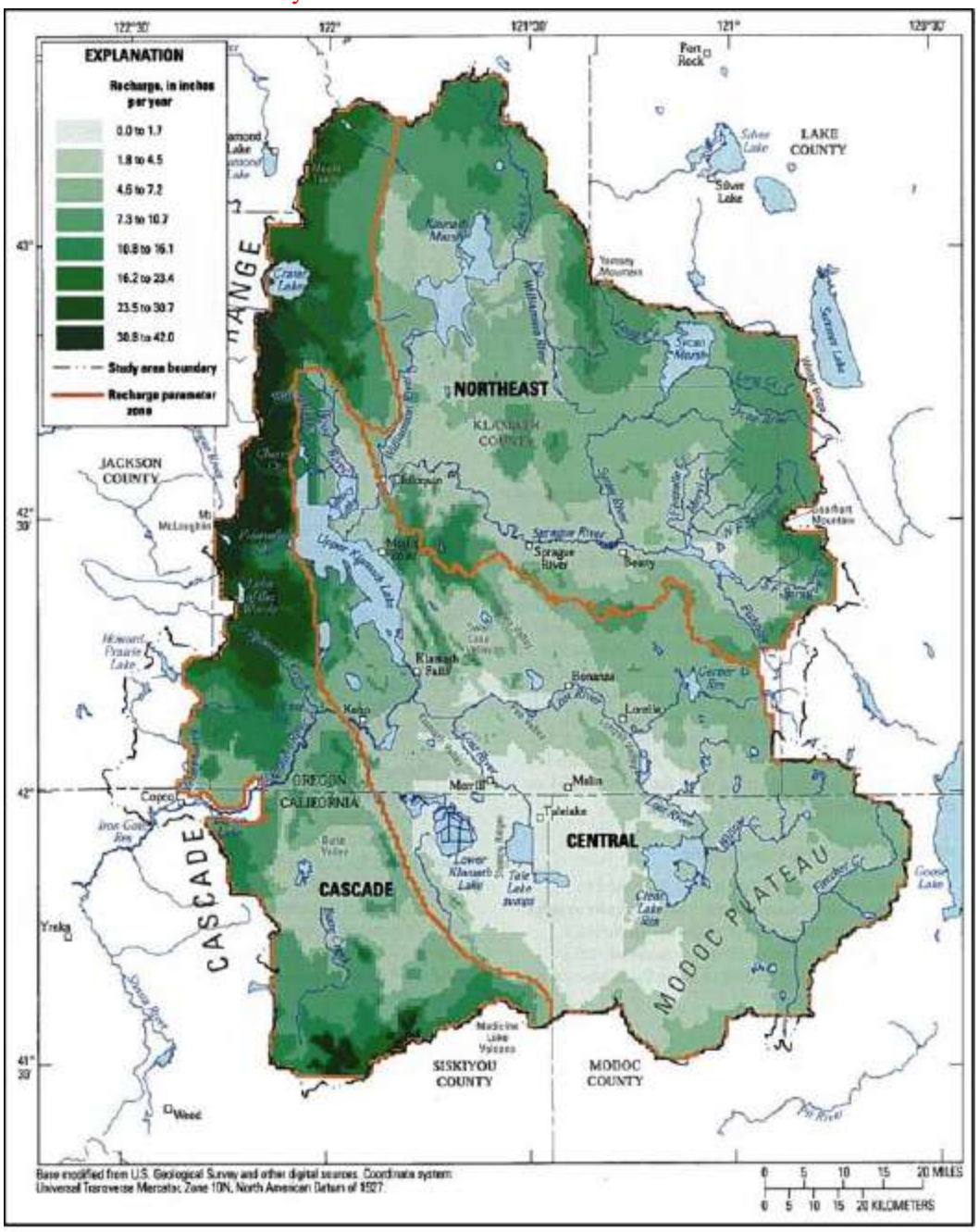
Figure 2-16. Generalized Water-Level Contours and Approximate Directions of Regional Groundwater Flow within the Upper Klamath Basin, Oregon, and California

2.2.1.5 Recharge Areas

Local precipitation and infiltration of surface water from the channels, lakes, and Sumps within ~~of~~ the ~~Lower Klamath and~~ Tule Lake subbasins provide recharge for the alluvial aquifer system. Water levels in the alluvial aquifer fluctuate seasonally in response to canal and irrigation operations (DWR, 2002). Surface water supplies available to the Tulelake Irrigation District provide an unknown amount of groundwater recharge. These surface water supplies include natural flow from the Klamath River, stored water from Upper Klamath Lake and Lake Ewauna, return flows from upstream irrigation, and flow from the Lost River.

Underflow from the adjacent, rapidly-replenished volcanic rocks are probably the principal sources of recharge in this basin. Because infiltration rates are very slow in the sedimentary deposits, underflow from adjacent volcanics is probably of major significance (DWR, 2003). Where the volcanic units are at or near the surface and are unconfined, water can percolate into fractures and vesicles that lead to lower units (DWR, 2002). The area surrounding this basin, and its extension into Oregon, primarily consists of Holocene to Miocene volcanic rocks that capture most of the incipient precipitation and intermittent streamflow by infiltration through fractures. Within the Tule Lake Subbasin, the exposed volcanic recharge areas are between the surficial alluvium and the boundaries of the basin at the eastern and western edges. These rocks probably function as a single, continuous, water-table aquifer that extends across faults and surrounds the basin. Hence, the two principal sources of recharge are underflow from the rapidly replenished and permeable unconfined system of the adjacent volcanic rocks; and less significantly, the very-slow vertical infiltration of surface water through marginally permeable sedimentary deposits (DWR, 2003). The general pattern of groundwater movement is from the north to the south.

During the development of the Model, the quantity and location of groundwater recharge was estimated within the Upper Klamath Basin, based on representative parameter values applied to the Model. Figure 2-17 identifies the estimated quantity and distribution of recharge in the Upper Klamath Basin, Oregon, and California. The average annual recharge from precipitation is estimated to be approximately 2.6 million acre-feet per year within the Upper Klamath Basin (Gannett et al., 2012).



Source: Gannett et al. *Ground-Water Hydrology of the Upper Klamath Basin, Oregon and California*, 2012.

Figure 2-17. Estimated Mean Annual Groundwater Recharge from Precipitation in the Upper Klamath Basin, Oregon, and California, 1970-2004, in inches, and Recharge Parameter Zones

2.2.1.6 Discharge

Aquifer discharge occurs when groundwater is extracted by wells, discharges to streams, ~~evapotranspired~~evapotranspiration by phreatophytes, or flows out of the groundwater basin in the subsurface (DWR, 2002). Most groundwater production in the Tule Lake Subbasin is from the underlying volcanic strata, volcanic deposits on the periphery of the basin, and volcanic deposits that partly overlie

basin-filling sediment in the Peninsula area. However, wells in any of these areas may produce from surficial volcanic deposits, basin filling sediments, or underlying volcanic strata (Pischel and Gannett, 2015). In general, inter-basin groundwater flow from the Tule Lake Subbasin is southward (Gannett et al., 2010).

The primary components of groundwater discharge include discharge to streams through a complex of springs within the Upper Klamath Basin interior, and discharge to wells at various locations and depths. Groundwater in the Upper Klamath Basin generally flows toward Upper Klamath Lake, the Klamath River Canyon, and the Tule Lake Subbasin (Figure 2-16; Gannett et al., 2010).

2.2.1.7 HCM Data Gaps

The HCM was collaboratively developed by multiple entities using the best available data. As appropriate, new data collected via the monitoring and management programs identified in Section 2.1.2, will be incorporated into the HCM for future GSP updates.

- Faults and structural features
    - The western and eastern boundaries of Tule Lake Subbasin are fault controlled, but the displacement and hydraulic properties of these faults are unknown.
- Aquifer interactions
    - Volcanic units and basin filled deposits are interbedded, making it difficult to define the bottom of the Subbasin and the connectivity between volcanic and alluvial aquifers.
    - Lack of detailed fracture mapping and permeability data in volcanic units adds uncertainty to flow modeling.
- Recharge and discharge quantifications
    - While recharge sources are identified,~~s~~ quantitative data on recharge rates and spatial variability are limited. Discharge through springs and streams is recognized, but spring discharge volume and seasonal variability are not well constrained.
- Groundwater flow directions
    - The general flow toward Upper Klamath Lake, Klamath River Canyon and Tule Lake Subbasin is known, but subsurface flow paths and vertical gradients are not well characterized near fault zones.

All data gaps identified will be addressed as new data becomes available to the GSAs.

2.2.1.8 References

A full list of references used in the creation of this GSP are included in Section 8.

2.2.2 Current and Historical Groundwater Conditions (Reg. § 354.16)

The main source of water within the Subbasin is surface water from the Klamath River. The water is made available to TID from the Klamath Reclamation Project for irrigation purposes through an intertie between the Klamath River and the Lost River. TID also receives tailwater from Klamath River water

users located north of the California-Oregon Stateline. At times, the Lost River provides some surface water to TID. Groundwater is pumped for uses other than irrigation, and to meet irrigation demands when not enough surface water supply is available. Groundwater levels within the Subbasin fluctuate partially as a result of the amount of surface water delivered to TID.

In 2001, TID constructed 10 groundwater wells to provide supplemental water supplies during dry years. TID only operated these wells during dry ~~years~~years, and the amount of supplemental water derived from groundwater generally represents a small portion of the total water supply in a given year. However, landowners within TID may operate private wells at any time. Beginning in 2001, reduction in available surface water supplies resulted in an increase in groundwater extraction.

Larger scale pumping in the Subbasin has been due to participation in water bank programs during years when surface water supplies have been limited. DWR has estimated that groundwater pumping during the 2001 through 2009 period, ranged from approximately 10,000 acre-feet to 70,000 acre-feet within the Subbasin (DWR, 2011). Similar programs were also established in 2012 through 2026, except for 2019 and 2025.~~,~~ ~~2013, 2014, 2015, 2018, and 2020.~~ This pumping estimate includes the 8,500 acre-feet of estimated pumping for domestic, stockwatering, and municipal supplies. Since 2020, the KPDRA has not offered groundwater programs~~...~~ due to decreased surface water supply having potential impacts on groundwater levels.

2.2.2.1 Historic Groundwater Elevations

Beginning in the 1980s, groundwater elevation data have been collected by DWR and the USGS within the GSP area. Prior to 1999, DWR monitored groundwater elevations in five wells twice each year (spring and fall). In 1999, an expanded groundwater monitoring program was developed through a contract with Reclamation to increase the monitoring well network from five wells to thirty-five (35) wells. By the mid-2000s the monitoring well network had expanded to an average of seventy (70) wells monitored on a monthly basis within the Subbasin and a~~n adjacent~~ nearby subbasin (the Lower Klamath Subbasin).

The groundwater elevation data for the representative monitoring wells is collected by DWR and other entities, including the District, and are uploaded to the Monitoring Network Module~~DWR Water Data Library (WDL)~~. Table 2-6 identifies the State Well Number (SWN), location, depth, depth of perforations, use type, and period of monitoring of the approximately 70 wells monitored within the Subbasin.

Table 2-6~~2.5~~. Wells Monitored for Groundwater Elevations within the Plan Area

State Well Number	Well Location		Well Depth (ft)	Perforations (ft)		Well Use	Period of Record	
	UTM East	UTM North		Top	Bottom		Begin	End
48N05E36K001M	636857	4646373	66	21	66	Stock	11/9/2001	Present
48N05E36A002M	637472	4646826	528	-	-	Irrigation	9/16/1998	Present
48N05E35F001M	634950	4646522	32	25	32	Domestic	8/22/1987	Present
48N05E33H001M	632533	4646676	57	-	-	Irrigation	9/10/1998	Present
48N05E26D001M	634823	4648412	1810	1250	1802	Irrigation	9/12/2001	Present

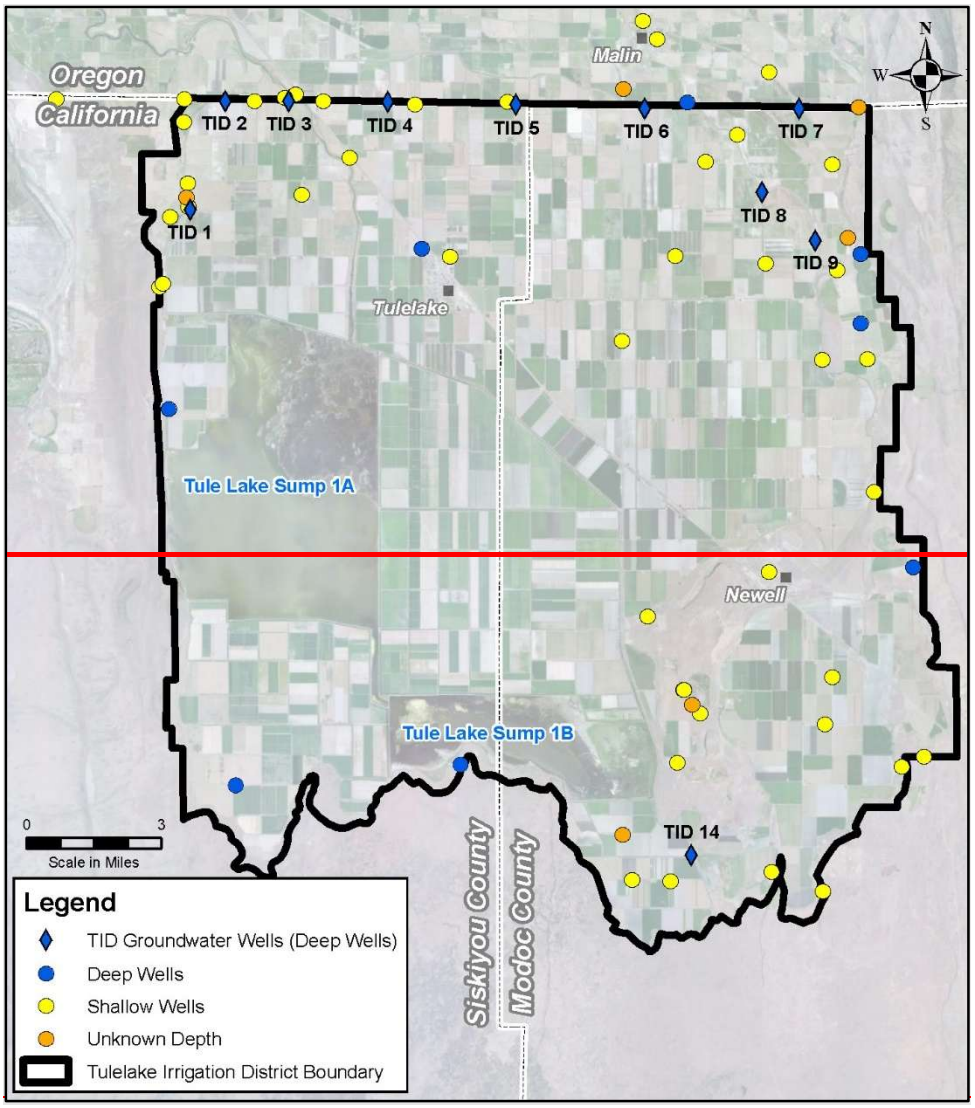
State Well Number	Well Location		Well Depth (ft)	Perforations (ft)		Well Use	Period of Record	
	UTM East	UTM North		Top	Bottom		Begin	End
(TID Well No. 8)								
48N05E25Q002M	637118	4647239	-	-	-	Domestic	11/9/2001	~~10/25/2017~~10/20/2022
48N05E24P001M	636676	4649183	112	-	-	Domestic	9/9/1998	Present
48N05E22L001M	633295	4649188	65	-	-	Stock	9/10/1998	Present
48N05E22H001M	634129	4649916	203	36	203	Irrigation	7/23/2002	8/27/2013
48N05E16P001M (TID Well No. 6)	631643	4650575	2600	823	2358	Irrigation	8/10/2001	~~Present~~12/1/2022
48N05E14R001M (TID Well No. 7)	635760	4650660	2030	814	2020	Irrigation	8/16/2001	Present
48N05E13R003M	637344	4650713	-	-	-	Domestic	4/25/2002	3/25/2014
48N04E35C001M	625776	4646739	2790	2561	2761	Municipal	12/22/2003	Present
48N04E35G001M	626538	4646542	220	-	-	Irrigation	8/13/1998	Present
48N05E36D001M (TID Well No. 9)	636270	4647161	2043	-	-	Irrigation	9/05/2001	~~Present~~4/1/2022
48N04E31N002M	618801	4645596	337	292	337	Domestic	10/17/1995	Present
48N04E31M001M	618885	4645689	40	-	-	Domestic	8/20/1998	~~Present~~5/20/2020
48N04E30F004M	619471	4647993	-	-	-	Domestic	11/7/2001	~~Present~~1/25/2023
48N04E30F002M (TID Well No. 1)	619583	4647681	740	260	700	Irrigation	6/27/2001	Present
48N04E30F001M	619526	4647740	142	-	-	Industrial	8/20/1998	Present
48N04E30E001M	619060	4647474	185	19	185	Domestic	9/30/1998	4/27/2011
48N04E30C002M	619503	4648378	84	69	74	Domestic	11/2/2001	Present
48N04E28D001M	622541	4648128	140	-	-	Irrigation	8/20/1998	~~Present~~5/18/2021
48N04E22M001M	623798	4649129	135	31	135	Domestic	11/8/2001	Present
48N04E19C001M	619377	4649996	38	22	38	Domestic	11/7/2001	Present
48N04E18L003M	619372	4650598	110	98	110	Domestic	8/19/1998	Present

State Well Number	Well Location		Well Depth (ft)	Perforations (ft)		Well Use	Period of Record	
	UTM East	UTM North		Top	Bottom		Begin	End
48N04E18J001M (TID Well No. 2)	620463	4650579	1550	1260	1540	Irrigation	8/27/2001	Present
48N04E17C001M	621254	4650589	159	89	129	Domestic	11/8/2007	Present
48N04E16M001M (TID Well No. 3)	622152	4650599	1710	1053	1681	Irrigation	8/16/2001	Present
48N04E16L002M	623088	4650624	150	50	150	Industrial	8/1/1998	Present
48N04E15K001M (TID Well No. 4)	624805	4650629	1440	1212	1433	Irrigation	8/10/2001	Present
48N04E14M001M	625532	4650579	127	-	-	Stock	9/16/1998	Present
48N04E13K001M (TID Well No. 5)	628217	4650610	1570	935	1557	Irrigation	8/12/2001	Present
48N03E34N001M	614107	4645584	262	-	-	Stock	9/1/1998	Present
48N03E14M001M	615964	4650542	454	-	-	Irrigation	9/11/1998	11/23/2009
48N02E14J001M	607580	4650361	203	21	200	Domestic	8/17/1998	2/25/2010
47N06E30H001M	639048	4638513	680	198	650	Irrigation	9/15/1998	~~Present~~10/26/2020
47N06E19D002M	637956	4640502	245	-	-	Irrigation	9/3/1998	Present
47N06E06N002M	637707	4644032	1575	-	-	Irrigation	9/3/1998	Present
47N06E06N001M	637714	4644033	85	-	-	Irrigation	9/3/1998	Present
47N05E33F001M	631976	4637066	54	-	-	Industrial	8/18/1998	Present
47N05E26F001M	635184	4638313	105	78	98	Irrigation	8/18/1998	Present
47N05E04M001M	631148	4644392	71	68	72	Industrial	10/28/1987	~~Present~~2/12/2025
47N05E01N001M	636509	4643988	65	49	65	Domestic	10/28/1987	Present
47N05E01H001M	637501	4644971	1000	-	-	Stock	3/18/1999	~~Present~~1/25/2023
47N04E07Q001M	619097	4642356	1170	146	289	Irrigation	9/2/1998	Present
46N06E08E001M	639424	4633481	213	-	-	Irrigation	9/8/1998	Present
46N06E07K002M	638839	4633192	101	-	-	Domestic	9/8/1998	Present
46N05E24P002M	636799	4629838	188	140	188	Irrigation	8/18/1998	Present

State Well Number	Well Location		Well Depth (ft)	Perforations (ft)		Well Use	Period of Record	
	UTM East	UTM North		Top	Bottom		Begin	End
46N05E23G002M	635418	4630333	209	150	190	Irrigation	8/14/1998	Present
46N05E22D001M (TID Well No. 14)	633266	4630751	571	114	554	Irrigation	7/31/2001	Present
46N05E21M001M	631682	4630060	325	32	100	Irrigation	7/24/2002	Present
46N05E21J001M	632719	4630034	32	-	-	Domestic	11/9/2001	Present
46N05E16N001M	631419	4631249	-	-	-	Domestic	11/9/2001	10/31/2018
46N05E09J003M	632842	4633205	132	-	-	Industrial	8/18/1998	Present
46N05E03P001M	633424	4634509	173	10	89	Monitoring	9/3/1998	Present
46N05E03M003M	633203	4634749	-	-	-	Irrigation	7/23/2008	Present
46N05E03M002M	632965	4635144	252	-	-	Irrigation	9/4/1998	Present
46N05E03M001M	632976	4635138	126	-	-	Irrigation	9/4/1998	Present
46N05E01P001M	636763	4634300	101	87	101	Domestic	10/25/1994	Present
46N05E01B001M	636943	4635559	140	-	-	Irrigation	5/24/2001	Present
41S12E23H001W	634935	4651610	150	-	-	Industrial	11/9/2001	Present
41S12E22Q001W	632785	4650754	600	-	-	Industrial	11/8/2001	Present
41S12E21Q001W	631062	4651080	-	-	-	Domestic	11/8/2001	Present
41S12E19Q001W	627992	4650692	65	-	-	Domestic	11/8/2001	Present
41S12E16J001W	631556	4652891	380	-	-	Municipal	11/8/2001	Present
41S12E15M002W	631946	4652420	84	-	-	Municipal	11/8/2001	~~9/4/2019~~Present
41S11E16R002W	622342	4650776	70	-	-	Industrial	8/28/2002	Present
41S11E16R001W	622046	4650694	70	-	-	Domestic	11/8/2001	Present
TL-T3 GP	627056	4633043	500	-	-	Monitoring	1/10/2011	Present
TL-T1 Q3B	621062	4632384	500	-	-	Monitoring	1/10/2011	Present

Note: Information was obtained from DWR's Water Data Library.
As additional information becomes available, this table will be updated.

Figure 2-18 identifies the distribution of groundwater wells actively monitored for groundwater elevations within and near the GSP area. The wells shown on this figure include groundwater wells drilled to depths such that extraction may occur from the alluvial aquifer or from the deeper, more productive volcanic aquifer. For the purposes of this GSP, wells that most likely pump from the alluvial aquifer (those with shallow perforation and depths less than ~~500~~ 450 feet) are described as "shallow groundwater wells". Wells with depths greater than ~~500~~ 450 feet and deep perforations most likely pump from the deeper volcanic aquifer and are described as "deep groundwater wells". Well depth and construction information, including perforations, are not available for all groundwater wells monitored for water elevation within the GSP area. Some wells with unknown depths are also shown on Figure 2-18. Additional hydrographs are included in Appendix M, which include information about domestic well construction depths. Domestic wells located in each public land survey section were grouped to nearby representative monitoring wells and then ranked from shallowest to deepest. Generally, the shallowest domestic well depth in each area was identified and used to establish minimum thresholds for the corresponding representative monitoring wells, where applicable.



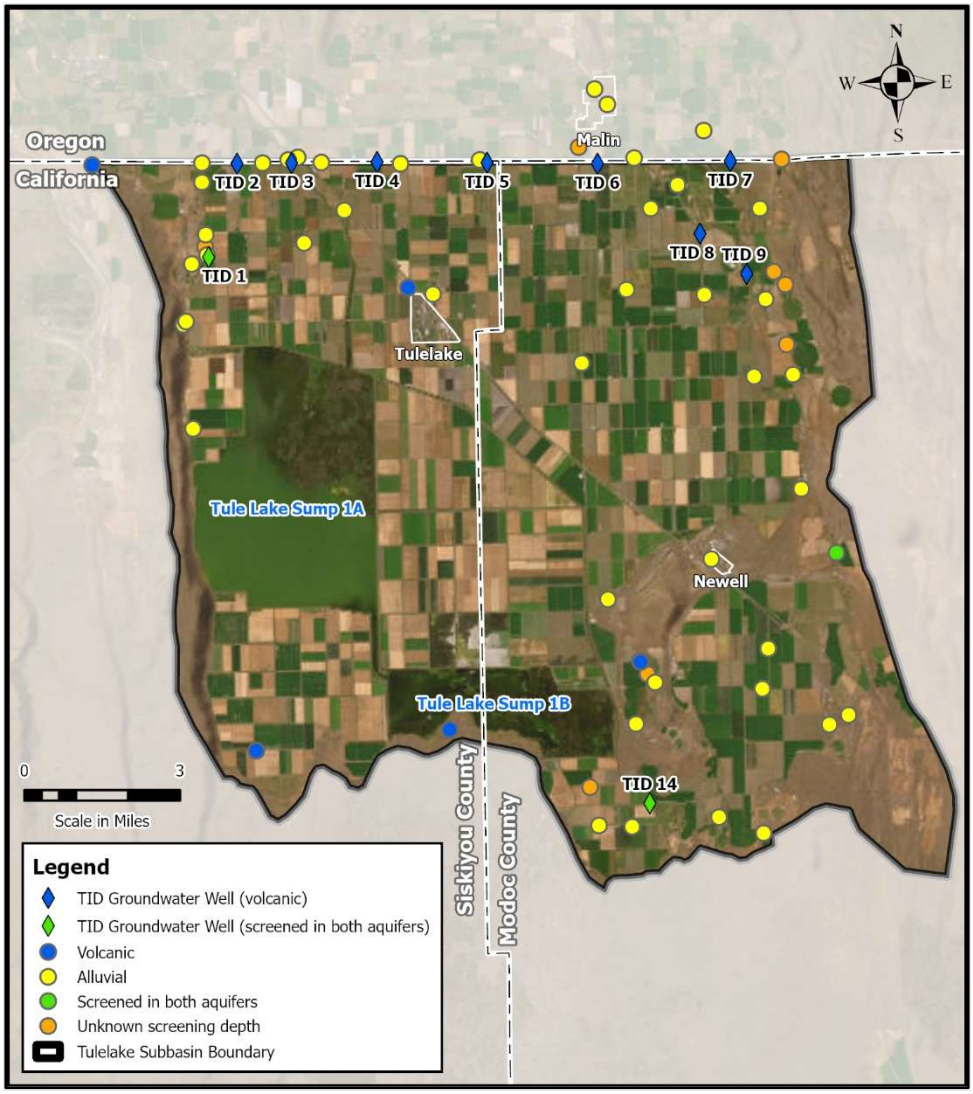


Figure 2-18. Wells Monitored for Groundwater Elevations within and near the GSP Area

Beginning in 2001, the reduction in available surface water supplies has resulted in an increase in groundwater extraction within the Klamath Reclamation Project, including the GSP area. As a result, recent trends in groundwater elevation are reflective of not only climatic conditions and surface water recharge, but also the generally increased (although varying) levels of annual groundwater extraction. Figure 2-19 identifies the location of the wells where static groundwater elevation data was reviewed and represented in hydrographs (Figure 2-20 through Figure 2-28).

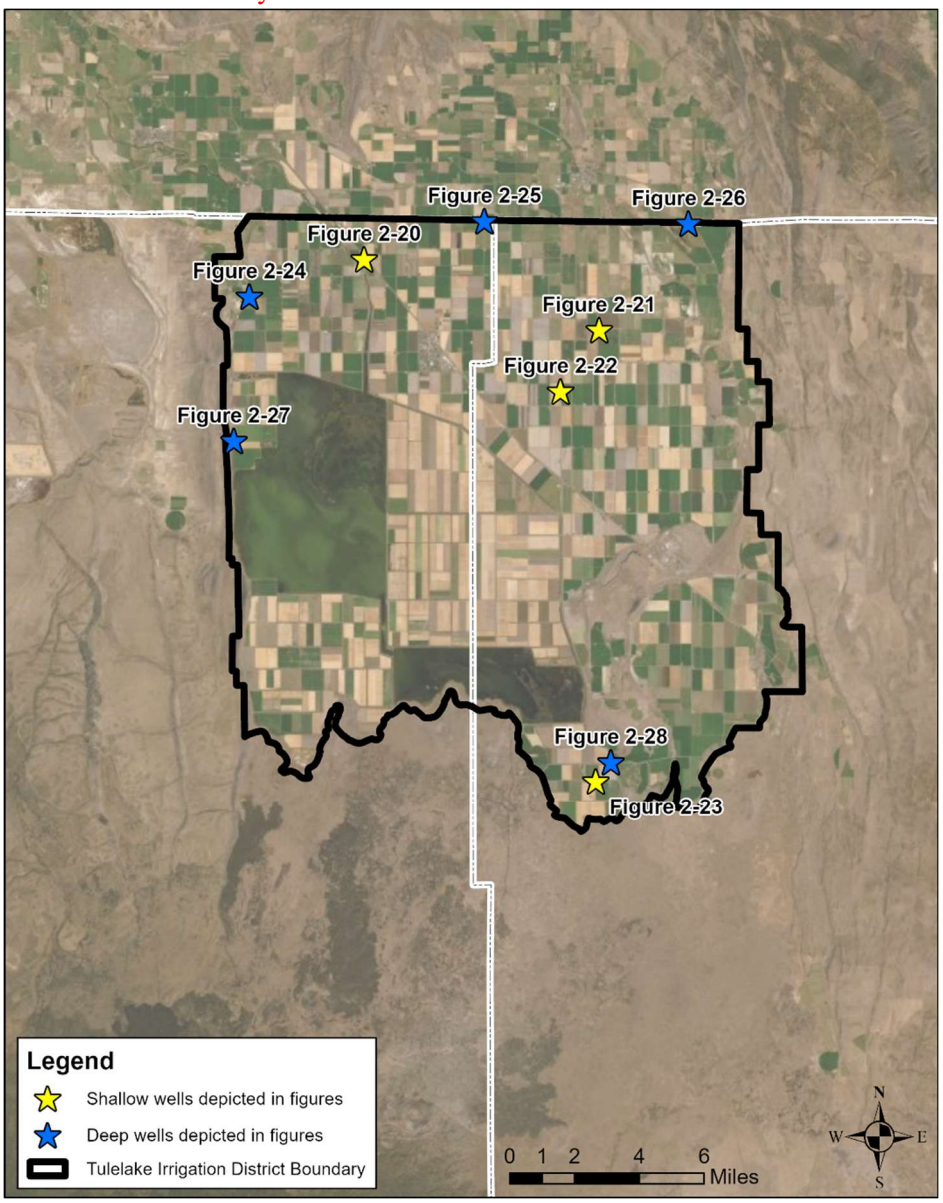


Figure 2-19. Wells Monitored for Groundwater Elevations within and near the GSP Area Represented in Figure 2-20 through Figure 2-28

Figure 2-20 through Figure 2-23 include wells described previously as relatively shallow groundwater wells, meaning those with drilling depths of less than ~~500~~ 450 feet. Figure 2-24 through Figure 2-28 include wells described as deep groundwater wells, i.e., those with well depths of greater than ~~500~~ 450 feet.



Figure 2-20. Groundwater Hydrograph for SWN: 48N04E22M001M

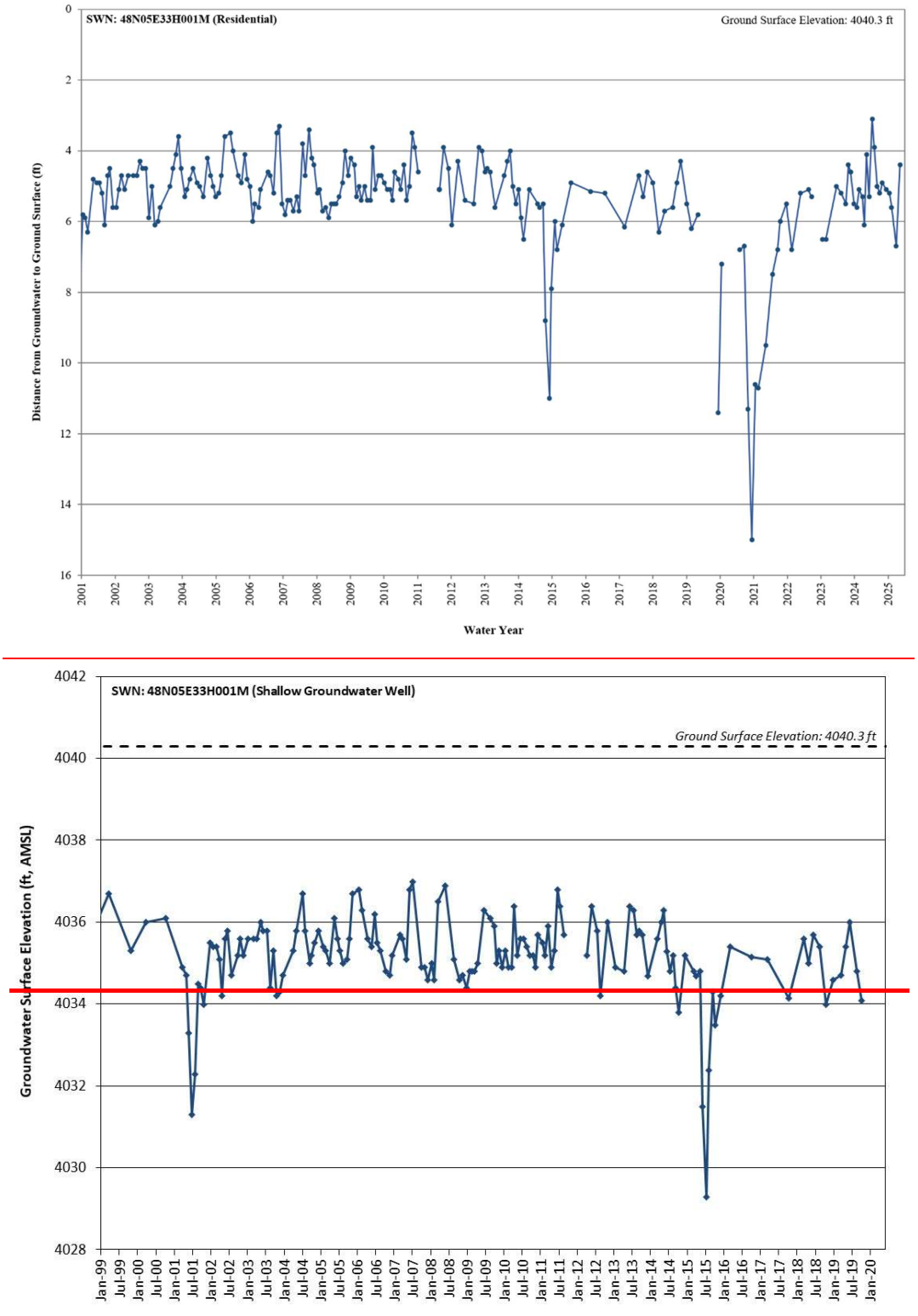


Figure 2-21. Groundwater Hydrograph for SWN: 48N05E33H001M

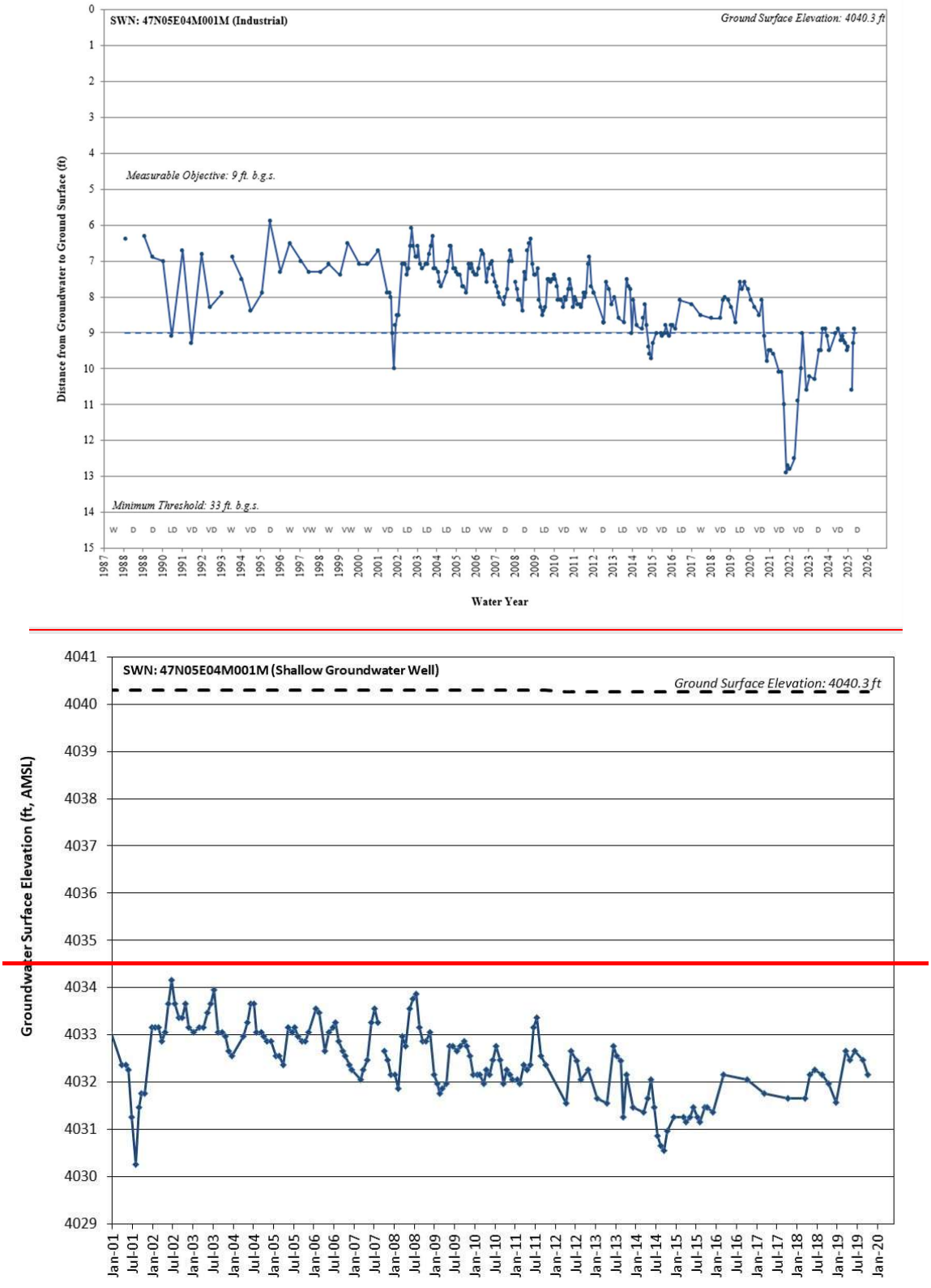
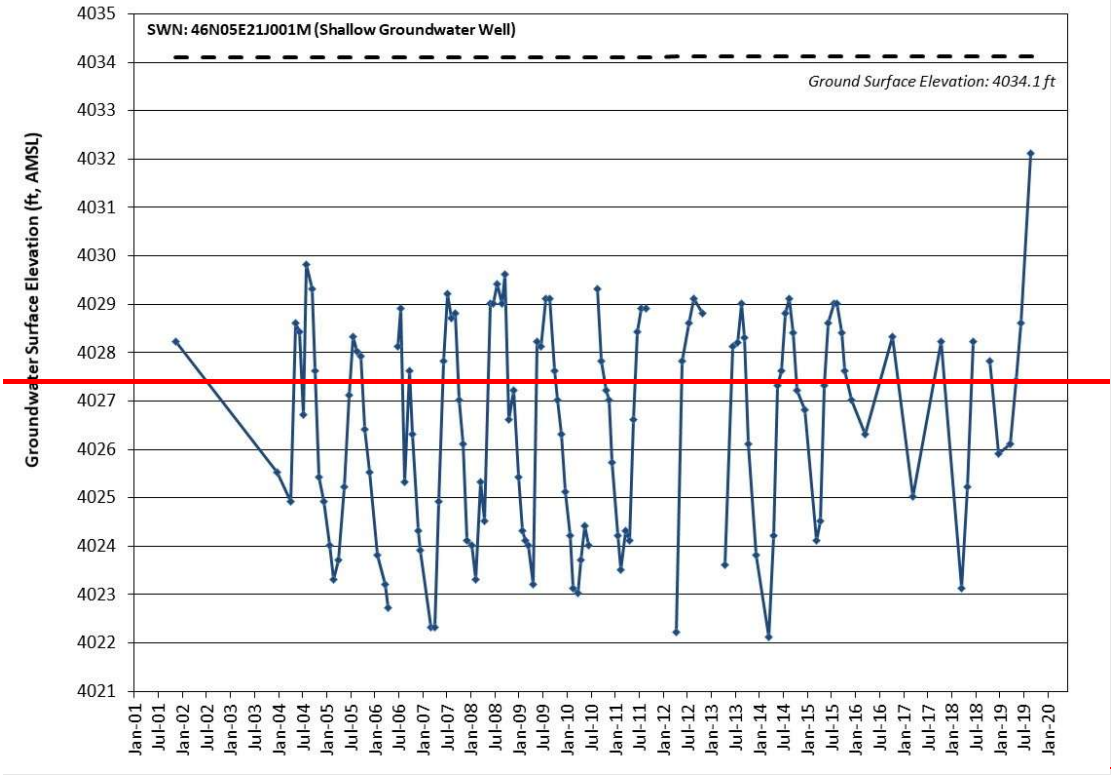


Figure 2-22. Groundwater Hydrograph for SWN: 47N05E04M001M



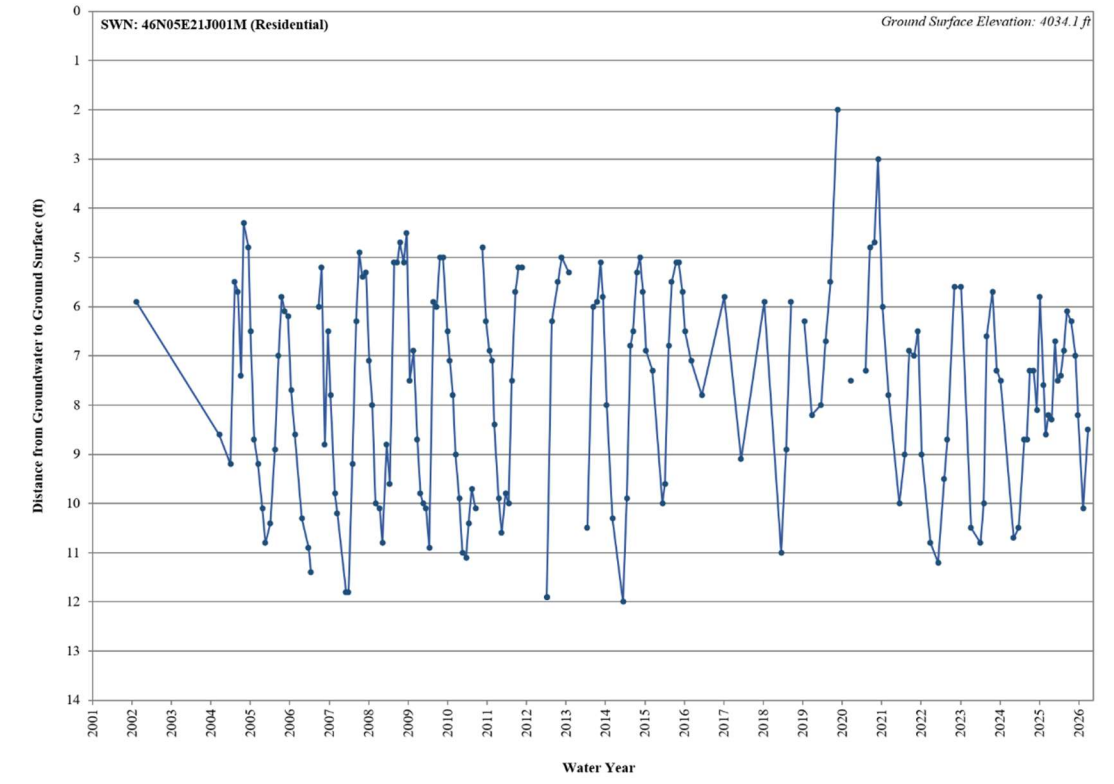


Figure 2-23. Groundwater Hydrograph for SWN: 46N05E21J001M

As shown on Figure 2-20 through Figure 2-23, relatively shallow groundwater wells within the GSP area show minimal changes (less than 1 foot) in groundwater elevations when comparing spring 2015 to spring ~~2019~~ 2025 groundwater elevations. This is indicative of these wells pumping from the alluvial (shallow) aquifer, which is likely recharged through local precipitation~~,~~; deep percolation of irrigation flows~~,~~; and canal seepage. Hydrographs of shallow wells throughout the GSP area identify a similar (minimal) change in groundwater elevations during this time period.

Figure 2-24 through Figure 2-28 show hydrographs for deeper wells within the alluvial aquifer (drilled deeper than ~~500~~ 450 feet).

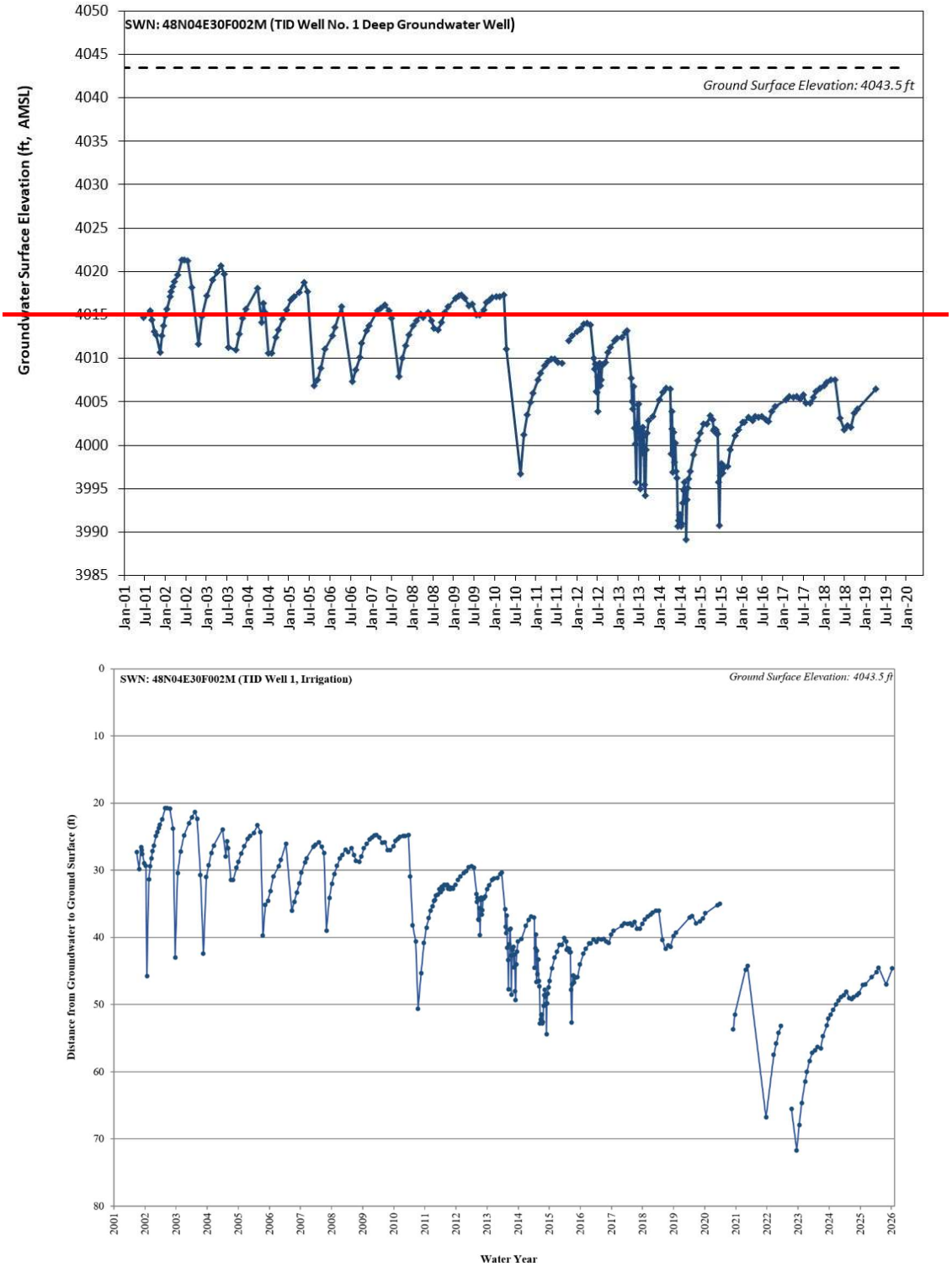


Figure 2-24. Groundwater Hydrograph for SWN: 48N04E30F002M (TID Well No. 1)

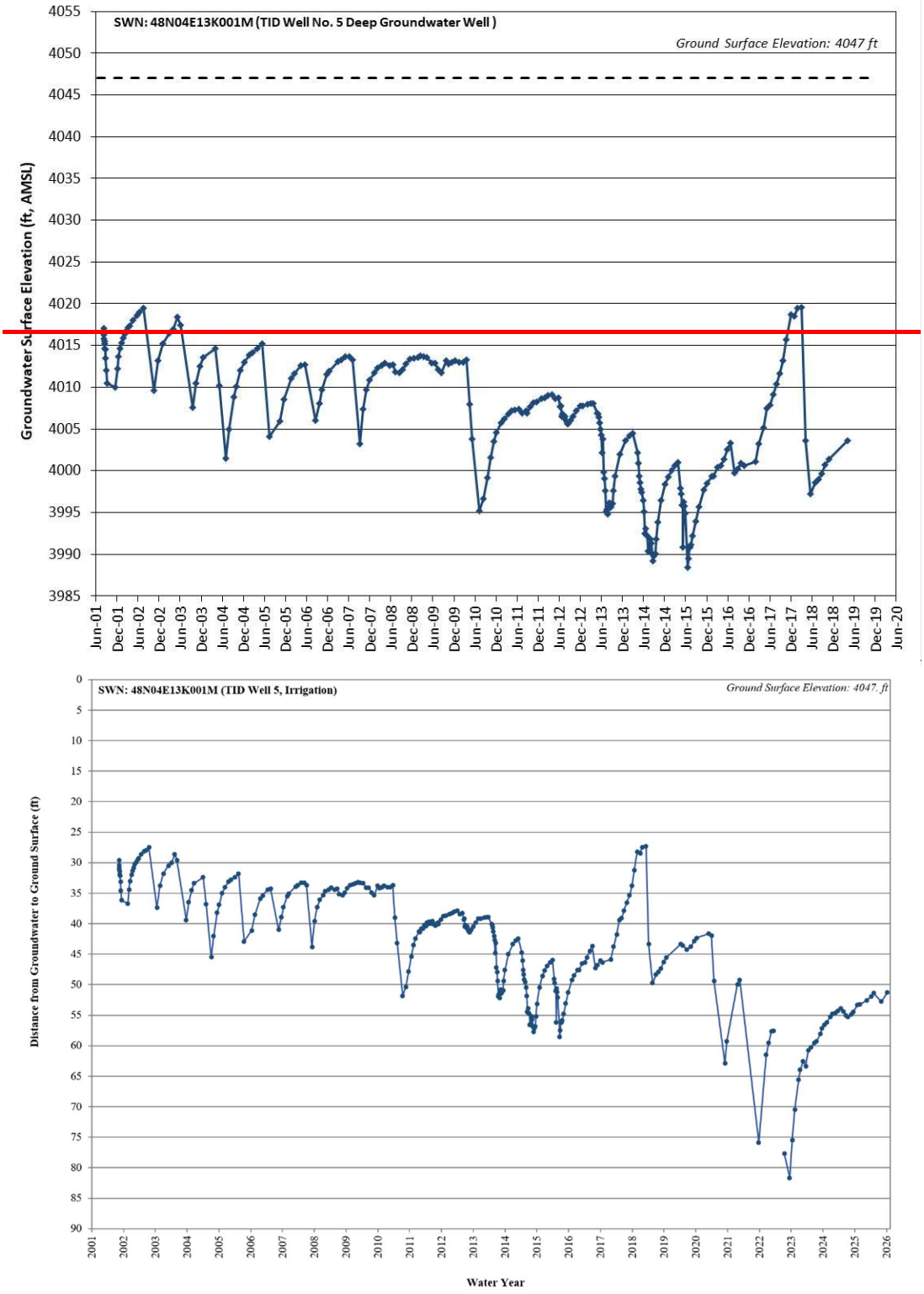


Figure 2-25. Groundwater Hydrograph for SWN: 48N04E13K001M (TID Well No. 5)

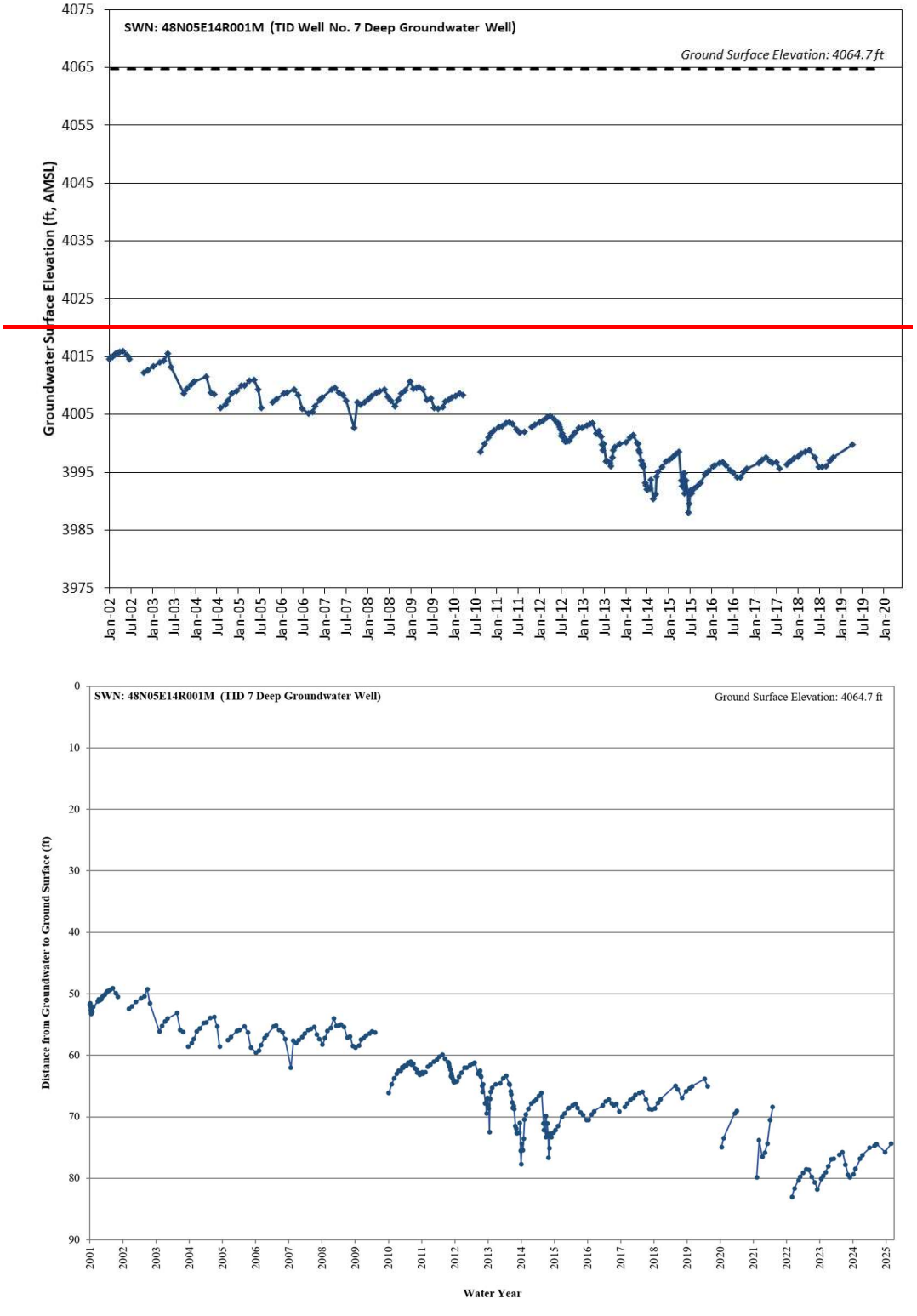


Figure 2-26. Groundwater Hydrograph for SWN: 48N05E14R001M (TID Well No. 7)

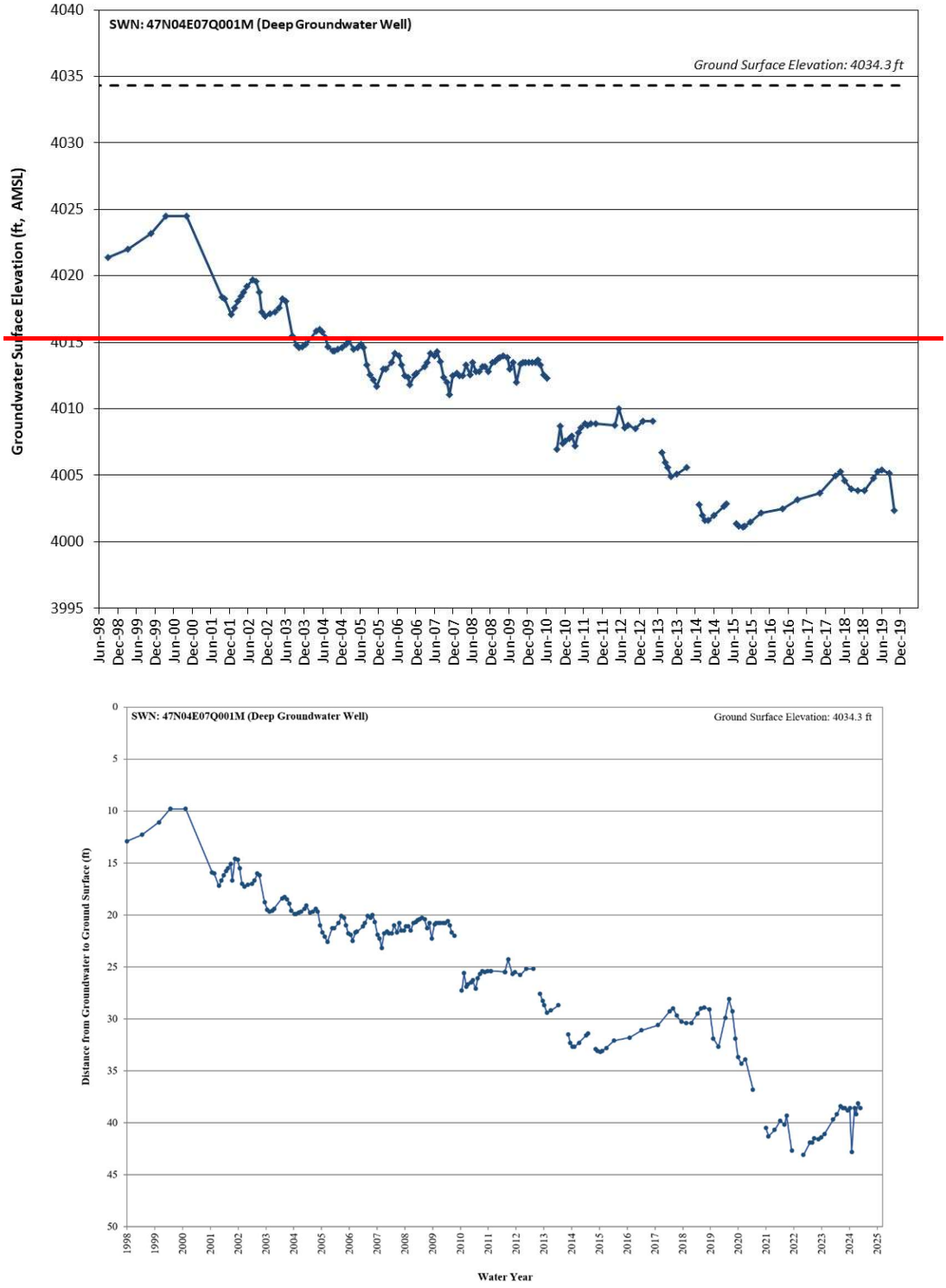


Figure 2-27. Groundwater Hydrograph for SWN: 47N04E07Q001M

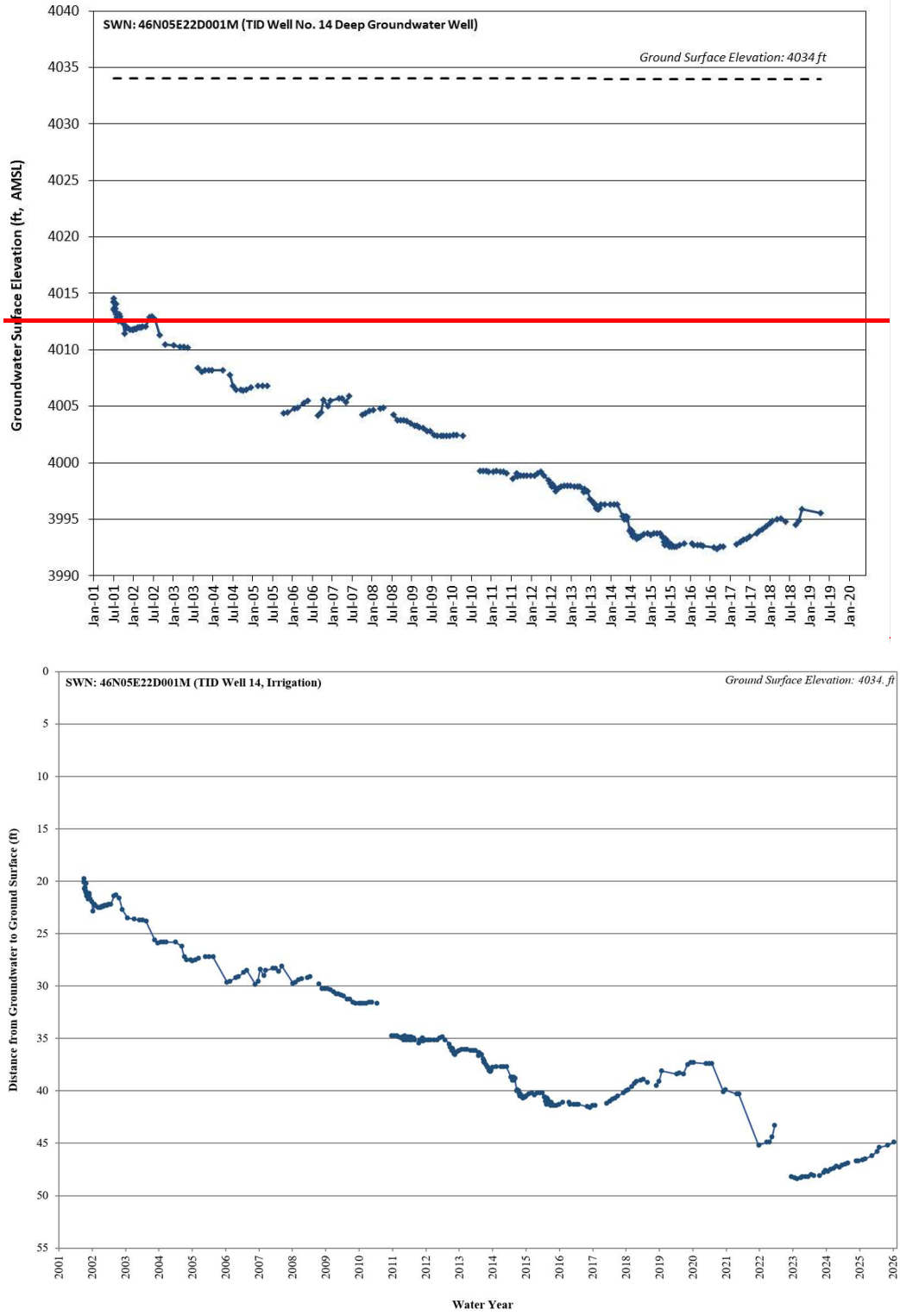


Figure 2-28. Groundwater Hydrograph for SWN: 46N05E22D001M (TID Well No. 14)

The hydrographs for deeper groundwater wells show a greater change in the groundwater elevations from spring 2015 to spring ~~2019~~2025, as compared to the hydrographs for ~~the shallow~~shallow groundwater wells. This deeper portion of the alluvial aquifer appears to be primarily recharged through precipitation and the groundwater movement of flows from north to south within the Upper Klamath Basin. It may also be influenced by the underlying volcanic aquifer. ~~, which is not considered a primary aquifer in the Subbasin.~~ The change in spring 2015 to spring ~~2019~~ 2025 elevation at these groundwater wells ranges from approximately -2 feet to approximately +4 feet.

2.2.2.2 Current Groundwater Elevations

The following figures represent groundwater elevation data from deep groundwater wells (deeper than ~~500~~ 450 feet), as these wells indicate the potential effects from both dry hydrologic conditions and groundwater pumping within the deeper portion of the alluvial aquifer.

Figure 2-29 and Figure 2-30 identify groundwater elevations and contours within the GSP area[1] for spring 2015 and spring 2019, respectively, prior to the groundwater pumping during the subsequent irrigation season (ft, AMSL).

[1] The groundwater elevation contours were created using available groundwater measurement data in the GSP area. However, the extent of the contours is limited because there are no wells with groundwater level measurements located immediately outside the Tule Lake Subbasin.

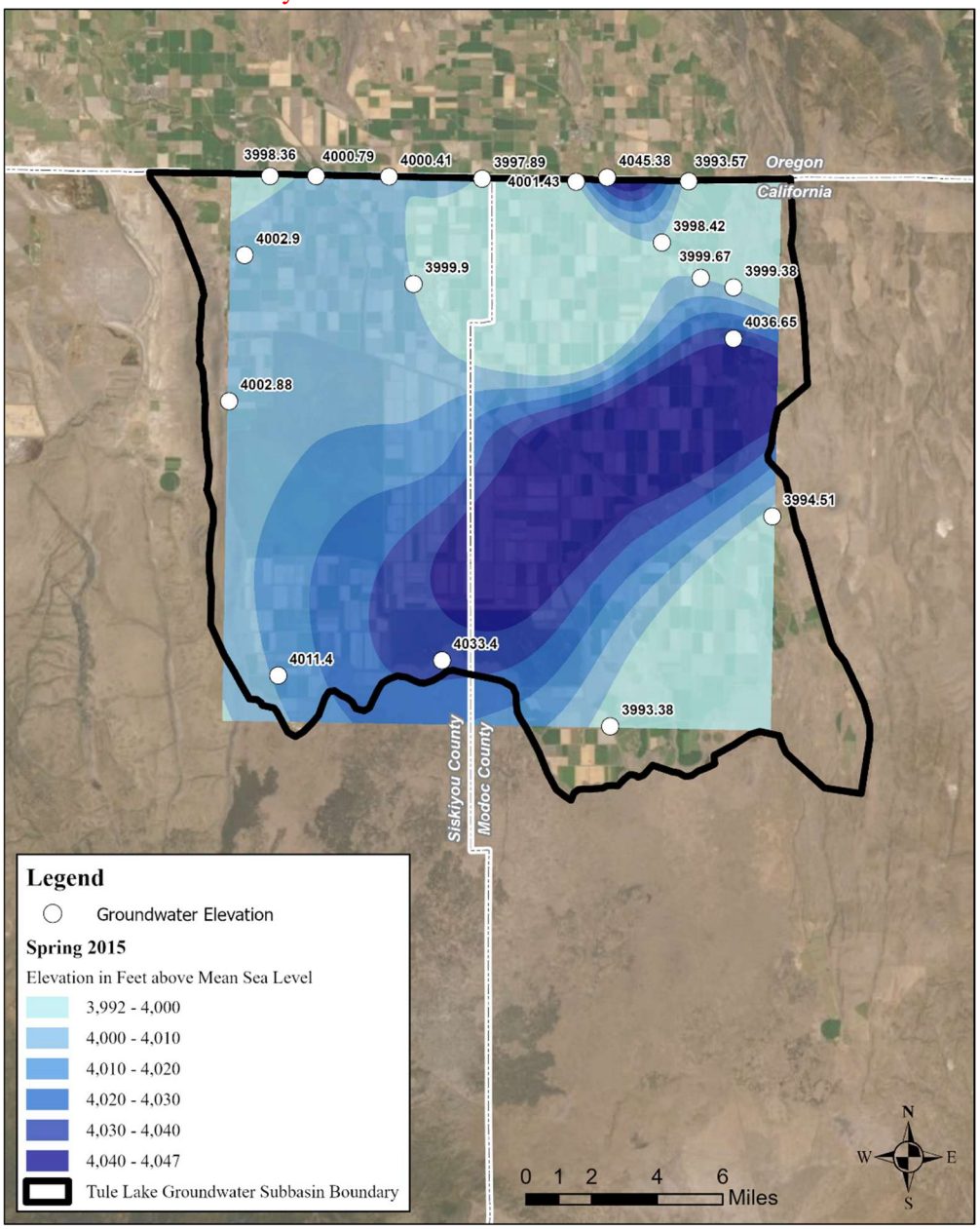
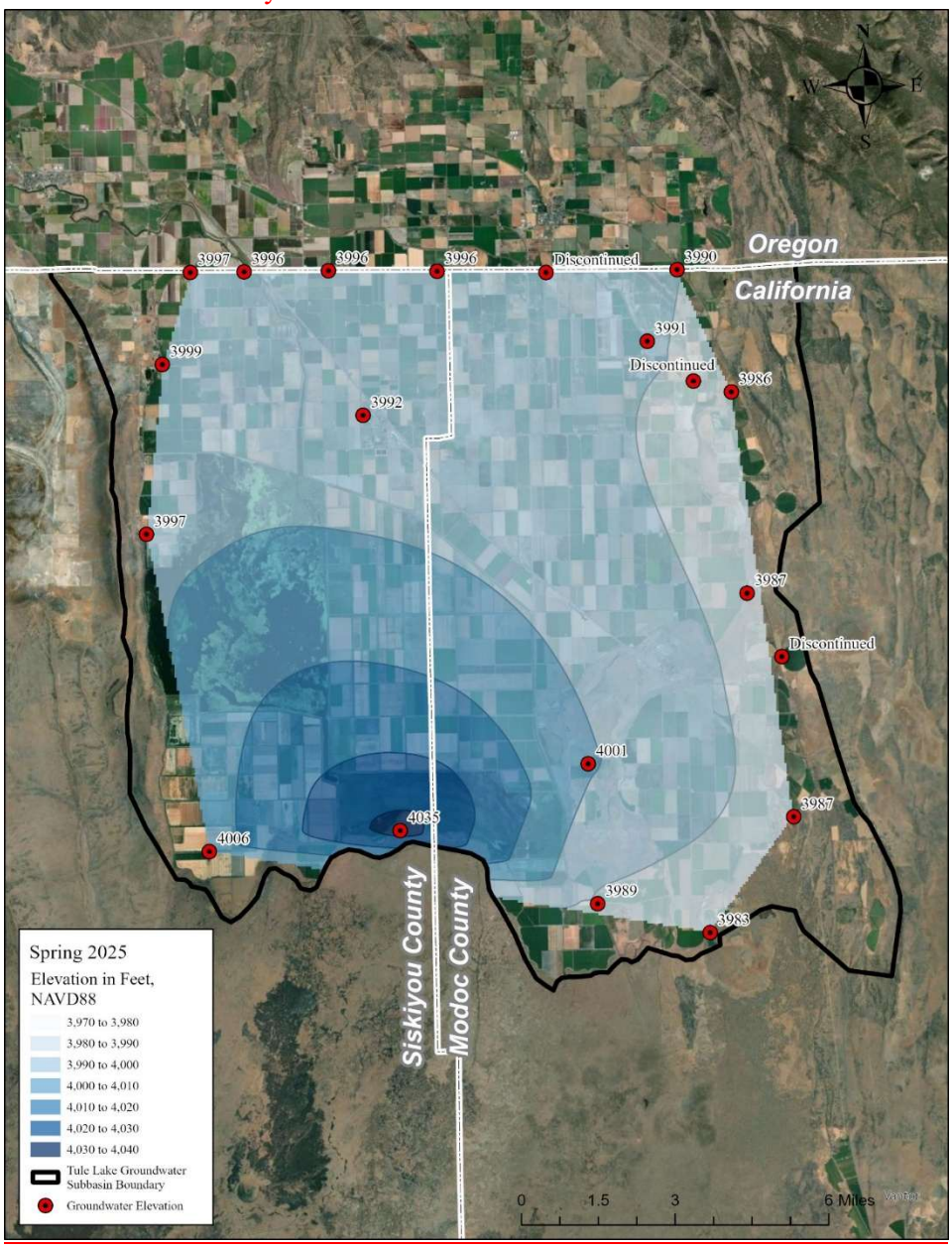


Figure 2-29. Spring 2015 Groundwater Surface Elevations


N
W
E
S
Oregon
California
3997
3996
3996
3996
Discontinued
3990
3991
Discontinued
3986
3999
3992
3997
3987
Discontinued
4001
3987
4035
4006
3989
3983
Siskiyou County
Modoc County
Spring 2025
Elevation in Feet, NAVD88
3,970 to 3,980
3,980 to 3,990
3,990 to 4,000
4,000 to 4,010
4,010 to 4,020
4,020 to 4,030
4,030 to 4,040
Tule Lake Groundwater Subbasin Boundary
Groundwater Elevation
0
1.5
3
6 Miles

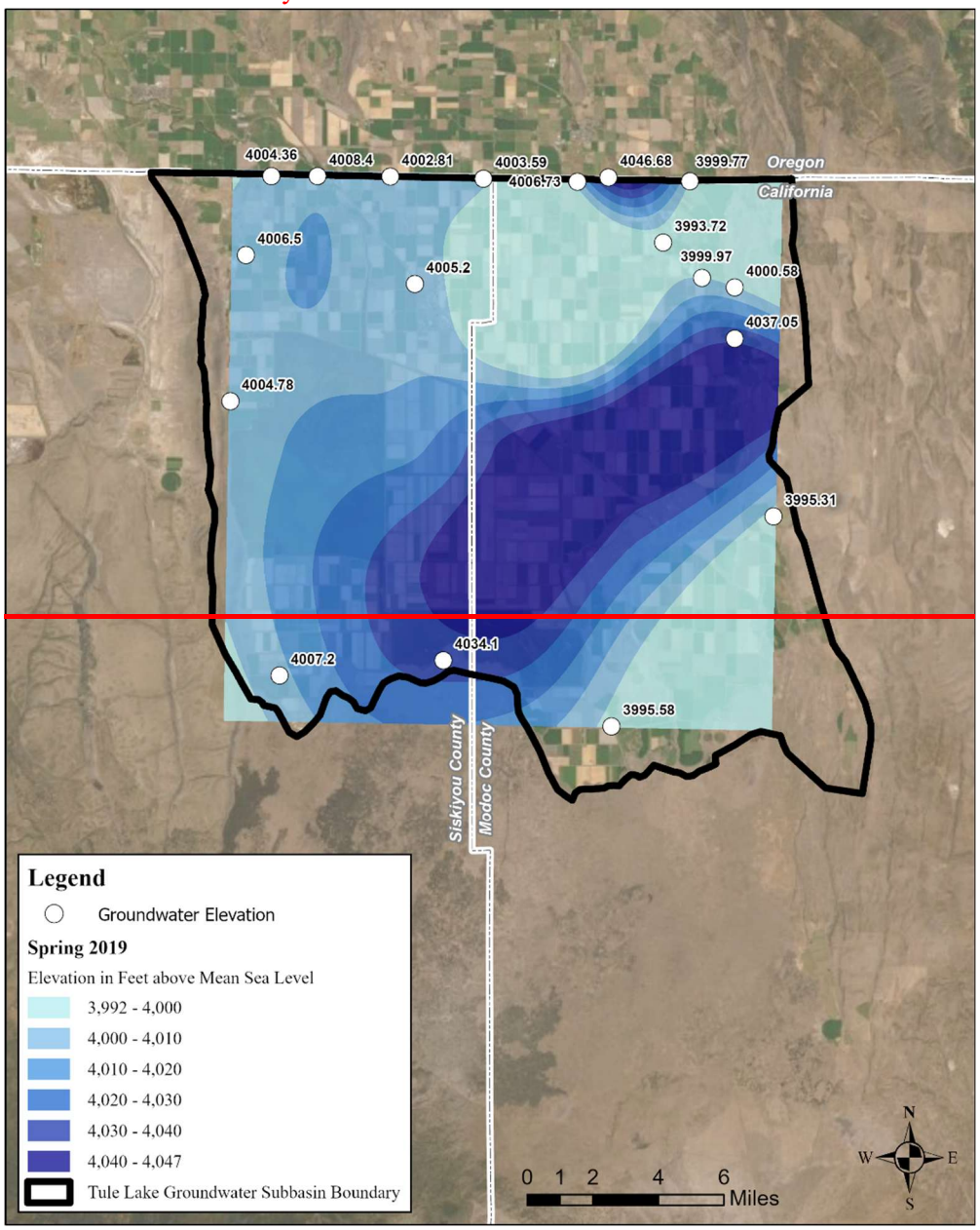


Figure 2-30. Spring ~~2019~~ 2025 Groundwater Surface Elevations

Figure 2-31 and Figure 2-32 identify groundwater elevations and contours within the GSP area for fall 2015 and fall 2019, respectively, after the groundwater pumping during the most recent irrigation season (ft, AMSL).

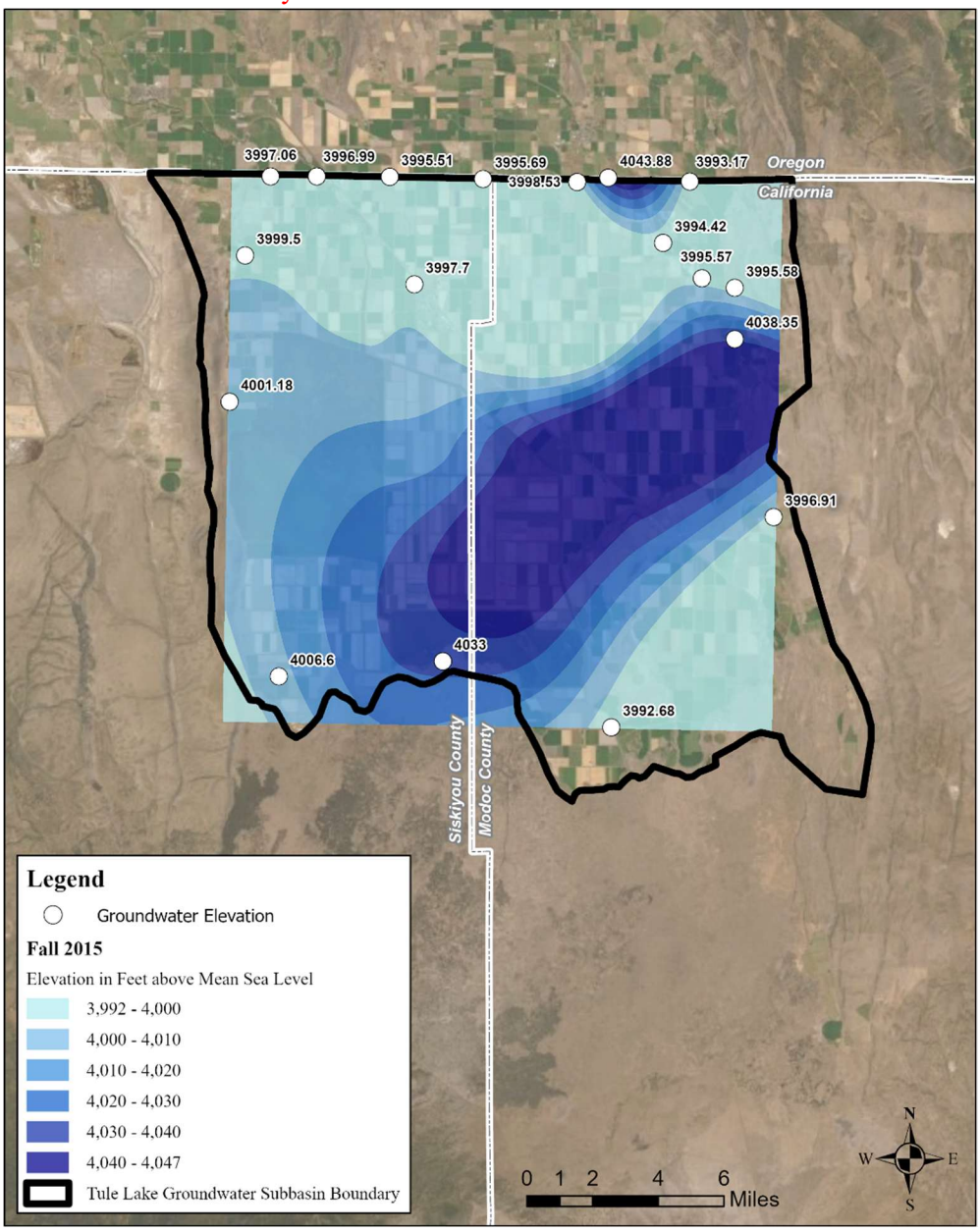
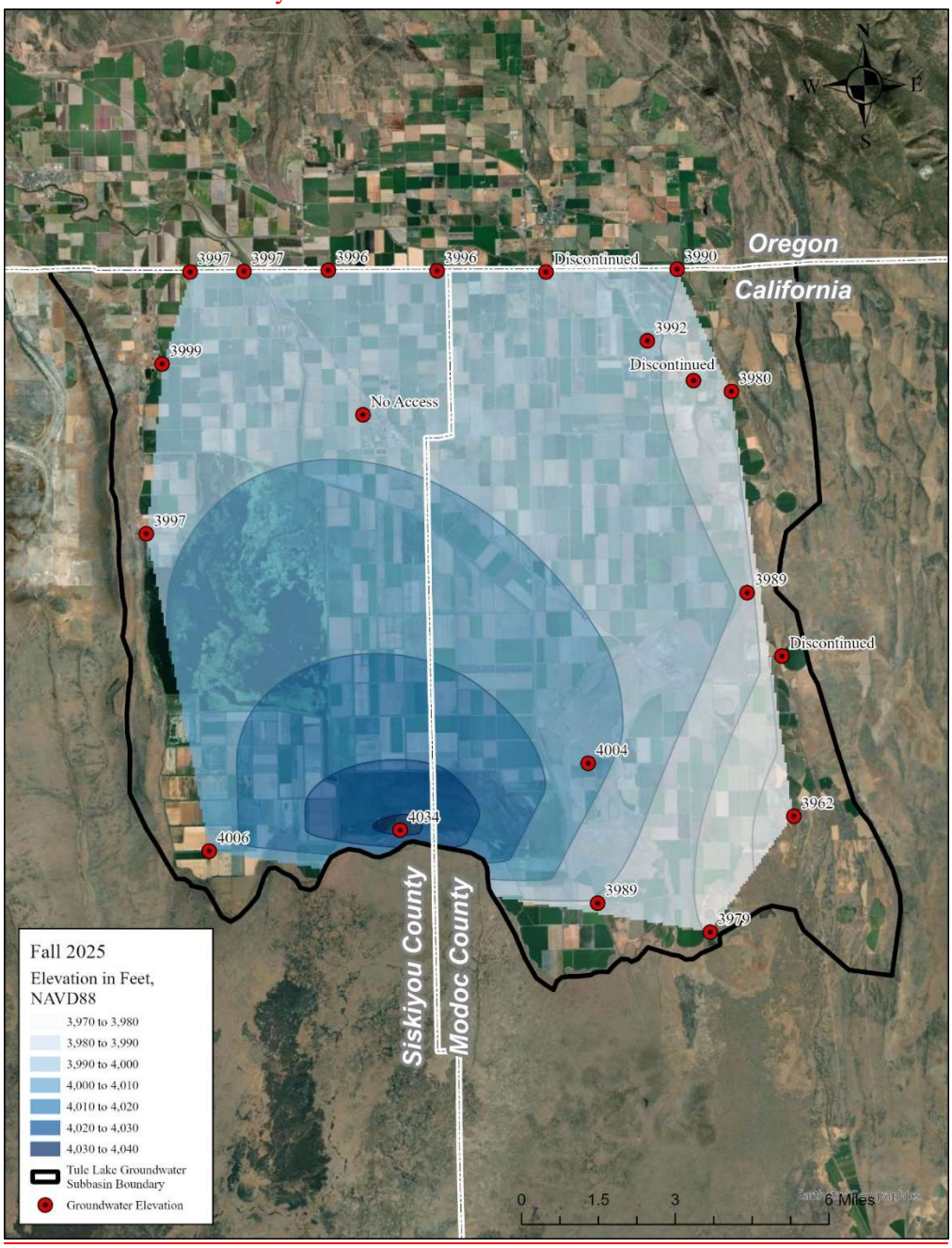


Figure 2-31. Fall 2015 Groundwater Surface Elevations


N
W
E
S
Oregon
California
3997
3997
3996
3996
Discontinued
3990
3992
Discontinued
3980
3999
No Access
3997
3989
Discontinued
4004
3962
4034
4006
3989
3979
Siskiyou County
Modoc County
Fall 2025
Elevation in Feet, NAVD88
3,970 to 3,980
3,980 to 3,990
3,990 to 4,000
4,000 to 4,010
4,010 to 4,020
4,020 to 4,030
4,030 to 4,040
Tule Lake Groundwater Subbasin Boundary
Groundwater Elevation
0
1.5
3
6 Miles

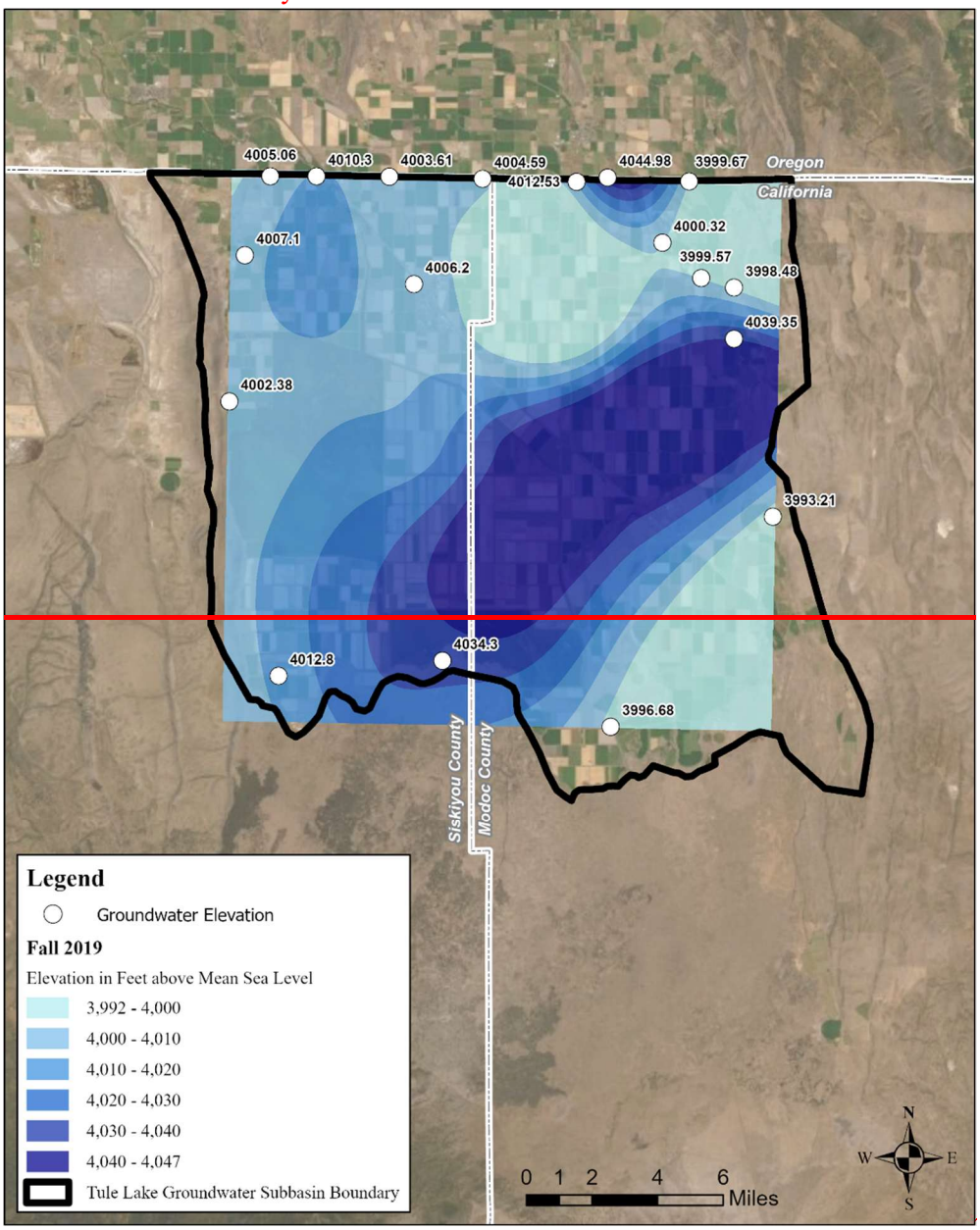


Figure 2-32. Fall ~~2019~~ 2025 Groundwater Surface Elevations

2.2.2.3 Vertical Gradients

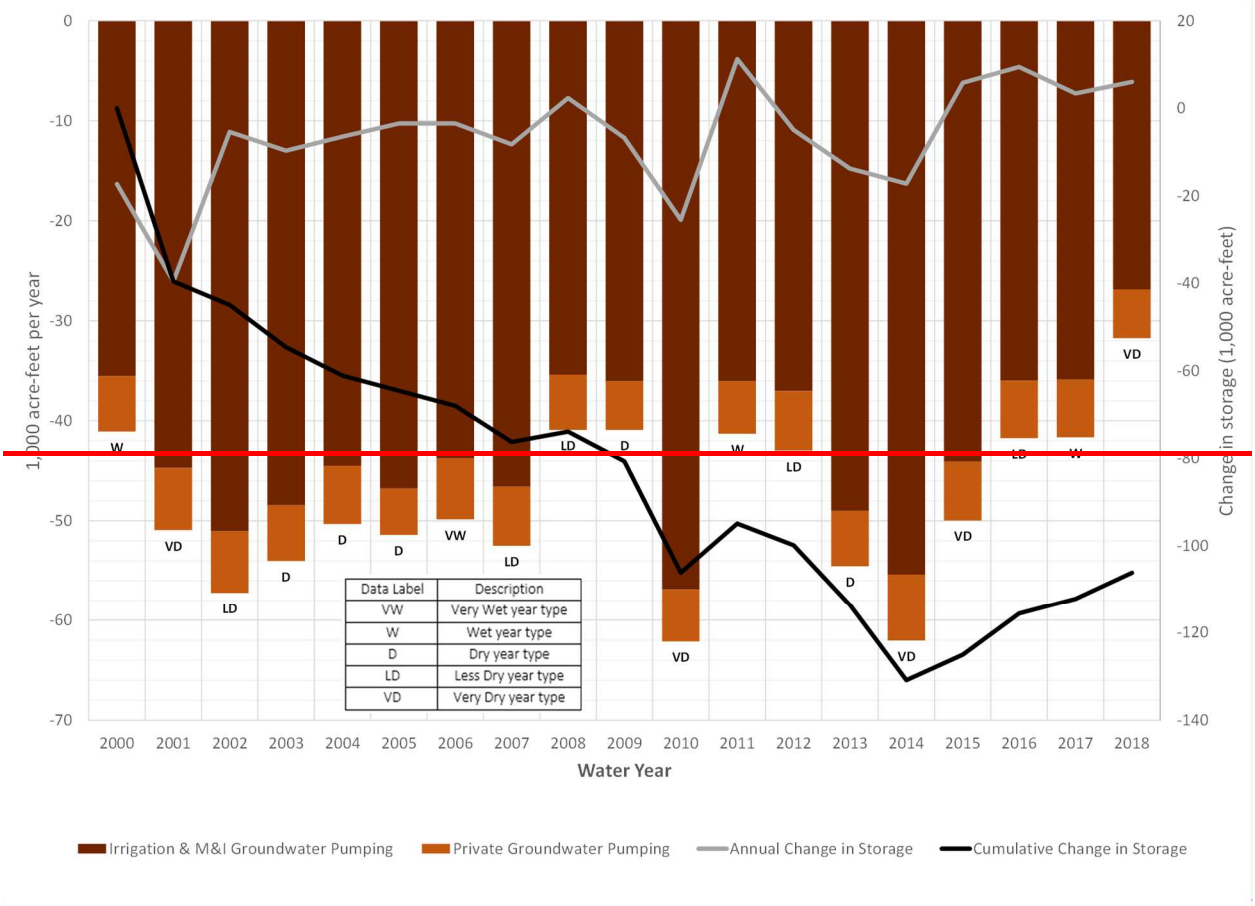
Vertical gradients can be used to describe the vertical movement of groundwater. Typically, vertical gradients are measured by comparing the elevations of groundwater in a well with multiple completions at different depths (multi-completion well). There are zero multi-completion wells located in the Tule Lake Subbasin. While the existing monitoring network is considered appropriate to ~~monitor for~~monitor trends, additional monitoring wells, including a multi-completion well(s) would help improve the understanding of the characteristics of the groundwater basin. In 2022, the GSAs applied for Technical Support Services (TSS) assistance, and DWR determined that a multi-completion well would best serve the GSAs' monitoring needs. However, the project has not yet been completed, and the GSAs are

awaiting an update from DWR. Therefore, vertical gradient data are not currently available for the Subbasin.

2.2.2.4 Groundwater Storage

Output from the model developed for this GSP was used to estimate the historical change in groundwater storage for the Subbasin. Additional details ~~on~~ regarding use of the model for water budgeting purposes is further discussed in Section 4. Figure 2-33 shows the annual change in storage and cumulative change in storage along with an indication of the water year type[2]. In addition, the annual estimated groundwater usage by users within the District service area (Irrigation and~~&~~ Municipal & Industrial [M&I] Groundwater Pumping) and users outside of the District service area (Private Groundwater Pumping) is shown in Figure 2-33.

[2] Water year types provide an indication of hydrology and are described in the technical memorandum provided in Appendix F.


1,000 acre-feet per year
Change in storage (1,000 acre-feet)
Water Year
0
-10
-20
-30
-40
-50
-60
-70
20
0
-20
-40
-60
-80
-100
-120
-140
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
W
VD
LD
D
D
D
VW
LD
LD
D
VD
W
LD
D
VD
VD
LD
W
VD
Data Label
Description
VW
Very Wet year type
W
Wet year type
D
Dry year type
LD
Less Dry year type
VD
Very Dry year type
Irrigation & M&I Groundwater Pumping
Private Groundwater Pumping
Annual Change in Storage
Cumulative Change in Storage

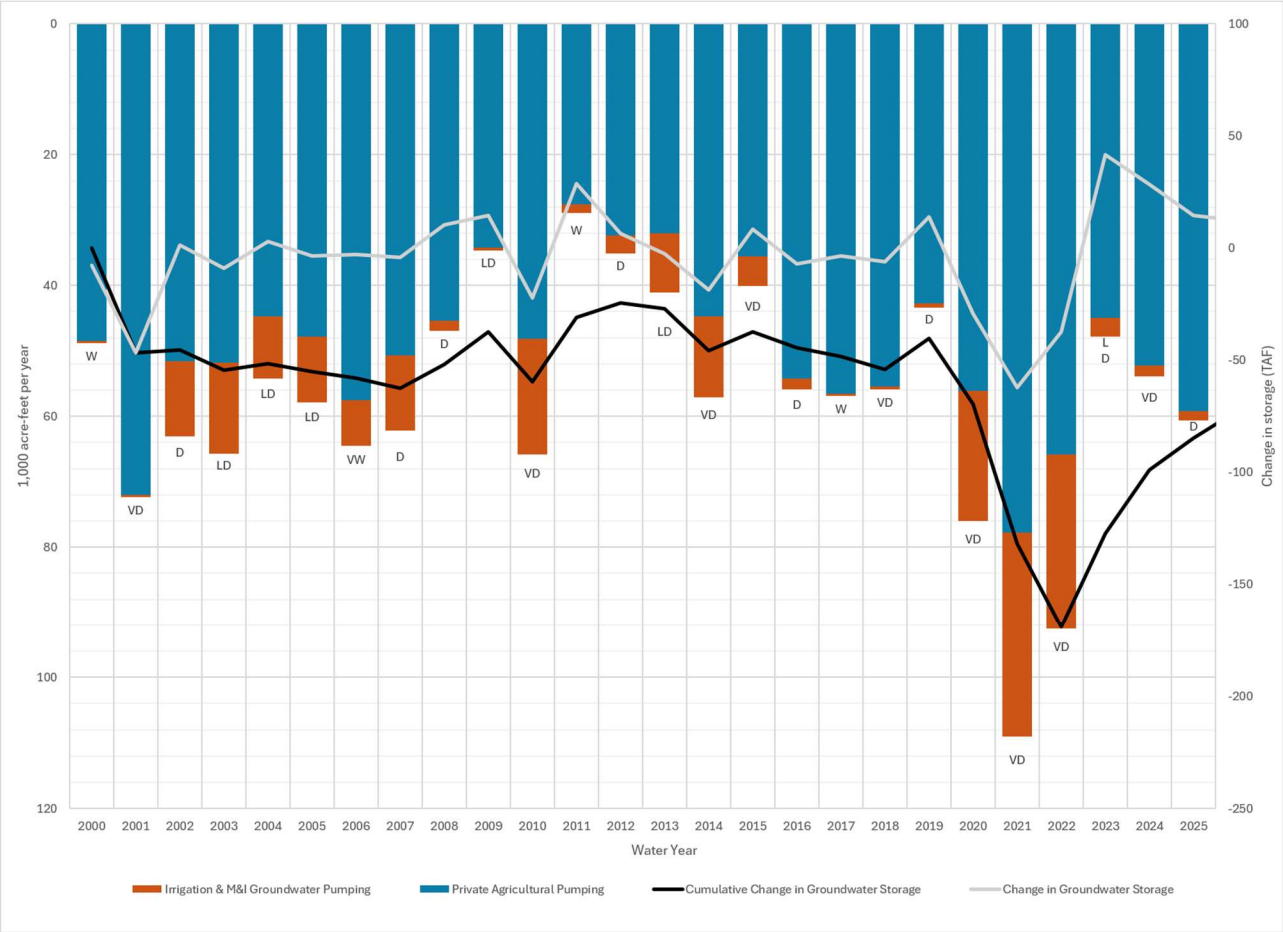


Figure 2-33. Estimated Groundwater Pumping and Change in Storage

~~2.2.2.4~~2.2.2.5 *Seawater Intrusion*

Due to its geographic location, seawater intrusion is not a concern for the Tule Lake Subbasin.

~~2.2.2.5~~2.2.2.6 *Groundwater Quality*

Limited groundwater quality monitoring data are available within Tule Lake Subbasin. In most instances, many of the groundwater wells have not been monitored frequently, with many wells being sampled only once during the period of record for a parameter. However, the quality of groundwater in the Subbasin is suitable for current uses. Public Water Suppliers rely on groundwater as it is their water source in the Subbasin. Therefore, it is important to note that the groundwater supply meets drinking water standards without treatment.

DWR Bulletin 118 generally describes the water quality of the groundwater within the Tule Lake Subbasin as ranging widely in response to the source and proximity to sources of surface and subsurface impairment. Water quality for wells constructed in the unconfined volcanic rocks within and adjacent to the Tule Lake Subbasin is good with a sodium-bicarbonate character and a total dissolved solids (TDS) ranging from 150 to 270 mg/L. A shift in water quality is observed with the unconfined volcanics that are proximate to lake sediments. The character shifts to a sodium/calcium/magnesium-bicarbonate/sulfate

water that is much higher in total dissolved solids (600 to 800 mg/L), which generally increases in proportion to the penetrated thickness of interfingering lake deposits (DWR, 2004).

The State Water Resources Control Board's GAMA Program has created tools to analyze groundwater throughout the State. Appendix G includes water quality information obtained from GAMA. Appendix N includes water quality information obtained from GeoTracker. A summary of key constituents in all wells monitored in the subbasin~~,~~ identified that major ions, volatile organic compounds (VOCs), trace elements, and TDS can be found in high concentrations throughout the subbasin. However, radionuclides, pesticides, and nutrients are typically only detected at low concentrations.

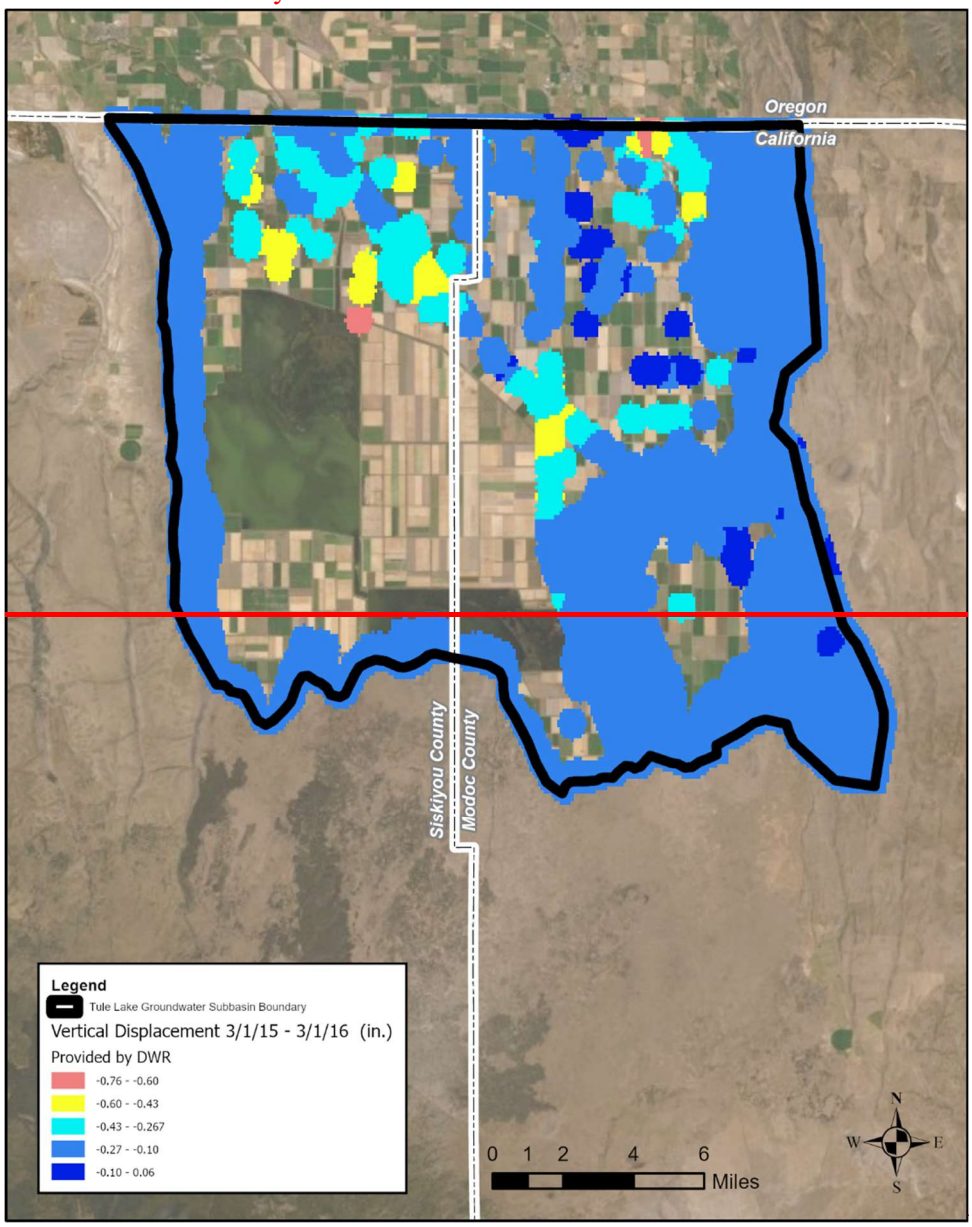
The SWRCB performed an analysis of domestic well water throughout ~~the state~~California. Data were collected over two years (summer 2017 – summer 2019) for chemical constituents that have an established maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL) along with several other constituents. The top six constituents were represented in the analysis: nitrate, arsenic, hexavalent chromium, uranium, 1,2,3 trichloropropane (1234 TCP), and perchlorate. The results of this study show that only arsenic exceeded the MCL of 10 micrograms per liter. However, the areas were all determined to be a Water Quality Grade 5, which indicates there are no recent exceedances (see Appendix G). Hexavalent chromium is identified as unknown for the area. It is assumed that this constituent was not tested for in the subbasin. The remaining four constituents did not exceed the established MCL or SMCL.

~~2.2.2.6~~2.2.2.7 *Land Subsidence Conditions*

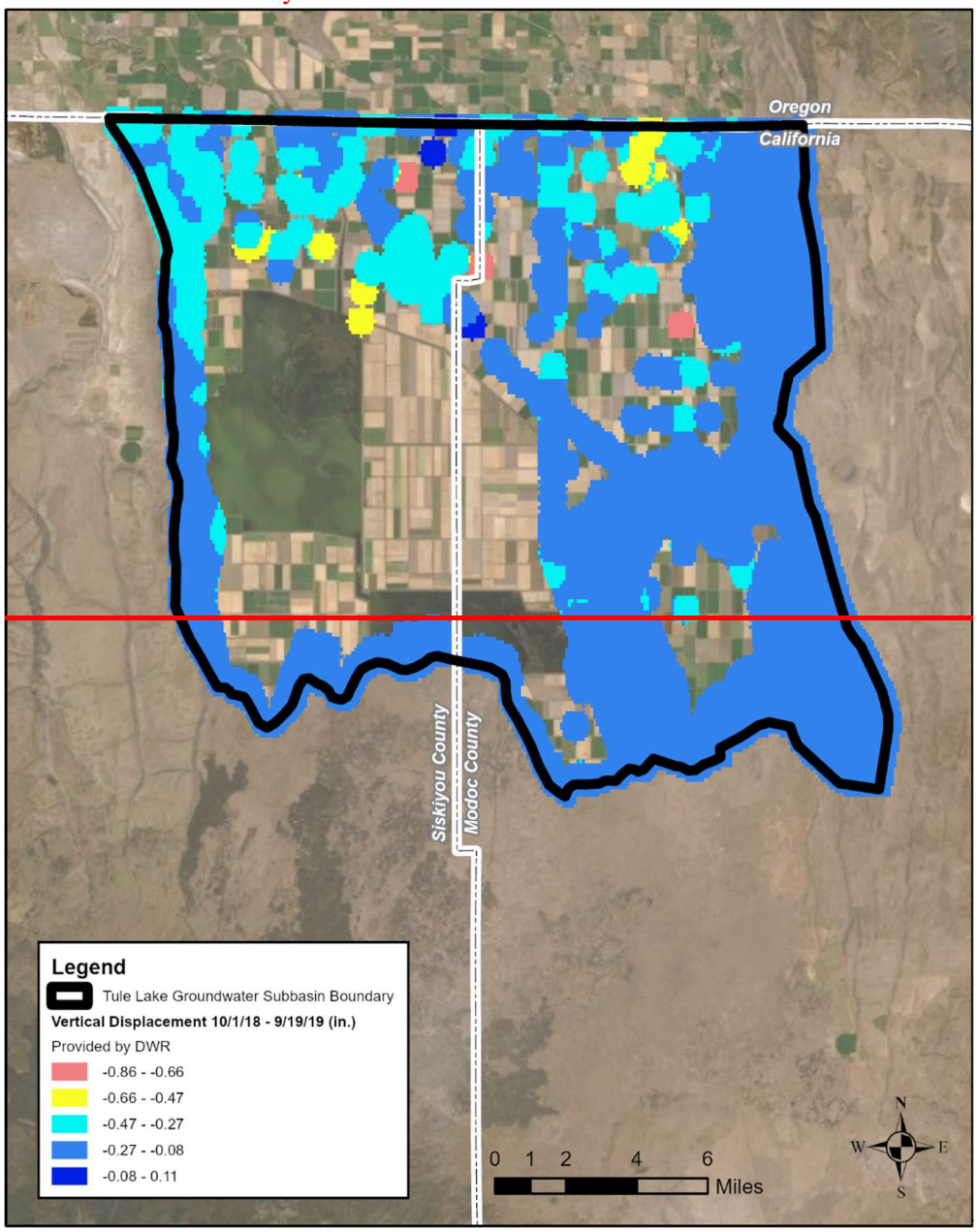
Land subsidence is the lowering of the ground surface through compaction of compressible, fine-grained strata. Compaction can be fully reversible (elastic) or permanent (inelastic). Elastic compaction and expansion generally occur in response to seasonal groundwater level fluctuations. Inelastic compaction is more likely to occur when prolonged dewatering of clay units occurs during periods when the aquifer is not fully recharged and groundwater levels reach historic lows.

Historically, land subsidence was monitored along transects by comparing periodic spirit level surveys conducted by the USGS and the NGS. In the mid-1980s, a transition was made from the spirit level surveys to GPS surveys. Like spirit level transects, GPS monitoring of subsidence relies on periodic resurveying of a network of monuments. In 2001, DWR defined a network of monuments and preformed a GPS survey of the ground surface elevation. In 2011, DWR re-surveyed 6 of the 23 monuments along the east and southeast portion of the Subbasin to identify any potential land subsidence. Results from the 2011 survey indicate that there has been no noticeable subsidence on the east side of the Subbasin (DWR, 2015).

As part of DWR's SGMA technical assistance, a statewide Interferometric Synthetic Aperture Radar dataset was acquired. InSAR is a satellite-based remote sensing technique that measures vertical ground surface displacement. TRE ALTIMIRA has processed the InSAR data, and DWR has made available vertical displacement raster data. Analysis of these images, from 2015 through ~~2019~~ 2025, show that the Subbasin has not experienced noticeable subsidence during recent years. TRE ALTIMIRA data for ~~2015~~ 2020 to ~~2016~~2025~~, and 2018 to 2019~~ are shown in ~~Figure 2-34~~.



~~Figure 2-34. Tule Lake Subbasin 2015-2016 Land Surface Displacement~~


Oregon
California
Siskiyou County
Modoc County
Legend
Tule Lake Groundwater Subbasin Boundary
Vertical Displacement 10/1/18 - 9/19/19 (in.)
Provided by DWR
-0.86 - -0.66
-0.66 - -0.47
-0.47 - -0.27
-0.27 - -0.08
-0.08 - 0.11
0 1 2 4 6
Miles
N
W
E
S

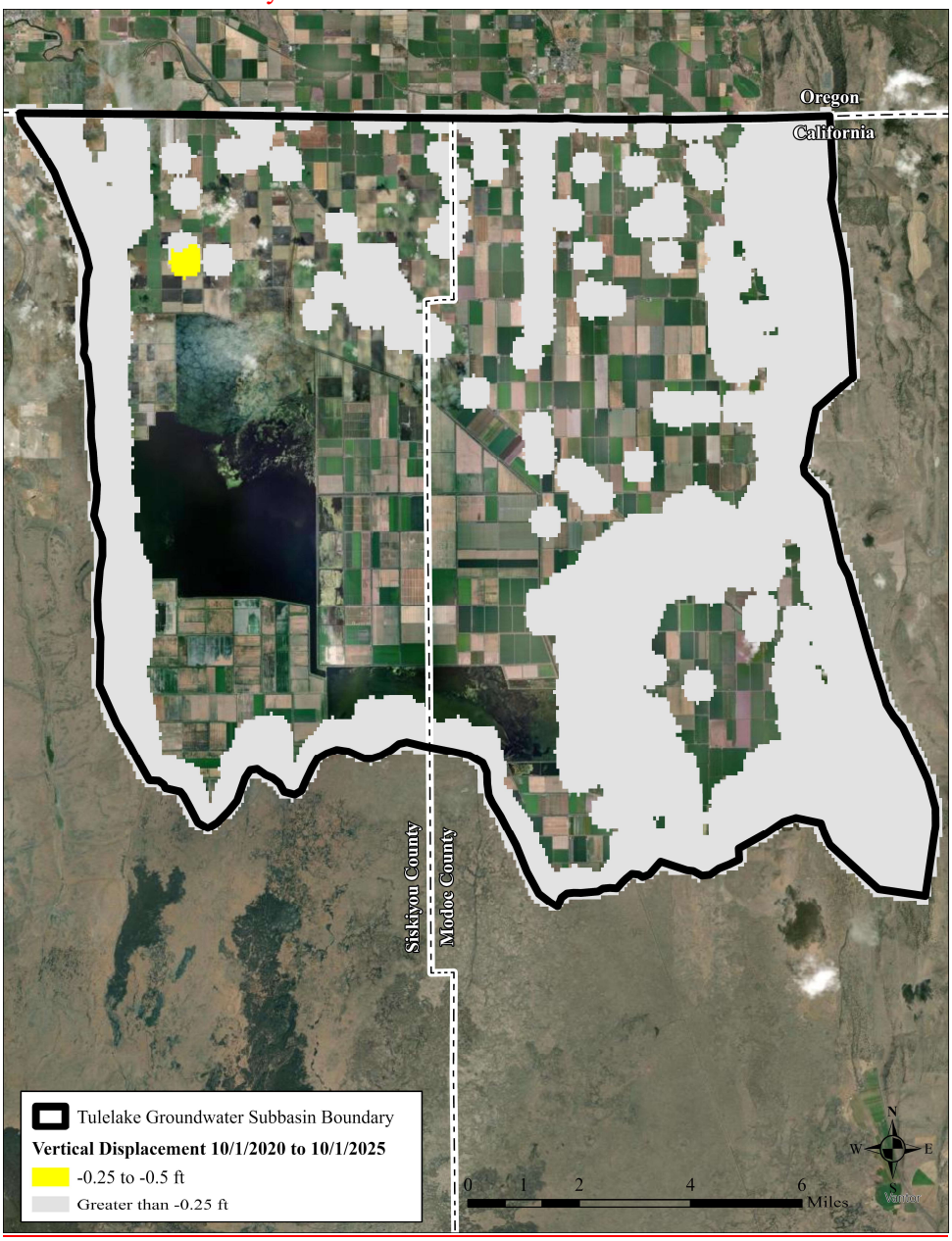


Figure 2-34. Tule Lake Subbasin ~~20182020-2019~~ 2025 Land Surface Displacement

~~2.2.2.7~~2.2.2.8 *Identification of Interconnected Surface Water Systems*

Interconnected surface water systems exist where there is a hydraulic connection between water flowing in surface water streams and water in the adjacent aquifers. The relative difference between the water surface elevation in the stream and aquifer determines the direction of flow. Flow from the aquifer to the stream creates a "gaining stream" and occurs in areas where near-stream groundwater elevations are higher than stream water surfaces. Areas where adjacent groundwater elevations are lower than stream water surfaces indicate flow from the stream to the aquifer or a "losing stream". Figure 2-35 is a conceptual illustration of these two conditions. The direction of the flow between a stream and aquifer can vary spatially along the length of the stream where there can be gaining reaches

and losing reaches. The direction can also vary through time with a stream gaining during some months or years and losing at other times.

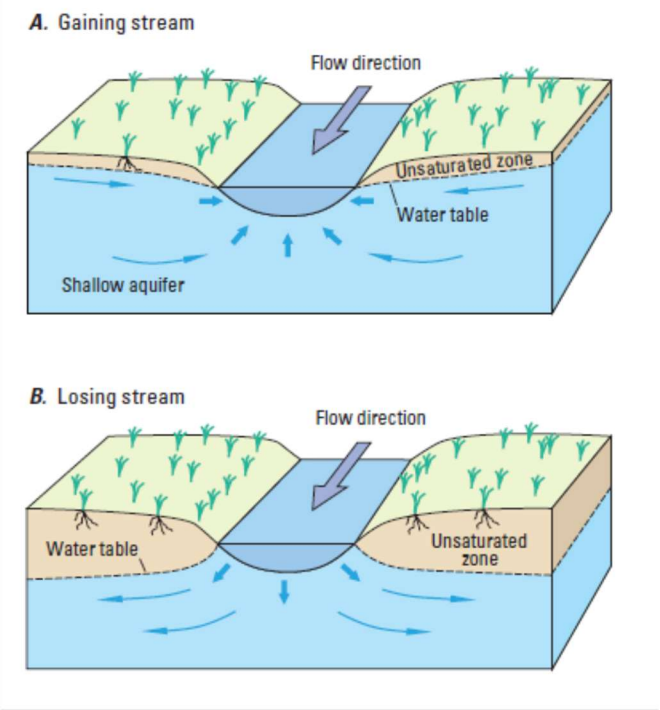


Figure 2-~~35~~2 ~~36~~. Gaining and Losing Streams (reproduced from USGS Circular 1376)

Interaction between groundwater and surface water in the Subbasin was analyzed through the use of the model. Direct measurement of the gain or loss from surface water to groundwater in the area is not feasible; however, the model provides sufficient information to characterize interconnected surface water systems. The model was used to develop estimates of timing and volume of gains and losses. Within the Subbasin, surface water systems include the small reach of the lower Lost River Improved Channel which extends into the Tule L~~l~~ake area and the "Sumps". This system is highly regulated as part of Reclamation's Klamath Project, and flows in the Lost River and water levels within the Sumps are dependent on surface water deliveries made available by Reclamation from the Klamath Project. The section of the Lost River within the Subbasin is referred to as the lower Lost River Improved Channel. Flow in this section is dependent on spill of Klamath Project water at the Anderson-Rose Dam during the irrigation season. Therefore, it is generally considered an irrigation channel and not a natural river channel.

The Tule Lake National Wildlife Refuge is located within the Subbasin and primarily consists of four "Sumps," two of which act as regulating reservoir within TID (Sumps 1A and 1B). The other two Sumps (Sumps 2 and 3) have been reclaimed and are farmed as lease and co-op lands. The operational spills and tailwater resulting from irrigation within TID are conveyed through TID's extensive drainage system, which utilizes gravity and pumped discharge into portions of the canal system or into the Tule Lake Sumps. Water regulated and stored within the Tule Lake Sumps may be diverted or rediverted for irrigation within TID or discharged by TID's D-Pumping Plant to the P-Canal, which serves the Lower Klamath National Wildlife Refuge and the water users on the P-Canal system of the Project.

The Sumps are operated by TID, and the surface water level must be maintained at specified elevations throughout the year. In alignment with the 2024 U.S. Fish and Wildlife Service (USFWS) Biological Opinion, Reclamation shall maintain Lower Klamath National Wildlife Refuge ~~(LKNWR)~~ Unit 2 at or above 4,082.7 feet NAVD88 (equivalent to 4,087.4 feet Reclamation Datum) and Tulelake National Wildlife Refuge ~~(TLNWR)~~ Sump 1A at or above 4,034.0 feet Reclamation Datum. These elevation requirements are to be met using return flows or other authorized sources, commensurate with prevailing hydrology and the habitat needs of listed sucker species. Adjustments to these thresholds may be coordinated with USFWS to address operational or safety concerns, including temporary modifications such as the 2025 allowance for TLNWR Sump 1A to be maintained at 4,033.5 feet until October 1, 2025. This language supersedes the prior seasonal elevation requirements included in the 2022 GSP and reflects current regulatory guidance. ~~Based on the Biological Opinion to protect the endangered sucker fish, the Sumps must be maintained at an elevation of at least 4,034.60 feet during April 1 through September 30; and, based on the Rules and Regulations relative to flood control, the elevation is maintained at 4,034.00 feet the remainder of the year.~~

~~2.2.2.8~~2.2.2.9 *Identification of Groundwater-Dependent Ecosystems*

Groundwater Dependent Ecosystems (GDE) are defined in the SGMA Regulations as, “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface”, (23 CCR § 351[m]). Identification of GDEs under SGMA is important because SGMA requires that all beneficial uses and users be considered in the development of GSPs. Fish and wildlife species that can be identified as beneficial users of groundwater include, but are not limited to, Lost River sucker; ~~,~~ shortnose sucker; ~~,~~ bald eagle; ~~,~~ greater sandhill crane; ~~,~~ Swainson’s hawk; ~~,~~ tricolored blackbird; ~~,~~ and the western pond turtle.

The Natural Communities Commonly Associated with Groundwater (NCCAG) database was used to identify plants commonly associated with groundwater use. The NCCAG was developed by a working group comprised of DWR, the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC), which reviewed publicly available datasets of mapped seeps; ~~,~~ springs; ~~,~~ vegetation; ~~,~~ and wetlands; ~~,~~ and conducted a screening process to exclude types less likely to be associated with groundwater and retain types commonly associated with groundwater. Two habitat classes are included in the NCCAG dataset: ~~1)~~ wetland features commonly associated with the surface expression of groundwater under natural, unmodified, conditions; and ~~2)~~ vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes). Figure 2-36 shows the wetland features and vegetation areas identified in the NCCAG database.

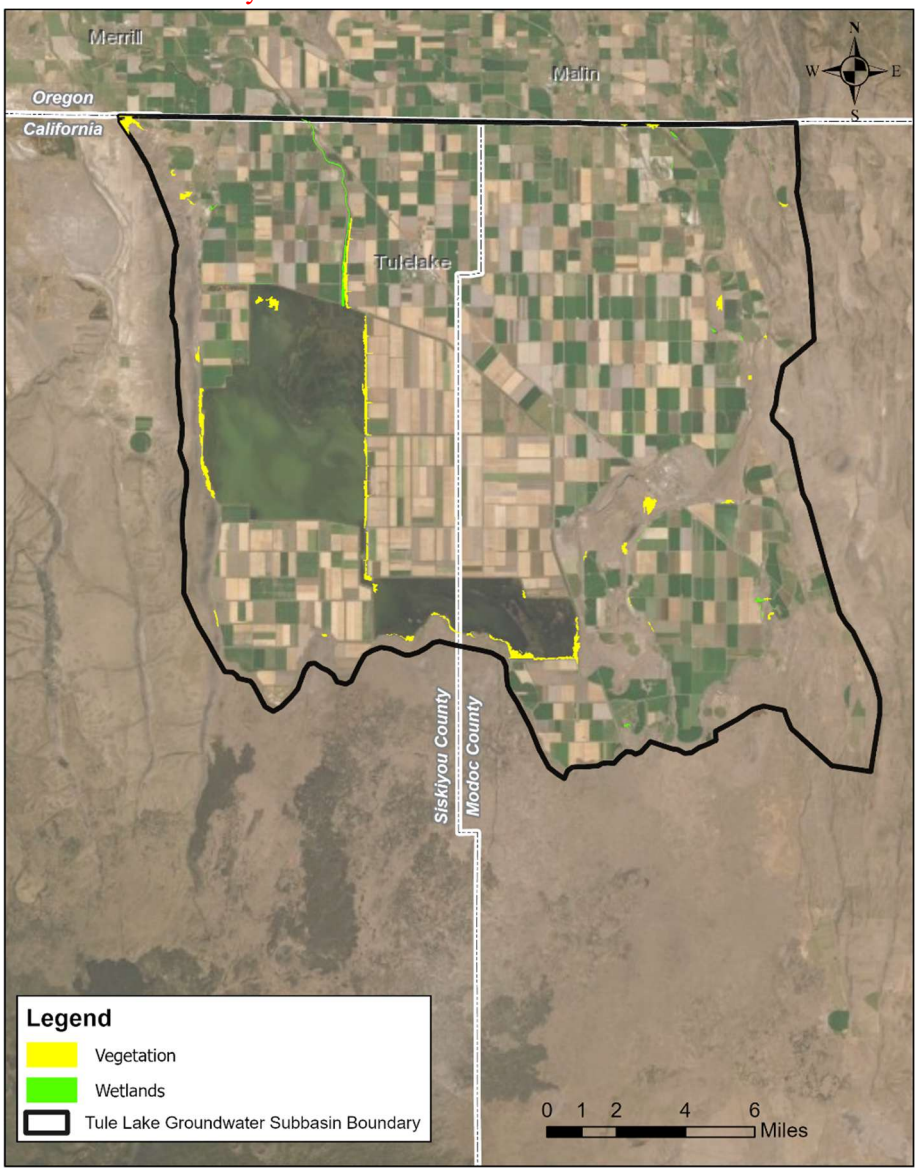


Figure 2-~~36~~2-~~37~~. Natural Communities Commonly Associated with Groundwater

However, identification as a NCCAG is not the same as being a GDE. An analysis was performed to evaluate each NCCAG against criteria to determine if it is a GDE. The following criteria ~~listed below~~ identify characteristics which would result in a NCCAG not being classified as a GDE.

1. Areas with a depth to groundwater greater than 30 feet – Oak trees are considered the deepest-rooted plant in California with typical root zone depth of 25 feet. TNC has developed guidance documents to help GSAs identify GDEs (TNC, 2018). These guidance documents suggest that depth to groundwater greater than 30 feet would not support a GDE. NCCAGs in areas with depth to groundwater greater than 30 feet are assumed to not access groundwater and are represented as "Areas with Depth to Groundwater > 30 feet" in Figure 2-37.

2. Areas adjacent to agricultural surface water – The majority of the Subbasin is agricultural land and intersected by a system of irrigation canals, ditches, and drains. The irrigation system brings in surface water which is available to the NCCAGs. NCCAGs adjacent to irrigation conveyance facilities are assumed to access the available surface water and are represented as "Areas Adjacent to Agricultural Surface Water" in Figure 2-37.

3. Areas adjacent to irrigated fields – Similar to areas adjacent to irrigation water conveyance facilities, areas near irrigated fields benefit from the irrigation water used to support crops. Irrigated fields are consuming the water that is applied and, therefore, less water is available to adjacent ecosystems as compared to the conveyance facilities. NCCAGs adjacent to irrigated fields are assumed to access the available surface water and are represented as "Areas Adjacent to Irrigated Fields" in Figure 2-37.

4. Areas adjacent to the Sumps – As described in Section 2.2.2.8, water levels are maintained in the Sumps year-round. The Sumps provide water for adjacent ecosystems. NCCAGs adjacent to the Sumps are assumed to access the available surface water and are represented as "Areas Adjacent to Tule Lake Sumps" in Figure 2-37.

The majority of the wetlands and vegetation shown are located along the perimeter of the Sumps or are adjacent to other surface water features. In addition, the TNC database for natural flows was reviewed for the Tule Lake Subbasin. Most of the surface water features identified in this database are District canals, District drains, the Lost River Improved Channel, and the Tule Lake Sumps. The functional flows identified in this database are minimal, likely for this reason. Although the TNC database identifies minimal flows in these surface water features, the GSAs have not incorporated this as exclusion criteria. Areas remaining after the four criteria above were applied have been identified as a data gap and are discussed further in Section 6.1.4. Appendix H is a technical memorandum describing this process in further detail and includes additional maps at a larger scale.

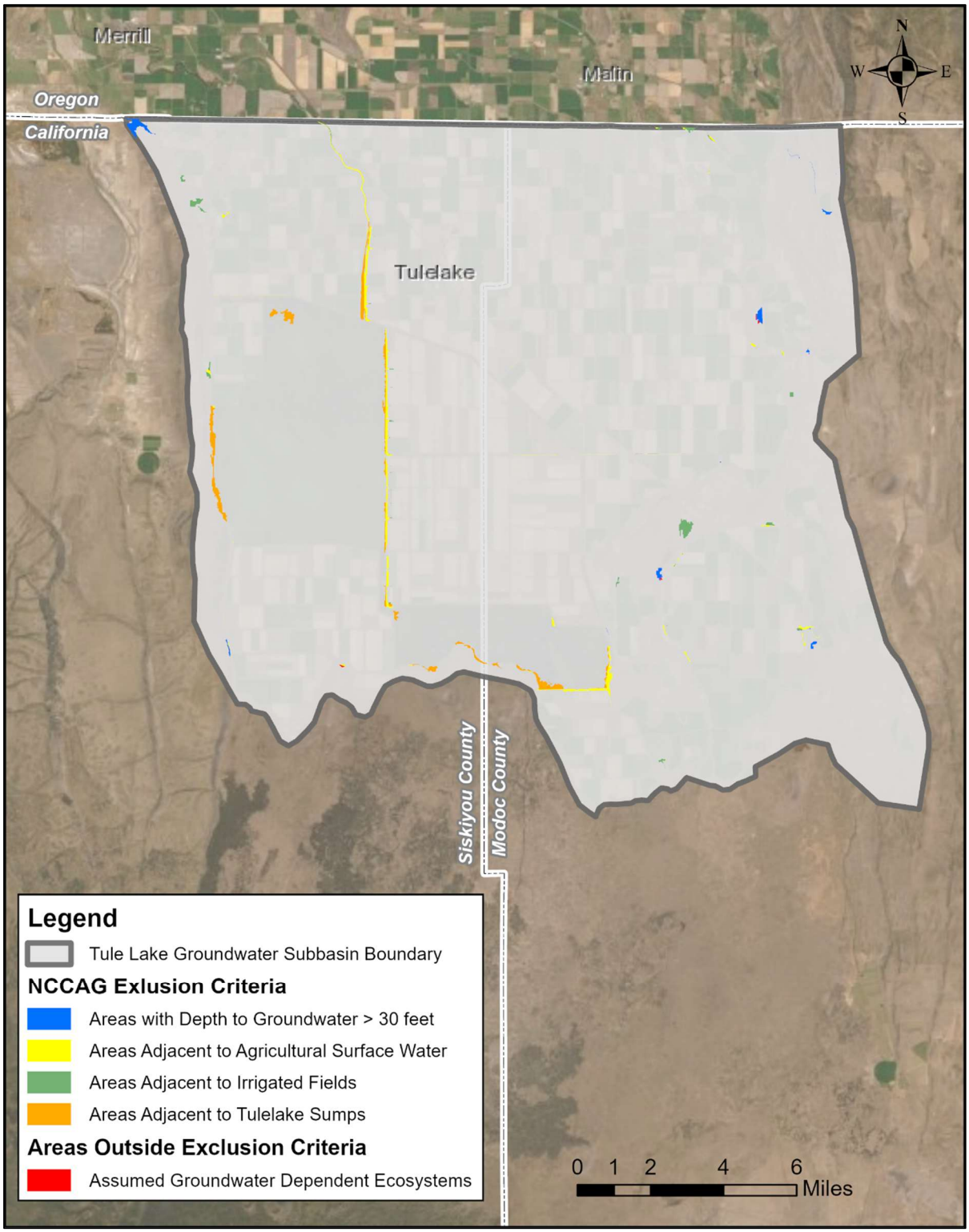


Figure 2-37~~2~~ ~~38~~. Assumed Groundwater Dependent Ecosystems

3 Monitoring Network

3.1 Description of the Monitoring Network (Reg. § 354.34)

This section discusses the monitoring networks identified to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface water conditions. In addition, these networks assist with the evaluation of changing conditions that occur through implementation of the Plan. A groundwater level monitoring network has been identified to avoid the undesirable result of chronic lowering of groundwater levels. Monitoring of groundwater levels will support the understanding of groundwater storage and be used as a proxy for the change-in-storage ~~and land subsidence~~ undesirable results. A groundwater quality monitoring network has been identified to avoid the undesirable result of degraded water quality. As discussed in Section 2.2.2.5, due to its geographic location, seawater intrusion is not a concern for the Tule Lake Subbasin. Therefore, a monitoring network for seawater intrusion has not been identified. As discussed in Section 2.2.2.9, the lower Lost River Improved Channel and Tule Lake Sumps are surface water systems within the Tule Lake Subbasin. See Section 3.3.1.5 for additional information on the monitoring network for these surface water systems.

3.2 Monitoring Networks Objective

The objective of the monitoring networks is to identify a sufficient number of wells that provide data to demonstrate measured progress toward achievement of the Subbasin's sustainability goal. In addition, the monitoring networks are intended to support subbasin management actions and future updates to this Plan.

The data from the wells within the monitoring network will continue to build on existing data to track short-term, seasonal, and long-term trends in groundwater and related surface conditions. The monitoring network, through evaluation of changes in groundwater levels, will support estimates of annual changes in water budget components.

3.3 Monitoring Networks

The existing groundwater level monitoring network described in Section 2.2.2.1, was used to develop the monitoring networks for this Plan. The monitoring networks for groundwater levels and groundwater quality were selected to provide an adequate amount of spatial density and temporal frequency to detect trends in groundwater conditions. The monitoring networks are described in the following sections.

3.3.1 Groundwater Level Monitoring Network

As discussed in Section 2.2.2.1, groundwater elevations in the Tule Lake Subbasin are monitored monthly by DWR and other entities, including TID. Figure 2-18 identifies the distribution of groundwater wells actively monitored for groundwater elevations within and near the GSP area.

3.3.1.1 Representative Groundwater Level Monitoring Network

A subset of the groundwater level monitoring network was identified as the representative groundwater level monitoring network based on their historical record of monitoring data and ability to represent local, regional, and long-term trends in the Subbasin. The wells in the representative groundwater level monitoring network were also selected based on their spatial distribution throughout the Subbasin and their construction/screening details. The representative groundwater level monitoring network is the network that is used to monitor chronic lowering of groundwater levels and~~,~~ changes in storage~~, and land subsidence~~. Measurable objectives and minimum thresholds for monitoring sustainability have been identified for each of the wells within this network. ~~Table 3.1~~ identifies the wells within the representative groundwater level monitoring network, including the construction details, current use, monitoring agency, and monitoring frequency. Figure 3-1 shows the location of each of these wells, which are distributed throughout the Subbasin and located in proximity to groundwater production wells. In addition, Appendix I includes the available well completion reports for each of these wells.

~~Table 3.1. Representative Groundwater Level Monitoring Network~~

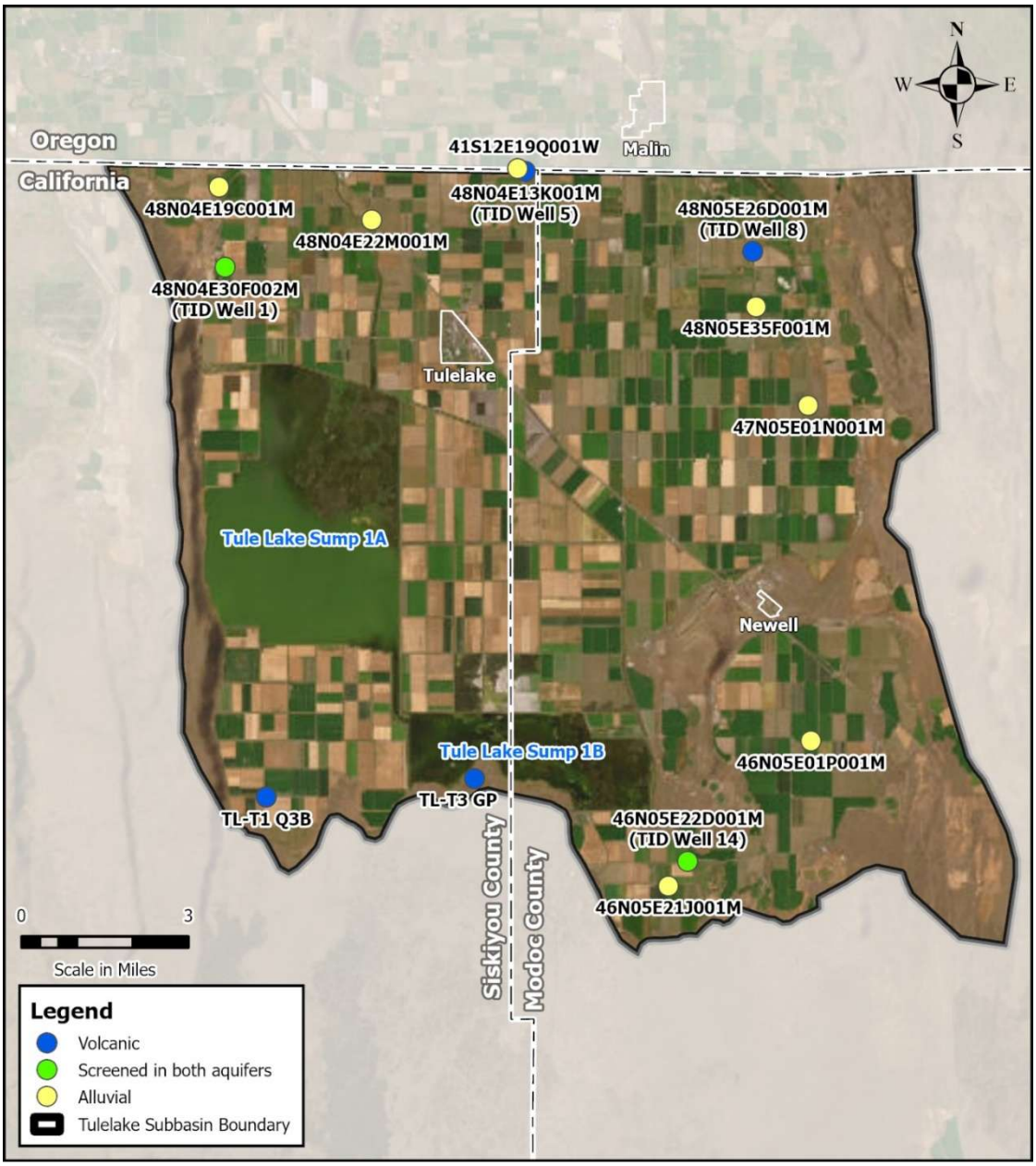


Figure 3-1. Representative Groundwater Level Monitoring Network

Table 3-~~11~~12. Wells within the Representative Groundwater Level Monitoring Network

State Well Number	Well Location		Perforations (ft)		Well Depth	Aquifer	Well Use	Monitoring Agency
	UTM East	UTM North	Top	Bottom				
48N05E35F001M	634950	4646826	25	32	32	Alluvial	Domestic	DWR
48N04E22M001M	623798	4649129	32	135	135	Alluvial	Domestic	DWR
48N04E19C001M	619377	4649996	22	38	38	Alluvial	Domestic	DWR

State Well Number	Well Location		Perforations (ft)		Well Depth	Aquifer	Well Use	Monitoring Agency
	UTM East	UTM North	Top	Bottom				
47N05E01N001M	636509	4643988	49	65	65	Alluvial	Domestic	DWR
46N05E21J001M	632719	4630034	-	-	32	Alluvial	Domestic	DWR
46N05E01P001M	636763	4634300	87	101	101	Alluvial	Domestic	DWR
41S12E19Q001W	627992	4650692	-	-	65	Alluvial	Domestic	DWR
48N04E30F002M (TID Well 1)[1]	619583	4647681	260	700	740	Both	Irrigation	TID
48N04E13K001M (TID Well 5)	628217	4650610	935	1557	1570	Volcanic	Irrigation	TID
48N05E26D001M (TID Well 8)	634823	4648412	1250	1802	1810	Volcanic	Irrigation	TID
46N05E22D001M (TID Well 14)[1]	633266	4630751	114	554	571	Both	Irrigation	TID
TL-T1 Q3B	621062	4632384	-	-	500	Volcanic	Monitoring	TID
TL-T3 GP	627056	4633043	-	-	500	Volcanic	Monitoring	TID

[1]The well has screened depths in the shallow alluvial aquifer and the deeper volcanic aquifer, the volcanic aquifer begins at about 4~~1~~50 feet

3.3.1.2 Spatial Density of Groundwater Level Monitoring Network

The Tule Lake Subbasin covers approximately 110,500 acres (approximately 172 square miles). As described in Section 2.2.2.1 Historic Groundwater Elevations, there are approximately 70 groundwater wells monitored in the Subbasin (see Figure 2-18). Therefore, the spatial density is approximately 40 wells per 100 square miles, which is more robust than the spatial density guidelines recommended by DWR in their best management practices (DWR, 2016). These recommendations from DWR are summarized in Table 3-2. Of these wells, ~~15~~ 13 have been included in the representative groundwater level monitoring network. This spatial density of the representative monitoring network is approximately seven ~~eight~~ wells per 100 square miles.~~-~~ While this is adequate to meet the suggested density recommended by DWR overall, when analyzing the Subbasin by aquifer the volcanic aquifer would benefit from an additional well to meet the density suggestions. In 2022 the GSAs submitted an application for assistance in installing a multi-completion well through the TSS program. Once this well is installed both aquifers will have enough wells to sufficiently meet the suggested density for a monitoring network.

Table 3-~~2223.2~~. Monitoring Network Density Recommendations

Reference	Monitoring Well Density (wells per 100 miles^2)
Heath (1976)	0.2-10
Sophocleous (1983)	6.3
Hopkins (1984)	
Basins pumping more than 10,000 AFY per 100 miles^2	4.0
Basins pumping between 1,000 and 10,000 AFY per 100 miles^2	2.0
Basins pumping between 250 and 1,000 AFY per 100 miles^2	1.0
Basins pumping between 100 and 250 AFY per 100 miles^2	0.7

3.3.1.3 Groundwater Level Monitoring Protocols

In regard to TID monitored groundwater wells, TID monitors on a monthly basis during the year and on a weekly basis when the pumps are operating. TID enrolled in the CASGEM program and prepared and submitted a groundwater monitoring plan to DWR (See Appendix J). Monitoring will be performed following the protocols described in that plan. DWR typically measures monitoring wells in the Subbasin on a bimonthly basis. For implementation of the GSP, static groundwater level measurements will continue to be obtained at each of the representative monitoring wells at least twice per year during the spring and fall to represent seasonal high and low conditions.

The monitoring frequencies, primarily monthly or bimonthly, allow for short-term and long-term evaluation of trends and conditions. Monthly/bimonthly measurements are adequate for evaluation of measurable objectives and minimum thresholds, while also showing fluctuations which may result from storm events, droughts, seasonal variation, and groundwater pumping.

3.3.1.4 Subsidence Monitoring

The InSAR dataset available on DWR's SGMA Data Viewer will be used to monitor land subsidence, which occurs when soils in some aquifer systems compact as a result of groundwater withdrawal. As noted in Section 2.2.2.7, no significant subsidence has been observed within the Subbasin to date. Monthly data from January 2015 through July 2025 is available for review, and subsidence will continue to be monitored as new data becomes available. The GSAs plan to evaluate the subsidence data on the timeline established in the Minimum Threshold (MT)~~MT~~. If subsidence data, relative to the Subbasin, are made available from other sources~~,~~ this information will also be reviewed.

~~3.3.1.4~~3.3.1.5 Depletion of Interconnected Surface Water

As previously stated, the only surface water within the Subbasin is a small portion of the lower Lost River Improved Channel, which terminates in the Tule Lake Sumps and the Sumps themselves. This system is

highly regulated as part of Reclamation's Klamath Project and flows in the lower Lost River Improved Channel and water levels within the Sumps are dependent on surface water deliveries made available by Reclamation from the Klamath Project. Flows in the section of the lower Lost River Improved Channel within the Tule Lake Subbasin are limited to spills at Anderson-Rose Dam. Any flow in this section of the lower Lost River Improved Channel goes into the Sumps. Due to the nature of the lower Lost River Improved Channel and Sumps, a separate monitoring network for groundwater-surface water interaction has not been developed. However, DWR Monitoring Well No. 48N04E22M001M (Amy King) is located adjacent to the lower Lost River Improved Channel and is included in the Groundwater Level Monitoring Network. It is noted that ~~the Department~~DWR is working on guidance related to depletions of interconnected surface water. Once the guidance is publicly available, the GSA will incorporate appropriate guidance approaches into their future periodic evaluations of the GSP. In addition, the GSAs conducted a preliminary analysis of interconnected surface water in the Subbasin, which is included in Appendix O.

~~*3.3.1.5*~~*3.3.1.6 Data Gaps*

The existing groundwater level monitoring network is sufficient to meet the requirements necessary for implementing the GSP; however, the GSAs will continue to review the monitoring network and the collected data to improve the understanding of the Subbasin and reduce uncertainty in collected data. Specifically, additional wells can be added to the representative monitoring network to improve the density and spatial distribution of wells throughout the Subbasin. In addition, there is a lack of dedicated monitoring wells within the Subbasin. The GSAs will continue to evaluate potential grant funding, including DWR's Technical Support Services, available to fund the construction of dedicated monitoring wells. One or more multi-completion monitoring wells would provide valuable data for the Subbasin. As of 2022, the TSS application has been filed, but no additional wells have been installed.

Currently, there are no monitoring wells located in the middle of the Subbasin; however, groundwater pumping in this area (referred to as the Lease Lands) is also limited. In addition, shallow monitoring wells in the vicinity of surface water in the Subbasin are limited, and the construction of dedicated monitoring wells near the Sumps would provide information regarding surface water interaction and potential GDEs. In 2022, the GSAs filed an application for TSS assistance the DWR TSS application requests installation of a multi-completion well. Therefore, once the multi-competition well is installed the GSAs plan to add it to the groundwater level representative monitoring network. ~~The GSAs will evaluate potential grant funding, including DWR's Technical Support Services, available to fund the construction of monitoring wells in these areas. Construction of a monitoring well will also be dependent on cooperation from a willing landowner.~~

3.3.2 Groundwater Quality Monitoring Network

As discussed in Section 2.2.2.6, there is limited groundwater quality monitoring within the Subbasin. ~~Because there are no known areas of degraded water quality or contaminant plumes which need to be actively monitored, this~~The monitoring network will rely on existing wells used for monitoring water quality within the Subbasin, which are public water supply wells. Other than the water quality study performed by SWRCB, there is currently no groundwater quality monitoring being performed by

agencies within the Subbasin. Figure 3-2 shows the Groundwater Quality Monitoring Network, which includes the public water supply wells.

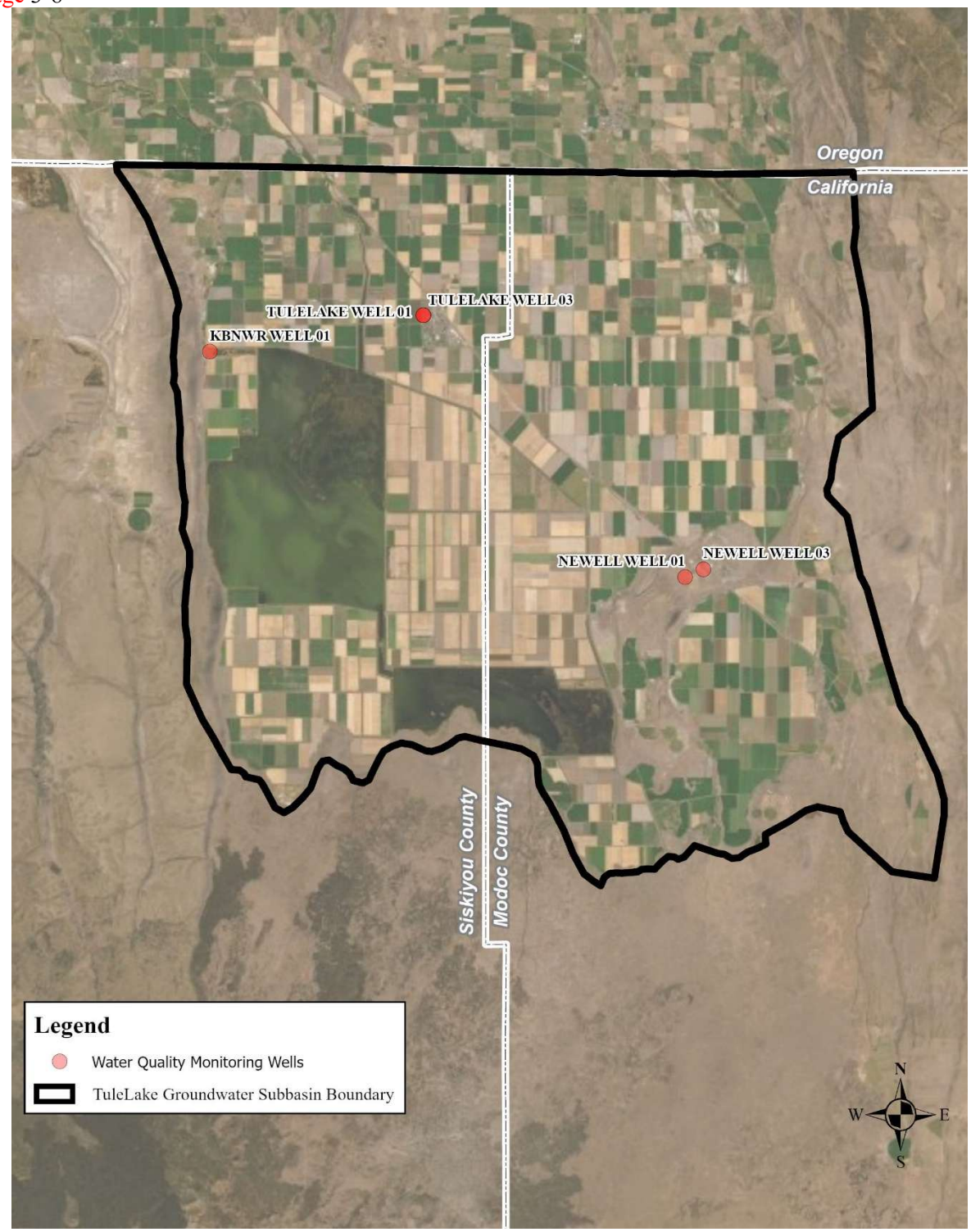


Figure 3-2. Groundwater Quality Monitoring Network

3.3.2.1 Representative Monitoring Network

The representative monitoring network includes all wells ~~which~~ that are identified in the Degraded Groundwater Quality Network. The representative network is used to evaluate nitrate, ~~and~~ total dissolved solids, ~~and~~ arsenic thresholds, and ~~not~~no other constituents. Table 3-3 summarizes the monitoring frequency of the constituents, for which sustainable management criteria have been established within the Subbasin.

Table 3-3. Groundwater Quality Monitoring Network

Agency	Number of Wells	Constituent	Monitoring Frequency
City of Tulelake	2	Nitrate	Every year
		TDS	Every 3 years
		Arsenic	Every 4 years
Newell County Water District	2	Nitrate	Every year
		TDS	Every 3 years
		Arsenic	Every 10 years
Klamath Basin National Wildlife Refuge (KBNWR)	1	Nitrate	Every year
		TDS	Not monitored
		Arsenic	Not monitored

Based on conversations with staff at the City of Tulelake, the two city drinking water wells are about 2,000 feet deep, and are therefore screened in the volcanic aquifer. This is also assumed to be true to the representative monitoring wells in the town of Newell. The well within the KBNWR is about 200 feet deep and screened within the alluvial aquifer.

While only nitrate, ~~and~~ TDS, and arsenic have established SMCs within the Subbasin, the GSAs will review data for other constituents (e.g., chloride, copper, lead, sodium, hardness, coliform~~, arsenic~~) monitored at the public supply wells to track long-term trends. If increasing trends emerge for these constituents, the GSAs will evaluate development of SMCs in future updates to the GSP.

3.3.2.2 Spatial Density

The groundwater quality monitoring network provides a spatial density of 2.9 wells per 100 square miles.

3.3.2.3 Monitoring Protocols and Frequency

Water quality data collection protocols and frequency is established by the requirements of the Public Water Suppliers within the Subbasin. The City of Tulelake GSA will provide its water quality monitoring

data as it becomes available. Monitoring data for the Newell County Water District and the Klamath Basin National Wildlife Refuge will be obtained from the Drinking Water Watch website[3].

3.3.2.4 Data Gaps

Groundwater quality monitoring gaps are the result of the need for denser and more frequent monitoring, potential access issues, and areal coverage. The spatial density of the wells in the groundwater quality monitoring network is less than what is recommended by DWR in their best management practices. Based on information in Table 3-2, an additional two (2) wells should be added to supplement the monitoring network. An additional well may be added to supplement the monitoring network in the City of Tulelake once the TSS request for an additional multi-completion well is complete.

Wells located in the northeast and southwest areas of the Subbasin will be evaluated for potential inclusion in future monitoring network development. If possible, wells included in the groundwater level monitoring network will be evaluated for potential benefits to the groundwater quality monitoring network.

3.3.3 Sustainability Indicators

Table 3-4 summarizes the representative monitoring networks' individual contributions to monitoring each Sustainability Indicator. Seawater Intrusion is not applicable to the Tule Lake Subbasin, and is therefore ~~is~~ not included. Land subsidence sustainable management criteria utilizes the InSAR dataset to evaluate vertical displacement, and is therefore not included.

Table 3-~~4453~~.4. Summary of Groundwater Sustainability Indicators

Monitoring Well	Chronic Lowering of Groundwater Levels	Depletion of Interconnected Surface Water	Degraded Water Quality	~~Land Subsidence~~	Reduction in Groundwater Storage
48N05E35F001M	✓			~~✓~~	✓
48N04E22M001M	✓	✓		~~✓~~	✓
~~48N04E31M001M~~	~~✓~~			~~✓~~	~~✓~~
48N04E19C001M	✓			~~✓~~	✓
~~47N05E04M001M~~	~~✓~~			~~✓~~	~~✓~~
47N05E01N001M	✓			~~✓~~	✓
46N05E21J001M	✓			~~✓~~	✓
46N05E01P001M	✓			~~✓~~	✓
41S12E19Q001W	✓			~~✓~~	✓

[3] https://sdwis.waterboards.ca.gov/PDWW/

Monitoring Well	Chronic Lowering of Groundwater Levels	Depletion of Interconnected Surface Water	Degraded Water Quality	~~Land Subsidence~~	Reduction in Groundwater Storage
48N04E30F002M (TID Well 1)	✓			~~✓~~	✓
48N04E13K001M (TID Well 5)	✓			~~✓~~	✓
48N05E26D001M (TID Well 8)	✓			~~✓~~	✓
46N05E22D001M (TID Well 14)	✓			~~✓~~	✓
TL-T1 Q3B	✓			~~✓~~	✓
TL-T3 GP	✓			~~✓~~	✓
TULELAKE WELL 03			✓		
TULELAKE WELL 01			✓		
KBNWR WELL 01			✓		
NEWELL WELL 01			✓		
NEWELL WELL 03			✓		

4 Water Budget Information (Reg. § 354.18)

The hydrologic cycle shown in Figure 4-1, describes how Earth's water is moved, stored, and exchanged between the atmosphere, land surface, and the subsurface.

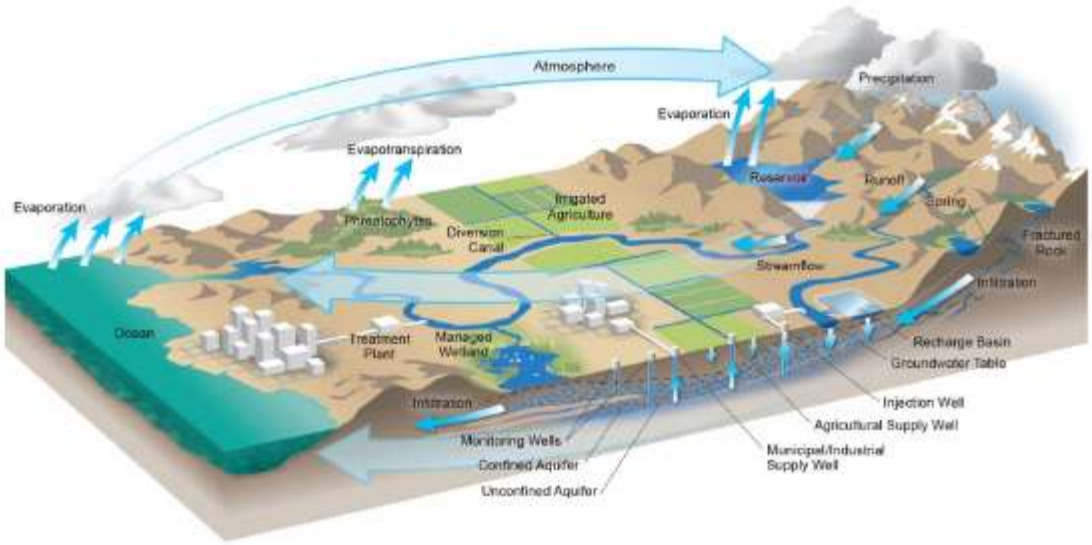


Figure 4-14-1. The Hydrologic Cycle (Source DWR 2016)

A water budget takes into account the storage and movement of water between the four physical systems of the hydrologic cycle. For the Tule Lake Subbasin these four systems are the atmospheric system, land surface system, surface water system, and the groundwater system. A water budget is a tool to compile and compare inflows and outflows, the difference being the change in the amount of water stored. Figure 4-2 identifies the specific components of a water budget and their interactions. Inflows are shown with blue arrows and outflows are shown with orange arrows. Flows between the systems are shown with purple arrows.

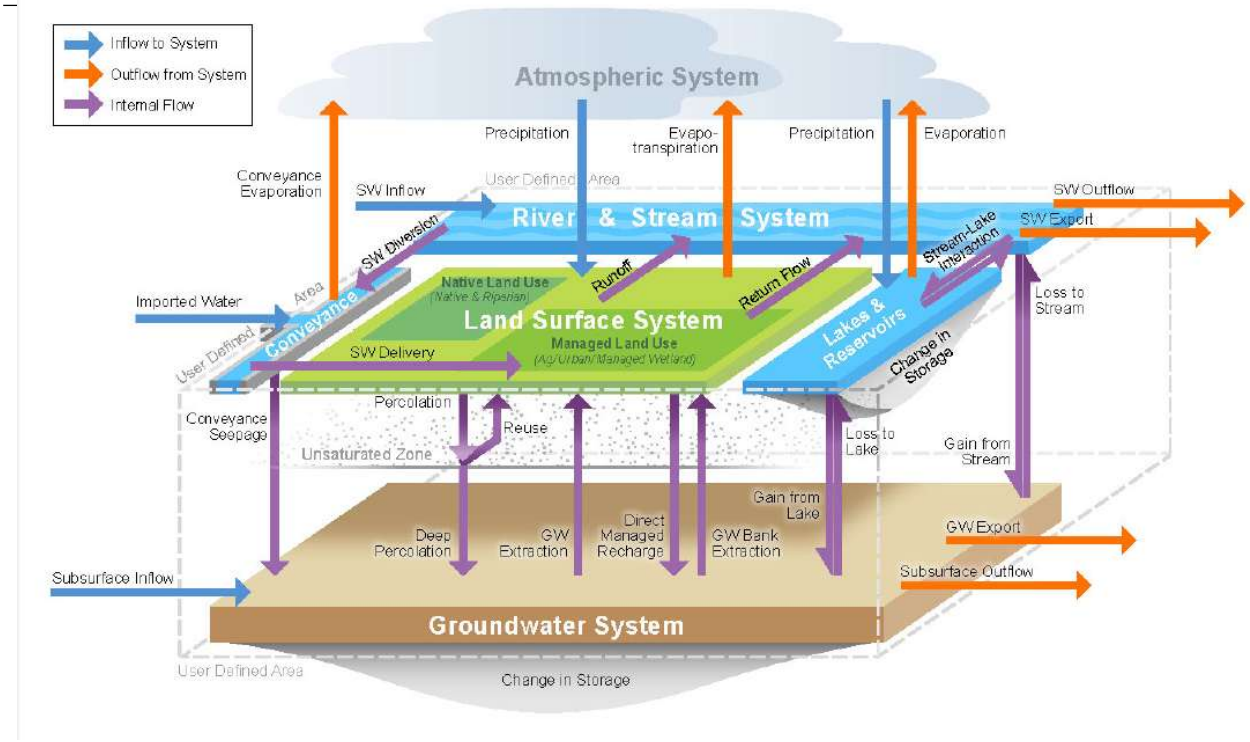


Figure 4-2. Water Budget Schematic, ~~(~~Source: ~~(~~DWR, 2016)

To prepare water budgets for the Subbasin, an integrated groundwater/~~-~~surface water flow model of the area encompassing the Subbasin in portions of Siskiyou and Modoc c~~C~~ounties, California, and extending to the north of the Subbasin within Klamath County, Oregon was developed. The m~~M~~odel integrates the three-dimensional (3D) groundwater and surface-water systems, land surface processes, and water management operations. Development of this model included the assimilation of information on land use, water infrastructure, hydrogeologic conditions, and agricultural water demands and supplies. The model was built upon two existing numerical groundwater flow models for the region developed by the ~~United States Geological Survey (~~USGS~~)~~ (Gannett et al., 2012; and Pischel and Gannett, 2015). The model is based upon the best available data and information as of Water Year 2025~~January 2020~~. It is expected that this model will be updated as additional monitoring data are collected and analyzed, and as knowledge of the hydrogeologic conceptual model evolves during implementation of the GSP.

4.1 Water Budget Data Sources

Due to the complexity of some of the components, precise and accurate quantification of each component of the water budget was not possible. Each component was estimated using readily available data; however, nearly all involved some level of assumption. In some cases, components were roughly estimated to ensure that the budget was balanced, and that both the budget and components were deemed reasonable. Over time, with additional and improved data, a budget that more closely reflects actual conditions will result in an improved tool for the Tule Lake Subbasin. Appendix K identifies the components of the water budget, data source(s), and assumptions. The following sections describe

~~water budgets for each of the systems shown in Figure 4-2: the groundwater system, the land surface~~ system, and the surface water system (i.e., Tule Lake Sumps).

4.1.1 Historical Water Budget

SGMA regulations require a 20-year historical period. Therefore, water years ~~1998~~ 2000 through ~~2018~~ 2025 were used for the historical model simulation period for the Tule Lake Subbasin. ~~. However, water years 2000 through 2018 are relied upon for the historical water budget due to the availability of data~~Table 4-1~~Table 4-1Table 4.1Table 4.1~~ summarizes the historical groundwater budget[4]. SGMA regulations also require quantification of overdraft, which is identified at the bottom of Table 4-1 as an average annual reduction in groundwater storage of 4 thousand acre-feet (TAF), which is a small amount relative to the magnitude of the total inflows and outflows. However, there is no clear evidence of recent overdraft since SGMA implementation in 2015.

Over the period evaluated by the~~20-year,~~ historical model simulation, groundwater storage declined by about 4 TAF per year, which is approximately 1.7% of the average total inflows and outflows of the system. Based on water levels shown in the hydrographs in Section 2.2.2.1 and the historical change in groundwater storage depicted in Figure 2-33, conditions within the basin have been fairly constant since 2015. This is further supported by the current water budget described ~~below~~in the following sections.

Although the historical water budget covers the period of water years 2000 through ~~2018~~2025, as defined in the SGMA regulations, GSPs are not required to address undesirable results that occurred before and have not been corrected by January 1, 2015. Therefore, this ~~Plan~~ GSP is not required to address overdraft or other undesirable results that occurred prior to January 1, 2015. In addition, DWR's 2020 Update to Bulletin 118[5] identifies the Tule Lake Subbasin as medium priority, meaning the Subbasin is not in a state of overdraft.

Table 4-1. Historical Groundwater Budget (Water Years 2000 – 2025~~18~~)

Groundwater Budget Term	WY Type Historical (2000-2025 [TAF]~~)~~					
	Very Dry	Less Dry	Dry	Wet	Very Wet	Average
Groundwater Recharge from Precipitation & Applied Water	48	53	66	70	92	66
Groundwater Recharge from Canal Laterals	36	52	55	49	50	48
Groundwater Recharge from Tule Lake Sumps	9	10	10	10	10	10
Groundwater Recharge from Main Canals	63	65	64	66	61	64
Groundwater Recharge from Lost River	5	7	8	8	8	7
Subsurface Flow Into Subbasin	17	18	16	17	21	18
Total Inflow	**178**	**205**	**219**	**220**	**242**	**213**
Irrigation & M&I Groundwater Pumping	13	8	4	1	7	7

[4] Additional details regarding the water budgets, including Water Budget Terms presented in this Section, and annual water budgets for the historic, current and projected period are provided in Appendix K.
[5] https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118#

Groundwater Budget Term	WY Type Historical (2000-2025 [TAF]})					
	Very Dry	Less Dry	Dry	Wet	Very Wet	Average
Private Groundwater Pumping	56	43	48	44	58	50
Groundwater Discharge to Drains	117	136	150	159	169	146
Shallow Groundwater Evapotranspiration	1	2	2	2	2	2
Groundwater Discharge to Tule Lake Sumps	0	0	0	0	0	0
Groundwater Discharge to Main Canals	0	0	0	0	0	0
Groundwater Discharge to Lost River	0	0	0	0	0	0
Subsurface Flow Out of Subbasin	12	9	9	8	9	9
Total Outflow	**199**	**198**	**213**	**214**	**245**	**214**
Change in Storage	-21	7	6	6	-3	-1

The groundwater system budget includes interactions between canals and drains with shallow groundwater. Groundwater discharge to drains is the largest outflow component. This component includes water that is applied to agricultural fields and then leaches or drains through the soil to a drainage canal adjacent to the field to ensure suitable rootzone moisture content for growing various crops. The model considers the portion of applied water ~~which~~ that is not used by the crop and flows from the field to a drain as "groundwater discharge to drains." While groundwater discharge to drains is the largest outflow component of the groundwater system, it is important to note that the majority of drain flows remain within the Subbasin as recirculated water for irrigation or flows to the Sumps.

Tulelake Irrigation District intends to continue to coordinate flows in order to allow lower Lost River Improved Channel water to flow into the Subbasin as it naturally did prior to construction of the Klamath Project. This operation will allow TID to charge irrigation canals and drains with water for recharge purposes, and will occur on an annual basis as lower Lost River Improved Channel water flows allow. Due to these~~There are not active groundwater recharge projects in the Tule Lake Subbasin; however, These~~ efforts, and since the Tule Lake Sumps and the District's conveyance facilities are unlined,~~which led to~~ groundwater recharge has occurred as shown in Table 4-1. In addition, with rising power costs, TID has minimized D-Plant pumping, which has led to increased surface water recirculation and increased groundwater recharge.

~~Similar to the aforementioned Groundwater Budget, a Land System Water Budget[6] was prepared to~~ analyze and compare inflows and outflows for that system. The historical water budget for the land system is included in Table 4-2.

Table 4-2. Land System Water Budget (Water Years 2000 – ~~20182025~~)

Land System Water Budget Term	Water Year Type - Historical (2000 - 2025 Avg [TAF])					
	Very Dry	Less Dry	Dry	Wet	Very Wet	Average
Precipitation	72	86	90	98	121	93
Shallow Groundwater into the Rootzone	1	2	2	2	2	2
Applied Water from Purveyor Deliveries	61	84	93	93	77	82
Applied Groundwater Outside of Purveyor Service Areas	60	45	52	47	61	53
Total Inflow	**194**	**217**	**237**	**240**	**261**	**230**
Evapotranspiration of Precipitation	35	43	32	35	23	34
Evapotranspiration of Applied Water	104	111	123	120	118	115
Runoff to Streams/Canals	7	8	12	13	25	13
Groundwater Recharge from Precipitation & Applied Water	48	53	66	70	92	66
Shallow Groundwater Evapotranspiration	1	2	2	2	2	2
Total Outflow	**195**	**217**	**235**	**240**	**260**	**230**

The water budget for the Tule Lake Sumps is included in Table 4-3. TID estimates D-Plant pumping, which is the only point of surface water outflow from the Subbasin. The D-Plant is operated, as needed, to maintain water levels in the Tule Lake Sumps. Therefore, water budget for the Sumps was prepared[7]. Inflows to the Tule Lake Sumps include surface water from irrigation drains, gains from groundwater, spill from the Lost River and precipitation. Outflows from the Tule Lake Sumps include irrigation ~~diversions~~ diversions, ~~and~~ D-Plant pumping, pumps R and 12 diversions, open-water evaporation, and groundwater recharge from Sumps. ~~-~~As shown in Table 4-3, the Sump Imbalance is positive in ~~18~~ 23 of the ~~19~~ 25 years analyzed. Therefore, the Tule Lake Sumps water budget is showing excess water in all but ~~one~~ two years, which indicates a conservative analysis.

[6] Additional details regarding the land system water budgets, including Water Budget Terms presented in this Section, and annual water budgets for the historic, current and projected period are provided in Appendix K.

[7] Additional details regarding the Tule Lake Sumps water budgets, including Water Budget Terms presented in this Section, and annual water budgets for the historic, current and projected period are provided in Appendix K.

Table 4-3. Tule Lake Sumps Water Budget (Water Years 2000-~~2018~~2025)

Water Year	Water Year Type*	Total Inflow (TAF)	Total Outflow (TAF)	Sump Imbalance (TAF)
2000	WW	225~~200,769~~	194-~~166,265~~	31~~34,503~~
2001	VDVD	178~~122,063~~	101-~~94,333~~	77~~27,730~~
2002	DLD	207~~211,597~~	208-~~202,924~~	-1~~8,672~~
2003	LDLD	192~~215,909~~	188-~~183,788~~	4~~32,121~~
2004	LDLD	185~~206,934~~	181-~~176,427~~	4~~30,507~~
2005	LDLD	195~~209,341~~	195-~~189,378~~	0~~19,963~~
2006	VWVW	228~~230,467~~	239-~~234,395~~	-11-~~3,928~~
2007	DD	187~~206,443~~	153-~~148,007~~	34~~58,436~~
2008	DD	185~~205,470~~	178-~~173,810~~	7~~31,660~~
2009	LDLD	167~~182,202~~	157-~~150,586~~	10~~31,616~~
2010	VDVD	142~~134,796~~	100-~~95,164~~	42~~39,632~~
2011	WW	178~~160,246~~	138-~~134,203~~	40~~26,043~~
2012	DD	164~~147,647~~	142-~~136,494~~	22~~11,154~~
2013	LDLD	165~~145,763~~	151-~~144,957~~	14~~806~~
2014	VDVD	149~~131,172~~	133-~~127,752~~	16~~3,420~~
2015	VDVD	171~~150,191~~	133-~~128,587~~	38~~21,604~~
2016	DLD	182~~168,178~~	148-~~143,164~~	34~~25,014~~
2017	WW	195~~183,967~~	155-~~149,009~~	40~~34,958~~
2018	VDVD	165~~166,696~~	132-~~126,694~~	33~~40,001~~
2019	D	186	150	36
2020	VD	155	134	21
2021	VD	111	92	19
2022	VD	74	56	18
2023	LD	102	94	8
2024	VD	204	153	51
2025	D	218	189	29

*Where VW = Very Wet, W = Wet, D = Dry, LD = Less Dry, VD = Very Dry

~~*Where VW = Very Wet, W = Wet, D = Dry, LD = Less Dry, VD = Very Dry~~

4.1.2 Current Water Budget

The current groundwater budget and land system budget is based on water year 2018-2025, which is the most recent year analyzed in the historical water budget and is included in Table 4-4 and Table 4-5. As shown, inflows to the groundwater system exceeded outflows during water year 2018, which

~~resulted in a positive change in storage of approximately 147 TAF. The current water budget for the Tule~~ Lake Sumps is included in Table 4-3.

Table 4-~~4~~4.4. Current Groundwater Budget (Water Year 2018-2025)

Groundwater Budget Term	Water Year Type - Current
	2018-2025
Groundwater Recharge from Precipitation & Applied Water	52
Groundwater Recharge from Canal Laterals	49
Groundwater Recharge from Tulelake Sumps	9
Groundwater Recharge from Main Canals	66
Groundwater Recharge from Lost River	5
Subsurface Flow Into Subbasin	17
Total Inflow	**198**
Irrigation & M&I Groundwater Pumping	11
Private Groundwater Pumping	57
Groundwater Discharge to Drains	120
Shallow Groundwater Evapotranspiration	1
Groundwater Discharge to Tulelake Sumps	0
Groundwater Discharge to Main Canals	0
Groundwater Discharge to Lost River	0
Subsurface Flow Out of Subbasin	13
Total Outflow	**202**
Change in Storage	-4

~~Groundwater Budget Term~~	~~Water Year Type - Current (2018 Avg [TAF])~~
	~~Very Dry~~
~~Groundwater Recharge from Precipitation & Applied Water~~	~~80~~
~~Canal Laterals Leakage~~	~~93~~
~~Tulelake Sumps Leakage~~	~~7~~
~~Main Canals and Lost River Leakage~~	~~72~~
~~Subsurface Flow Into Subbasin~~	~~17~~
~~**Total Inflow**~~	~~**268**~~
~~Irrigation & M&I Groundwater Pumping~~	~~27~~
~~Private Groundwater Pumping~~	~~5~~
~~Groundwater Discharge to Drains~~	~~192~~
~~Shallow Groundwater Evapotranspiration~~	~~4~~

~~Groundwater Discharge to Tulelake Sumps~~	~~0~~
~~Groundwater Discharge to Main Canals and Lost Rivers~~	~~2~~
~~Subsurface Flow Out of Subbasin~~	~~21~~
~~**Total Outflow**~~	~~**251**~~
~~Change in Storage~~	~~17~~

Table 4-~~5~~4.5. Current Land System Water Budget (Water Year 2018-2025)

Land System Water Budget Term	Water Year Type – Current 2018-2025
Precipitation	79
Shallow Groundwater into the Rootzone	65
Applied Water from Purveyor Deliveries	61
Applied Groundwater Outside of Purveyor Service Areas	1
Total Inflow	206
Evapotranspiration of Precipitation	8
Evapotranspiration of Applied Water	36
Runoff to Streams/Canals	1
Groundwater Recharge from Precipitation & Applied Water	108
Shallow Groundwater Evapotranspiration	52
Total Outflow	205

~~Land System Water Budget Term~~	~~Water Year Type – Current (2018 Avg [TAF])~~ ~~Very Dry~~
~~Precipitation~~	~~116~~
~~Water into the Rootzone~~	~~4~~
~~Surface Water Deliveries~~	~~89~~
~~Groundwater Deliveries~~	~~5~~
~~**Total Inflow**~~	~~**214**~~
~~Evapotranspiration of Precipitation~~	~~59~~
~~Evapotranspiration of Applied Water~~	~~80~~
~~Runoff From Farm~~	~~10~~
~~Groundwater Recharge from Precipitation & Applied Water~~	~~61~~
~~Shallow Groundwater Evapotranspiration~~	~~4~~
~~**Total Outflow**~~	~~**214**~~

4.1.3 Projected Water Budget

SGMA Regulations require the preparation of a projected water budget, which must be based on at least 50 years of historic climate data along with estimates of future land and water use. In addition, the SGMA regulations require an analysis of future conditions with potential climate change incorporated.

~~As previously stated, the historical period is 20 25 years long (water years 1999-2018 2000 – 2025).~~ Therefore, the climate data from that period was repeated 2.5 times to achieve a 50-year period for projections. These data were used to develop the projected water budget baseline (i.e., without climate change). See Appendix K for further discussion on this topic.

Table 4-6 summarizes the projected groundwater budget baseline, which projects an average annual change in storage of 0 acre-feet. This appears to be reasonable, as there is no assumed change to current crop patterns (which accounts for 55 percent of the land within the Subbasin) nor expected population growth within the Subbasin. The Subbasin is known to experience annual fluctuations depending on hydrology and surface water supply available from the Klamath Project; however, groundwater levels in the Subbasin have remained relatively stable over the last ~~six~~ twelve years (water years 2013 – ~~2018~~2025), with seasonal fluctuations.

Table 4-6. Projected Groundwater Budget Baseline

Groundwater Budget Term	**Projected Baseline WY 2026 - 2071 Avg (TAF)**
Groundwater Recharge from Precipitation & Applied Water	56
Groundwater Recharge from Canal Laterals	44
Groundwater Recharge from Tulelake Sumps	11
Groundwater Recharge from Main Canals	63
Groundwater Recharge from Lost River	9
Subsurface Flow Into Subbasin	17
Total Inflow	**200**
Irrigation & M&I Groundwater Pumping	8
Private Groundwater Pumping	63
Groundwater Discharge to Drains	117
Shallow Groundwater Evapotranspiration	1
Groundwater Discharge to Tulelake Sumps	0
Groundwater Discharge to Main Canals	0
Groundwater Discharge to Lost River	0
Subsurface Flow Out of Subbasin	12
Total Outflow	**201**
Change in Storage	0

~~**Groundwater Budget Term**~~	~~**Projected Baseline WY 2019 - 2071 Avg (TAF)**~~
~~Groundwater Recharge from Precipitation & Applied Water~~	~~59~~
~~Canal Laterals Leakage~~	~~93~~
~~Tulelake Sumps Leakage~~	~~6~~
~~Main Canals and Lost River Leakage~~	~~66~~
~~Subsurface Flow Into Subbasin~~	~~15~~
~~**Total Inflow**~~	~~**238**~~

~~Irrigation & M&I Groundwater Pumping~~	~~42~~
~~Private Groundwater Pumping~~	~~6~~
~~Groundwater Discharge to Drains~~	~~165~~
~~Shallow Groundwater Evapotranspiration~~	~~5~~
~~Groundwater Discharge to Tulelake Sumps~~	~~0~~
~~Groundwater Discharge to Main Canals and Lost Rivers~~	~~1~~
~~Subsurface Flow Out of Subbasin~~	~~20~~
~~**Total Outflow**~~	~~**238**~~
~~Change in Storage~~	~~0~~

Figure 4-3 shows the complete water budget (water years ~~2019~~ 2000 – 2071) without climate change. The gray line on the figure shows the annual change in groundwater storage which fluctuates based on the balance of inflows. The black line is the cumulative of the annual change in groundwater storage over the length of the model period.

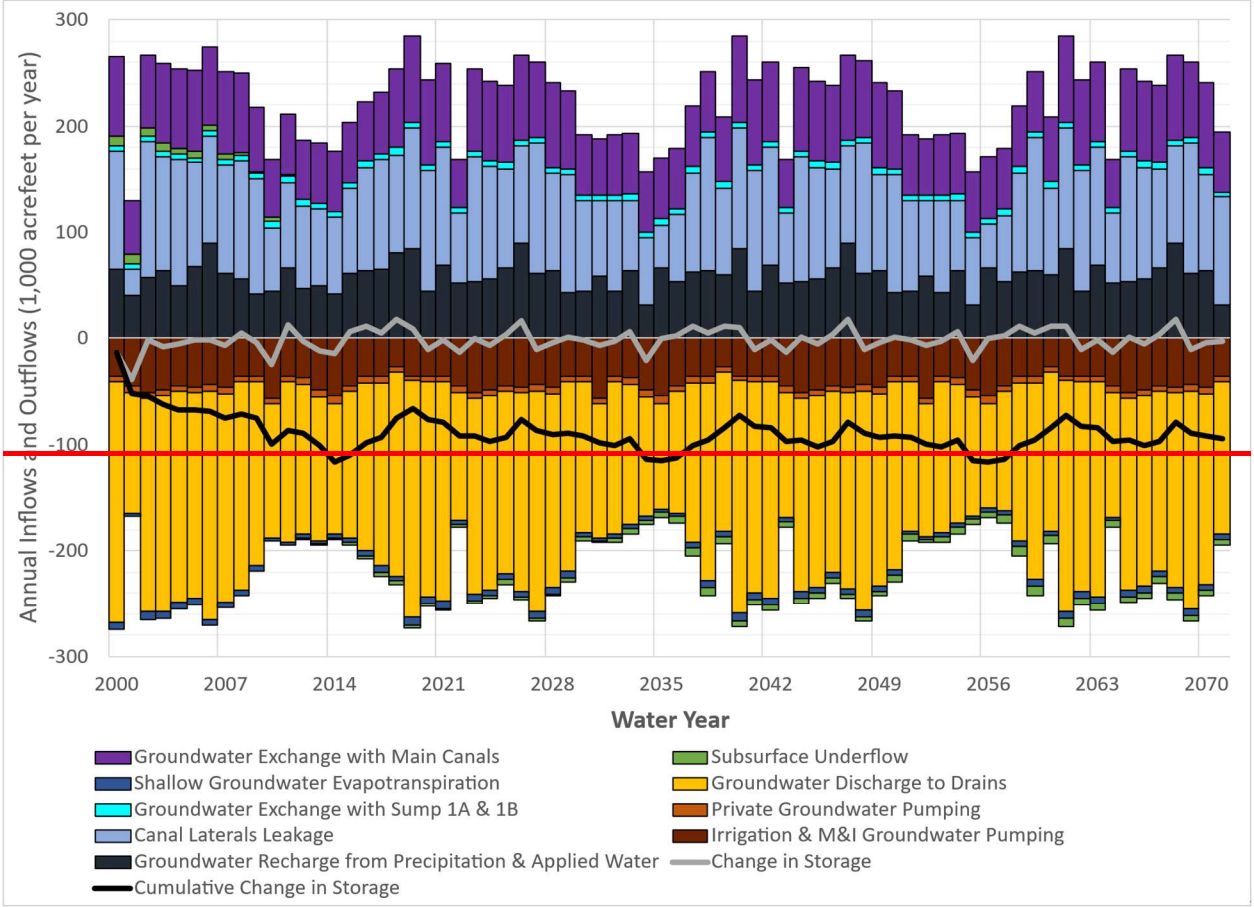
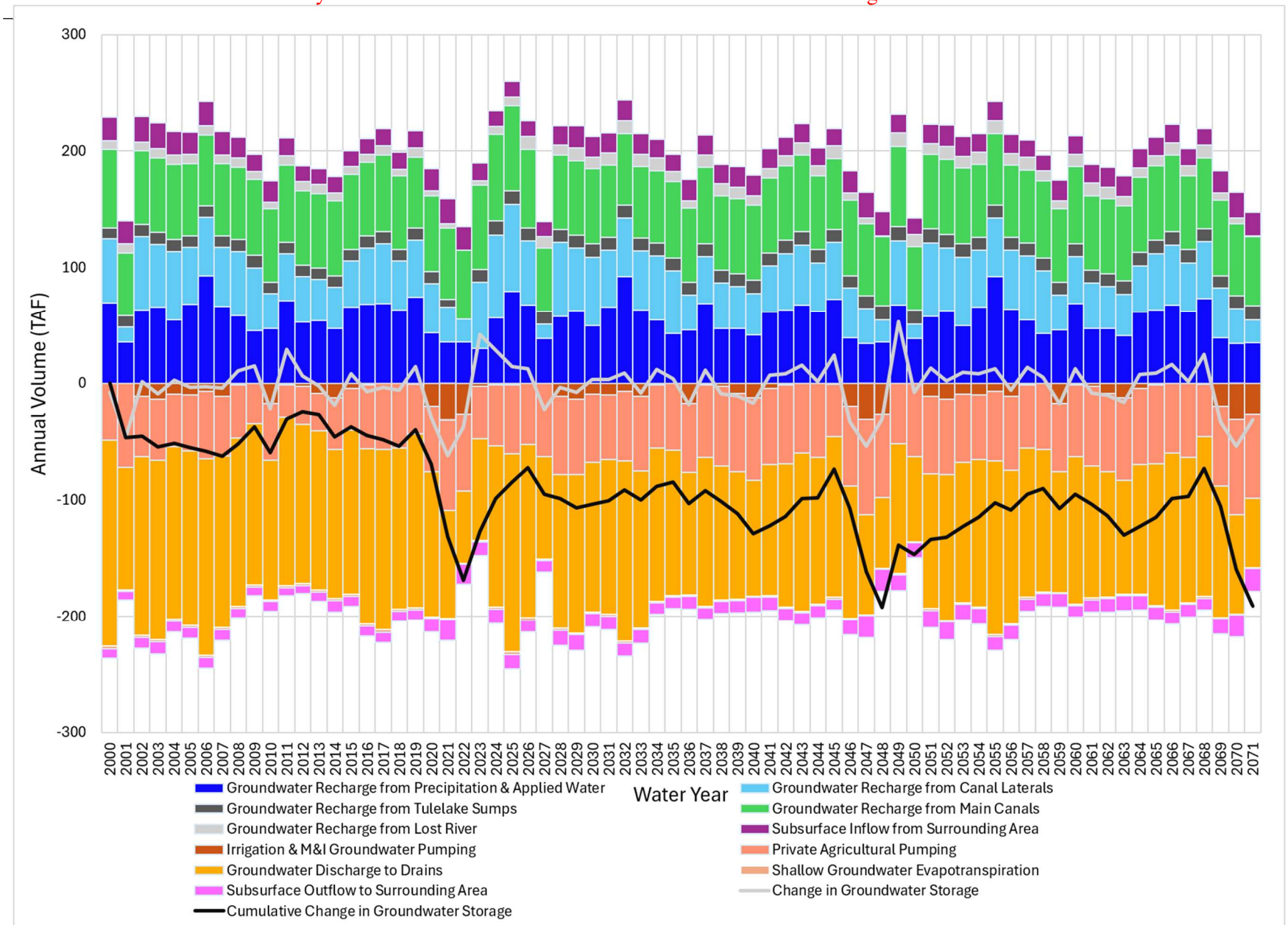


Figure 4-3. Water Budget – Future with no Climate Change
(from Appendix K)


300
200
100
0
-100
-200
-300
Annual Volume (TAF)
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071
Water Year
Groundwater Recharge from Precipitation & Applied Water
Groundwater Recharge from Tulelake Sumps
Groundwater Recharge from Lost River
Irrigation & M&I Groundwater Pumping
Groundwater Discharge to Drains
Subsurface Outflow to Surrounding Area
Cumulative Change in Groundwater Storage
Groundwater Recharge from Canal Laterals
Groundwater Recharge from Main Canals
Subsurface Inflow from Surrounding Area
Private Agricultural Pumping
Shallow Groundwater Evapotranspiration
Change in Groundwater Storage

For the projected water budget with climate change, DWR provided alternatives for use by GSAs, which included climate change factors. ~~Reclamation, in coordination with DWR and the Oregon Water Resources Department, released the Klamath River Basin Study in 2019 (Study) (USBR, 2016). The Study evaluated water supply and demand including projected impacts of climate change.~~ The Tule Lake Subbasin selected the 2070 ~~central tendency~~Drier Extreme Warming (DEW) alternative based on~~-~~ input from DWR.~~knowledge of Reclamation modeling efforts for the Klamath Project. Information from the Study provided estimated impacts to mean Project Supply based on the 2070 central tendency which were incorporated into the water budget model.~~ In addition, the 2070 ~~central tendency~~DEW climate change factors for temperature and rainfall, developed and provided by DWR, were applied to the 50 years of projected climate data. See Appendix K for additional information on this topic.

Table 4-7 summarizes the projected groundwater budget baseline, which projects an average annual change in storage of -3~~0~~ acre-feet. As with the projection without climate change, this projection is likely reasonable, as the 2070 ~~central tendency~~DEW scenario projects increased temperatures and ~~increased~~ decreased precipitation during the irrigation season. ~~In addition, the Study projected little to no change in mean Project Supply under this climate change scenario.~~

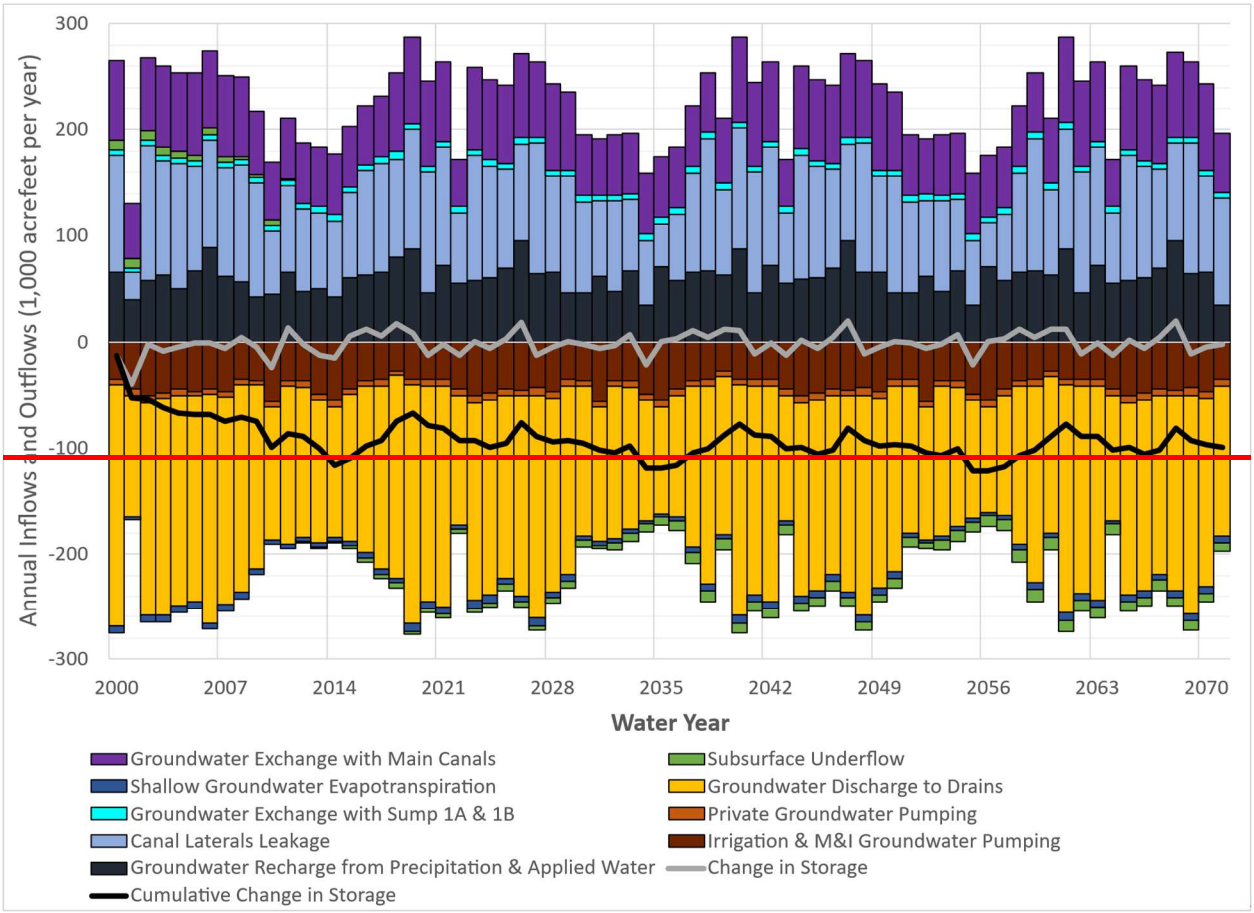
Table 4-7. Projected Groundwater Budget with Climate Change Incorporated

Groundwater Budget Term	Projected Baseline w/ Climate Change
	WY 2026 - 2071 Avg (TAF)
Groundwater Recharge from Precipitation & Applied Water	53
Groundwater Recharge from Canal Laterals	44
Groundwater Recharge from Tulelake Sumps	12
Groundwater Recharge from Main Canals	64
Groundwater Recharge from Lost River	9
Subsurface Flow into Subbasin	16
Total Inflow	**198**
Irrigation & M&I Groundwater Pumping	8
Private Groundwater Pumping	72
Groundwater Discharge to Drains	102
Shallow Groundwater Evapotranspiration	1
Groundwater Discharge to Tulelake Sumps	0
Groundwater Discharge to Main Canals	0
Groundwater Discharge to Lost River	0
Subsurface Flow Out of Subbasin	18
Total Outflow	**201**
Change in Storage	-3

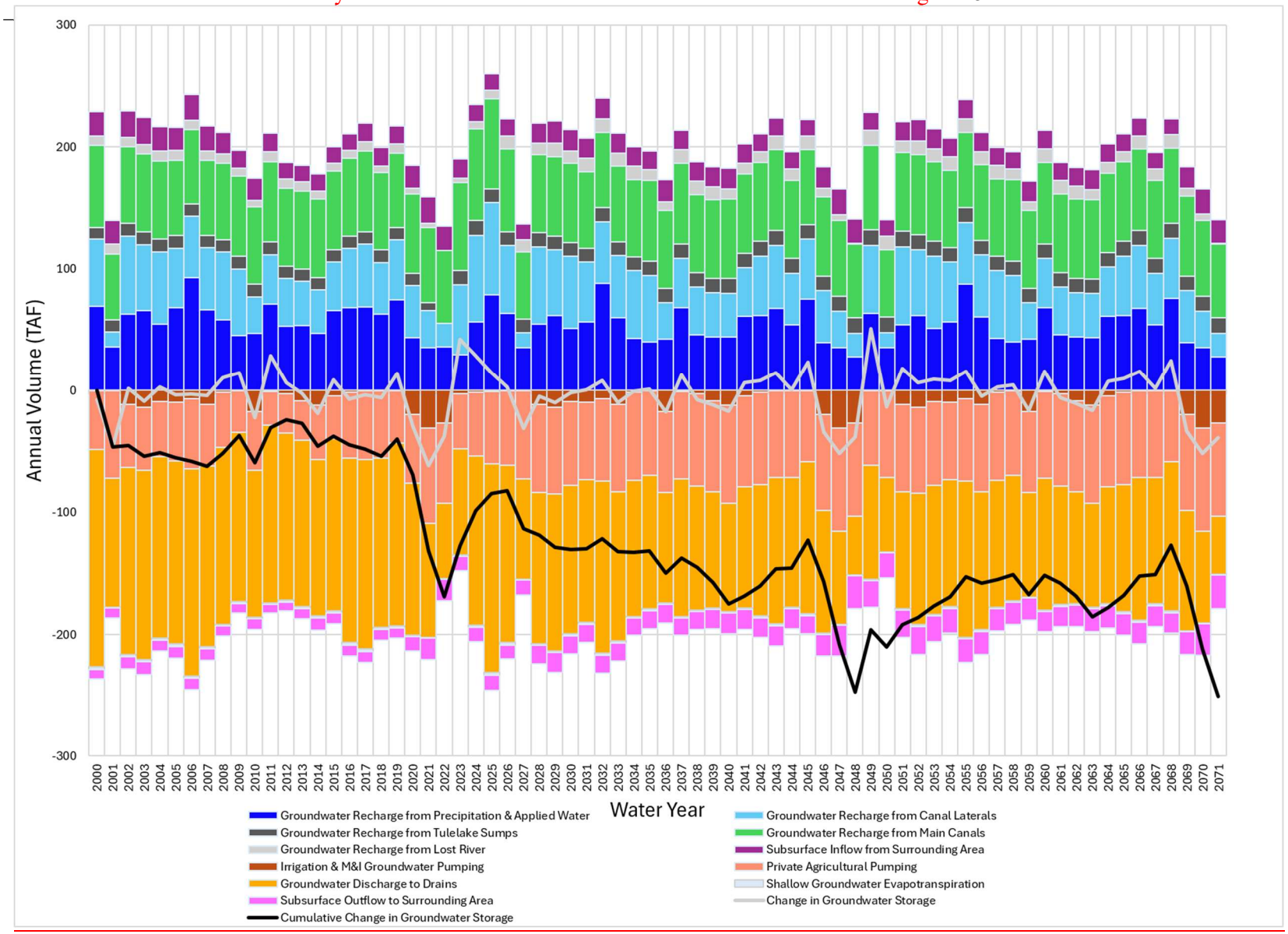
~~Groundwater Budget Term~~	~~Projected Baseline w/ Climate Change~~
	~~WY 2019 - 2071 Avg (TAF)~~
~~Groundwater Recharge from Precipitation & Applied Water~~	~~63~~

~~Canal Laterals Leakage~~	~~93~~
~~Tulelake Sumps Leakage~~	~~6~~
~~Main Canals and Lost River Leakage~~	~~66~~
~~Subsurface Flow Into Subbasin~~	~~14~~
~~**Total Inflow**~~	~~**242**~~
~~Irrigation & M&I Groundwater Pumping~~	~~42~~
~~Private Groundwater Pumping~~	~~6~~
~~Groundwater Discharge to Drains~~	~~165~~
~~Shallow Groundwater Evapotranspiration~~	~~5~~
~~Groundwater Discharge to Tulelake Sumps~~	~~0~~
~~Groundwater Discharge to Main Canals and Lost Rivers~~	~~1~~
~~Subsurface Flow Out of Subbasin~~	~~22~~
~~**Total Outflow**~~	~~**242**~~
~~Change in Storage~~	~~0~~

Figure 4-4 shows the complete water budget (~~WY~~ water years 2000 – 2071) with climate change. The gray line on the figure shows the annual change in groundwater storage which fluctuates based on the balance of inflows. The black line is the cumulative of the annual change in groundwater storage over the length of the model period.



~~Figure 4-44-4. Water Budget - Future with Climate Change~~


Annual Volume (TAF)
300
200
100
0
-100
-200
-300
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071
Water Year
Groundwater Recharge from Precipitation & Applied Water
Groundwater Recharge from Tulelake Sumps
Groundwater Recharge from Lost River
Irrigation & M&I Groundwater Pumping
Groundwater Discharge to Drains
Subsurface Outflow to Surrounding Area
Cumulative Change in Groundwater Storage
Groundwater Recharge from Canal Laterals
Groundwater Recharge from Main Canals
Subsurface Inflow from Surrounding Area
Private Agricultural Pumping
Shallow Groundwater Evapotranspiration
Change in Groundwater Storage

~~Figure~~ 4 ~~445. Water Budget - Future with Climate Change (from Appendix K) Annual Groundwater from WY 2000 through 2071~~

The SGMA Regulations require Plans to identify an estimate of the sustainable yield for the subbasin. This requirement is interpreted as the average annual groundwater pumping that can occur, which does not lead to overdraft of the groundwater resource. As shown in Table 4-7 and ~~Figure 4-4~~, the projected average annual long term groundwater pumping is approximately ~~48,000~~57,000 acre-feet. The Tule Lake Subbasin has historically demonstrated that the Subbasin can accommodate that level of groundwater pumping, which is further confirmed through the projected water budgets. Therefore, the estimated sustainable yield for the Tule Lake Subbasin is ~~48,000~~57,000 acre-feet. The estimate of sustainable yield will be re-evaluated in future updates to this GSP as additional information becomes available.

5 Sustainable Management Criteria (Reg. § 354.22-30)

This section of the Plan describes the sustainable management criteria for the Tule Lake Subbasin. The SMCs define conditions that constitute sustainable groundwater management for the Subbasin, which includes the sustainability goal, undesirable results, and minimum thresholds for each applicable sustainability indicator. Below are definitions of key terms described in the GSP Regulations.

Sustainability Goal: GSAs' objectives and desired conditions of the groundwater basin, how the basin will get to that condition, and why the measures planned will lead to success.

Sustainability Indicator: Sustainability indicators are the six effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, are undesirable results. The sustainability indicators are listed below:

- Chronic Lowering of Groundwater Levels
- Depletion of Interconnected Surface Water
- Degraded Water Quality
- Land Subsidence
- Seawater Intrusion (not applicable to Tule Lake Subbasin)
- Reduction in Groundwater Storage

Undesirable Results: Undesirable results occur when conditions related to any of the six sustainability indicators become significant and unreasonable.

Measurable Objective (MO): A measurable objective is a quantitative goal that reflects the desired groundwater conditions and allows the GSAs to achieve the sustainability goal within 20 years.

Interim Milestones: Interim milestones are set to guide conditions during implementation of the GSP to define a pathway to reach sustainability within 20 years. In the Tule Lake Subbasin, the interim milestones are currently assumed to not be needed, as implementation activities are not required to achieve the measurable objectives. However, for the purpose of the GSP, the interim milestones are set at the same levels as the measurable objectives.

Minimum Threshold ~~(MT)~~: A minimum threshold is the quantitative value that represents the groundwater conditions at a representative monitoring site that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause an undesirable result(s) in the basin.

Figure 5-1 illustrates the relationship between the sustainability indicators, SMCs, MTs, and undesirable results.

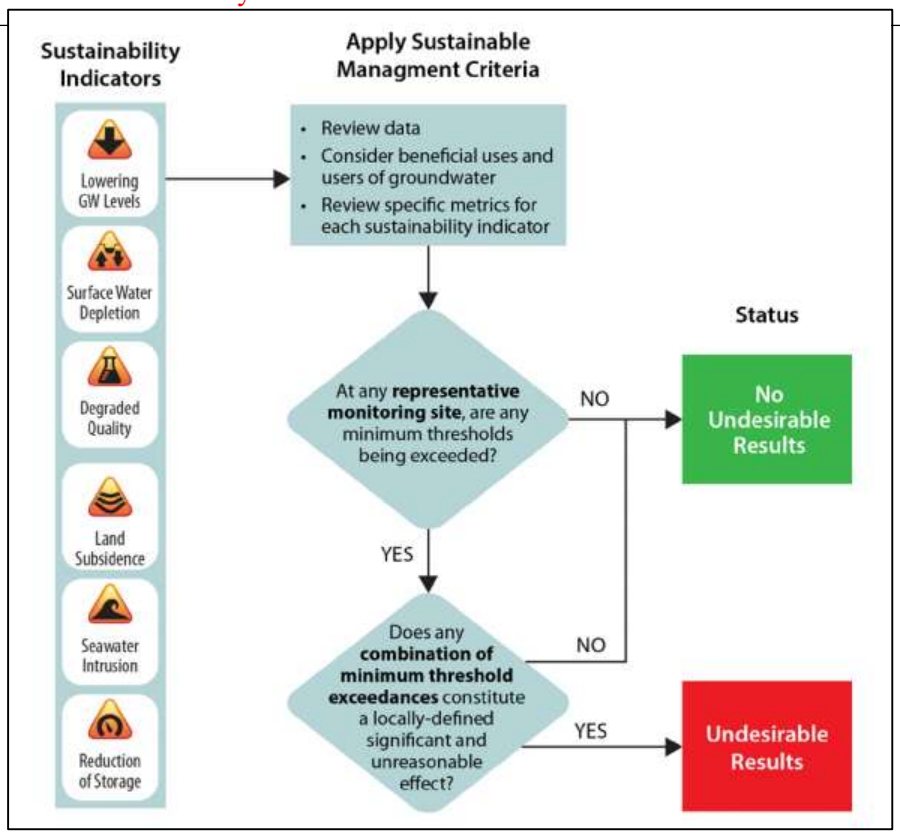


Figure 5-1. Relationship of Sustainability Indicators, SMCs, MTs, and Undesirable Results (DWR)

5.1 Sustainability Goal

As described in this ~~Plan~~GSP, the primary use of water in the Subbasin is for agricultural purposes. In addition, Modoc County meets the requirements of a ~~severely~~ Severely D~~d~~isadvantaged C~~c~~ommunity~~y~~ ~~(SDAC)~~. Similarly, Siskiyou County meets the requirements of a D~~d~~isadvantaged C~~c~~ommunity ~~(DAC)~~. These communities are reliant upon the local forestry and agriculture industries. Therefore, the sustainability goal for the Tule Lake Subbasin is to maintain a locally governed, economically viable, reliable, and sustainable groundwater subbasin for current and future beneficial uses, without causing undesirable results.

The water budgets included in Section 4 of this Plan show that the Subbasin is currently, and is projected to remain, sustainably managed. Therefore, the sustainability goal is achieved through continued local management of the Subbasin. In addition, implementation of measures to operate within the sustainable yield are not necessary. However, as described in Section 6.1.7 of this Plan, adaptive management will be utilized if necessary.

5.2 Undesirable Results

SGMA Regulations require undesirable results definitions for each applicable sustainability indicator. In addition, GSPs are required to identify potential causes that would lead to undesirable results, criteria to define undesirable results based on MTs, and the potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are

~~occurring from undesirable results. MTs have been established for each representative monitoring site~~ and are described in Section **Error! Reference source not found.**~~5.3~~.

5.2.1 Chronic Lowering of Groundwater Levels

The following subsections describe the undesirable result of chronic lowering of groundwater levels in more detail.

5.2.1.1 Description of the Chronic Lowering of Groundwater Levels

The undesirable result of the chronic lowering of groundwater levels is a result that would cause significant and unreasonable impacts to beneficial uses and users of groundwater over the implementation period of this GSP.

5.2.1.2 Potential Causes and Effects of the Chronic Lowering of Groundwater Levels

As shown in Section 6 of this Plan, the Tule Lake Subbasin is currently being sustainably managed. The primary land use is agriculture, and the GSAs do not anticipate changes in agricultural cropping patterns. Thus, even when the effects of climate change are considered, water demand is not projected to significantly increase. The primary water source in the Subbasin is surface water deliveries via Reclamation. Therefore, if surface water supply were to decrease, groundwater extractions would likely increase (initially by the District's groundwater wells, and then, if necessary, private irrigation wells), potentially leading to the chronic lowering of groundwater levels. Lowering of groundwater levels would result in increased power costs to extract groundwater and potentially impact users of groundwater. In extreme cases, groundwater levels may decrease to an extent where it becomes necessary to lower pump bowls and/or deepen the well. Appendix M includes an analysis by the GSAs of the potential impacts to private irrigation wells. Table 2 of Appendix M identifies the representative monitoring wells that are identified as irrigation wells. Table 5 of Appendix M provides a summary of potential dewatered wells if an MT is reached or exceeded. Based on this summary, the MTs of the representative monitoring wells for irrigation (TID Well 1, TID Well 5, TID Well 8, and TID Well 14) could be exceeded by up to 10 feet and there would not be any dewatered private irrigation wells. Chronic lowering of groundwater levels may also affect GDEs as described in Appendix M. ~~However~~Although, further identification of potential GDEs and groundwater level monitoring near potential GDEs have been identified as data gaps, GDEs were considered when setting the identification of undesirable result for chronic lowering of groundwater levels.

5.2.1.3 Criteria Used to Define Chronic Lowering of Groundwater Levels

The GSAs elected to form an Ad Hoc Committee to discuss and define undesirable results and MTs. A meeting summary is included in Appendix L. Since that meeting the GSAs have updated the definition of undesirable results to the criteria shown below. ~~The undesirable result definition for chronic lowering of groundwater levels is provided below.~~

Groundwater elevations dropping below the Minimum Threshold criteria at four representative monitoring locations over ~~three~~ two consecutive ~~spring~~ fall measurements.

~~The Ad Hoc Committee agreed to use a combination of shallowest domestic wells depths within a 3-mile~~ radius of representative monitoring wells or the historical low groundwater level measurement at the representative monitoring well plus a 10% buffer. The 10% buffer is based on feet below ground surface. A summary of the methodology for determination of MTs and additional information relative to the undesirable result definition is included in Appendix M. The aforementioned undesirable result definition ~~above~~ identifies ~~spring~~ fall groundwater level measurements; however, as described in this Plan, many of the wells within the groundwater monitoring network for the Tule Lake Subbasin are monitored on a quarterly or more frequent basis. The groundwater data collected as part of the monitoring effort will be reviewed during the GSA coordination meetings. Therefore, the GSAs will be monitoring conditions on a more frequent basis.

5.2.2 Reduction in Groundwater Storage

The following subsections describe the undesirable result of reduced groundwater storage in more detail.

5.2.2.1 Description of the Reduction in Groundwater Storage

The undesirable result of the reduction in groundwater storage is a result of groundwater extraction that would cause significant and unreasonable impacts to beneficial uses and users of groundwater over the implementation period of this GSP. Reduction in groundwater storage is related to lowering of groundwater levels. Reduction in groundwater storage would occur when outflows from the groundwater system exceed inflows. This may occur on a short-term basis (e.g., during dry hydrologic conditions), but is defined as significant and unreasonable when groundwater levels are below the MT for ~~three~~ two consecutive ~~spring~~ fall measurements.

5.2.2.2 Potential Causes and Effects of Reduction in Groundwater Storage

As shown in Section 6 of this Plan, the Tule Lake Subbasin is currently being sustainably managed. The primary land use is agriculture, and the GSAs do not anticipate changes in agricultural cropping patterns. Thus, even when the effects of climate change are considered, water demand is not projected to significantly increase. The primary water source in the Subbasin is surface water deliveries via Reclamation. Therefore, if surface water supply were to decrease, groundwater extractions would likely increase potentially leading to the reduction of groundwater storage. Reduction in groundwater storage would result in increased power costs to extract groundwater. In extreme cases, groundwater levels may decrease to an extent where the cost to pump water exceeds the value of the agriculture or potentially affects domestic wells as described in Appendix M.

5.2.2.3 Criteria Used to Define Reduction in Groundwater Storage

The GSAs elected to form an Ad Hoc Committee to discuss and define undesirable results and MTs. In regard to reduction in groundwater storage, groundwater levels were identified as a proxy metric. This means that the identifications of undesirable results for chronic lowering of groundwater levels are equivalent to the identifications of undesirable results for reduction in groundwater storage. The use of groundwater levels as a proxy for this sustainability indicator is justified due to the correlation between groundwater levels and groundwater storage (i.e., as groundwater levels decline, there is a decrease in groundwater storage). The MTs for groundwater levels were developed based on considerations for

~~historical uses and users of water as well as historical groundwater levels. Although annual fluctuations~~ in groundwater storage are anticipated as shown in Figure 4-3 and ~~Figure 4-4~~, the MTs are intended to ensure that there will be no long-term decline in groundwater storage.

5.2.3 Land Subsidence

The following subsections describe the undesirable result of land subsidence and its potential effects in more detail.

5.2.3.1 Description of Land Subsidence

The undesirable result of land subsidence is a result of groundwater extraction that would cause significant and unreasonable impacts to infrastructure, including water conveyance facilities, over the implementation period of this GSP. As described in Section 2.2.2.7, there has been no noticeable subsidence within the subbasin since at least 2001. Because of this experience, with no known subsidence even during periods of decreasing groundwater levels, it is assumed that there are not soils susceptible to compression within the subbasin.

5.2.3.2 Potential Causes and Effects of the Land Subsidence

As shown in Section 4 of this Plan, the Tule Lake Subbasin is currently being sustainably managed. The primary land use is agriculture, and the GSAs do not anticipate changes in agricultural cropping patterns. Thus, even when the effects of climate change are considered, water demand is not projected to significantly increase. The primary water source in the Subbasin is surface water deliveries via Reclamation. Therefore, if surface water supply were to decrease, groundwater extractions would likely increase, potentially leading to land subsidence.

Subsidence is known to cause damage to water conveyance facilities and flood control facilities. This could potentially impact the canals and drains within the Tulelake Irrigation District and result in surface water delivery inefficiencies and subsequent increases in groundwater use. Subsidence within the vicinity of the Tule Lake Sumps could impact the levees and flood control structures.

5.2.3.3 Criteria Used to Define Land Subsidence

~~The GSAs elected to form an Ad Hoc Committee to discuss and define undesirable results and MTs. In regard to Land Subsidence, groundwater levels were identified as a proxy metric. The use of groundwater levels as a proxy for this sustainability indicator is justified due to the correlation between groundwater levels and land subsidence. Although the Groundwater Level Monitoring Network will be used to monitor potential subsidence, the GSAs will also review DWR's active subsidence network. This network includes InSAR data for the Subbasin. However, the data need to be processed and are not made available in real time. The data will be reviewed as it becomes available to confirm the adequacy of the Groundwater Level Monitoring Network.~~To monitor land subsidence, the GSAs will review DWR's active land subsidence network. This network includes InSAR data for the Subbasin.~~,~~ D~~d~~ata will be reviewed as it becomes available and evaluated based on time periods established in the MTs. To establish minimum thresholds (MTs) and define undesirable results for land subsidence, InSAR data was used for monitoring and evaluation. An undesirable result is identified when the minimum threshold is

~~exceeded within 5 square miles. The minimum threshold is defined as 0.5 feet of vertical displacement~~ within a five-year period.

5.2.4 Depletion of Interconnected Surface Water~~:~~

The following subsections describe the undesirable result of the depletion of interconnected surface water in more detail.

5.2.4.1 Description of Depletion of Interconnected Surface Water

Shallow groundwater and surface water systems can be hydraulically connected. The surface water bodies can either be gaining (receiving water from the groundwater system) or losing (losing water to the groundwater system). As shown in the water budgets (see Section 4), there is interaction between the groundwater system and the land system within the Tule Lake Subbasin. However, the majority of surface water in the Subbasin consists of water within the Tulelake Irrigation District canals, drains, and the Tule Lake Sumps as a result of deliveries from the Klamath Project.

5.2.4.2 Potential Causes and Effects of Depletion of Interconnected Surface Water

Because chronic lowering of groundwater levels is used as a proxy for depletion of interconnected surface water, the causes of this undesirable result are the same as those for groundwater levels. Lowering groundwater levels in the vicinity of the lower Lost River Improved Channel and the Tule Lake Sumps may result in increased depletions from the surface water to the groundwater system. The lower Lost River Improved Channel does not have minimum flow requirements and flows intermittently. However, the water surface elevations in the Tule Lake Sumps will continue to be met, as required by the Biological Opinion. Undesirable results occur when there are adverse effects on the beneficial users of interconnected surface waters in the Subbasin over the implementation period of this ~~.~~GSP. Depletion of interconnected surface waters undesirable results could include increased demand for groundwater pumping and increased power costs. Additionally, depletion of interconnected surface waters could require beneficial users to deepen their wells and/or lower their pump bowls which another cost. Depletion of interconnected surface waters may also contribute to significant and unreasonable impacts on GDEs.

5.2.4.3 Criteria Used to Define Depletion of Interconnected Surface Water

In regard to depletion of interconnected surface water, groundwater levels were identified as a proxy metric. The use of groundwater levels as a proxy for this sustainability indicator is justified due to the correlation between shallow groundwater levels and surface water. As identified in Section 3, the only surface water within the Subbasin, including the lower Lost River Improved Channel and the Sumps, is highly regulated as part of ~~the US Bureau of~~ Reclamation's Klamath Project. Therefore, a separate monitoring network for groundwater-surface water interaction has not been developed. However, DWR Monitoring Well No. 48N04E22M001M (local well name is Amy King) is located adjacent to the lower Lost River Improved Channel and is included in the Groundwater Level Monitoring Network. The GSAs elected to form an Ad Hoc Committee to discuss and define undesirable results and MTs. A meeting summary is included in Appendix

L. Since that meeting the GSAs have updated the definition of undesirable results to the criteria shown below.~~The Ad Hoc Committee identified the following definition:~~

Groundwater elevations dropping below the Minimum Threshold criteria at this representative monitoring location over ~~three~~ two consecutive ~~spring~~ fall measurements.

The model used to develop the water budgets presented in Section 4 includes surface water components, including the Sumps. As described in Section 3.3.1.6, monitoring of shallow groundwater wells in the vicinity of the sumps is identified as a data gap, and the construction of dedicated monitoring wells near the Sumps would provide information regarding surface water interaction. Assuming construction of a monitoring well in this area, groundwater level measurements would be obtained, along with other observations, to be incorporated into the model through SGMA implementation. Through implementation, the model may be used as a tool for evaluating potential depletion of interconnected surface water and incorporated into the criteria used to define depletion of interconnected surface water. Evaluation of model data to create a preliminary analysis of the location and timing of interconnected surface waters can be found in Appendix O.

5.2.5 Degraded Water Quality

The following subsections describe the undesirable result degraded water quality in more detail.

5.2.5.1 Description of the Degraded Water Quality

The undesirable result of degraded water quality is a result of groundwater management activities (such as groundwater extraction and groundwater recharge) and groundwater quality that cause significant and unreasonable reductions in the long-term viability of domestic, agricultural, municipal, and environmental uses over the planning and implementation horizon of this GSP.

5.2.5.2 Potential Causes and Effects of Degraded Water Quality

There are no anticipated changes in water quality, and specifically, no anticipated changes in water quality due to groundwater management actions. Potential causes of degraded water quality could be the result of significant increases in groundwater pumping, which is not projected to occur, as described in Section 4. In addition, there are no known significant water quality issues or contaminant plumes that could spread through additional groundwater pumping.

If groundwater quality degraded to an undesirable result level, then the water may not be usable for beneficial uses within the Subbasin (domestic and agriculture) without treatment. This would lead to an economic burden on water users. Additionally, changes in water quality could impact GDEs, damage crops and/or result in changes to the crops grown and cause other economic effects.

5.2.5.3 Criteria Used to Define Degraded Water Quality

The GSAs elected to form an Ad Hoc Committee to discuss and define undesirable results and MTs. Since that meeting the GSAs have updated the definition of undesirable results to the criteria shown below.~~Below is the undesirable result definition for degraded water quality.~~

Changes in groundwater quality due to ~~groundwater management activities (such as~~ groundwater extraction ~~and groundwater recharge) and groundwater quality~~ that causes significant and unreasonable reductions in long-term viability of domestic, agricultural, municipal, and environmental uses over the planning and implementation horizon of this GSP as indicated by water quality data measured in at least 50% of representative monitoring wells exceeding the minimum thresholds for a groundwater quality constituent for two consecutive measurements at each location. ~~locatioduring non-drought years.~~

5.2.6 Seawater Intrusion (not applicable to Tule Lake Subbasin)

The Tule Lake Subbasin is not located near an ocean. Therefore, seawater intrusion is not present and not likely to occur. Thus, SMCs are not required for seawater intrusion.

5.3 Quantitative Sustainable Management Criteria

The sustainability goal and undesirable results are qualitative descriptions of basin conditions which are supported by quantitative criteria. The Minimum Thresholds and Measurable Objectives provide quantitative criteria to allow the GSAs to clearly demonstrate sustainability.

Measurable Objectives are the quantitative goals that reflect the desired groundwater conditions. The Subbasin is currently, and is projected to remain, sustainably managed and meeting its sustainability goal, as demonstrated by the water budgets in Section 4. Therefore, the MOs established for each applicable sustainability indicator are intended to continue meeting the sustainability goal. There is a margin of operational flexibility between the MOs and MTs to accommodate droughts, climate change, conjunctive use operations, and other groundwater management activities that may occur in the Subbasin.

Minimum Thresholds are the quantitative values that represent the groundwater conditions at a representative monitoring site that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause an undesirable result(s) in the basin. MTs (which consider beneficial uses and users of groundwater, land uses, and property interests) have been established for each representative monitoring site using the same metrics as the measurable objectives.

5.3.1 Groundwater Level Quantitative Sustainable Management Criteria

This section establishes the MOs and MTs for the ~~four~~ three applicable sustainability indicators related to groundwater levels: chronic lowering of groundwater levels, reduction in groundwater storage~~, land subsidence~~, and interconnected surface water.

5.3.1.1 Groundwater Level Measurable Objectives

Groundwater level MOs were established based on average spring groundwater levels obtained since 2015 at each representative monitoring well. These values generally represent recent sustainable conditions since SGMA implementation and under which there were no reported negative impacts on

~~beneficial uses and users. In the case that negative impacts to domestic wells caused by groundwater~~ management activities are reported to the GSAs, then the GSAs will provide assistance as described in Section 6.1.6, and MOs will be re-evaluated in a future 5-year update or amendment, as appropriate. Because groundwater level is used as a proxy for groundwater storage, the minimum thresholds established for representative monitoring wells also serve as the minimum thresholds for groundwater storage. Accordingly, the criteria for undesirable results and measurable objectives defined for the chronic lowering of groundwater levels also apply to the reduction in groundwater storage sustainability indicator.

5.3.1.2 Groundwater Level Minimum Thresholds

The groundwater level MTs were determined by considering historical basin conditions, and are based on considerations for beneficial users and uses of groundwater, including groundwater dependent ecosystems. Two different sets of criteria were developed to establish groundwater level MTs for the representative monitoring wells, which are identified below and in Appendix M.

1. Representative monitoring wells that are used for irrigation have MTs set to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer, based on the depth of water below ground surface. ~~.~~

2. The "Near" function in ArcGIS Pro software was used to associate each WCR with the closest representative monitoring well. All representative monitoring wells that are not an irrigation well have MTs set to either the shallowest or second shallowest well within its Near grouping. However, if there are not any wells within a representative monitoring well's Near grouping, then the MT is equal to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer.

Table 5-1 shows the MO and MT established for each representative groundwater level monitoring well. Hydrographs showing historical groundwater level measurement along with the MO and MT for each representation groundwater level monitoring well are included in Appendix M.

Table 5-1. Groundwater Level Minimum Thresholds

State Well Number	Historic Low* (ft bgs)	Min. Domestic Well Depth (ft bgs)	Minimum Threshold (ft bgs)	Measurable Objective (ft bgs)
48N05E35F001M	11	29	29	8
48N04E22M001M	29	120	120	15
~~48N04E31M001M~~	~~31~~	~~29~~	~~29~~	~~23~~
48N04E19C001M	15	28	28	11
~~47N05E04M001M~~	~~10~~	~~33~~	~~33~~	~~9~~
47N05E01N001M	22	42	42	15
46N05E21J001M	12	32	32	10

State Well Number	Historic Low* (ft bgs)	Min. Domestic Well Depth (ft bgs)	Minimum Threshold (ft bgs)	Measurable Objective (ft bgs)
46N05E01P001M	13	24	24	11
41S12E19Q001W	14	50	50	6
48N04E30F002M (TID Well 1)	72	-	79	38
48N04E13K001M (TID Well 5)	82	-	90	42
48N05E26D001M (TID Well 8)	67	-	74	48
46N05E22D001M (TID Well 14)	48	-	54	40
TL-T1 Q3B	31	-	35	27
TL-T3 GP	14	-	16	12
*Historic Low is from monitored period prior to 2022				

5.3.2 Water Quality Quantitative Sustainable Management Criteria

This section establishes MOs and MTs for the wells in the representative water quality monitoring network. Each of these wells is operated and monitored by a public water system (PWS). MOs and MTs have been developed for ~~two~~ three water quality constituents – nitrate, ~~and~~ TDS, and arsenic – based on federal- and state-established goals and standards.

5.3.2.1 Water Quality Measurable Objectives

The water quality MOs reflect the desired conditions and are based on maintaining the current water quality in the Subbasin. The MOs are established based on the average of measurements obtained for these constituents since 2015. For nitrate, where the average levels have recently been below 1.0 mg/L, the MO was established at 2.0 mg/L which is well below the maximum contaminant level goal.

5.3.2.2 Water Quality Minimum Thresholds

The MTs for nitrate and TDS have been set equal to 10% less than the federal and/or state established goals. For nitrate, the MT is equal to 9.0 milligrams per liter (mg/L), which is less than the maximum contaminant level goal (MCLG) of 10 ~~milligrams per liter (~~mg/L~~)~~. This MT allows for continued use of groundwater as a drinking water supply without local public water suppliers needing to invest in systems for nitrate removal. For TDS, the MT is equal to 900 mg/L which is less than the State of California secondary drinking water standard upper limit of 1,000 mg/L. This MT is protective of the secondary standard for drinking water and water quality needed for irrigation purposes. For arsenic, the MT is equal to 9.0 micrograms per liter (µg/L), which is less than the State of California's primary standard maximum contaminant level of 10 µg/L. This MT is protective of the primary standard for public water systems. These MTs are applied to all representative water quality monitoring wells.

5.3.2.3 Water Quality Quantitative Summary

Table 5-2 shows the MO and MT established for each representative groundwater level monitoring well.

Table 5-2. Water Quality Quantitative Sustainable Management Criteria

WQ Monitoring Well	Nitrate (mg/L)		Total Dissolved Solids (mg/L)		Arsenic (µg/L)	
	MO	MT	MO	MT	MO	MT
TULELAKE WELL 03	2	9	205	900	2	9
TULELAKE WELL 01	2	9	190	900	2	9
KBNWR WELL 01	2	9	n/a	900	2	9
NEWELL WELL 01	2	9	540	900	9	9
NEWELL WELL 03	2	9	610	900	3	9
Note: There have been no measurements of TDS at KBNWR Well 01 since 2015.						

~~5.3.3 Land Subsidence Quantitative Sustainable Management Criteria~~

This section establishes the MOs and MTs for the land subsidence monitoring network, which includes InSAR data published by DWR.

5.3.3.1 Land Subsidence Measurable Objectives

The measurable objective and interim milestone for land subsidence is set to 0.25 feet of subsidence over a 5-year period, within 5 square miles. While this rate is small, it recognizes the accuracy limitations of the InSAR dataset.

5.3.3.2 Land Subsidence Minimum Threshold

The minimum threshold for land subsidence is established to prevent the occurrence of the undesirable result established in section 5.2.3.1. The minimum threshold is set to 0.5 feet of subsidence over a 5-year period, within 5 square miles. This threshold of subsidence is expected to avoid impacts to infrastructure, including water conveyance facilities, over the implementation period of this GSP.

6 Projects and Management Actions to Maintain Sustainability (Reg. § 354.44)

The projects and management actions identified in this section allow for continued sustainability in the Tule Lake Subbasin. In addition, they promote better understanding of the subbasin through additional collected information, which will assist to fill data gaps previously identified in this ~~plan~~GSP. As shown in prior sections of this ~~plan~~Plan, the Tule Lake Subbasin is currently being sustainably managed. Therefore, no projects or management actions are required to achieve sustainability; however, the Tule Lake Subbasin GSAs have identified the following projects and management actions ~~below~~ to improve their understanding of the groundwater subbasin. The completion of projects and management actions will help ensure the sustainable management of the Subbasin. The GSAs will incorporate information obtained from the stated actions ~~below~~ into future iterations of this GSP, which will likely result in new projects and management actions being developed in the future. Due to the standing of the subbasin, these projects and management actions will be implemented based on the availability of resources and funding.

6.1 Projects and Management Actions

The GSAs have identified the following projects and management actions for the Tule Lake Subbasin, which are in addition to ongoing water use efficiency projects undertaken by Tulelake Irrigation District and the City of Tulelake. These projects do not rely on additional water from outside the jurisdiction of the GSAs. The GSAs have taken into account the level of uncertainty associated with the basin setting when developing these projects and management actions. Estimated costs of these projects range from less than $50,000 to greater than $150,000, which is discussed in Section 7.1 of this Plan.

6.1.1 Well Inventory

Section 2.1.1.6 identified the inventory of wells within the Tule Lake Subbasin by county and type. DWR's well completion report database was utilized to prepare the inventory. As noted in that section of the Plan, it is unknown how many of these wells are actively used or how many of these wells have been abandoned and/or destroyed as this information is not always reported. The GSAs have identified a review of these reports as a project that will provide a better understanding of existing wells. An initial review~~This review is scheduled to be~~ was completed within the first 5 years of implementation. The GSAs understand that this effort is ongoing as wells are abandoned and/or destroyed, and as new wells are constructed.

6.1.2 Groundwater Level Monitoring Wells

Section 2.2.2.3 identified a lack of multi-completion wells within the Tule Lake Subbasin, which if present, would improve understanding of vertical movement of groundwater. The GSAs have identified this as a data gap, which can be addressed with the installation of one or more multi-completion wells. DWR's ~~Technical Support Services (~~TSS~~)~~ office assists with this type of project. ~~Therefore,~~ The ~~the~~ GSAs ~~plan to~~ filed an application in 2022 for ~~with~~ TSS assistance to aid with ~~for~~ a monitoring well installation ~~within the first year of implementation~~.

~~Section 3.3.1.6 also identified a lack of dedicated monitoring wells within the Subbasin. Therefore, the~~ installation of a multi-completion monitoring well and one or more shallow monitoring wells in the vicinity of the Sumps will provide valuable data for the Subbasin.

6.1.3 Water Quality Monitoring Network

Section 3.3.2.4 identified a need for denser and more frequent monitoring of water quality. Therefore, the GSAs plan to identify a minimum of two additional wells, which will be added to the water quality (WQ) monitoring network. The GSAs reviewed data using the GAMA groundwater information system and were unable to identify additional representative monitoring wells for the Subbasin; however, the DWR TSS application requests installation of a multi-completion well, which once installed will include groundwater quality monitoring. Therefore, once the multi-competition well is installed the GSAs plan to add it to the WQ representative monitoring network.~~This process is scheduled to be completed within the first year of implementation.~~

6.1.4 Groundwater Dependent Ecosystems

Section 2.2.2.9 identified areas that remained after filtering criteria were applied to the NCCAG dataset. The GSAs have identified this as a data gap, which can be addressed with field inspections of these areas to better understand if there is vegetation present and if so, analyze the availability of non-groundwater sources. NCCAGs are potential GDEs, and as such, they will be revaluated as new data becomes available to determine the status of the NCCAGs. Initial field inspections were performed in May 2021 and are documented in a technical memorandum included in Appendix H.~~These field inspections and follow-up reviews are scheduled to be completed within the first 5 years of implementation.~~ In addition, pending availability of resources and funding, the GSAs plan to expand this project such that a field inspection is conducted to view each potential GDE identified in the NCCAG dataset.

6.1.5 Groundwater Recharge Projects

The GSAs are interested in, and will continue to investigate, potential groundwater recharge projects in the Subbasin. They anticipate the data collected by DWR's airborne electromagnetic (AEM) surveys of the Subbasin will assist with this effort by providing a greater understanding of the Subbasin characteristics, and by identifying locations which may be suitable for groundwater recharge projects (DWR, 2020b). ~~The GSAs' understanding is that DWR will conduct the AEM surveys during 2021. Following the release of the data collected during the AEM surveys the GSAs will perform a review of the data within the first 3 years of implementation.~~

In addition, Tulelake Irrigation District intends to continue to coordinate flows in order to allow lower Lost River Improved Channel water to flow into the Subbasin as it naturally did prior to construction of the Klamath Project. This operation will allow TID to charge irrigation canals and drains with water for recharge purposes and will occur on an annual basis as lower Lost River Improved Channel water flows allow.

6.1.6 Domestic Well Assistance

During 2021, and some prior years, domestic wells within the Subbasin have experienced issues where the supply has gone dry. As identified in section 2.1.2.10 of the GSP, domestic well assistance efforts have occurred during these prior years. During each of those years the District coordinated with the entity administering the domestic well assistance program. This has occurred primarily during years of low surface water supply from the Klamath Project. If TID and other Klamath Project water users receive a water supply consistent with the historical pattern of surface water deliveries, then domestic well issues are not expected to occur. ~~The GSAs are aware of current (2021) efforts and similar to prior years will continue to coordinate with local agencies, such as the Klamath Water Users Association; the Klamath Project Drought Response Agency; and local, state, county, and city agencies to address domestic well issues.~~During years of low surface water supply, the GSAs will investigate the availability of federal, state, and/or local funding to assist impacted well owners. As identified in this GSP, Modoc County meets the requirements of a S~~s~~severely D~~d~~isadvantaged C~~c~~ommunity and Siskiyou County meets the requirements of a D~~d~~isadvantaged C~~c~~ommunity. Therefore, assistance by the GSAs will likely require grant funding. The result of this investigation may include a program that assists with the deepening or replacement of wells impacted during the implementation period of this GSP. Due to these factors, details of this type of domestic well assistance will be developed on a case-by-case basis.

6.1.7 Adaptive Management Strategy

The GSAs intend to use an adaptive management strategy to investigate a MT exceedance at a single representative monitoring location. As discussed in Section 5 of this Plan, the GSAs have defined undesirable results for the Subbasin, which include meeting or exceeding the MT at multiple representative monitoring locations. If a MT exceedance is observed at a single location, it will be brought to the attention of the GSAs to determine if additional monitoring at or around the site is needed to understand the exceedance. The GSAs will also determine if additional actions are needed to be implemented to ensure the levels at the monitoring location recover to above the MT. In addition, as identified in Section 2.1.2.10 of this Plan, the Tulelake Irrigation District assisted with formation and current administration of KPDRA programs within the Klamath Project. These programs are a form of adaptive management as they are developed based on Klamath Project surface water supply. Therefore, during years of reduced supply the KPDRA provides coordination and assistance to growers within the Subbasin to idle their fields. As identified in this plan, the Subbasin is currently and projected to be sustainably managed. Therefore, details of this type of adaptive management strategy will be developed on a case-by-case basis as appropriate.

6.1.8 Summary

A summary of projects and management actions following the implementation of the GSP is provided in Table 6-1.

Table 6-1. Summary of Projects and Management Actions

Project or Management Action	Start Date	Timeline	Completion Date Goal
Perform Well Inventory	Implementation of GSP	~~5 years~~Ongoing (Yearly)	~~2027~~Ongoing (Yearly)
File for well installation application with TSS	Implementation of GSP	1 year	~~2023~~Ongoing (Awaiting DWR)
Add 2 wells to WQ Monitoring Network	Implementation of GSP	1 year	~~2023~~Ongoing (Awaiting DWR)
Complete field inspections of GDEs	Implementation of GSP	~~5 years~~Ongoing (As budget allows)	~~2027~~Ongoing (As budget allows)
~~Review AEM survey data~~	~~Release of data~~	~~3 years~~	~~2025~~
Recharge via Operation of Station 48	Implementation of GSP	Ongoing (Yearly)	Ongoing (Yearly)
Provide Domestic Well Assistance	Implementation of GSP	Ongoing (As needed)	Ongoing (As needed)
Adaptive Management Strategy	Implementation of GSP	Ongoing (As needed)	Ongoing (As needed)

6.2 Public Noticing

The purpose of the projects and management actions identified above is to improve the understanding of the Tule Lake Subbasin. ~~These activities do not require public notice and outreach; however~~ T~~,~~ the GSAs plan to provide updates during Core Team meetings to allow for public comment. Updates on the status of these activities will be provided in the annual reports. All Public noticing will adhere to SGMA and GSP Regulations.

6.3 Legal Authority, Permitting and Regulatory Process

The purpose of the aforementioned projects and management actions identified ~~above~~ is to improve the understanding of the Tule Lake Subbasin. As identified in Section 1.3 of this Plan, the GSAs have the legal authority and resources to implement this GSP. Except for monitoring well installation, these activities do not have permitting requirements. The GSAs will coordinate with DWR, and the local regulatory agency or agencies~~(s)~~ for the monitoring well installation.

6.4 Expected Benefits

The purpose of the aforementioned projects and management actions identified ~~above~~ is to improve the understanding of the Tule Lake Subbasin. Therefore, the benefits from these activities will be continuous throughout GSP implementation.

7 Plan Implementation

Implementation of this GSP includes consideration of the implementation costs, the schedule of implementation, reporting, and periodic evaluations. These considerations cover both the projects and management actions described in Section 6 as well as non-project and non-management actions that are required in order to successfully implement the Plan.

7.1 Estimate for GSP Implementation Costs

This section provides an overview of the estimated costs to implement this Plan and generally describes how the Tule Lake Subbasin GSAs plan to meet those costs.

Table 7-1 below provides a summary of the estimated costs for implementation of this Plan. These cost estimates will be refined during implementation as more information becomes available. The MOU, described in Section 1.3.1 and included in Appendix B, identifies the financial responsibilities of each GSA. As identified in Section 1.3 of this Plan, Modoc County meets the requirements of a S~~s~~severely D~~d~~isadvantaged ~~c~~Community. Similarly, Siskiyou County meets the requirements of a D~~d~~isadvantaged ~~c~~Community. Therefore, the GSAs will pursue grant funding as available and as appropriate to assist with implementation. In the case that sufficient grant funding is unavailable to assist with implementation, the GSAs may consider imposing fees.

Table 7-1. Summary of Estimated Costs for Implementation

Description	<$50,000	$50,000-$150,000	>$150,000
Annual Reports	X		
5-Year Plan Updates		~~X~~	X
Projects & Management Actions			
Well Inventory	X		
Groundwater Level Monitoring Wells[1]~~1~~	X	X	
Water Quality Monitoring Network	X		
Groundwater Dependent Ecosystems	X		
Groundwater Recharge Project(s)	X	X	X
Domestic Well Assistance[1]~~1~~	X	X	X
Adaptive Management Strategy[1]~~1~~	X	X	X

[1] Cost is dependent on the size of the project. As appropriate, these costs will be further defined.

7.2 Schedule for Implementation

The GSP Amendment 1 and accompanying Periodic Evaluation~~final Plan~~ will be submitted to DWR no later than January 31, 202~~2~~7. Following the submittal there are reporting and periodic evaluation requirements, as described in Section 7.3. In addition, the GSAs plan to hold at least quarterly public meetings to discuss the status of the reporting requirements, the projects, and management actions described in Section 6, and ongoing public outreach and education. Ahead of the quarterly public meetings, the agenda and any documents that will be discussed are provided to the interested parties so that the public is informed of GSP implementation. These meetings will help to ensure that the GSP is implemented, and that the sustainability goal is maintained.

7.3 Reporting and Periodic Evaluations

The following section ~~below~~ describes the reporting and periodic evaluations part of Plan Implementation.

7.3.1 Annual Reports

SGMA Regulations require submittal of annual reports by April 1st of each year following GSP adoption, except for those years when 5-Year Plan updates are submitted. Annual Reports will be prepared and submitted to DWR under the guidance of the GSAs and Plan Manager.

The Annual Reports will be prepared consistent with the Annual Report's Elements Guide, provided by DWR, which requires the following components be reported for the preceding water year:

- General information, including an executive summary and a location map depicting the basin covered by the report.
- A detailed description and graphical representation of the following conditions of the basin managed in the Plan:
    - Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:
        - Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.
        - Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.
- Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.

- ~~Surface water supply used or available for use, for groundwater recharge or in lieu use~~ shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.
- Total water use shall be collected using the best available measurement methods and shall be reported in a table that summarizes total water use by water use sector, water source type, and identifies the method of measurement (direct or estimate) and accuracy of measurements. Existing water use data from the most recent Urban Water Management Plans or Agricultural Water Management Plans within the basin may be used, as long as the data are reported by water year.
- Change in groundwater in storage shall include the following:
  - Change in groundwater in storage maps for each principal aquifer in the basin.
  - A graph depicting water year type, groundwater use, the annual change in groundwater in storage, and the cumulative change in groundwater in storage for the basin based on historical data to the greatest extent available, including from January 1, 2015, to the current reporting year.
- A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report.

7.3.2 5-Year Plan Updates

The GSP Regulations require evaluation of the GSP at least every five years and with every amendment and provide a written assessment to DWR, the first of which is to be submitted to DWR by January 31, 2027. Assessments will be prepared and submitted to DWR under the guidance of the GSAs and Plan Manager.

The assessments will be prepared as is consistent with the GSP Regulations, which require the following components:

- A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones, and minimum thresholds.
- A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.
- Elements of the GSP, including the Basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.
- An evaluation of the Basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the GSAs' evaluation shows that the Basin is experiencing overdraft conditions, the GSAs shall include an assessment of measures to mitigate that overdraft.

- ~~A description of the monitoring network within the Basin, including whether data gaps~~ exist, or any areas within the Basin are represented by data that does not satisfy the requirements of Sections 352.4 and 354.34(c). The description shall include the following:
    - An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38.
    - If the GSA's identify data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan.
    - The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.
- A description of significant new information that has been made available since Plan adoption or amendment, or the last five-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.
- A description of relevant actions taken by the GSAs, including a summary of regulations or ordinances related to the Plan.
- Information describing any enforcement or legal actions taken by the GSAs in furtherance of the sustainability goal for the basin.
- A description of completed or proposed Plan amendments.
- Where appropriate, a summary of coordination that occurred between multiple agencies in a single basin, agencies in hydrologically connected basins, and land use agencies.
- Other information the GSAs deem appropriate, along with any information required by the DWR to conduct a periodic review as required by Water Code Section 10733.

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appendices ~~placeholder~~

Appendix K

Jacobs

Numerical Groundwater Flow Model Documentation

Document No.: 260914152317_e3c598c8
Revision: 1

MBK Engineers
TID Groundwater Sustainability Plan
October 2, 2026



Numerical Groundwater Flow Model Documentation

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Project Name:	TID Groundwater Sustainability Plan		
Document No.:	260914152317_e3c598c8	**Project No.:**	D4040200
Revision:	1	**Project Manager:**	Lindsay Larsen
Date:	October 2, 2026	**Prepared by:**	Jacobs Engineering Group Inc.

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Acronyms and Abbreviations

3D	3 dimensional
AEM	Airborne Electromagnetic
ASCII	American Standard Code for Information Interchange
BCM	Basin Characterization Model
bgs	below ground surface
CIMIS	California Irrigation Management Information System
DEW	Drier Extreme Warming
DRN	Drain
DWR	California Department of Water Resources
ET	evapotranspiration
ET_0	reference evapotranspiration
FMP	Farm Process Package
GHB	General Head Boundary
GSA	Groundwater Sustainability Agency
GSA Model	an integrated groundwater/surface-water flow model of an area encompassing the Tulelake Subbasin of the Klamath River Valley Groundwater Basin in portions of Siskiyou and Modoc Counties, California, and extending to the north of the Tulelake Subbasin within Klamath County, Oregon
GSP	Groundwater Sustainability Plan
Jacobs	Jacobs Engineering Group Inc.
KBPM	Klamath Basin Planning Model
Kc	crop coefficient
Kh	vertical hydraulic conductivity
Kv	horizontal hydraulic conductivity
M&I	municipal and industrial
MND	Multi-Node Well
MR	mean residual
NAVD88	North American Vertical Datum of 1988
NRD	non-routed delivery

OneWater	USGS code MODFLOW-OWHM: One Water Hydrologic Flow Model
R^2	coefficient of determination
RIV	River
RMSR	root mean squared residual
SGMA	Sustainable Groundwater Management Act
Subbasin	the portion of the physical Tulelake Subbasin located in California
Ss	specific storage
Sy	specific yield
TAF	thousand acre-feet
TAFY	thousand acre-feet per year
TID	Tulelake Irrigation District
USGS	United States Geological Survey
WBS	water balance subarea
WY	water year

1. Introduction

On behalf of the Tulelake Subbasin Groundwater Sustainability Agencies (GSAs), CH2M HILL Engineers, Inc. (CH2M and now Jacobs Engineering Group Inc. [Jacobs]) has developed an integrated groundwater/surface-water flow model of an area encompassing the Tulelake Subbasin of the Klamath River Valley Groundwater Basin in portions of Siskiyou and Modoc Counties, California, and extending to the north of the Subbasin within Klamath County, Oregon. Although the physical subbasin extends into Oregon, for the purposes of this report and the Sustainable Groundwater Management Act (SGMA), the term "Subbasin" refers to the portion of the physical subbasin located in California.

This model is hereafter referred to as the GSA Model to differentiate it from other numerical models developed in recent years for this area and to emphasize its intended use to support the GSAs in the development of the Groundwater Sustainability Plan (GSP) for the Subbasin. The GSA Model was originally developed to support development of the original GSP for the Subbasin, which was submitted to the California Department of Water Resources (DWR) in January 2022 (MBK, 2024). The GSA Model was updated to support the 5-year period evaluation and amendment to the Subbasin GSP. This report was prepared by Jacobs and documents the development, calibration, and application of this numerical model to support the GSAs in updating the GSP. This report is intended to replace the previous documentation of the GSA Model, which was included in the 2022 submittal to DWR.

The GSA Model integrates the three-dimensional (3D) groundwater and surface-water systems, land surface processes, and water management operations. Development of this model included the assimilation of information on land use, water infrastructure, hydrogeologic conditions, and agricultural water demands and supplies. The GSA Model was built upon two existing numerical groundwater flow models for the region developed by the United States Geological Survey (USGS) (Gannett et al., 2012; Pischel et al., 2015). The GSA Model is based upon the best available data and information as of January 2026. It is expected that this model will be updated as additional monitoring data are collected and analyzed and as knowledge of the hydrogeologic conceptual model evolves during implementation of the GSP.

The center of the Subbasin is located at latitude 41.94°N and longitude 121.42°W, approximately 300 miles north of downtown Sacramento. Figure 1-1 (figures are located at the end of their respective sections) shows the location of the Subbasin within the Klamath River Valley Groundwater Basin. The model domain boundary (shown in purple on Figure 1-1) was selected to coincide with natural hydrologic features (surface-water catchments) and Subbasin (1-002.01) boundaries, to help establish a hydrologic framework for the GSA Model.

1.1 Background

In 2014, in response to the continued overdraft of many of California's groundwater basins, the State of California enacted SGMA to provide local and regional agencies the authority to sustainably manage groundwater. The Subbasin is subject to SGMA because it is one of 127 basins and subbasins identified in 2014 by DWR as being medium- or high-priority, based on population, groundwater use, and other factors. Under SGMA, high- and medium-priority basins not identified as critically overdrafted must be managed according to a GSP by January 31, 2022. DWR has identified the Subbasin (1-002.01) as a medium-priority subbasin. SGMA requires medium-priority groundwater subbasins being managed by a GSA to reach or maintain sustainability within 20 years of implementing its GSP. Within the framework of the SGMA, sustainable groundwater management is defined as the management and use of groundwater in a manner that can be maintained during the planning and implementation period without causing undesirable results. The GSA Model has been developed to help prepare water budgets and guide planning efforts associated with the GSP.

1.2 Modeling Objectives

The modeling objectives include the following:

- Support development of land, surface-water, and groundwater budgets for historical, current, and future conditions within the Subbasin to support preparation of the GSP.
- Help guide the development of sustainable management criteria as part of the GSP process.
- Support refinement of monitoring networks during implementation of the GSP, if needed.
- Provide insights into how implementation of projects and management actions, if needed, could potentially affect groundwater conditions during implementation of the GSP.

The GSA Model is only one line of analysis being used to help the GSAs develop and implement its GSP. This model will not ultimately "decide" whether the Subbasin is being managed sustainably. Collection, reporting, and analysis of field data during GSP implementation will be used in conjunction with sustainable management criteria to demonstrate to DWR whether the Subbasin is being managed sustainably. One of the main purposes of the model is to provide plausible water budgets associated with potential future conditions, so the GSAs can develop a plan for the continued responsible management of the Subbasin.

1.3 Model Function

To achieve the modeling objectives, the GSA Model was developed and calibrated using available data and professional judgment. This 3D model was constructed and calibrated to simulate monthly groundwater and surface-water flow conditions within a 610-square-mile area encompassing the Subbasin. The USGS codes MODFLOW-OWHM: One Water Hydrologic Flow Model (OneWater) version 2 (Boyce et al., 2020) and the Basin Characterization Model (BCM) version 8 (Flint et al., 2013; Flint and Flint, 2014) were used in conjunction with the graphical-user-interface Groundwater Vistas version 9 (ESI, 2024) and other custom utilities to develop and use the GSA Model to achieve the modeling objectives. Subsequent sections of this report provide additional details regarding the development and application of the GSA Model.

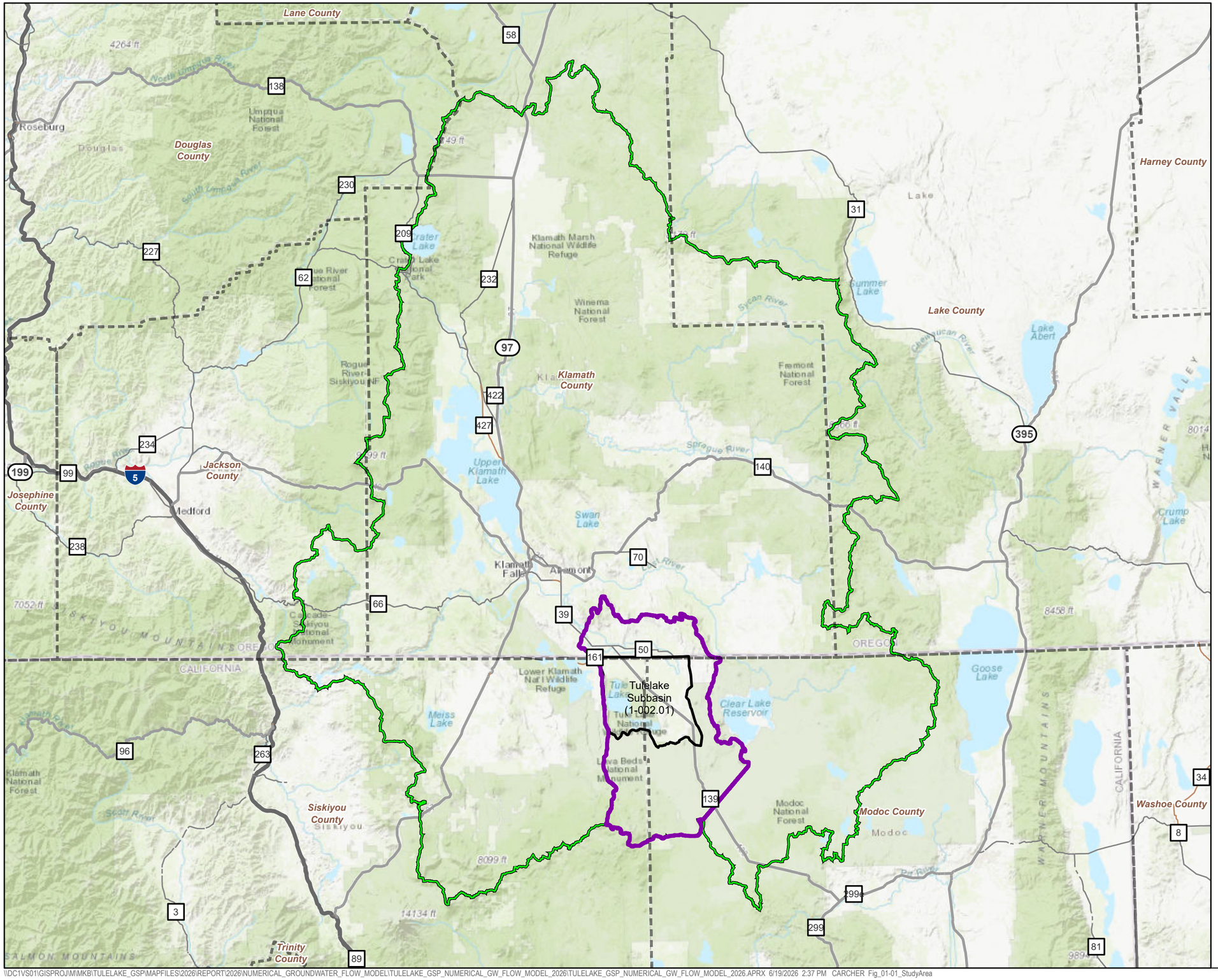
1.4 Model Assumptions and Limitations

The development of the GSA Model included the following assumptions and limitations:

- Subsurface geologic materials, including granular unconsolidated material (e.g., gravel, sand, silt, and clay), and volcanic material (weathered and competent) are all modeled as equivalent porous media.
- Groundwater and surface water are modeled as a single-density fluid.
- Monthly stress periods have been incorporated into the simulations. As such, variations in flow processes that occur within a given month are not explicitly simulated; instead, monthly average flow rates are implemented.
- In the absence of detailed well logs, assumptions had to be made regarding well construction and locations for some of the pumping wells represented in the model.
- Mathematical models like the GSA Model described herein can only approximate surface and subsurface flow processes, despite their high degree of precision. A major cause of uncertainty in these types of models is the discrepancy between the coverage of measurements needed to understand site conditions and the coverage of measurements generally made under the constraints of limited time and budget (Rojstaczer, 1994).

- Because the GSA Model is a flow model, it cannot perform solute transport calculations. Therefore, it cannot directly provide estimates or forecasts of constituent concentrations in the modeled environment. Therefore, other approaches are being implemented to support the GSA in addressing water quality aspects of its GSPs.

Given these assumptions and limitations, numerical flow models like the GSA Model should be considered tools to provide insight and qualitative projections of future conditions. Therefore, important planning decisions that use output from the GSA Model must be made with an understanding of the uncertainty in and sensitivity to model input parameters. These planning decisions should also consider other site data, local and regional drivers, professional judgment, and the inclusion of safety factors.



LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Interstate
- Highway
- Major Road
- Local Road

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, USGS, NGA, EPA, NPS
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

Figure 1-1
Study Area
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

2. Conceptual Model Overview

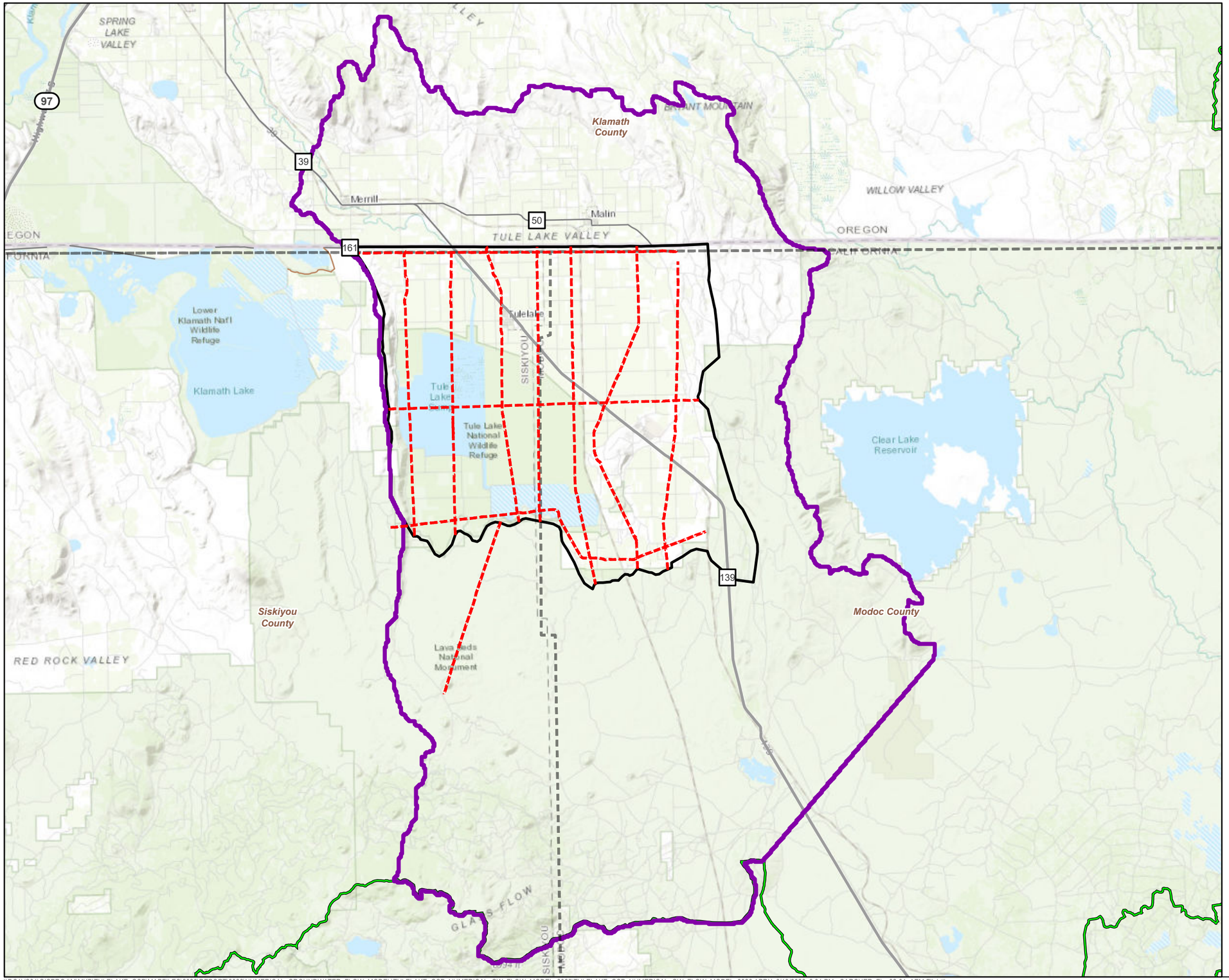
The greater physical subbasin is a portion of the Klamath River Valley Groundwater Basin located in California and Oregon. The greater physical subbasin is bounded to the west by the Gillems Bluff Fault, which extends beneath and is a major structural feature of the Medicine Lake volcanic highlands (Lavine, 1994). The fault forms the steep eastern escarpment of Sheepy Ridge, which separates the Tulelake and Lower Klamath Subbasins (DWR, 2003a). The greater physical subbasin boundary extends to the fault-controlled drainage divide between the Tulelake and Lower Klamath Subbasins (the crest of Sheepy Ridge). Tertiary volcanic deposits extend eastward from the crest beneath the Quaternary sediment and are penetrated by wells, which are producing from the volcanic deposits on the west margin of the Subbasin (Gannett, 2012). The greater physical subbasin is bounded to the east by the Saddle Blanket Fault Zone, a north-trending normal fault that forms the western edge of the block faulted mountains between Tule Lake and Clear Lake Reservoir. The greater physical subbasin extends into Quaternary volcanic deposits that host active irrigation wells (Gannett et al., 2007). Clear Lake Reservoir is the headwaters of Lost River. Lost River flows north into Oregon, and meanders through the Poe and Langell Valleys before it flows south into California and ends at the Tulelake Sump (DWR, 2003a). The greater physical subbasin is bounded to the south by the low-lying volcanic fields on the north slope of the Medicine Lake Highlands. Medicine Lake occupies the crater at the peak of this large, relatively young shield volcano. The greater physical subbasin includes the Peninsula and extends to the east to the Saddle Blanket Fault Zone. Wells in these areas where the volcanics are exposed mostly produce from the surficial Quaternary volcanic deposits, but some wells penetrate through the surficial deposits and underlying basin-filling sediments to the underlying late Tertiary volcanic strata (Gannett, 2012). To the north, the greater physical subbasin extends into Oregon and is bounded by northwest-trending normal faults on the southern side of the mountain block dividing Poe Valley from the greater physical subbasin. Approximately two thirds of the greater physical subbasin is in California (DWR 2003a). Although the physical subbasin extends into Oregon, for the purposes of this report and SGMA, the Subbasin is bounded to the north by the state boundary of Oregon and California.

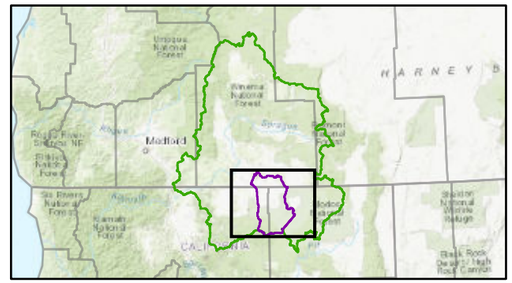
The greater physical subbasin is composed of a down-dropped basin, bordered by normal faults—the Gillems Bluff Fault to the west and the Saddle Blanket Fault to the east. The late Tertiary volcanic rocks that form the bottom of the greater physical subbasin are overlain either by late Miocene or Pliocene sedimentary rocks or by late Pliocene to Quaternary sedimentary deposits. Sedimentary rocks consist of tuffaceous sandstone, ashy diatomite, mudstone, siltstone, and some conglomerates. Up to 1,740 feet of basin-fill sediments underlie the city of Tulelake, consisting of silt, sand, clay, and diatomite (Gannett et al., 2007).

Data from the DWR Statewide Airborne Electromagnetic (AEM) Survey Project were used to refine the information presented above. AEM flightlines were only available within the Subbasin, with one flightline extending southwest into Lava Beds National Monument (Figure 2-1). Therefore, the data were used specifically to refine the contact between basin-fill sediments and underlying volcanic rock. The maximum depth of the AEM data was approximately 1,000 feet below ground surface (bgs) in the Subbasin; and therefore, the bottom of basin-fill sediments was not visible. However, although the AEM data did not present the full thickness of the basin-fill sediments, it supported refinement of the depth and geometry of the contact with the underlying volcanic rocks along the Subbasin margins, where the contact resided at shallower depths (Figure 2-2).

Local precipitation and infiltration of surface water from the channels, lakes, and sumps of the Lower Klamath and Tulelake Subbasins provide recharge for the alluvial aquifer system. Water levels in the alluvial aquifer fluctuate seasonally in response to canal and irrigation operations (DWR, 2003b). Surface-water supplies available to the Tulelake Irrigation District (TID) provide an unknown amount of groundwater recharge. These surface-water supplies include natural flow from the Klamath River, stored water from Upper Klamath Lake and Lake Ewauna, return flows from upstream irrigation, and flow from the Lost River.

Aquifer discharge occurs when groundwater is extracted by wells, discharges to streams, is evapotranspired by phreatophytes, or flows out of the Subbasin in the subsurface (DWR, 2003b). Most groundwater production in the Subbasin is from the underlying volcanic strata, volcanic deposits on the periphery of the basin, and volcanic deposits that partly overlie basin-filling sediment in the Peninsula area. However, wells in any of these areas may produce from surficial volcanic deposits, basin-filling sediments, or underlying volcanic strata (Pischel and Gannett, 2015). In general, interbasin groundwater flow from the Subbasin is southward (Gannett et al., 2007).





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- AEM Flightlines

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

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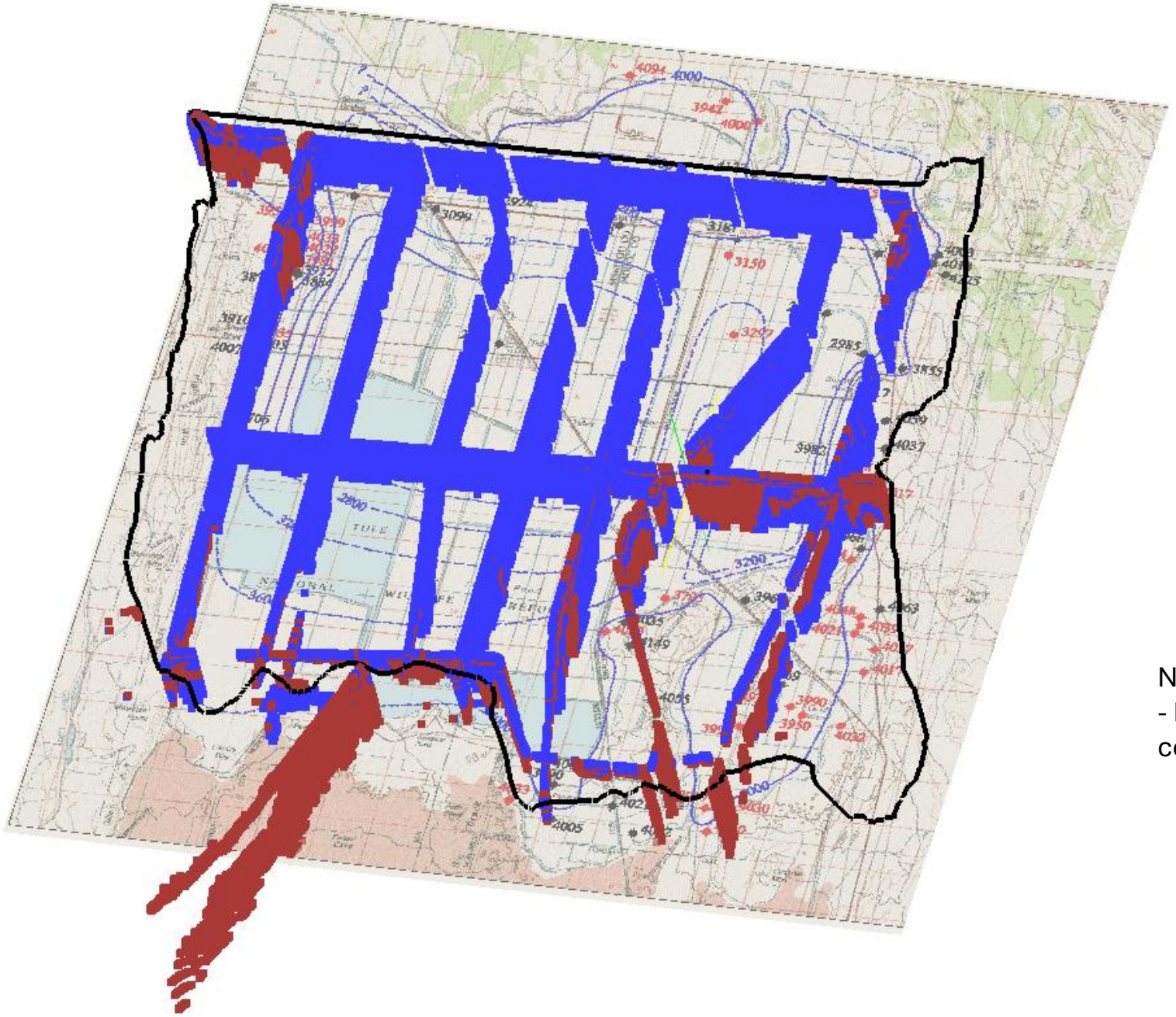
Figure 2-1
AEM Flightlines
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 6/19/2026 3:01 PM CARCHER Fig_02-01_AEM Flightlines



- AEM Data (Coarse Fraction = 0)

- AEM Data (Coarse Fraction = 1)

- Tulelake Subbasin Boundary

Notes:
- Basemap presents DWR top of volcanic structure contours.

Figure 2-2
AEM Data – Basin Fill Versus Volcanics
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

3. Numerical Model Construction

The following steps were implemented to translate the hydrogeologic conceptual model into a form that is suitable for numerical modeling:

1. Selecting numerical codes for groundwater and surface-water flow
2. Establishing a model domain and developing a model grid
3. Spatially distributing surface parameter values
4. Spatially distributing subsurface parameter values
5. Selecting a time-discretization approach appropriate for evaluating the field problem and achieving the modeling objections (Section 1.2)
6. Establishing initial flow conditions for groundwater and surface-water flow
7. Establishing boundary conditions for groundwater and surface-water flow

The following subsections describe the methodology performed to implement these design steps.

3.1 Code Selection

OneWater (Boyce et al., 2020) was selected for this modeling effort, in conjunction with the graphical-user-interface Groundwater Vistas version 9 (ESI, 2024) and other custom utilities to develop the GSA Model. OneWater is an updated formulation, built upon the MODFLOW-2005 (Harbaugh, 2005) framework. OneWater accommodates the development of a 3D, physically based, spatially distributed, integrated groundwater/surface-water flow model. The OneWater code was selected for the following reasons:

- OneWater is based on MODFLOW-2005, which has been used extensively in groundwater evaluations worldwide for many years and is well-documented. OneWater contains an improved solution scheme that can handle a variety of complex, variably saturated flow conditions, which are relevant to groundwater conditions in the Subbasin.
- OneWater has been benchmarked and verified, so the numerical solutions generated by the code have been compared with analytical solutions, subjected to scientific review, and used on other modeling projects. Verification of the code confirms that OneWater can accurately solve the governing equations that constitute the mathematical model.
- OneWater accommodates a comprehensive suite of groundwater and surface-water boundary conditions.

In addition to using OneWater as the primary mathematical code upon which the GSA Model is built, version 8 of the BCM (Flint et al. 2013; Flint and Flint, 2014; Flint et al., 2021) was selected for use as a companion rainfall-runoff model. The BCM was used to help provide estimates of precipitation and reference evapotranspiration (ET_0) throughout the GSA Model. The use of BCM to support development of climate input data is described in more detail in Section 3.7.1.1.

3.1.1 Numerical Assumptions

OneWater is conceptualized mathematically into two hydrologic flow regimes: surface flow and subsurface flow. The surface-flow regime, as configured for the GSA Model described herein, includes runoff and channel flow interaction with the subsurface. The subsurface-flow regime underlies the surface-flow regime and includes variably saturated zones representing porous media through which groundwater flows and can interact with the surface-flow regime. Interactions between the surface- and subsurface-flow regimes are established through the Farm Process Package (FMP) of OneWater establishing linkages with other MODFLOW packages to facilitate the simulation of various hydrologic processes. In general, input to the FMP includes, but is not limited to, precipitation and potential evapotranspiration (ET), land use, root zone and irrigation parameterization, rainfall-runoff process parameterization, and land surface-water balance tracking areas. Within the FMP, these types of input data establish conditions for the simulation of the rainfall-runoff and irrigation process. This includes the portioning of natural and anthropogenic sources of water into runoff, ET, surface evaporation, and infiltration. As the fate of these water sources is simulated, the FMP communicates with packages to simulate connections between surface processes and between surface and subsurface processes.

From a water supply and outdoor water-demand standpoint, the FMP simulates a specific hierarchy of water sources available to meet potential crop consumptive use. Indoor water use demand is generally not explicitly simulated as part of the GSA Model given the complexities of the urban water balance. The hierarchy of water supplies (as configured for this project) to meet monthly outdoor water demands is as follows:

1. Shallow groundwater through root uptake – If rooting depths are near or intersect the water table during a given month.
2. Precipitation – if available during a given month.
3. Water deliveries (i.e., diverted surface water and/or from purveyor supply wells or private agricultural wells) – if the monthly outdoor demand has not been satisfied by shallow groundwater and precipitation, and supplies are available to meet demands, then water deliveries are simulated.
4. Groundwater pumping – if the monthly outdoor water demand has not been met by the first three sources of water, the FMP will make up the remaining deficit through distributed groundwater pumping in areas where this functionality has been established in the model.

Deliveries of surface water and groundwater pumping require the user to establish monthly rates of available sources of water. Each of these sources of supply plays a role in the numerical simulation of the surface- and subsurface-flow regimes, depending on the area and the specific water management activities within that area. Further details on the specific configuration of the FMP in the GSA Model are provided in Section 3.7.

3.1.2 Scientific Basis

The theory and numerical techniques that are incorporated into OneWater have been scientifically tested. The governing equations of variably saturated subsurface flow have been solved by several modeling codes over the past few decades, on a wide range of field problems. Therefore, the scientific basis of the theory and the numerical techniques for solving these equations have been well-established. The OneWater user's manual (Boyce et al., 2020) details the governing equations and other information on the codes.

3.1.3 Data Formats

Several American Standard Code for Information Interchange (ASCII) data files were used to parameterize the GSA Model. Table 3-1 shows the grouping of various data items in the GSA Model input files.

Table 3-1. OneWater Input File Description

File Extension	Version	Purpose[a]	Parameters[a], [b]
BAS	6	▪ Basic Package establishes active and inactive cells and initial heads.	▪ IBOUND array by layer (active domain) ▪ Initial heads by layer
DIS	NA	▪ Discretization Package establishes information on how time and space are subdivided. ▪ Establishes whether the numerical solution is steady state or transient.	▪ Grid cell dimensions ▪ Layer interface elevations ▪ Stress period durations ▪ Number of time steps per stress period ▪ Time step multiplier ▪ Stress period type (steady state or transient)
UPW	1	▪ Upstream Weighting Package contains aquifer hydraulic parameters, which constrain flow between model cells.	▪ Horizontal and vertical hydraulic conductivity ▪ Groundwater storage parameters
FMP	4	▪ Farm Process contains soil, vegetation, water source, and water use information. ▪ Controls supply and demand to facilitate computation of runoff, groundwater recharge from precipitation and applied water, and agricultural pumping.	▪ Consumptive use terms ▪ Soil type ▪ Rooting depths ▪ Irrigation efficiency ▪ Groundwater root flag and root pressures ▪ Capillary fringe ▪ Vadose zone options ▪ ET factors ▪ Water source and delivery information ▪ Irrigation fractions
GHB	OWHM	▪ General Head Boundary Package controls groundwater inflow and outflow from the Tulelake Sumps and through lateral subsurface boundaries.	▪ Boundary head and conductance by stress period ▪ Model layer designations
RIV	OWHM	▪ River Package controls surface-water and groundwater exchanges associated with the Lost River and primary conveyance canals within the Subbasin.	▪ Boundary head and conductance by stress period ▪ Model layer designations

File Extension	Version	Purpose[a]	Parameters[a], [b]
DRN	7	▪ Drain Package represents TID drainage network. The Drain Package removes water from the model; however, this flow is a component of the Tulelake Sump water balance.	▪ Drain head and conductance
MNW	2	▪ Multi-Node Well Package simulates agricultural groundwater pumping.	▪ Well dimension and construction information ▪ Groundwater pumping rate by stress period ▪ Model layer(s) designations
NWT	1.2.0	▪ Newton Solver solves the governing-flow equations.	▪ Solver iteration and closure terms ▪ Backtracking and other solver options
NAM	NA	▪ Name File specifies names of input and output files.	▪ No parameters are included
OC	NA	▪ Output Control File specifies the type of runtime information to write to output files.	▪ User-defined print and save statements

[a] As implemented in the GSA Model. Alternative uses of the package are also possible.

[b] Not intended to be an exhaustive list of input parameters. Refer to the model code documentation and online resources for additional information.

NA = not applicable, because it is built into the main OneWater code

Output from the GSA Model also follows the USGS MODFLOW output file formats and includes ASCII as well as binary files. Although a variety of optional output files can be generated with the OneWater code, Table 3-2 summarizes the main output files used for this modeling effort.

Table 3-2. Selected OneWater Output File Description

File Name or Extension	Content
LST	ASCII listing file containing runtime information included in the simulation
FB-Details	ASCII file containing FMP inflows and outflows by water balance subregions for all output times
FDS	ASCII file containing supply and demand information for all output times
HDS	Binary file containing cell-by-cell modeled groundwater elevations for all output times
CBB	Binary file containing cell-by-cell subsurface flows for all output times

3.2 Model Domain

A numerical model must use discrete space to represent the hydrologic system. The simplest way to discretize space is to subdivide the study area into many subregions (i.e., grid blocks) of the same size. This grid-building strategy was implemented for this modeling effort and is described in the following subsections. The model domain of the GSA Model was developed to fully encompass the greater physical subbasin as defined by the final Basin Boundary Modifications distributed in 2018 by DWR. In general, the model boundary was extended beyond the Subbasin to the watershed margins to fully capture the extent of the greater basin from which water may contribute to the Subbasin. In some instances, there are boundaries for which the contributing area intersects lower elevations within valleys from which the GSP Model extent was delineated. At these locations, groundwater elevations will be prescribed based on available groundwater elevation data to account for potential flow across these boundaries as discussed in Section 3.7.2.1.

3.2.1 Areal Characteristics of Model Grid

The GSA Model grid mathematically represents a 610-square-mile area that includes the Subbasin and a portion of the surrounding contributing area. The model grid is aligned north-south and east-west and georeferenced to the 1983 North American Datum (NAD83) of the Universal Transverse Mercator (UTM) Zone 10 North coordinate system, in units of U.S. feet. The GSA Model boundary follows hydrologic boundaries surrounding the Subbasin to encompass areas that are potentially hydraulically connected to the Subbasin. Figure 3-1 shows the GSA Model domain, which is partitioned into grid blocks (i.e., cells) horizontally spaced on 250-foot centers, which results in 272,064 active cells per model layer. The 250-foot cell spacing allows for sufficient spatial resolution to support development of water budgets for the GSP.

3.2.2 Vertical Characteristics of Model Grid

The GSA Model was subdivided into six vertically stacked layers to provide a 3D representation of the principal aquifers. Table 3-3 lists the model layer designations and thicknesses. These layers were developed to provide sufficient vertical resolution to facilitate the following:

- Evaluation of the effects of groundwater pumping on shallow and regional water resources
- Assignment of pumping stresses to appropriate depths within the aquifer that reflect the major producing zones within the aquifer system

Table 3-3. Summary of Model Layers

Model Layer	Description	Model Layer Thickness (feet)	Depth of Layer Bottom (feet bgs)
1	Composed primarily of Quaternary sedimentary deposits within the greater physical subbasin surrounded by Quaternary volcanic rocks, and Tertiary volcanic rocks	0.4 to 3,743	0.4 to 3,743
2	Composed primarily of Tertiary sediments within the greater physical subbasin surrounded by Tertiary volcanic rocks	183 to 900	202 to 3,943
3	Composed primarily of Tertiary sediments within the greater physical subbasin surrounded by Tertiary volcanic rocks	100 to 900	402 to 4,143

Model Layer	Description	Model Layer Thickness (feet)	Depth of Layer Bottom (feet bgs)
4	Composed primarily of Tertiary mixed sedimentary and volcanic deposits within the greater physical subbasin surrounded by Tertiary volcanic rocks	175 to 1,150	935 to 4,818
5	Composed primarily of Tertiary mixed sedimentary and volcanic deposits within the greater physical subbasin surrounded by Tertiary volcanic rocks	300 to 800	1,420 to 5,493
6	Composed primarily of Tertiary mixed sedimentary and volcanic deposits within the greater physical subbasin surrounded by Tertiary volcanic rocks	200 to 1,100	1,931 to 6,593

Model Layer 1 is set as an unconfined, convertible layer to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and horizontal hydraulic conductivity. Model Layers 2, 3, 4, 5, and 6 are set as confined, so transmissivity only varies spatially according to the cell thickness and horizontal hydraulic conductivity therein.

Layer thicknesses were devised based on the USGS regional model, DWR-derived top of volcanic contours and cross-sections developed as part of the Upper Klamath Basin Hydrogeologic Investigation, and AEM data provided by DWR (DWR, 2003b; CNRA, 2023). Model Layer 1 thicknesses of the GSP Model were established to be the same thickness as the USGS regional model. Total thickness of Model Layers 2 and 3 of the GSP Model were initially established based on the Layer 2 thicknesses of the USGS model. Model Layer 3, however, was modified to better reflect the bottom of basin-fill sediments based on DWR top of volcanic structure contours and cross-sections as well as AEM data. Model Layers 4 and 5 were split into an even thickness to capture screening intervals from pumping wells that extend through these depths. Finally, Model Layer 6 was extended beyond the deepest pumping wells in the region to provide an adequate buffer between the deepest pumping wells and the bottom-most layer of the GSP Model.

3.3 Surface Parameters

The surface parameters required by the GSA Model are the land surface elevations, surface-water feature characteristics, soils distribution, land use, and water balance subarea distribution.

3.3.1 Topography

A 10-meter digital elevation model raster dataset along with 1-meter light detection and ranging (LiDAR) data forms the basis for land surface elevations covering the modeling domain. These land surface elevations were assigned to the top of Model Layer 1. Elevation data were processed using ArcGIS Version 10 software. Figure 3-2 illustrates the land surface elevations incorporated into the top of the model grid.

3.3.2 Soils Data

Soils data were obtained from the Natural Resource Conservation Service Soil Survey Geographic Database for the extent of the GSA Model. Soil Survey Geographic Database data were processed to obtain a distribution of texture classification across the model domain. Texture classification was then translated into a simulated soil category to serve as input to the FMP (Table 3-4). Dominant soil type was then assigned to each model grid cell based on the spatial distribution of each simulated soil category (Figure 3-3).

Table 3-4. Translation of Natural Resources Conservation Service Texture Class to Simulated Soil Category

Simulated Soil Category	Texture Classification
Sand	Sand
	Cinders
	Fragmental Material
Sandy Loam	Clay Loam
	Silty Clay Loam
	Silty Clay
	Clay
Silt	Silt Loam
Silty Clay	Loamy Sand
	Sandy Loam
	Loam
	Slightly Decomposed Plant Material
	Cobbly Loam
	Stony Loam
	Gravelly Loam
	Gravelly Sand
	Unweathered Bedrock

3.3.3 Surface-Water Features

Within the Subbasin, a complex series of conveyance systems exist that are used to convey water throughout TID. The following sections provide a description of these surface-water conveyance features and their characterization for implementation in the GSA Model.

3.3.3.1 Lost River and Tulelake Irrigation District Conveyance System

TID is composed of a system of main canals and canal laterals that receive water from the Lost River and other conveyance systems in the Oregon extent of the GSA Model. Figure 3-4 presents the extent of TID's main canals, canal laterals, and Lost River as simulated in the GSA Model. Flow through the Lost River is diverted into TID's conveyance system from which water is distributed throughout the Subbasin to provide water for irrigation use. Assumptions associated with the simulation of these surface-water features are discussed further under Section 3.7.2.2.

Adjacent to TID's main canals and laterals are a series of open-ditch drains that are used to drain agricultural fields and convey water throughout the irrigation district. Figure 3-5 presents the extent of TID's drain system through the Subbasin as simulated in the GSA Model. Assumptions associated with the simulation of TID's drain system is discussed further under Section 3.7.2.3.

3.3.3.2 Tulelake Sumps

Within the Subbasin exist two surface-water features, referred to as the Tulelake Sumps, that serve as important habitat for wildlife refuge, collection and containment of drainage water and flood flows, and to supply irrigation water throughout the Subbasin (TID, 2017). Figure 3-6 presents the extent of the Tulelake Sumps as simulated in the GSA Model. The Tulelake Sumps are operated in accordance with the 2024 United States Fish and Wildlife Service Biological Opinion and the 1999 Regulation for Tule Lake Sump Modified Rules. The Biological Opinion prescribes water level requirements throughout the year in order to maintain appropriate conditions to prevent flooding and to provide suitable habitat for wildlife. To control water levels in the Tulelake Sumps, TID recirculates water from the sumps into the irrigation system and uses the D-Plant pumping station to remove water from the Tulelake Sumps. The location of the D-Plant pumping station is shown on Figure 3-6. Water removed through D-Plant is pumped through Sheepy Ridge to the west, providing water to refuges and conveyance systems to the west of the Subbasin. Assumptions associated with the simulation of the Tulelake Sumps are discussed further under Section 3.7.2.4.

3.3.4 Land Use

The following subsections describe land use assumptions associated with lands supplied with water by TID, other Klamath Project water users in the Oregon portion of the GSA Model domain, and privately owned lands outside of a purveyor delivery area.

3.3.4.1 Tulelake Irrigation District

Available land use datasets were compiled from Modoc and Siskiyou Counties and TID to establish a set of land use conditions throughout the Subbasin. Within the Subbasin, land use is primarily composed of agricultural crop categories along with some riparian and native vegetation and urban areas. Riparian and native vegetation areas were assumed to persist throughout the analysis period of the GSA Model as established through the county datasets. However, agricultural land use conditions within TID vary from year to year based on water availability. For the GSA Model, five different agricultural land use conditions were identified and used to represent changes in agricultural conditions within the Subbasin during the historical period. As discussed in the following paragraphs, the five different land use conditions within TID that were identified represent 2008 (Figure 3-7), 2010 (Figure 3-8), 2019 (Figure 3-9), 2022 (Figure 3-10), and 2024 (Figure 3-11) conditions.

TID annual crop acreage data for years 2000 through 2025 were analyzed to develop crop categories and land use conditions that could be simulated in the GSA Model. Crop categories provided in the TID reports were lumped into six different crop categories for inclusion in the GSA Model based on similar annual crop consumptive use requirements of each crop type. Crops with similar demands were combined to create a single category for simulation in the GSA Model (Table 3-5). In general, the predominant crop types within TID are alfalfa, grains, mint, potatoes, and pasture. Mint, potatoes, and a number of other crops were combined based on similar consumptive use requirements into an 'All Other Crops' category. Additionally, the crop type with the larger area per field boundary was selected to be the representative crop type for that field in the GSA Model, since subcropping area boundaries were not readily available for all years of available land use data.

Table 3-5 presents crop acreage for years 2008, 2010, 2019, 2022, and 2024 based on the GSA Model crop category and the associated TID crop report category. Generally, the crops grown within TID have been relatively stable over the analysis period; however, there has been some shifting of crops grown. For example, alfalfa acreage tended to increase over the 2000 through 2025 period. The trend noted for other crops was (1) increase in acreage from 2000 through 2009, (2) no substantive changes in acreages between 2009 and 2019, and (3) decreases in acreages between 2019 and 2025. One deviation to this

trend was noted for grain acreages, which remained relatively stable throughout the 2000 through 2019 period and decreased in recent years. Aside from these shifts in cropping patterns there are years where significant idling of fields occurred due to availability of water and various water management programs instituted to support farmers in fallowing fields within a given year. Most notably are the years 2001, 2010, 2022, and 2024, when significant idling occurred throughout TID. Based on the crop acreage trends, specific years from the 5 representative years were selected to represent land use conditions throughout TID during the historical simulation period to capture the changes in land use that occurred.

Table 3-5. Simulated Crop Category and Average Tulelake Irrigation District Crop Acreage for Historical Period

Model Category	TID Crop Report Category	2008 Acreage	2010 Acreage	2019 Acreage	2022 Acreage	2024 Acreage
Alfalfa	Alfalfa	19,921	16,120	25,011	21,105	24,486
	Other Hay	2,541	3,564	1,654	1,903	258
All Other Crops	Onions	2,449	1,874	2,764	953	1,152
	Mint	2,584	3,035	1,876	946	661
	Beets	0	0	0	0	0
	Peas	153	0	50	0	0
	Horseradish	436	358	495	507	588
	Strawberries	0	81	0	0	0
	Potatoes/Spuds	8,033	5,770	7,130	4,794	7,022
Grains	Barley	3,582	8,030	9,478	769	2,973
	Wheat	17,471	9,850	10,226	4,590	10,613
	Oats	114	360	42	44	60
	Rye	40	55	0	0	0
Idle	Idle	1,863	11,695	1,697	26,184	13,571
	House/Farmstead	658	671	731	731	731
Pasture	Pasture	1,283	1,314	1,135	377	760
Urban	Res. Comm. Ind.	289	338	374	374	363

3.3.4.2 Oregon Klamath Project Water Users and Private Groundwater Pumping

While the primary focus of the GSA Model is to simulate groundwater conditions in the Subbasin, significant irrigation occurs just beyond the California-Oregon border, to the north of the Subbasin. Similar to TID, most of the area within the Oregon portion of the GSA Model domain is composed of water users that receive surface-water supply from the Bureau of Reclamation's Klamath Project. Limited spatially distributed land use data for these water users were available during the development of the GSA Model. Thus, estimates of irrigable acreage and crop consumptive use for the year 2008 were used from the On-Project Plan to help inform potential consumptive use quantities of water for areas within the Oregon portion of the GSA Model domain. Table 3-6 presents estimates of irrigable acreage, consumptive use, water requirements, and on-farm efficiencies for districts within the Oregon portion of the GSA Model domain.

Based on the estimated on-field water requirement for these irrigation districts, the regions within the GSA Model for each irrigation district were assigned a crop coefficient based on the alfalfa crop, which has an approximate water requirement of 33 acre-inch per acre, which aligns closely to the on-field water requirements presented in Table 3-6.

Table 3-6. Estimates of Crop Consumptive Use for Oregon-Based Irrigation Districts

District Name	Total District Irrigable Acreage[a]	Consumptive Use (AFY)	On-Field Water Requirement (AFY)	On-Field Water Requirement (acre-inch/acre)	On-Farm Efficiency Estimate
Klamath Irrigation District	49,980	116,570	140,060	33.6	0.83
Malin Irrigation District	3,480	8,080	9,700	33.4	0.83
Shasta View Irrigation District	4,900	11,140	13,360	32.7	0.83
Van Brimmer Ditch Company	4,790	11,560	14,220	35.6	0.81

[a] Total district acreages presented represent the total acres within the Klamath Project and do not necessarily reflect district acreages contained in the GSA Model.

AFY = acre-feet per year

3.3.4.3 Private Lands

Most of the irrigated agricultural lands within the GSA Model are within the Klamath Project and receive a surface-water supply. However, there are some areas where agriculture is dependent solely on groundwater pumping. Limited information is known regarding irrigation demands, on-farm efficiency, and well locations for these areas. Areas were identified through discussions with local stakeholders and through consultation of aerial imagery to identify areas outside of known water purveyor service areas that appear to contain irrigated agriculture. Consumptive use estimates for these areas were assumed to be consistent with an alfalfa crop.

3.3.5 Water Balance Subarea Delineation

As part of FMP development, water balance subareas (WBS) are designated to help control supply and demand specifications and input and output data. WBS specifications for the GSA Model were delineated based primarily on TID distribution systems, Klamath Project water users within the GSA Model domain, and areas that are deemed irrigated but do not receive water as part of an irrigation district. Figure 3-12 presents the distribution of WBS throughout the GSA Model domain.

3.4 Subsurface Flow Parameters

The subsurface hydraulic parameters required by the GSA Model are the horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv), specific yield (Sy), and specific storage (Ss).

3.4.1 Hydraulic Conductivity

Hydraulic conductivity values in the GSA Model were initially adopted from the Klamath River Valley Groundwater Basin groundwater flow model developed by USGS (Gannett et al., 2012) and were refined during calibration of the GSA Model for the Subbasin GSP submitted in 2022. Additional refinements to the hydraulic conductivity zones developed in 2022 were made based on review of AEM data as well as more recent water level data sets and water delivery operations data. The AEM dataset included two-dimensional subsurface panels (fence-diagram) throughout the Subbasin that clearly distinguished basin-fill sediments from the underlying and surrounding volcanic rocks. Contacts shown in these panels were compared with the existing distribution of hydraulic properties; and where these two datasets were not aligned, the AEM data were preferred. Although the deeper layers of the model are beyond the maximum depth of the AEM data, this process allowed for improvements in the characterization of aquifer boundaries in Layers 2 and 3.

Figures 3-13 through 3-15 present the refined hydraulic property zonation for Layers 1 through 6. In Layer 1, the Tulelake region is composed of primarily Quaternary sediments throughout the greater physical subbasin with Quaternary volcanic deposits to the south of the Tulelake Sumps and Tertiary volcanic deposits to the east of the Subbasin. Hydraulic property zonation for Layer 1 is based on geologic mapping of surficial units (Figure 3-13). In Layers 2 and 3, the majority of the Subbasin is composed of Tertiary sediments of younger basins and Tertiary volcanic rocks to the south and east. Hydraulic property zonation for Layers 2 and 3 is primarily based on Layer 2 of the Klamath River Valley Groundwater Basin groundwater flow model, with refinements made to the contacts between Tertiary sediments and Tertiary volcanic rocks along the west, south, and southeast boundaries of Tertiary sediments (Figure 3-14). Finally, in Layers 4 through 6, the Subbasin is composed of primarily Tertiary mixed sedimentary and volcanic deposits with Tertiary volcanic rocks to the south and east. Hydraulic property zonation for Layers 4 through 6 is based on Layer 3 of the Klamath River Valley Groundwater Basin groundwater flow model (Figure 3-15). Table 3-7 presents the initial hydraulic conductivity and vertical anisotropy ratio for each of the primary units in Layers 1 through 6 from the GSA Model. Additional layer and parameter refinements were made during the calibration process of the GSA Model as discussed in Section 4.

Table 3-7. Initial Subsurface Parameters

Model Layer	Unit	Hydraulic Conductivity (ft/day)	Vertical Anisotropy (Kh:Kv)	Specific Storage
1	Qs	100	100	2.40E-03
	Qv	5	100	2.40E-03
	Tve	1	1,000	2.40E-03
	Tvw	1	1,000	2.40E-03
	Tsy	25	10	2.40E-03
	Tso	25	10	2.40E-03
2	Tso	25	10	4.36E-05
	Tsv	25	10	4.36E-05
	Tsy	25	10	4.36E-05
	Tve	1	100	4.36E-05
	Tvw	1	100	4.36E-05
3	Tso	25	10	4.36E-05
	Tsv	25	10	4.36E-05
	Tsy	25	10	4.36E-05
	Tve	1	1,000	4.36E-05
	Tvw	1	1,000	4.36E-05
4	Tsv	3	10	1.68E-05
	Tve	1	1,000	1.68E-05
	Tvw	1	1,000	1.68E-05
5	Tsv	3	10	1.68E-05
	Tve	1	1,000	1.68E-05
	Tvw	1	1,000	1.68E-05

Model Layer	Unit	Hydraulic Conductivity (ft/day)	Vertical Anisotropy (Kh:Kv)	Specific Storage
6	Tsv	3	10	1.05E-05
	Tve	1	1,000	1.05E-05
	Tvw	1	1,000	1.05E-05

Notes:

Vertical anisotropy represents the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity.

Specific yield is specified as 10 percent for Layer 1; Layers 2 through 4 do not have a specific yield because these layers are simulated as confined.

ft/day = foot per day
Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)
Tsy = Tertiary basin-filling sediments (younger basins)
Tso = Tertiary sediments (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

3.4.2 Groundwater Storage

Groundwater storage (i.e., storativity) is handled through the assignment of two parameters, including the Sy and Ss. Model Layer 1 is set as an unconfined, convertible layer to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and Kh. These model layers require the user to input both Sy and Ss values, which can vary on a cell-by-cell basis. If a model cell during a given stress period in Model Layer 1 is fully saturated, then the model computes a storativity as the product of the Ss and cell thickness. If a model cell during a given stress period in Model Layer 1 is partially saturated, then the model uses the Sy. Model Layers 2, 3, 4, 5, and 6 are set as confined, so the model computes for each stress period a storativity value as the product of the Ss and cell thickness for these model layers. Thus, groundwater storage properties do not vary temporally in Model Layers 2, 3, 4, 5, and 6. The GSA Model was initially assigned uniform Sy and Ss values of 10 percent and 1×10^{-6} per foot (ft^{-1}), respectively, based on literature values and professional judgment. Section 4 describes the modification of these values during the calibration process.

3.5 Time Discretization

The calibration version of the GSA Model simulates historical hydrologic conditions from October 1997 through September 2025, whereas the projection version of the GSA Model simulates future hydrologic conditions from October 2025 through September 2071. All versions of the GSA Model include monthly stress periods to adequately simulate seasonal hydrologic processes.

3.6 Initial Flow Conditions

The establishment of a transient GSA Model necessitates establishment of initial flow conditions in the hydrologic system. Initial conditions refer to the initial distribution of heads (i.e., groundwater elevations) throughout the model domain. Initial conditions for the calibration simulations were established in a "spin-up" manner. This step involved assigning initial heads intended to approximate September 1997 conditions and then allowing the monthly stress periods to "work through" the monthly conditions through September 1999 (i.e., the end of the spin-up period). Additionally, most data used in development of GSA Model boundary conditions started in the year 2000. Therefore, model output data from the spin-up period are not included in the assessment of calibration or water budgets. Thus, presentation of calibration results and water budgets described in Sections 4 and 5 are representative of October 1, 1999, through September 30, 2025 (i.e., water years [WYs] 2000 through 2025).

3.7 Boundary Conditions

Boundary conditions are mathematical statements (i.e., rules) that specify head (i.e., groundwater elevation) or water flux at particular locations within the model domain. The following three types of boundary conditions were used in the GSA Model during calibration:

- Specified flux – Water fluxes are assigned to selected model cells and remain unchanged during a monthly stress period. A specified-flux boundary condition is a two-way boundary condition whereby values indicate either water inflow or outflow rates.
- Head-dependent flux – Head and hydraulic conductance values are assigned to selected model cells, and water fluxes are computed by the model code across the boundary using an appropriate governing-flow equation, based on the head assigned to the boundary condition and the simulated groundwater elevation. A head-dependent flux boundary condition is also a two-way boundary condition, depending on the direction of the hydraulic gradient (into or out of the modeled aquifer system).
- No flow – Water can flow parallel to the boundary, but not across it.

Table 3-8 summarizes these boundary conditions and their respective hydrologic process used to calibrate the GSA Model.

Table 3-8. Summary of Groundwater Sustainability Agency Model Boundary Conditions for Calibration

Hydrologic Process	Specified Flux	Head-Dependent Flux
Precipitation	X[a]	
Evapotranspiration		X[a]
Applied Water	X[a]	X[a]
Groundwater Recharge from Precipitation and Applied Water	X[a]	X[a]
Groundwater/Surface-Water Interaction	X	X
Groundwater Pumping	X[a]	X
Subsurface Lateral Flow Exchange with Surrounding Areas		X

Note:

No-flow boundaries are simulated at lateral boundaries of active surface and subsurface cells not already assigned specified fluxes and at the bottom of the deepest model layer (i.e., Model Layer 6).

[a] Processed and managed through the FMP, which includes some aspects of both specified-flux and head-dependent flux boundary conditions.

3.7.1 Specified Fluxes

The following section describes boundary conditions in the GSA Model where either a volumetric or linear flux is used to simulate various flow processes.

3.7.1.1 Precipitation and Reference Evapotranspiration

The FMP requires input of precipitation and ET_0 to establish climatic conditions in the land surface system water budget. Precipitation and ET_0 were processed from the USGS BCM (Flint et al., 2013). BCM used a down-scaling approach to process PRISM-based climate data from 800-meter down to 270-meter resolution to provide more spatial variability. Precipitation and ET_0 data were then mapped to each model grid cell of the GSP Model to provide monthly precipitation and ET_0 rates throughout the model domain for the entire model simulation period.

An analysis was conducted to compare the BCM-based gridded precipitation to measured precipitation data from California Irrigation Management Information System (CIMIS) Station # 91 within the Subbasin. Based on this analysis, adjustment factors were applied to the BCM precipitation dataset to better reflect local conditions measured at the CIMIS station. In general, the adjustment has lowered the BCM estimates of precipitation for use in the GSA Model. Figure 3-16 presents historical annual precipitation totals based on the gridded BCM data mapped across the extent of GSA Model. On average, the region experiences approximately 9.3 inches per year over the 1998 through 2025 period with a low of 5.5 inches per year in water year 2020 and a maximum of 16.0 inches per year in water year 1998. The cumulative departure for WYs 1998 through 2025 is also presented on Figure 3-16 (shown as the black solid line) and is computed by accumulating the annual departures (i.e., the yellow bars) from WY 1998 forward in time. The annual and cumulative departures give an indication of a good mix of wet and dry conditions for model calibration.

An analysis was conducted to compare the BCM-based gridded ET_0 to an average of two local AgriMet stations in the Klamath Region (Klamath Falls and Worden stations). Figure 3-17 presents annual estimates of ET_0 based on an average of all grid cells in the model domain versus the average of the two AgriMet stations. In general, the AgriMet stations measured a larger amount of annual ET_0 as compared to the gridded BCM data. In part, this is because the reference crop from the AgriMet stations is based on alfalfa rather than a short or long grass reference crop. Based on this comparison, and the difference in reference crops, a correction factor was applied to the BCM gridded data to better reflect local measurements of ET_0 and the alfalfa reference crop.

Figure 3-18 presents monthly average BCM potential ET before and after adjusting to local AgriMet station data. In general, the applied correction factor increases ET_0 from May through September during the irrigation season of the region. Additionally, as shown on Figure 3-18, the annual BCM-adjusted ET_0 ends up being larger than the AgriMet station average because the AgriMet station only measured ET_0 during the growing season (March through October), whereas the adjusted BCM dataset includes estimates of ET_0 during the winter, which were retained for the GSA Model.

3.7.1.2 Consumptive Use

To estimate crop consumptive use, the FMP uses ET_0 and crop coefficients to determine a crop-specific consumptive use estimate. Monthly crop coefficients were developed based on AgriMet station data for crop-specific actual ET in conjunction with the ET_0. Figure 3-19 presents monthly crop coefficients (Kc) for each of the GSA Model crop categories. Consumptive use is related to the Kc and ET_0 based on Equation 3-1, as follows:

$$\text{Consumptive Use} = Kc \times ET_0 \qquad (3\text{-}1)$$

Kc values were associated with crop category and land use polygons throughout the model domain (Figures 3-7 through 3-11). These data, along with areal fractions of land use per cell, serve as input to the GSA Model to define the consumptive use of water for each WBS.

3.7.1.3 Tulelake Irrigation District Water Deliveries

Within the FMP, shallow groundwater and precipitation serve as the first sources of water used to meet consumptive use demands within a WBS. In areas of irrigated agriculture within TID, an additional source of water is provided through non-routed deliveries (NRDs) specified as part of the FMP. NRDs represent the delivery of combined surface water and groundwater from TID as specified monthly volumes of water available for consumptive use demands. Water delivery estimates were provided by TID based on the deliveries of water from each canal system. Delivery estimates were then distributed to each WBS representative of TID. Figure 3-20 presents the annual TID water deliveries for each of the TID WBS

as presented on Figure 3-12. The majority of TID's water deliveries occur within the California portion of the J System at approximately 43 thousand acre-feet per year (TAFY) on average during the historical simulation period. The remaining water deliveries average approximately 38 TAFY for a total of approximately 81 TAFY for the historical simulation period.

3.7.1.4 Oregon Irrigation District Water Deliveries

Surface-water deliveries for the irrigation districts located in Oregon (Figure 3-12) are simulated in the FMP similar to the NRDs for TID described above. Annual surface-water allocation estimates were available for WYs 2018 through 2025 (Table 3-9) (Knutson, pers. comm., 2026a). These estimates were implemented directly for the associated WYs. The average annual allocations, excluding critically dry WY 2021 and WY 2022, were implemented for WYs 1998 through 2017.

Table 3-9. Summary of Estimated Annual Surface-Water Allocations, Oregon Water Districts

Water Year	Klamath Irrigation District (TAF)[a]	Malin Irrigation District (TAF)	Shasta View Irrigation District (TAF)	Van Brimmer Ditch Company (TAF)
2018	50.8	1.6	17.5	14.8
2019	50.8	7.9	1.7	14.8
2020	50.8	1.0	0.0	14.8
2021	0.0	0.0	0.0	0.0
2022	50.8	0.0	3.5	10.6
2023	50.8	2.0	3.5	14.8
2024	50.8	2.0	17.5	14.8
2025	50.8	7.9	17.5	14.8
Average	50.8	3.73	7.75	14.8

[a] The annual Klamath Irrigation District surface-water allotment was modified during GSA Model calibration to promote more agricultural groundwater pumping within the FMP. A final surface-water allocation of 36.6 TAFY was simulated.

TAF = thousand acre-feet

3.7.1.5 Tulelake Irrigation District and Municipal Groundwater Pumping

Throughout the Subbasin, groundwater is pumped from TID wells, and private users augment surface-water supplies for irrigation. Figure 3-21 presents the locations of simulated pumping wells in the GSA Model. TID maintains 10 pumping wells throughout the Subbasin that are used to augment supplies in the TID conveyance system. Annual production rates for the TID pumping wells were available throughout the historical simulation period of the GSA Model. Annual rates were distributed into monthly pumping rates for incorporation in the Multi-Node Well (MNW) Package of the GSA Model.

The City of Tulelake operates a municipal well within the Subbasin to meet supplies within the city's service area. Monthly pumping rates provided by the City of Tulelake (Knutson, pers. comm., 2026b) were incorporated into MNW Package of the GSA Model. The City of Merril operates a municipal well outside of the Subbasin. A constant pumping rate of 195 gallons per minute was incorporated into the MNW Package of the GSA Model.

The vertical distribution of groundwater pumping was assigned to the model layer(s) intersected by the known (in the case of TID wells) or assumed (in the case of municipal wells) well screen intervals.

3.7.1.6 Estimated Private Groundwater Pumping

Private groundwater pumping in the GSA Model is estimated and simulated through the FMP. Model cells associated with irrigated land uses can pump groundwater from a 'virtual well' to supplement sources of water. In the case where a water source is not provided, the irrigated area is assumed to use local groundwater as the sole supply. Irrigation requirements, and ultimately private groundwater pumping, are based on the consumptive use of the model cell's land use minus the availability of precipitation and shallow groundwater to satisfy consumptive use demands. As shown on Figure 3-21, private groundwater pumping within the Subbasin was assigned to discrete well locations. Because of the uncertainty associated with discrete pumping locations in Oregon, demand-driven pumping was distributed across the respective WBS. The vertical distribution of private pumping varied spatially and was based on estimated well construction. The vertical distribution of pumping varied during model calibration.

3.7.1.7 Canal Lateral Leakage

Leakage to groundwater associated with the TID canal laterals was specified directly in the GSA Model as a linear flux. Monthly estimates of canal lateral leakage were obtained from TID's H20Sys water budget accounting dataset. Canal system specific rates were distributed evenly across model grid cells that intersect with the canal laterals (Figure 3-4). Figure 3-22 presents the estimated annual canal lateral leakage by canal system. The J System makes up the bulk of the conveyance system and, therefore, canal lateral leakage ranging from a low of approximately 12 TAFY in WY 2001 to a maximum of 97 TAFY in WY 2025. The amount of canal lateral leakage is dependent on the surface-water availability from the Klamath Project for that year, where 2001 was a low surface-water supply year resulting in minimal leakage from canals. The North N, Q and R, and M and South N Systems all portray a similar low in canal lateral leakage in 2001. Total canal lateral leakage for the entire TID conveyance system is approximately 98 TAFY on average. In recent years, additional flows from the Lost River have been conveyed into TID's system to provide a source of groundwater recharge to the Subbasin. Higher annual canal lateral leakage in WYs 2023 through 2025 (Figure 3-22) are likely attributed to these additional flows from the Lost River.

3.7.2 Head-Dependent Fluxes

The following section describes boundary conditions in the GSA Model where the flux used to simulate various hydrologic processes is dependent on groundwater elevations (i.e., heads) in the aquifer.

3.7.2.1 Subsurface Lateral Flow Exchange with Surrounding Areas

Head-dependent subsurface lateral flow boundary conditions were implemented in three separate locations to account for potential subsurface inflow and outflow along the GSA Model boundaries. Figure 3-23 presents the locations of the Northern, Northwestern, and Southern subsurface lateral boundary conditions. Head and conductance values were specified for each stress period of the GSA Model to represent head conditions along each of these boundary locations to allow for subsurface flow across the model boundary. Measured water levels at wells near to the boundary were used to assign head values through time (Figure 3-23). Figures 3-24 and 3-25 present measured water level data and the resulting simulated groundwater elevation simulated in the GSA Model for the Northern and Southern lateral subsurface flow boundaries. Limited measured data were available in proximity to the Northwestern subsurface lateral boundary; thus, a static average value of 4,047.7 feet above North American Vertical Datum of 1988 (NAVD88) was specified for this boundary.

3.7.2.2 Lost River and Tulelake Irrigation District Main Canals

Minimum elevations were extracted from the topographic surface used to define the top elevation of Layer 1 of the GSA Model at each of the model grid cells that comprise the Lost River and TID main canals (Figure 3-4). A scheme was developed to represent the timing of flows through the Lost River and TID's main canals where the elevation assigned to respective cells of the River (RIV) Package are either assigned a stage elevation (system is flowing) or a channel bottom elevation (system is not flowing) depending on the timing of flows through the system. The stage elevation was assumed to be 5 feet greater than the channel bottom elevation to reflect conditions of the channel feature passing flow through the system. Leakage from the Lost River and TID main canals is computed through the RIV Package based on assigned conductance values for each grid cell. Conductance values and timing of flows will be adjusted during the calibration process as described under Section 4.

3.7.2.3 Tulelake Irrigation District Drains

Groundwater discharge to drains is simulated through the Drain (DRN) Package. Minimum topographic elevations were extracted and assigned for each grid cell intersected by TID drains (Figure 3-5). To reduce any potential numerical feedback between boundary conditions, conductance values of DRN cells that overlap with RIV Package cells were set to zero, effectively turning off the DRN Package in this cell (i.e., where there were overlapping DRN and RIV cells, preference was given to simulating the RIV boundary condition). Flow to drains is then calculated based on the gradient between the underlying water table and the elevation assigned at the drain cell, scaled by the conductance term of the drain cell.

3.7.2.4 Tulelake Sumps

Surface-water and groundwater exchange from the Tulelake Sumps is simulated through the General Head Boundary (GHB) Package. GSA Model grid cells covering the extent of the Tulelake Sumps serve as the spatial extent of the GHB (Figure 3-6). Conductance values and head elevation values are specified for each cell of the GHB Package. Figure 3-26 presents monthly average measured Tulelake Sump water surface elevations specified for each cell of the Tulelake Sump GHB as provided by TID. An average value of 4,034.74 was assigned for the first 2 years of the historical simulation period due to limited availability of measured data during this time. In WYs 2021 and 2022, there was a period where the Tulelake Sumps ran dry due to extended drought conditions in the Subbasin. The conductance term of the GHB representing the Tulelake Sumps was turned to zero during this period to keep the Tulelake Sumps from acting as a source of recharge to the aquifer. Although there is potential for groundwater discharge to the Tulelake Sumps during this period, which the model will not simulate because of the zero conductance values, the volume of potential groundwater discharge to the Tulelake Sumps was assumed to be minimal.

3.7.2.5 Groundwater Recharge from Precipitation

Groundwater recharge from precipitation is computed by the FMP Package, whereby the water that is not consumed through consumptive use is available for either recharge or overland runoff.

3.7.2.6 Groundwater Recharge from Applied Water

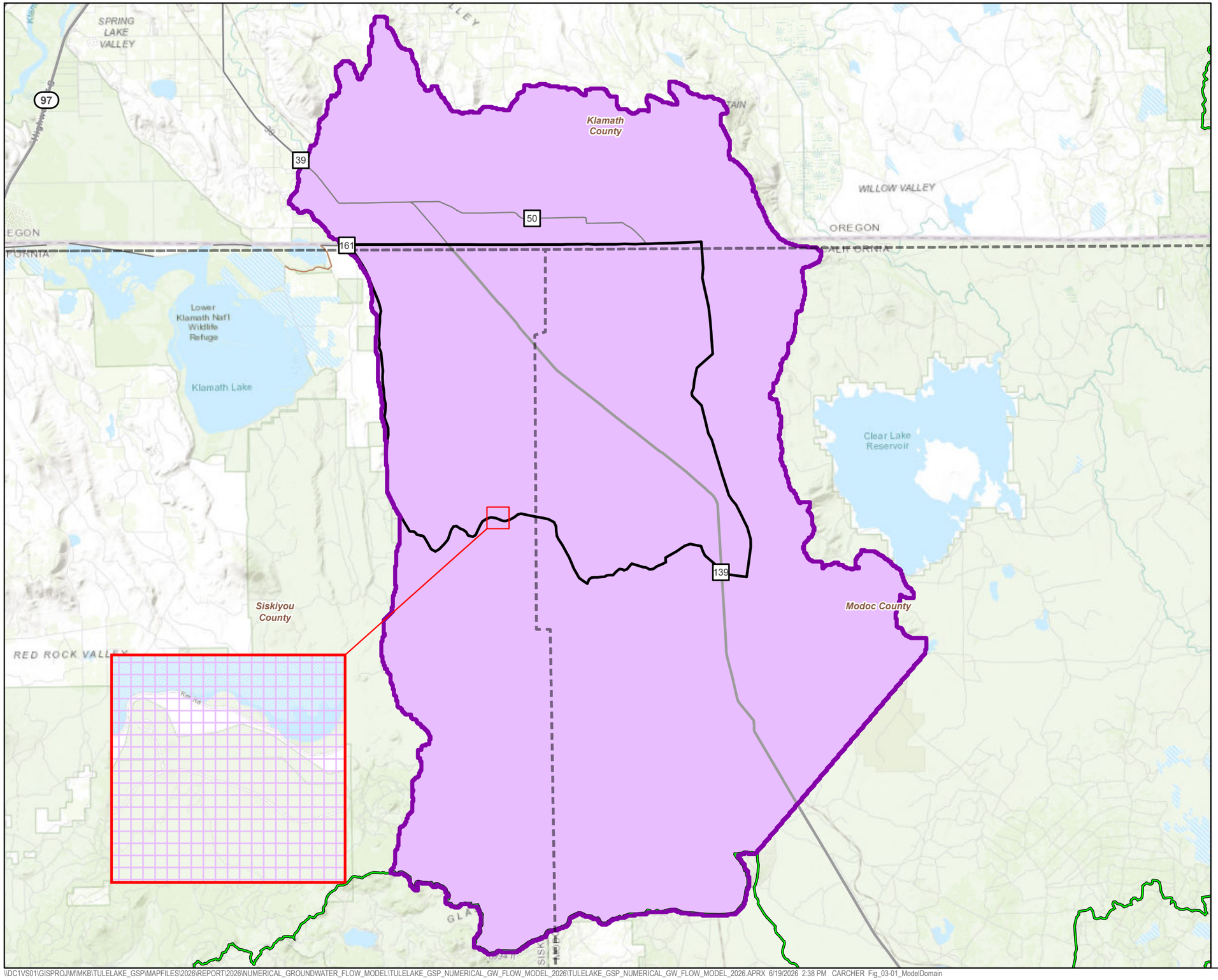
Groundwater recharge from applied water is derived through the FMP Package, based on the on-farm efficiency term. The inefficient losses, like precipitation, can either recharge the aquifer or become overland runoff. This boundary condition only applies to irrigated crops.

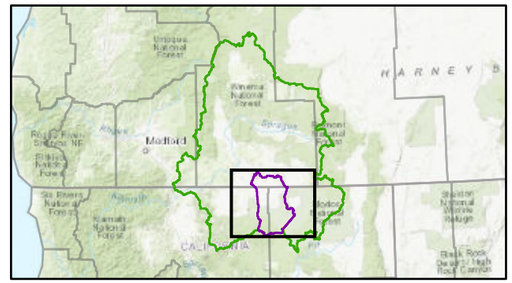
3.7.2.7 Shallow Groundwater Evapotranspiration

Shallow groundwater uptake is simulated through the FMP Package, whereby crops can use shallow groundwater as a source of supply to meet consumptive use water demands. Access to shallow groundwater is determined based on the crop rooting depths, capillary fringe height, and the elevation of the water table during a given month in the simulation. This boundary condition is applied areally across the top of the entire model domain.

3.7.3 No-Flow Boundaries

No-flow boundary conditions are used to simulate the extent of the active model domain. This includes cells along the lateral model domain boundary depicted on Figure 3-1, except where GHB boundary conditions are assigned and the bottom of the deepest model layer (i.e., Model Layer 6). Inherent with the assignment of no-flow boundaries is the assumption that these boundaries coincide with locations of groundwater divides.





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World Topographic Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

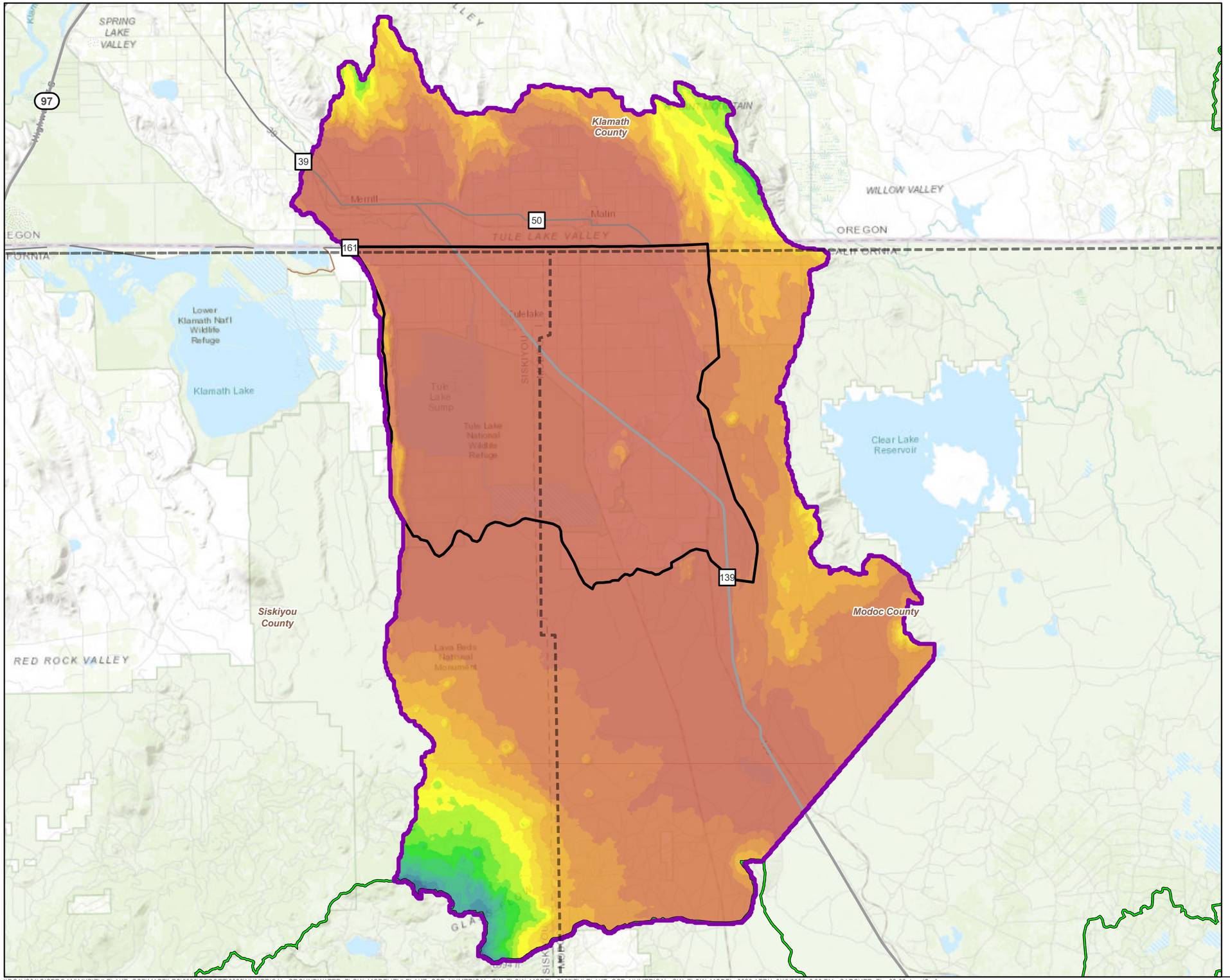
0 4 8 Miles

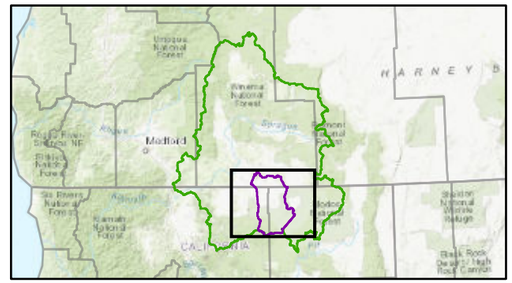
N

Figure 3-1
Model Domain: Plan View
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 6/19/2026 2:38 PM CARCHER Fig_03-01_ModelDomain





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Modeled Land Surface Elevation (feet)

4,000 - 4,250	6,000 - 6,250
4,250 - 4,500	6,250 - 6,500
4,500 - 4,750	6,500 - 6,750
4,750 - 5,000	6,750 - 7,000
5,000 - 5,250	7,000 - 7,250
5,250 - 5,500	7,250 - 7,500
5,500 - 5,750	7,500 - 7,750
5,750 - 6,000	7,750 - 8,000

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

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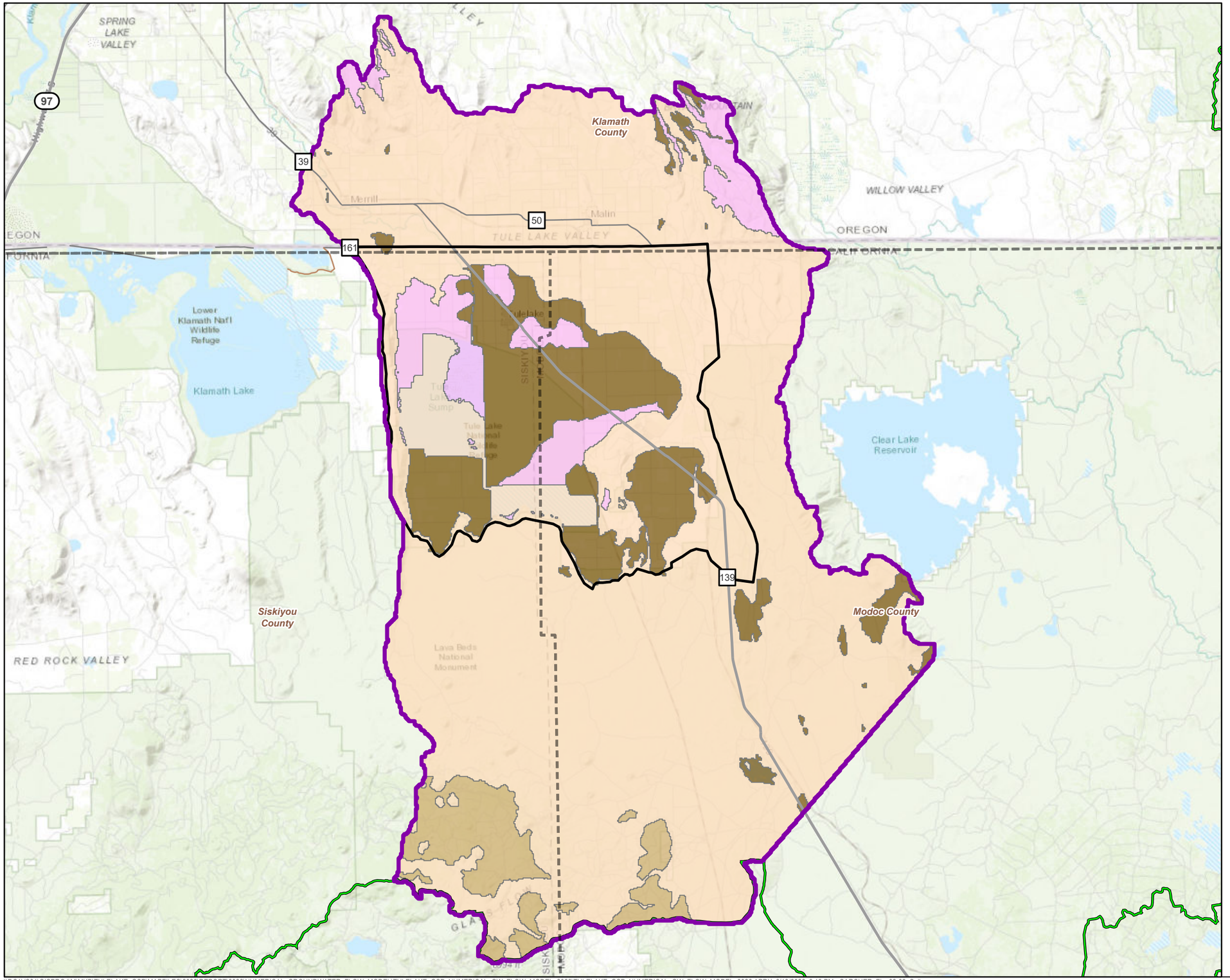
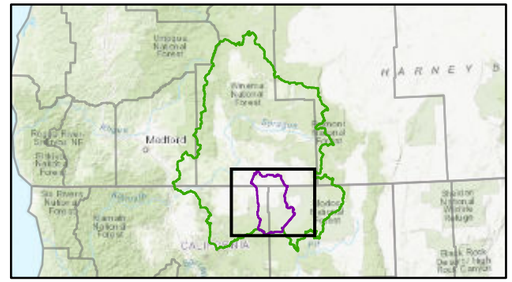
Figure 3-2
Modeled Land Surface Elevations
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Soil Type

- Sand
- Sandy Loam
- Silt
- Silty Clay

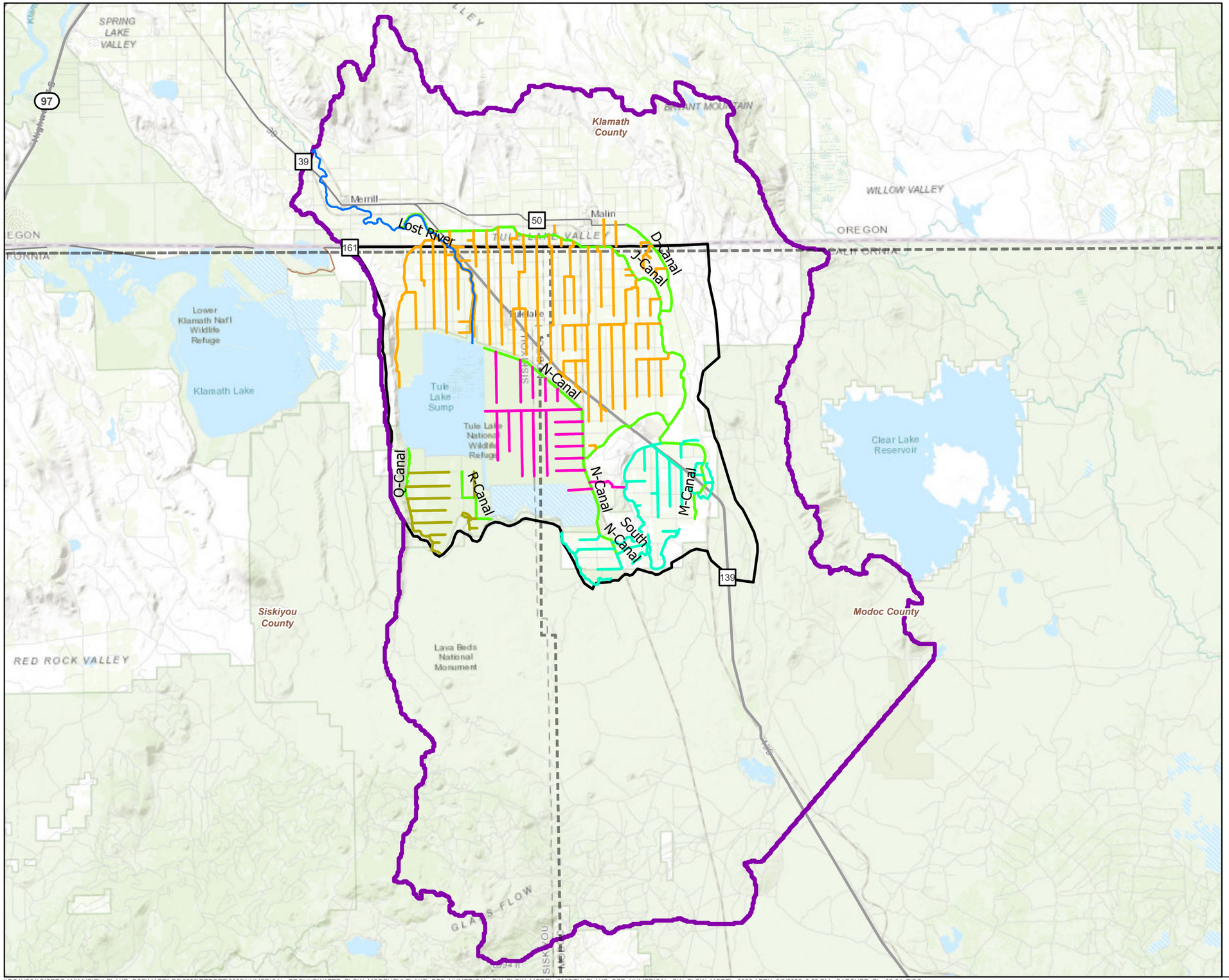
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

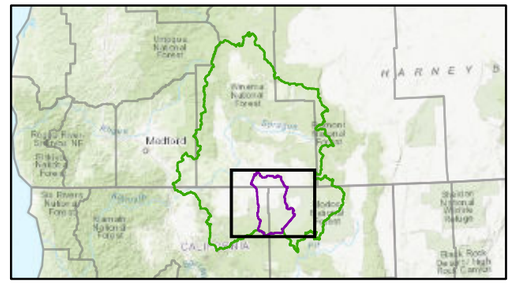
Miles
0 4 8

N

Figure 3-3
Modeled Distribution of Soil Types
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Lost River

TID Canal Laterals

- J System
- North N System
- M & South N Systems
- Q & R Systems

Notes:
TID = Tulelake Irrigation District

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

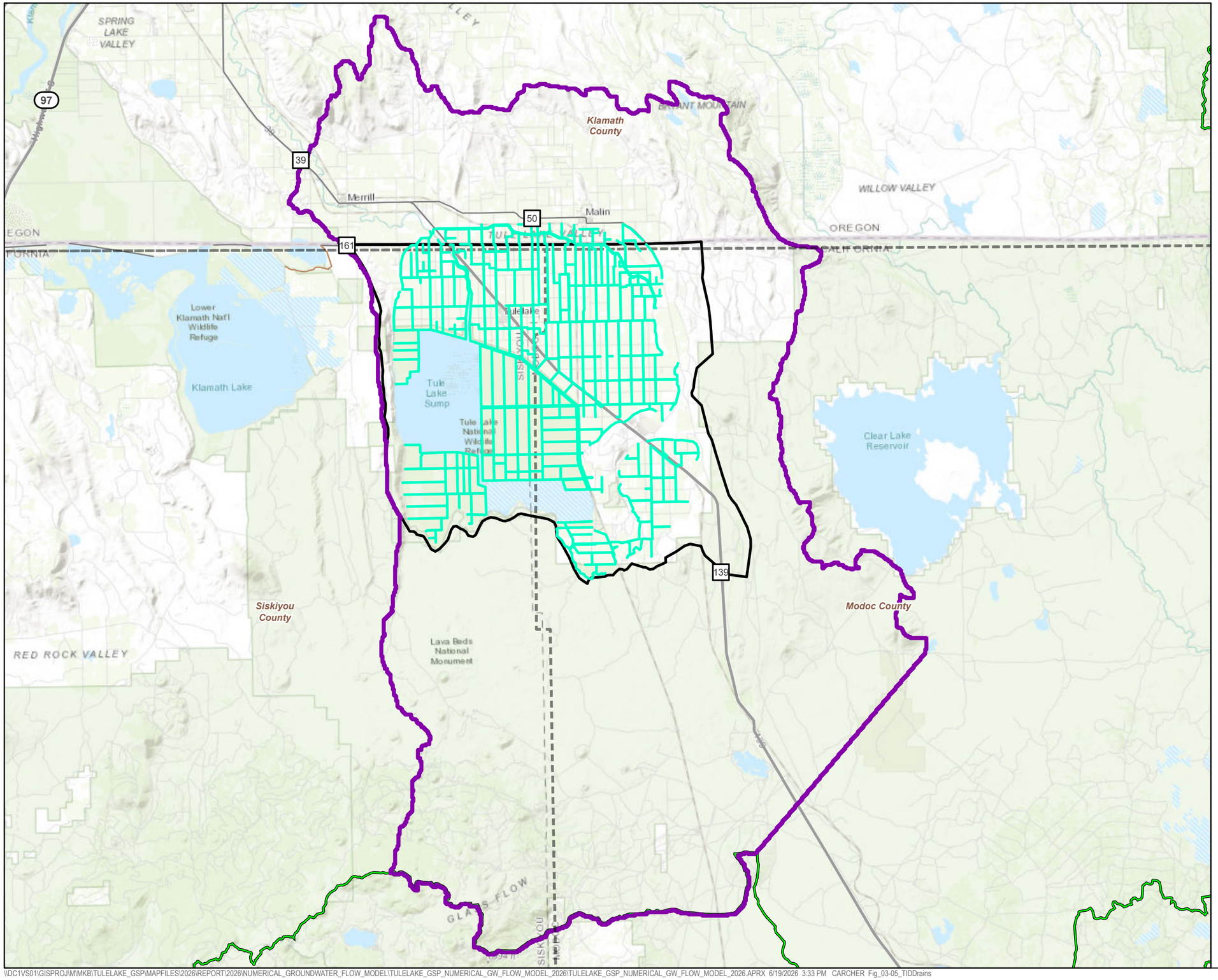
Miles
0 4 8

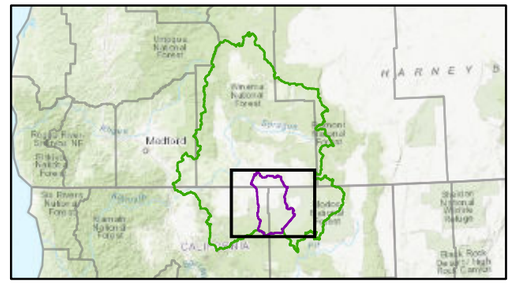
N

Figure 3-4
Simulated Lost River and Tulelake Irrigation District Conveyance Systems
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 9/9/2026 3:23 PM CARCHER Fig_03-04_TIDConveyance





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- TID Drains

Notes:
TID = Tulelake Irrigation District

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
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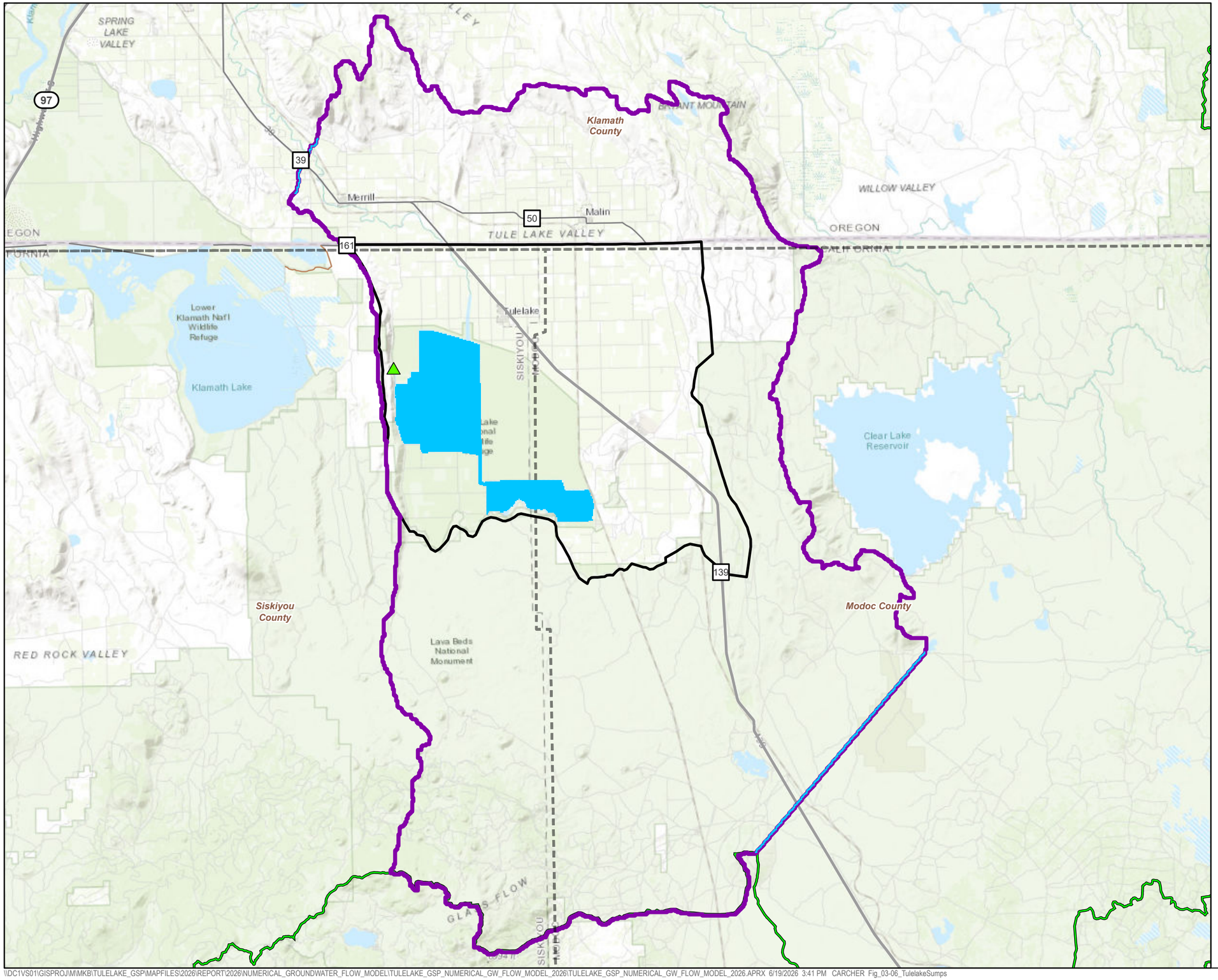
World Hillshade: Esri, NASA, NGA, USGS

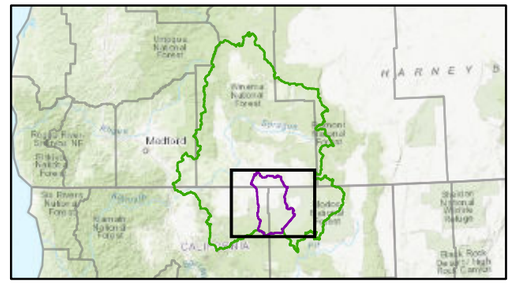
0 4 8 Miles

N

Figure 3-5
Simulated Tulelake Irrigation District Drains
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Model Grid
- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- D-Plant Pumping Location
- Tulelake Sumps

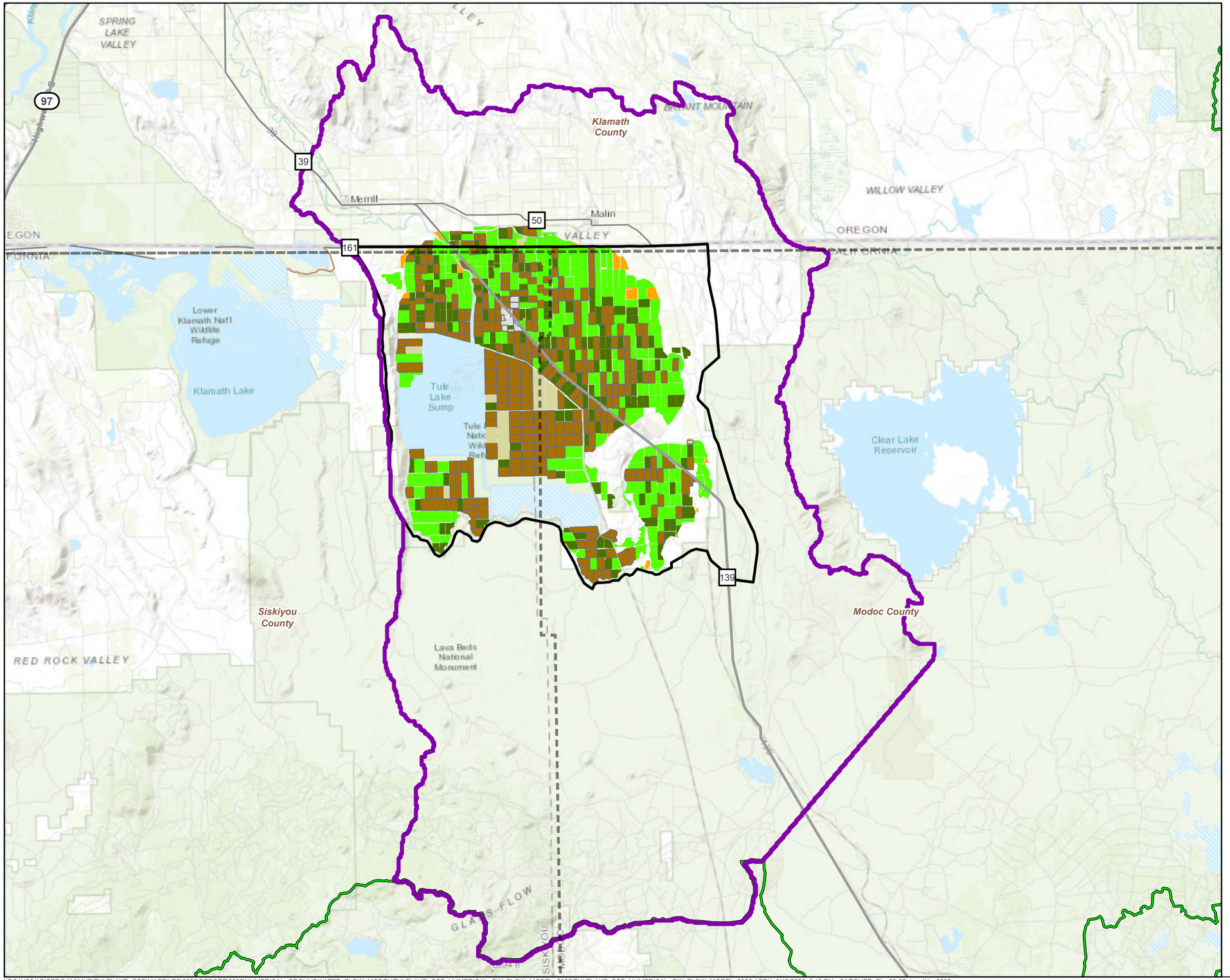
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

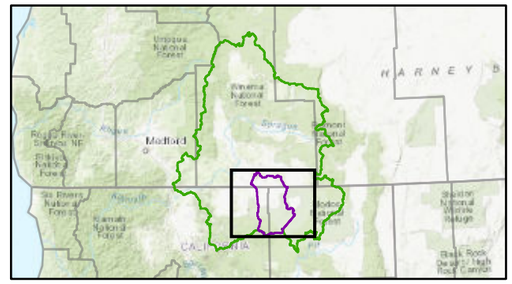
0 4 8 Miles

N

Figure 3-6
Simulated Tulelake Sumps
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Simulated Crop Category

- Alfalfa
- All Other Crops
- Grains
- Idle
- Pasture
- Urban

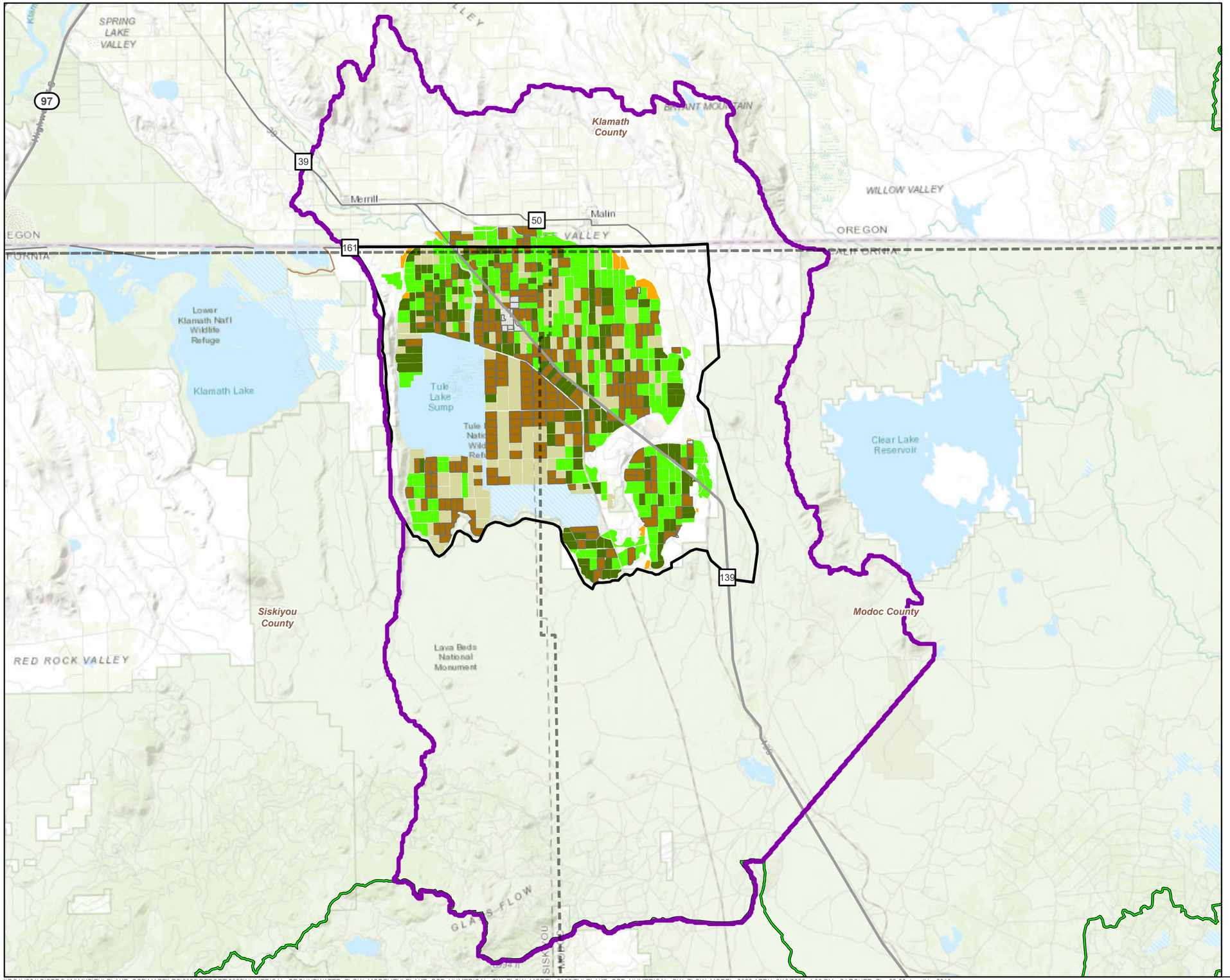
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

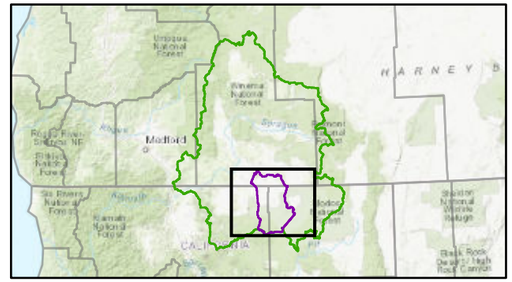
Miles
0 4 8

N

Figure 3-7
2008 Simulated Tulelake Irrigation District Land Use
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Simulated Crop Category

- Alfalfa
- All Other Crops
- Grains
- Idle
- Pasture
- Urban

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

Figure 3-8
2010 Simulated Tulelake Irrigation District Land Use
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

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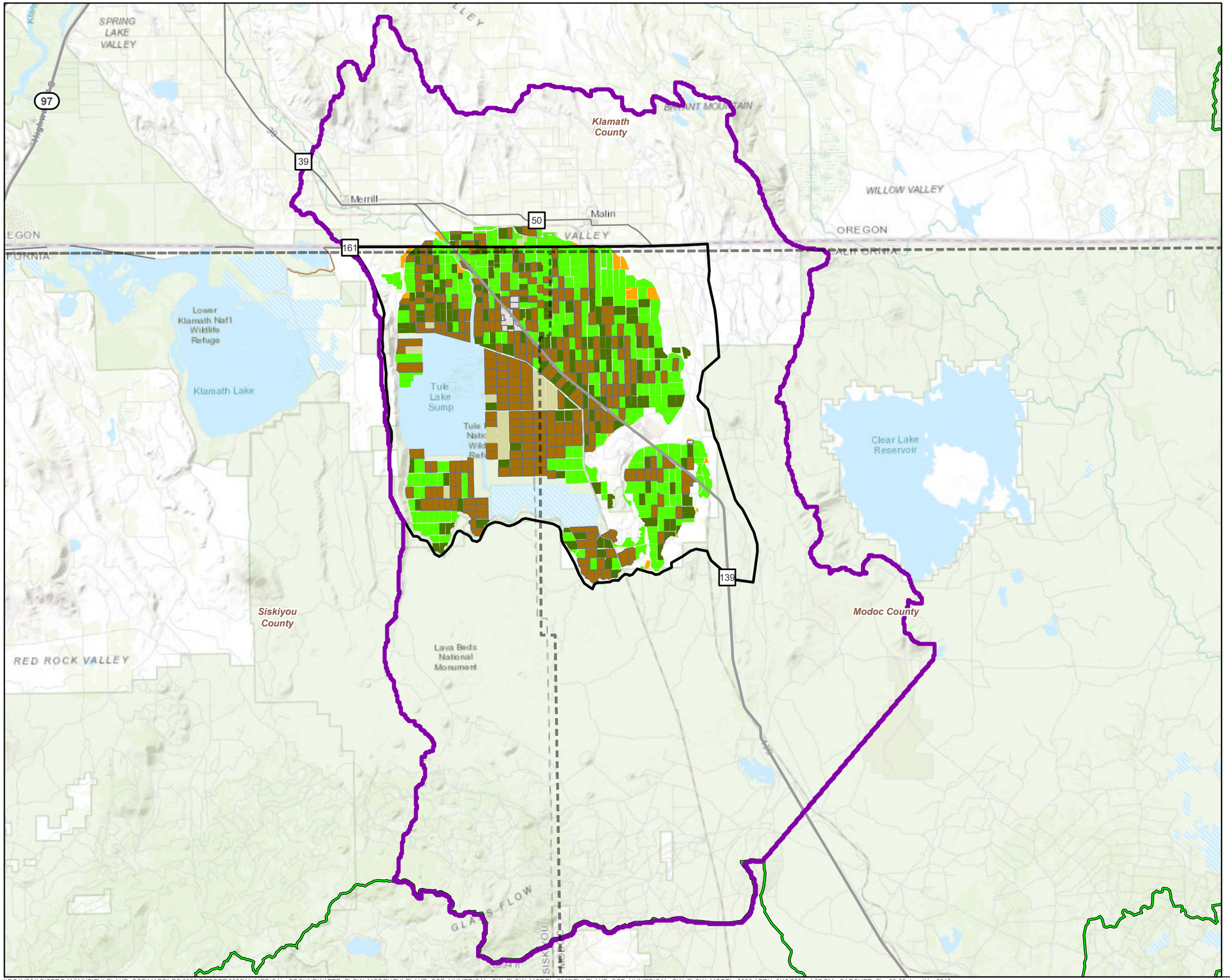
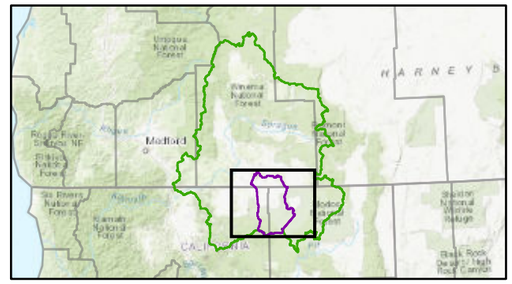




LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Simulated Crop Category

- Alfalfa
- All Other Crops
- Grains
- Idle
- Pasture
- Urban

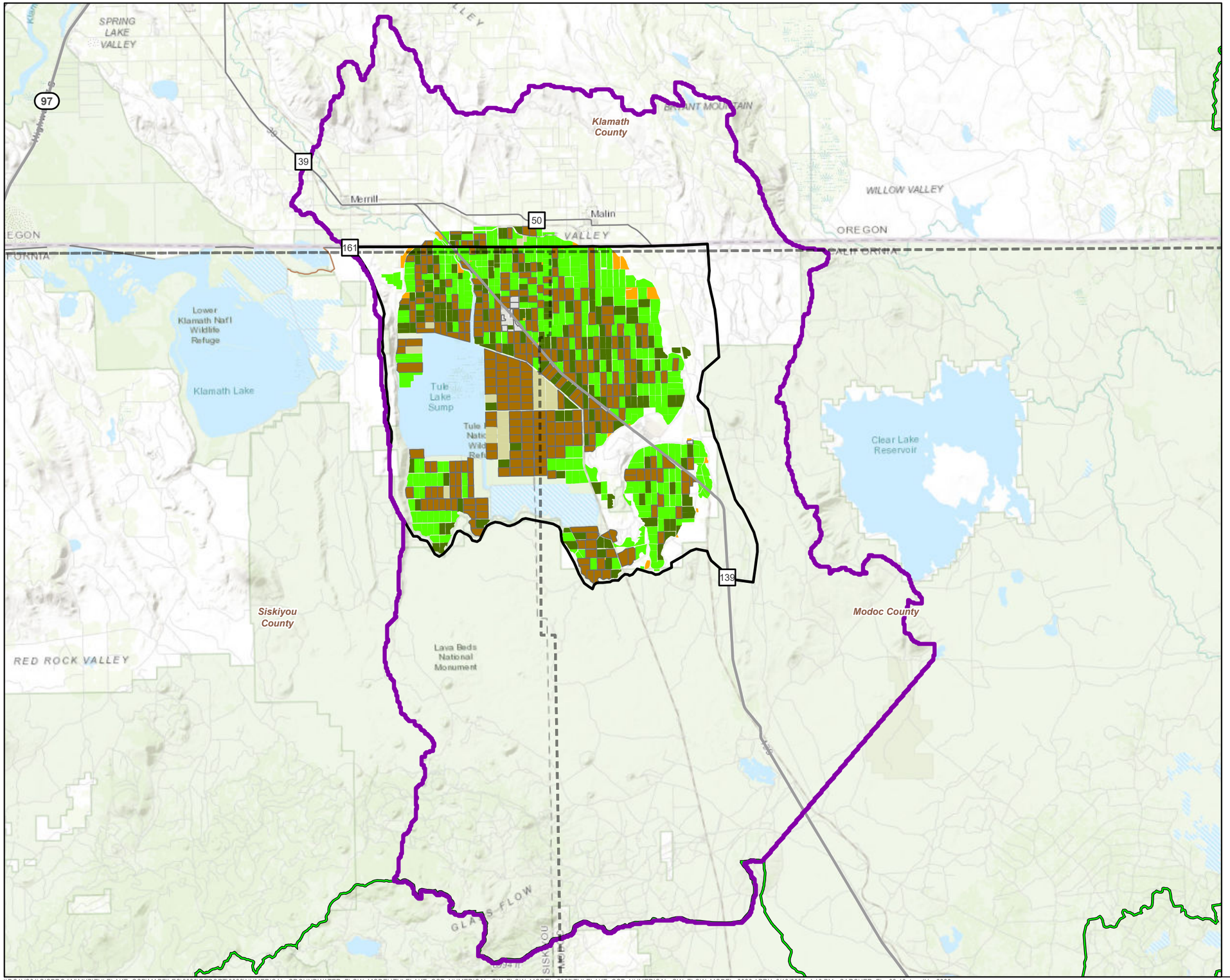
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

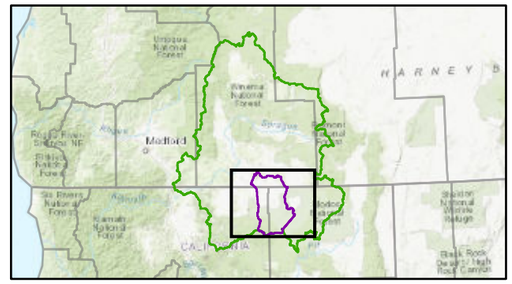
0 4 8 Miles

N

Figure 3-9
2019 Simulated Tulelake Irrigation District Land Use
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Simulated Crop Category

- Alfalfa
- All Other Crops
- Grains
- Idle
- Pasture
- Urban

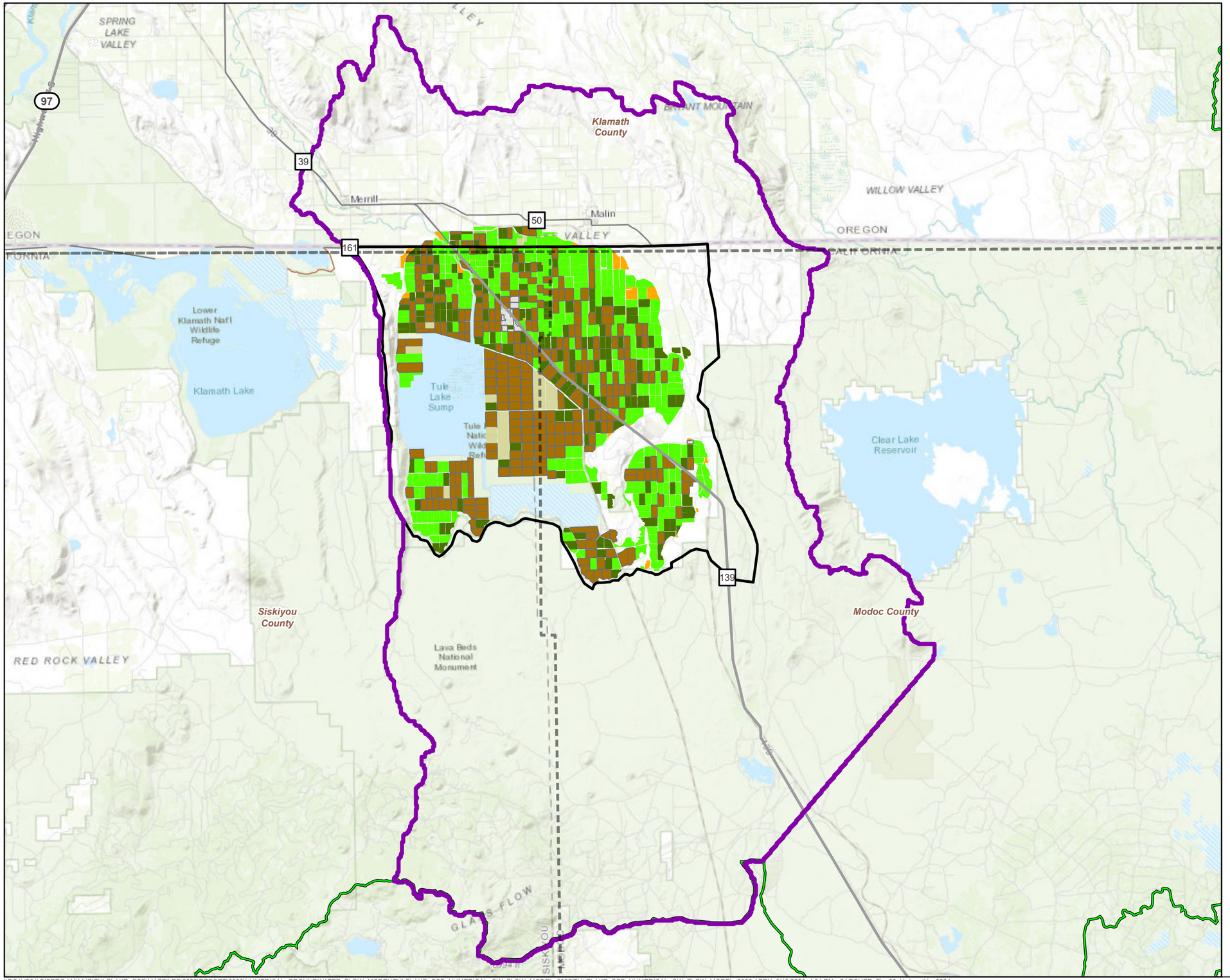
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

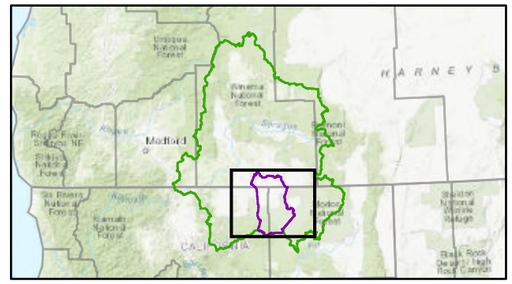
0 4 8 Miles

N

Figure 3-10
2022 Simulated Tulelake Irrigation District Land Use
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Simulated Crop Category

- Alfalfa
- All Other Crops
- Grains
- Idle
- Pasture
- Urban

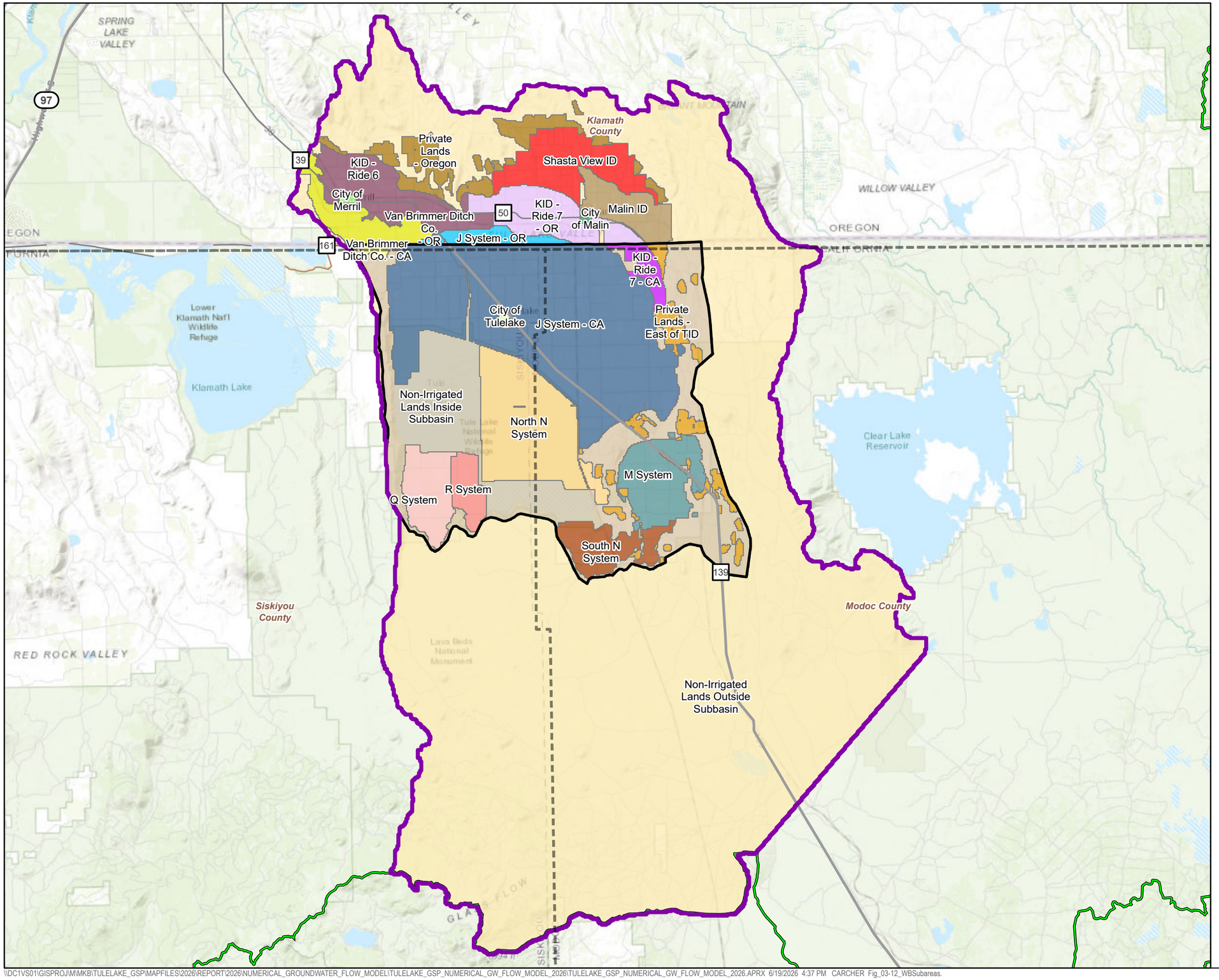
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

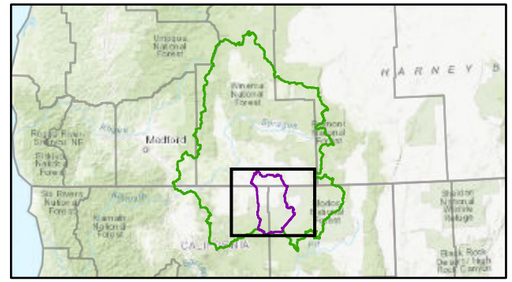
0 4 8 Miles

N

Figure 3-11
2024 Simulated Tulelake Irrigation District Land Use
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Water Balance Subareas

- City of Malin
- City of Merril
- City of Tulelake
- J System - CA
- J System - OR
- KID - Ride 6
- KID - Ride 7 - CA
- KID - Ride 7 - OR
- M System
- Malin ID
- Non-Irrigated Lands Inside Subbasin
- Non-Irrigated Lands Outside Subbasin
- North N System
- Private Lands - East of TID
- Private Lands - Oregon
- Q System
- R System
- Shasta View ID
- South N System
- Van Brimmer Ditch Co. - CA
- Van Brimmer Ditch Co. - OR

Notes:
TID = Tulelake Irrigation District
KID = Klamath Irrigation District
ID = Irrigation District
CA = California
OR = Oregon

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

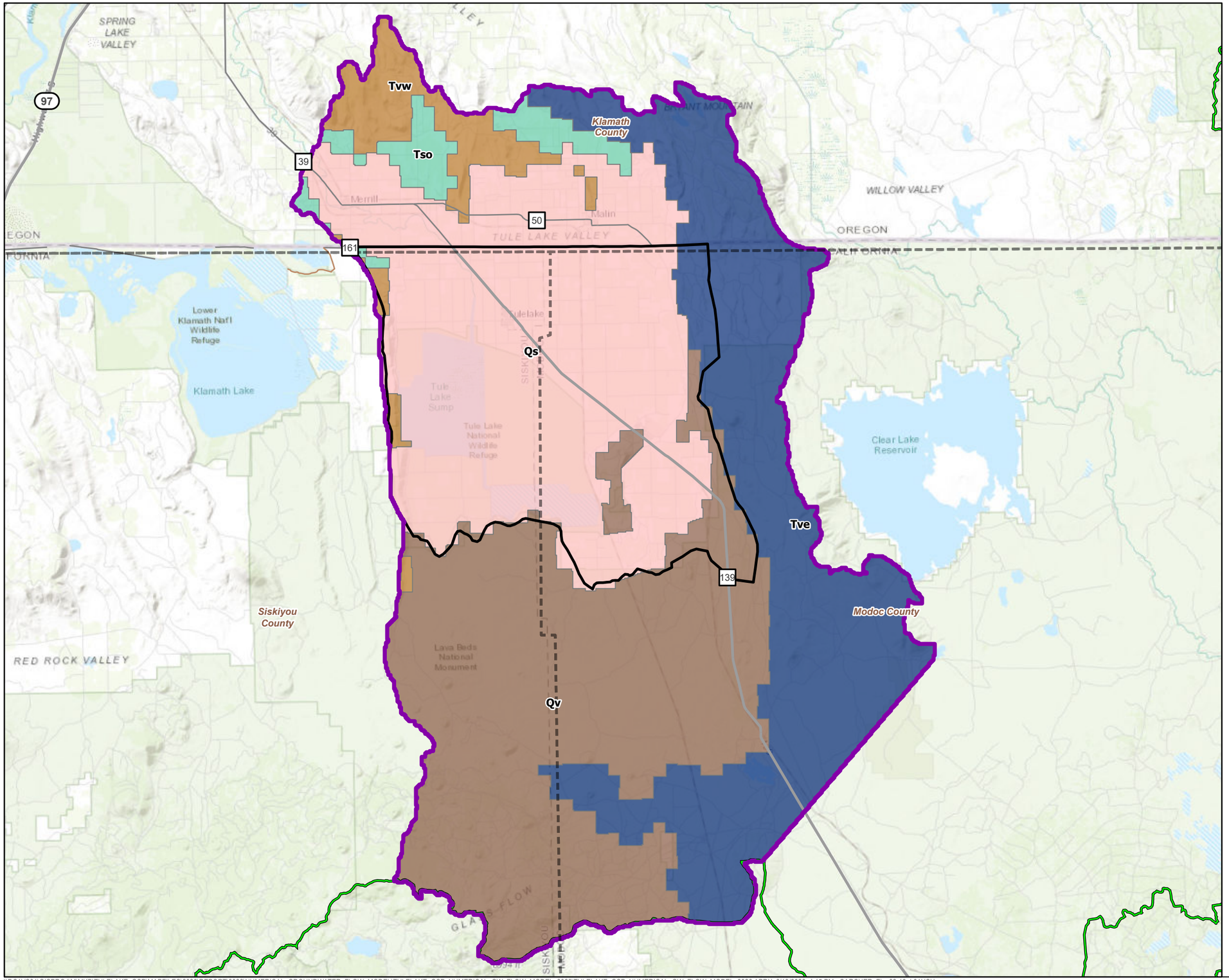
0 4 8 Miles

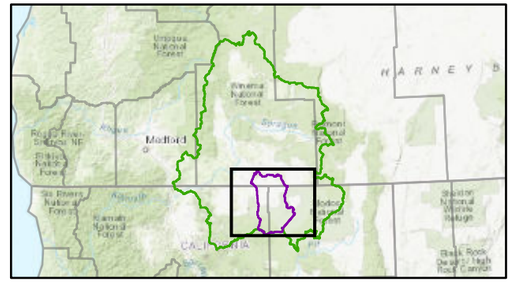
N

Figure 3-12
Modeled Water Balance Subareas
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 6/19/2026 4:37 PM CARCHER Fig_03-12_WBSubareas.





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Hydrostratigraphic Unit

- Qs
- Qv
- Tso
- Tve
- Tvw

Notes:
Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tso = Tertiary sedimentary rocks (older basins)
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)

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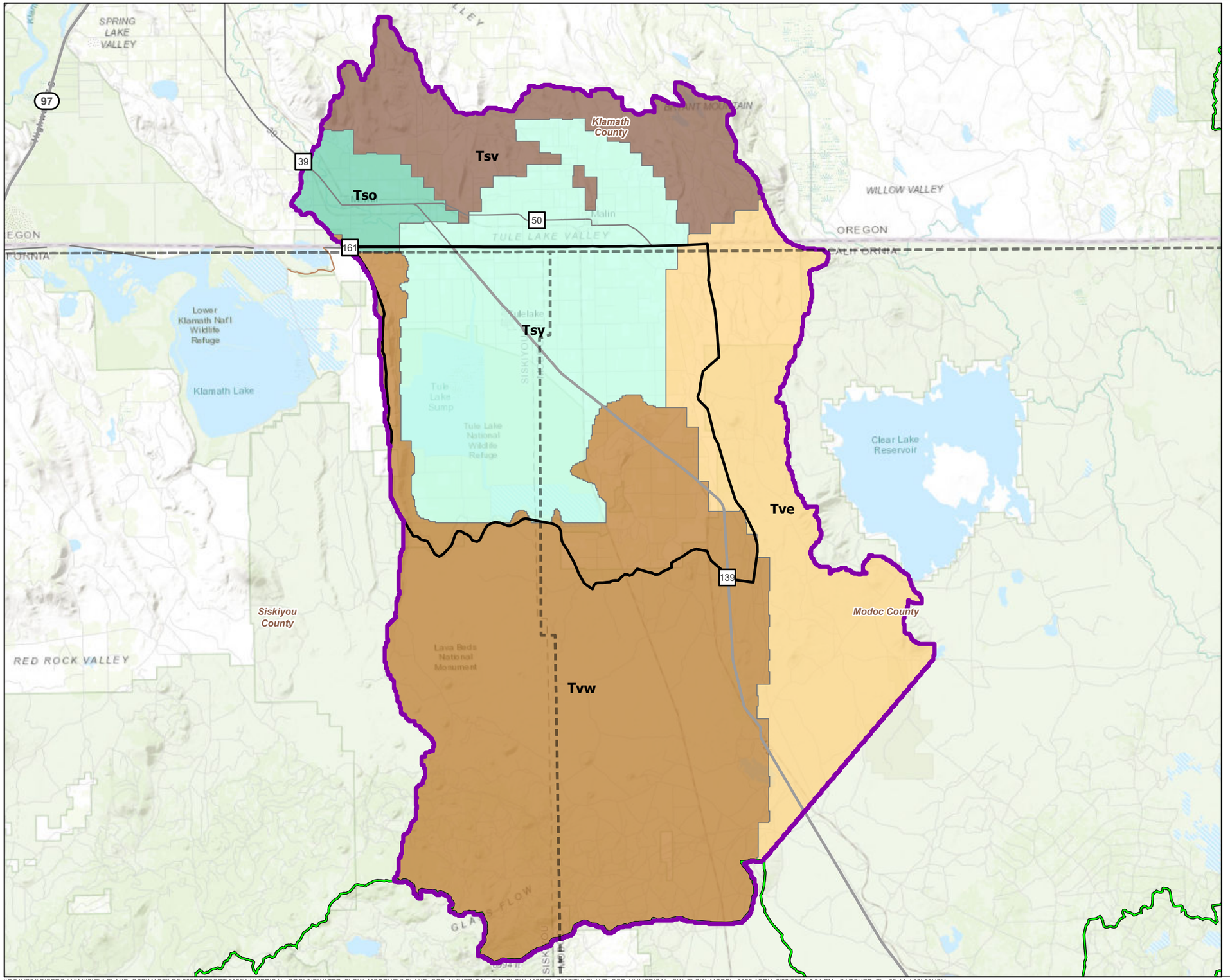
World Hillshade: Esri, NASA, NGA, USGS

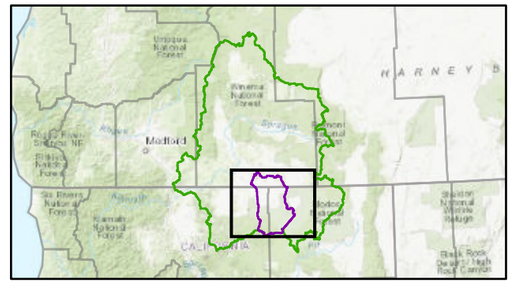
0 4 8 Miles

N

Figure 3-13
Model Layer 1 Hydrostratigraphic Units
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Hydrostratigraphic Unit

- Tso
- Tsv
- Tsy
- Tve
- Tvw

Notes:
Tso = Tertiary sedimentary rocks (older basins)
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)
Tsv = Tertiary mixed sedimentary and volcanic deposits
Tsy = Tertiary sedimentary rocks (younger basins)

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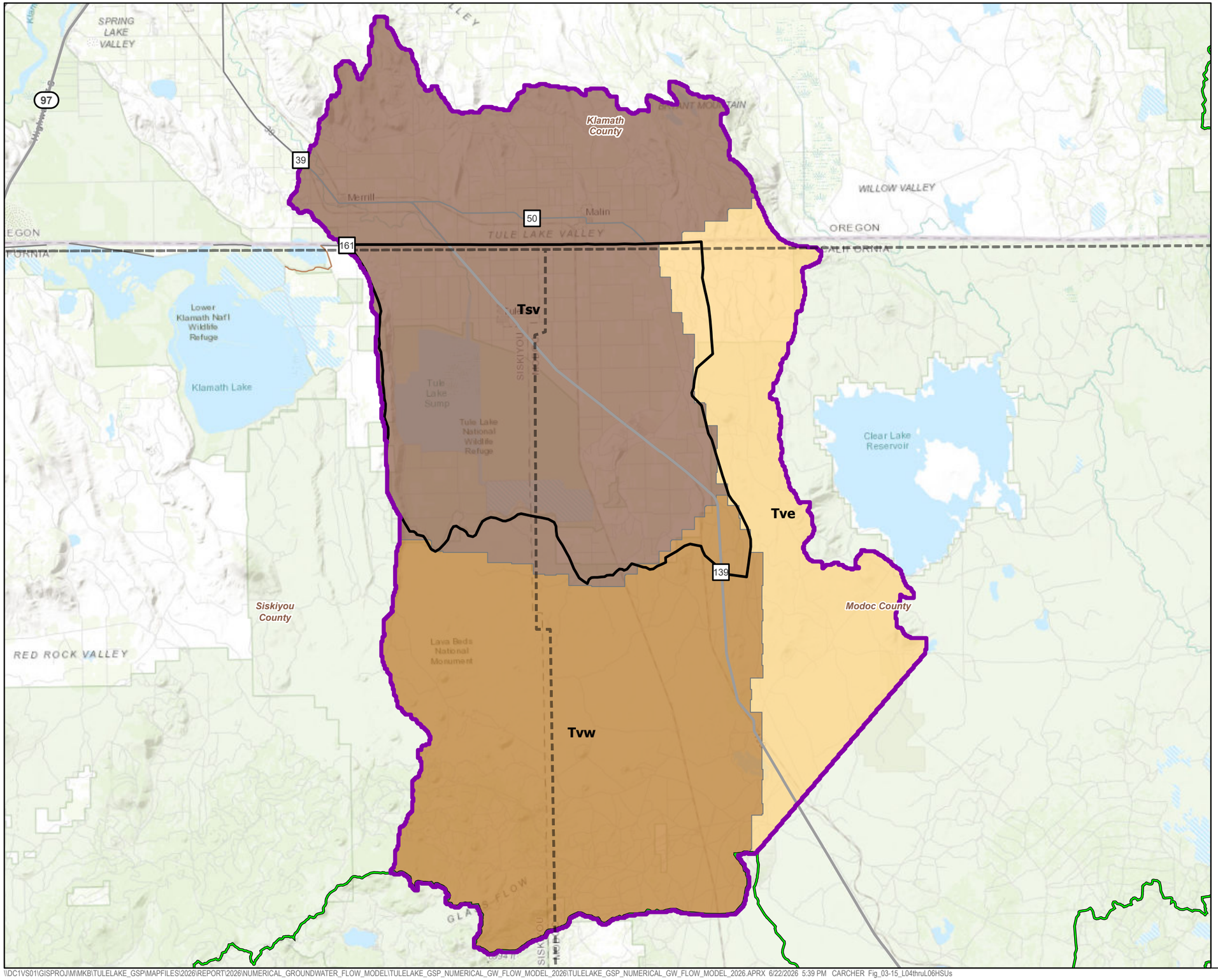
World Hillshade: Esri, NASA, NGA, USGS

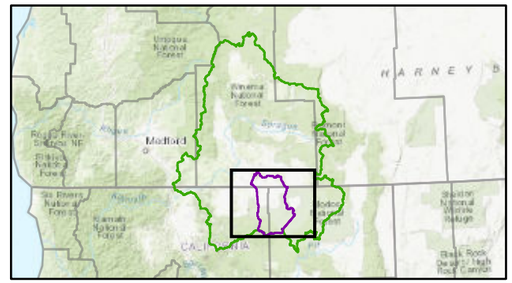
Miles
0 4 8

N

Figure 3-14
Model Layers 2 and 3 Hydrostratigraphic Units
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Hydrostratigraphic Unit

- Tsv
- Tve
- Tvw

Notes:
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)
Tsv = Tertiary mixed sedimentary and volcanic deposits

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

Figure 3-15
Model Layers 4 through 6 Hydrostratigraphic Units
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

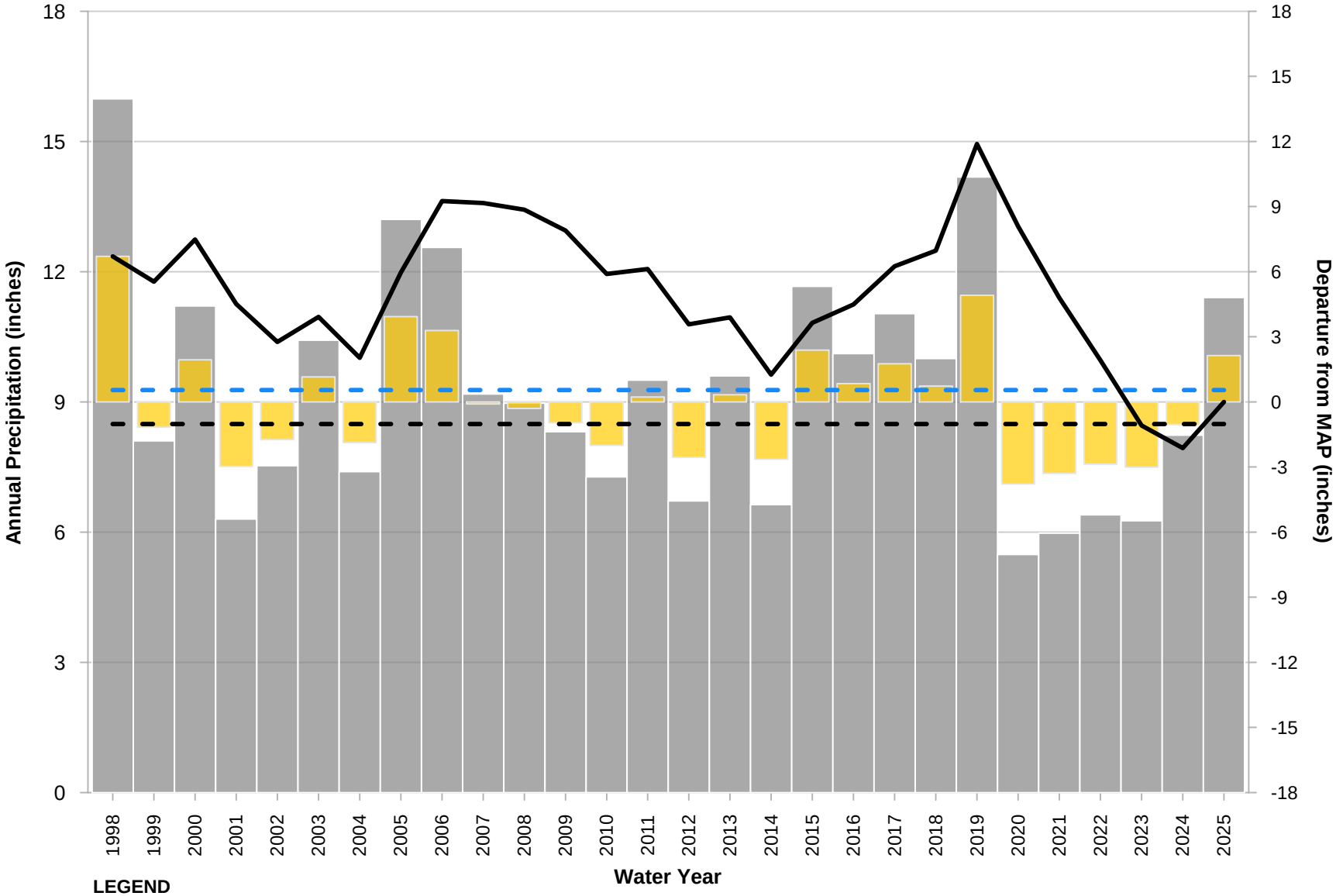


Figure 3-16
Modeled Historical Annual Precipitation
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

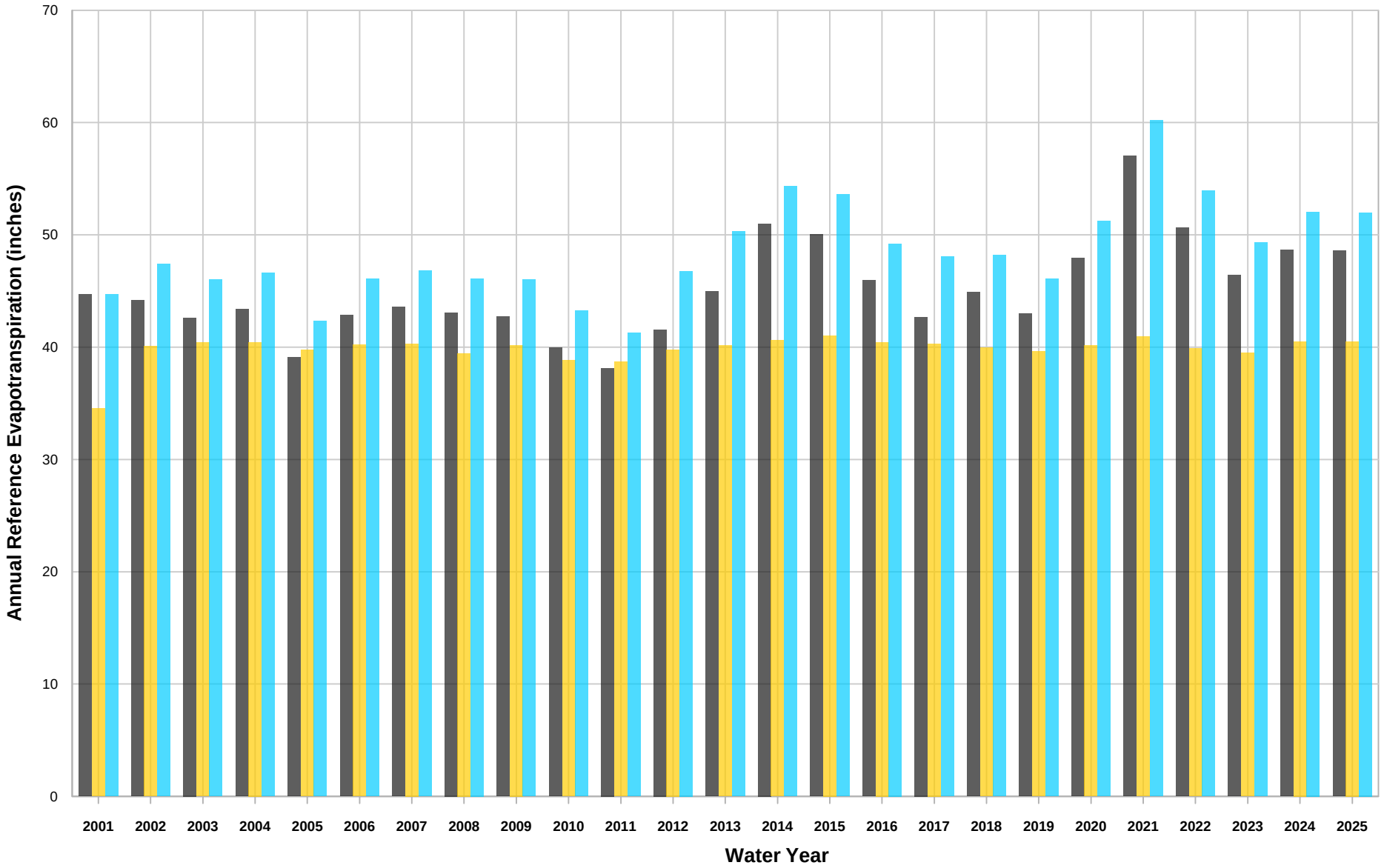


Figure 3-17
Historical Annual Reference Evapotranspiration
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

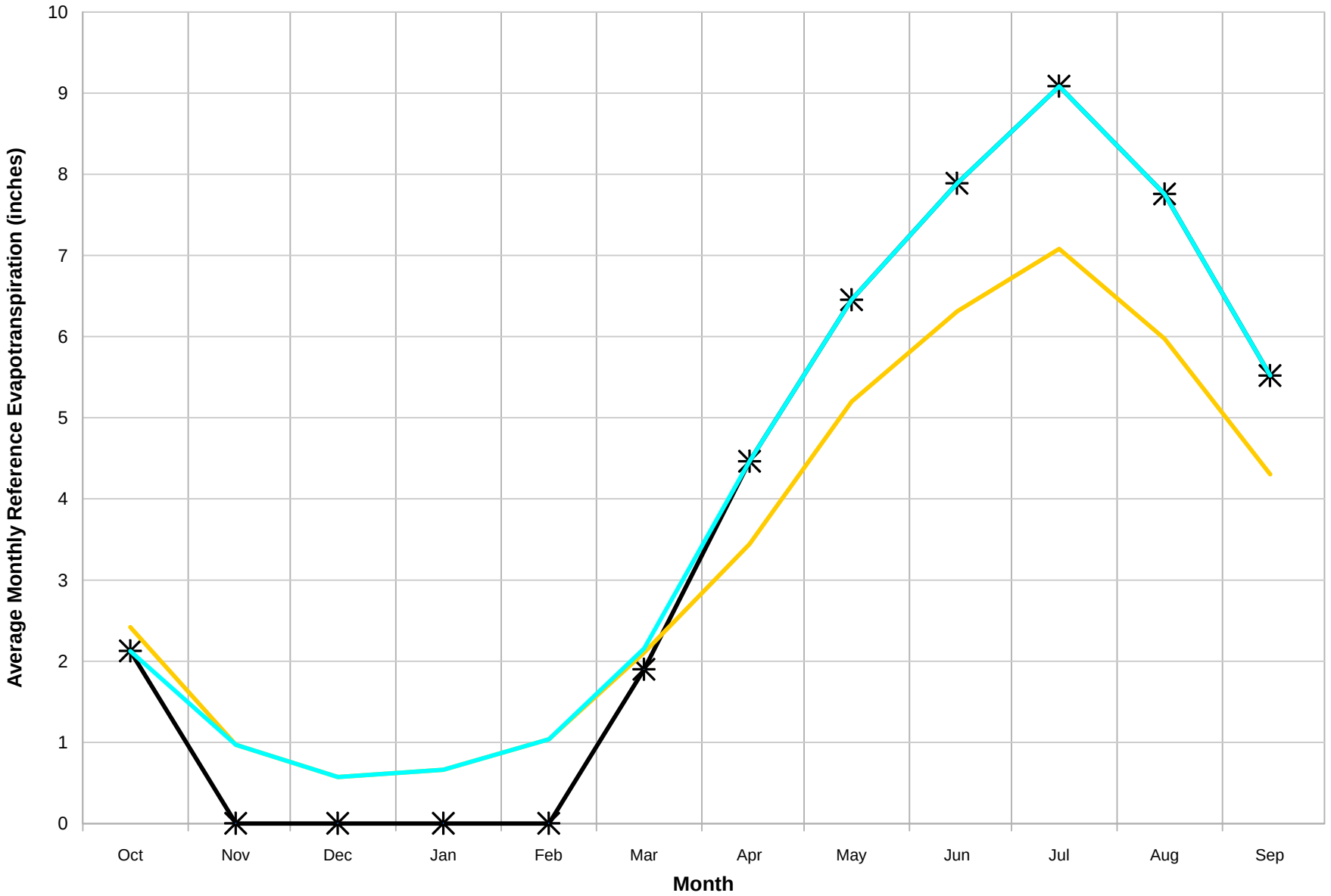


Figure 3-18
Monthly Average Reference Evapotranspiration
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

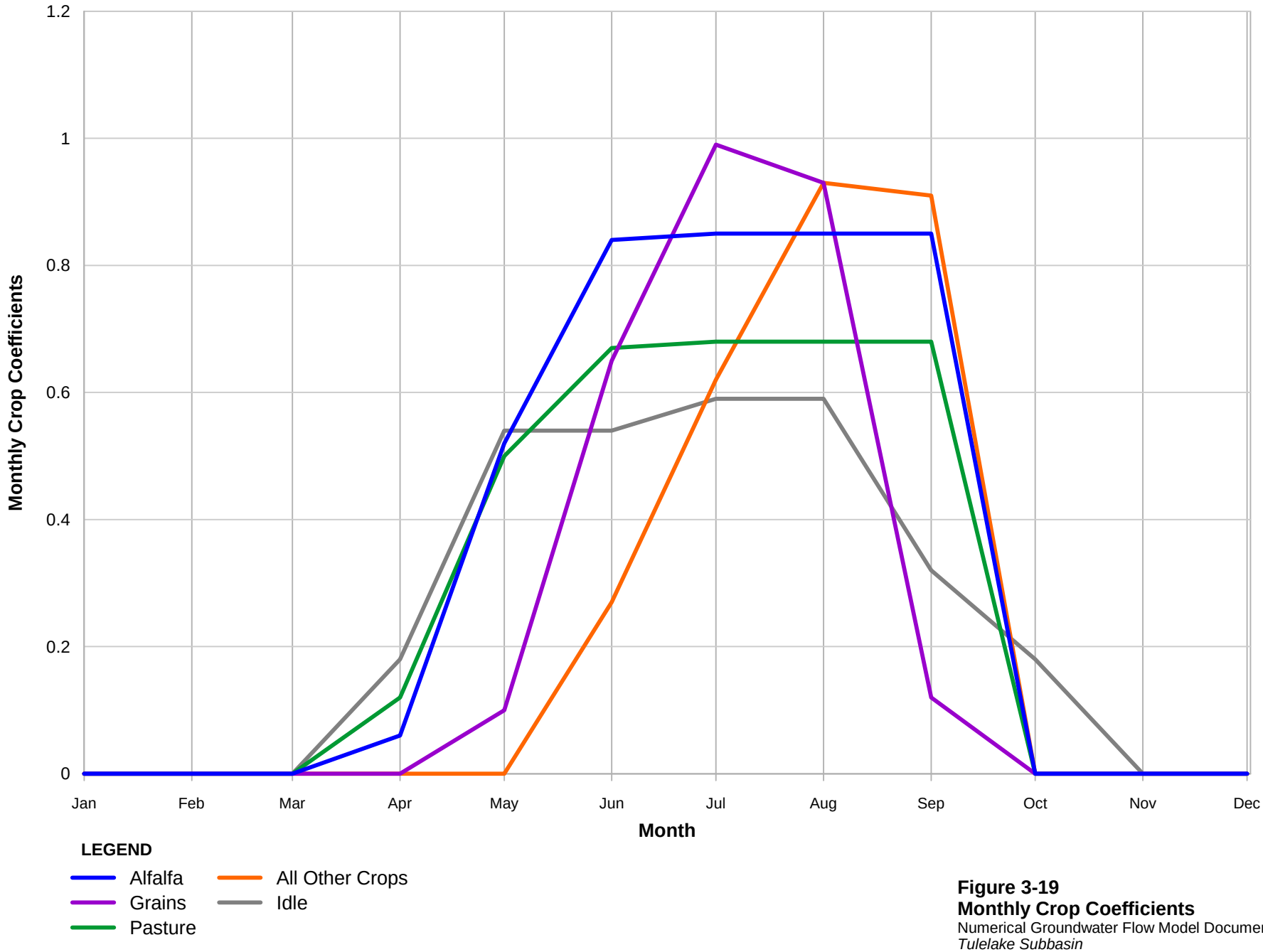


Figure 3-19
Monthly Crop Coefficients
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

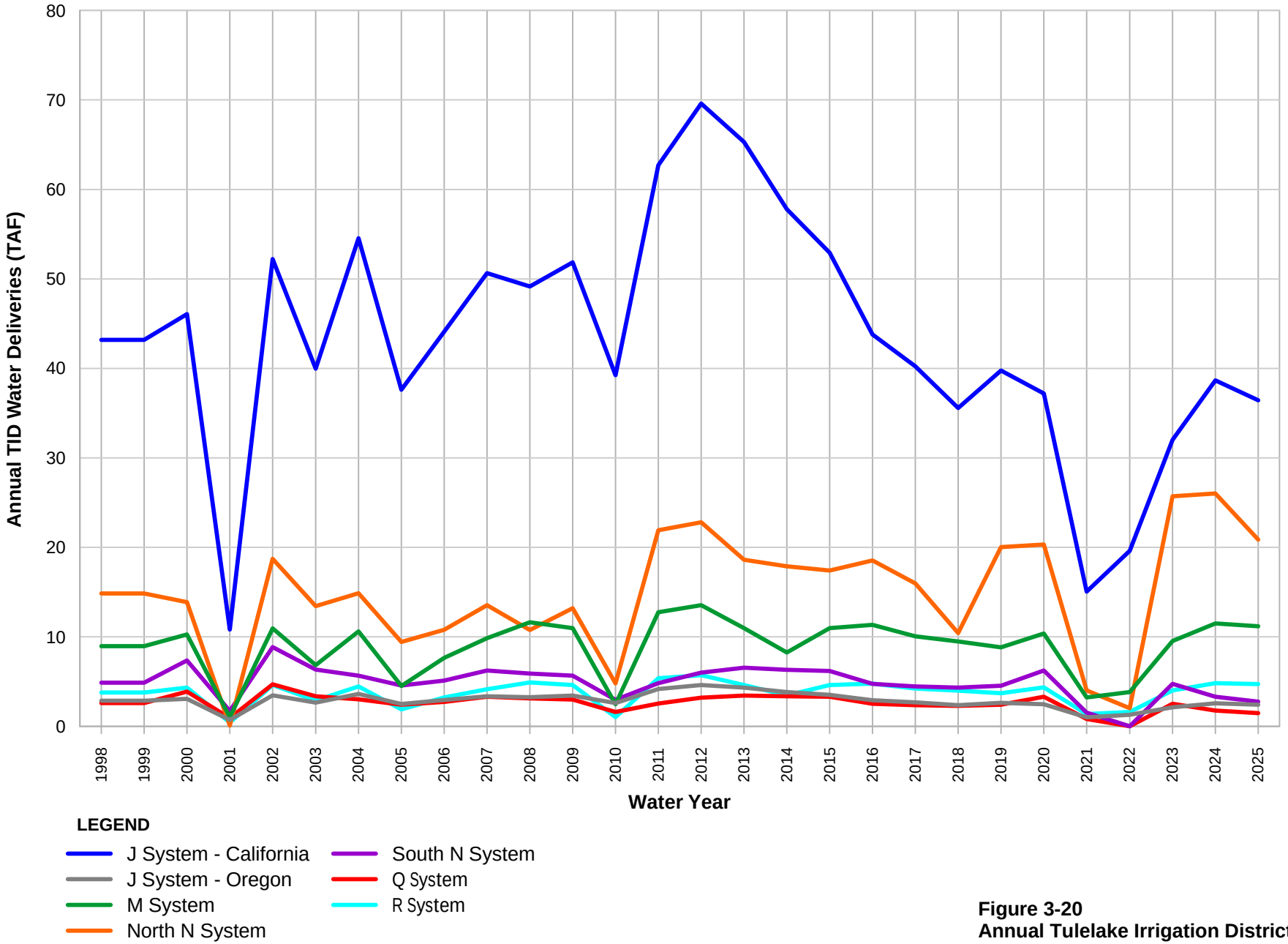
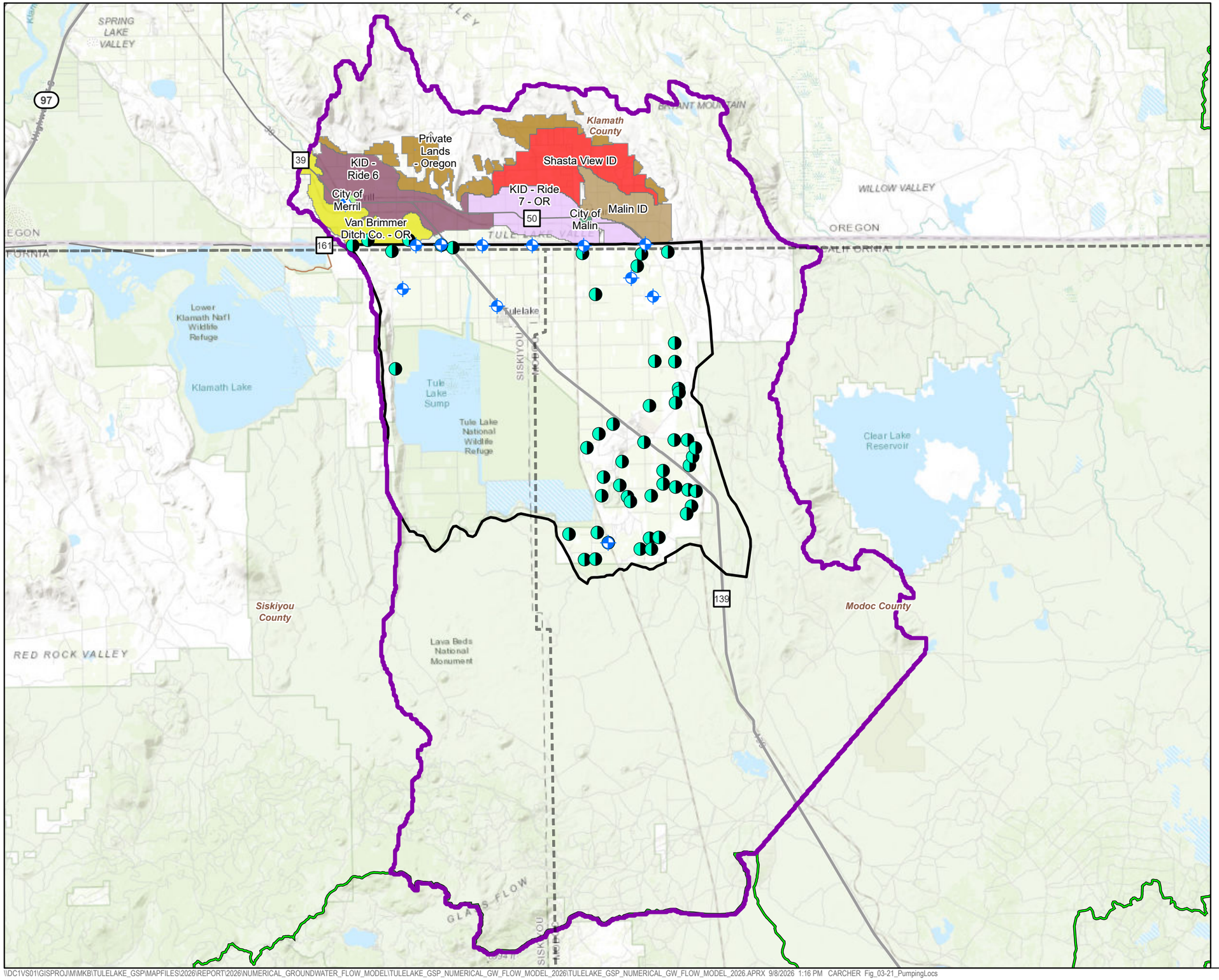
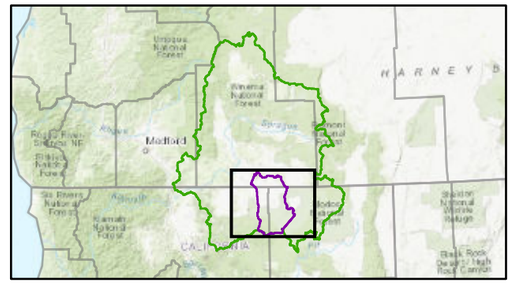


Figure 3-20
Annual Tulelake Irrigation District Water Deliveries
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Water Balance Subareas

- City of Malin
- City of Merril
- KID - Ride 6
- KID - Ride 7 - OR
- Malin ID
- Private Lands - Oregon
- Shasta View ID
- Van Brimmer Ditch Co. - OR

Multi-Node Well 2 Package

- Private Agricultural Pumping Well (FMP)
- TID or Municipal Pumping Well (Measured Rates)

Notes:

1. Private agricultural pumping is calculated by FMP based on any demand remaining after precipitation, shallow groundwater, and available surface water supplies.
2. Private agricultural pumping in Oregon is distributed across the water budget areas presented.

FMP = Farm Process Package
ID = Irrigation District
KID = Klamath Irrigation District
OR = Oregon
TID = Tulelake Irrigation District

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

Figure 3-21
Simulated Pumping Well Locations
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

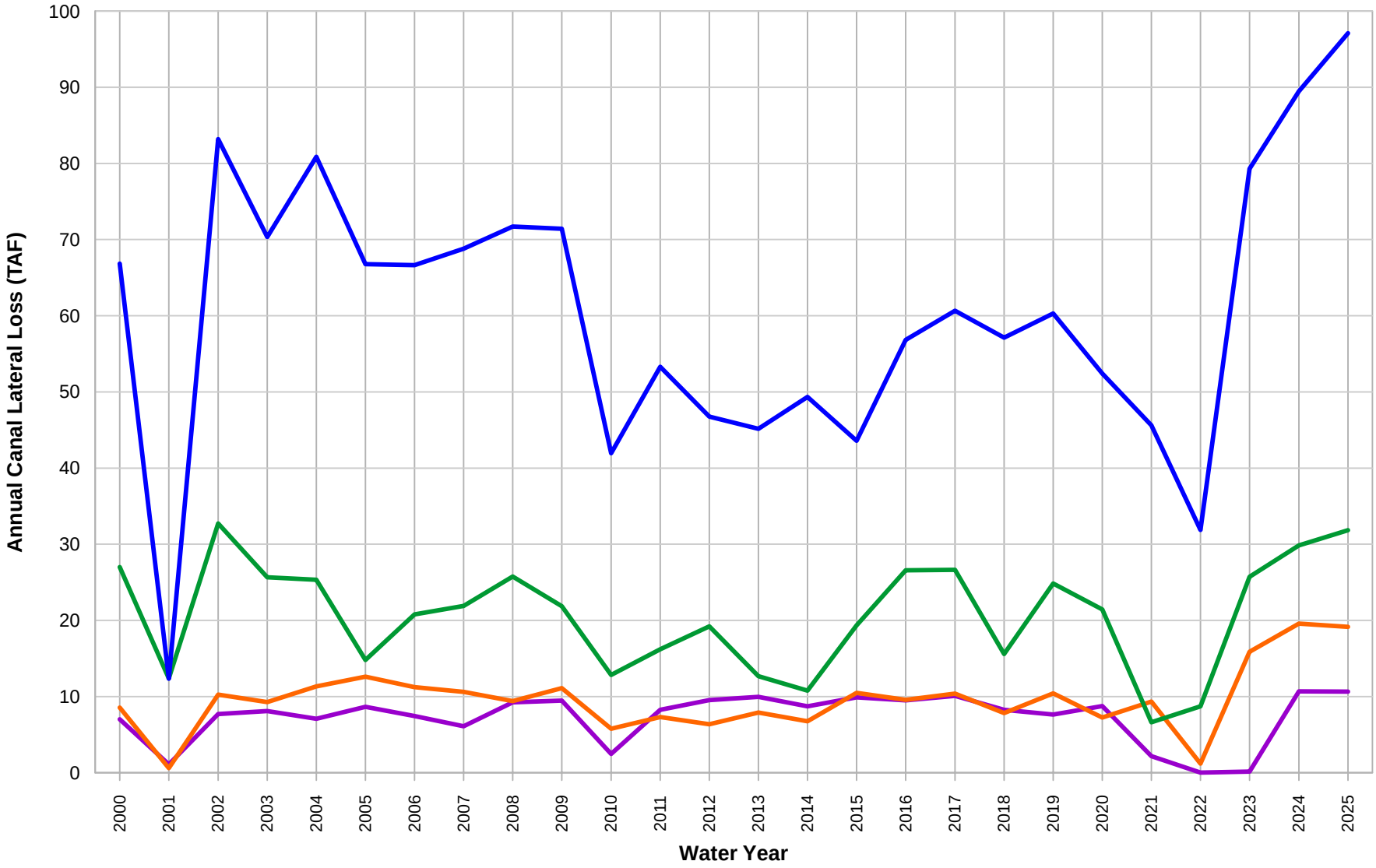
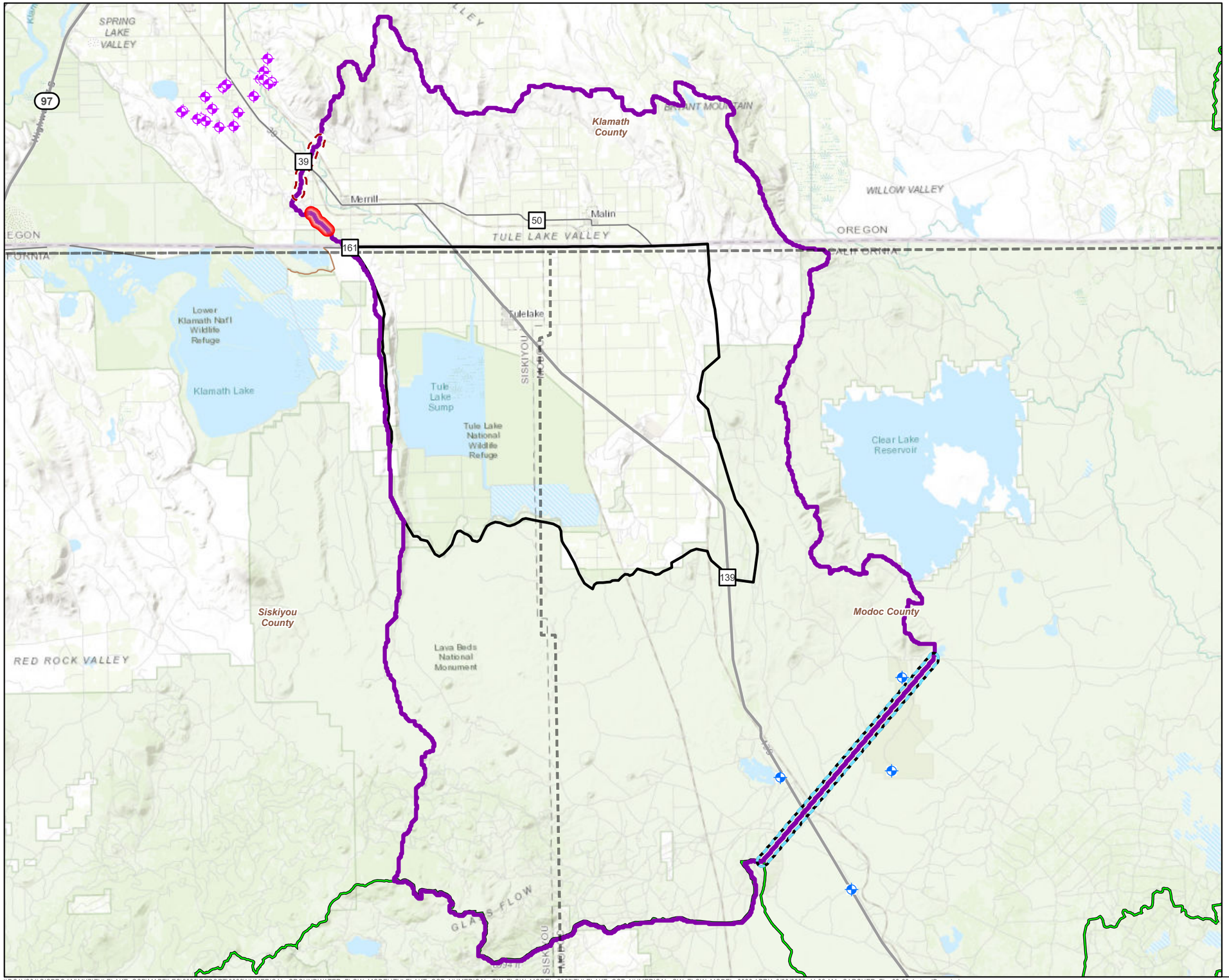
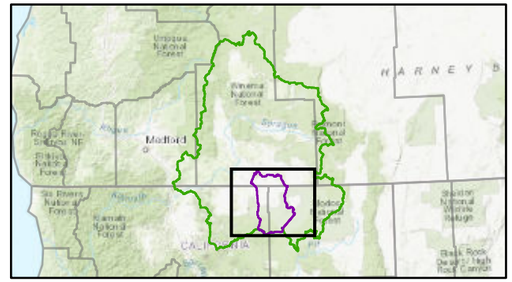


Figure 3-22
Annual Estimated Canal Lateral Leakage
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Northwestern General Head Boundary
- Southern General Head Boundary
- Northern General Head Boundary
- Northern Boundary Wells
- Southern Boundary Wells

Service Layer Credits: USA Counties - Generalized: Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS)
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

FIGURE 3-23
Lateral Subsurface Boundary Locations
Numerical Groundwater Flow Model Documentation
Tulelake Groundwater Subbasin

Jacobs

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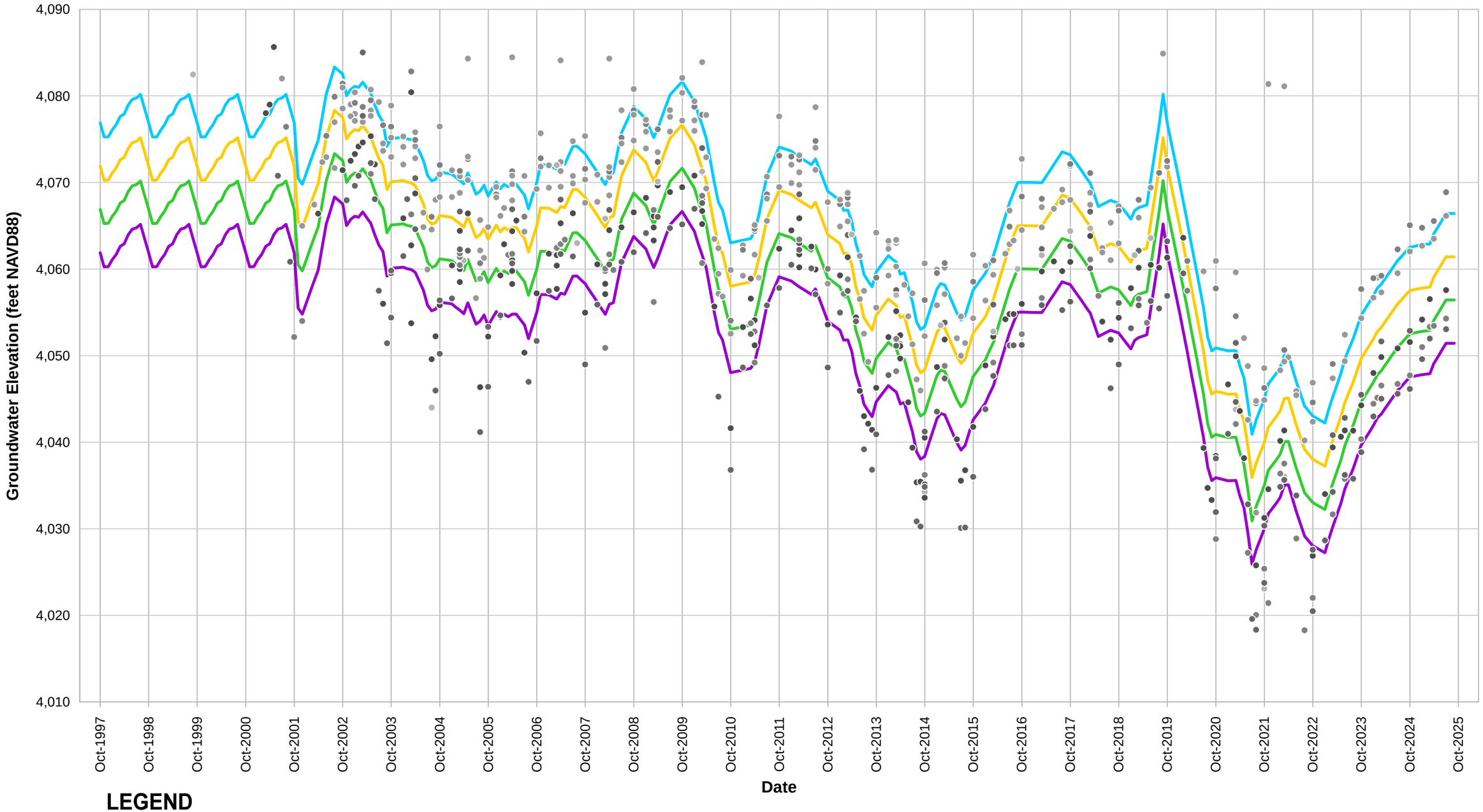
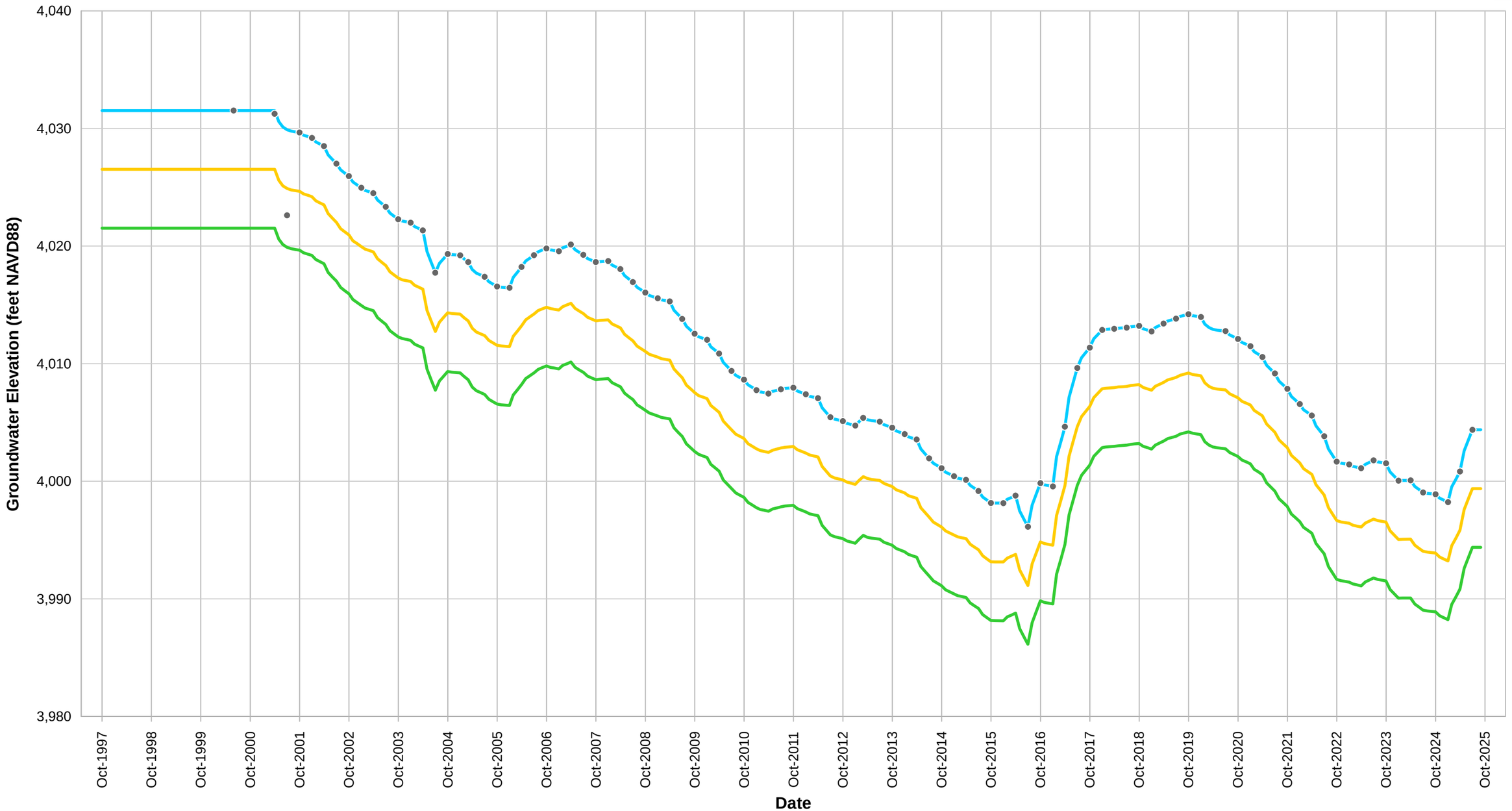


Figure 3-24
Northern General Head Boundary Water Level Data
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs



LEGEND

- Simulated Head (Layer 1-Layer 4)
- Simulated Head (Layer 5)
- Simulated Head (Layer 6)
- USGS-414043121155501

Figure 3-25
Southern General Head Boundary Water Level Data
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

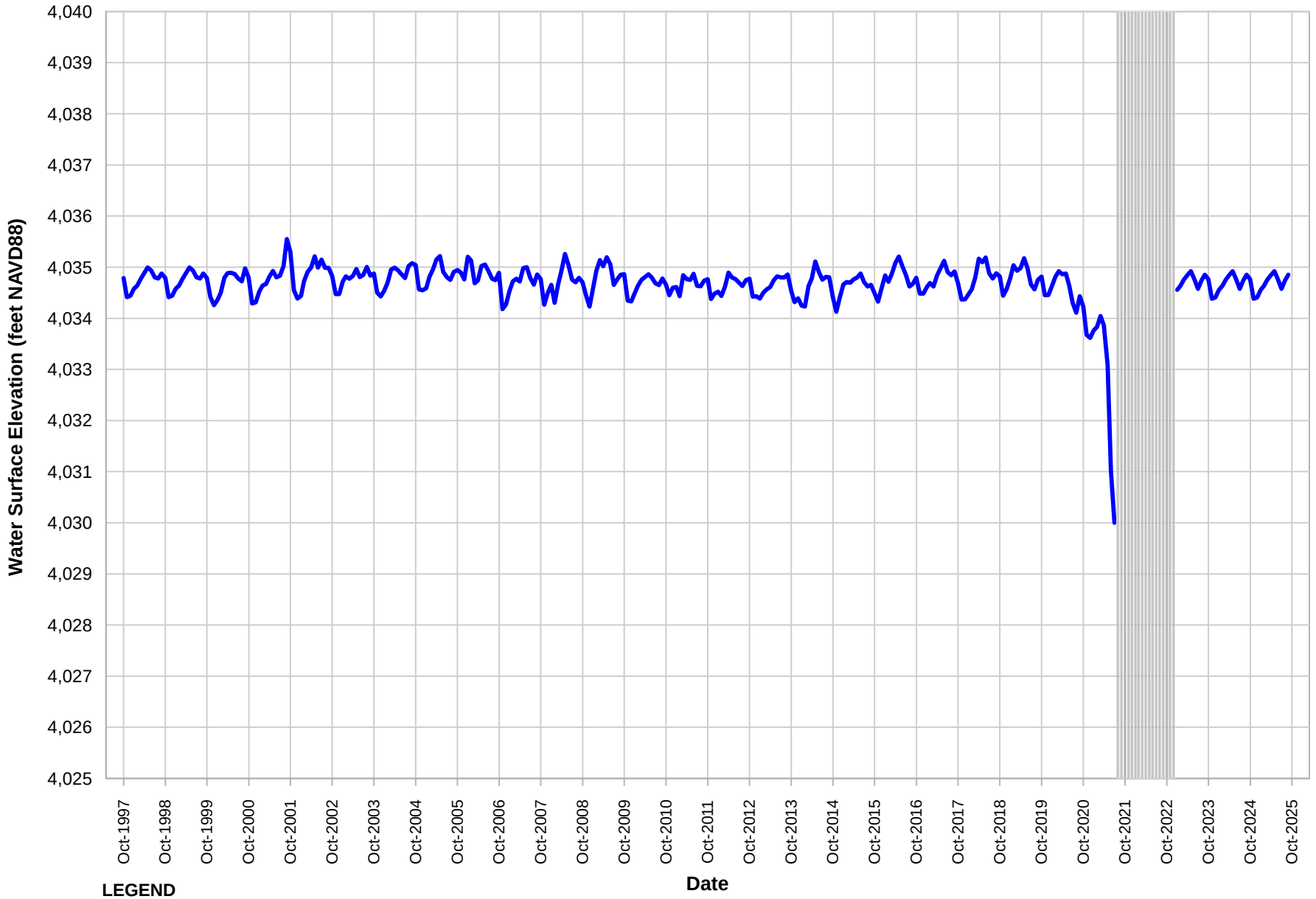


Figure 3-26
Tulelake Sumps Historical Water Surface Elevation
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

4. Model Calibration

Model calibration is a process of tuning numerical model parameters to adequately replicate measured field conditions of interest. The numerical models described herein were calibrated in accordance with the Standard Guide for Calibrating a Ground-Water Flow Model Application (American Society for Testing and Materials, 1996) and the Modeling BMP (DWR, 2016a). As described in Section 3.5, WYs 1998 through 2025 were selected as the historical simulation period; however, the historical calibration period has been selected as WYs 2000 through 2025 due to the availability of data associated with surface-water conditions, land use, groundwater pumping, and Tulelake Sump water surface elevation. This section discusses the calibration targets, process, and results, including the historical and current water budgets.

4.1 Calibration Targets

Quantitative and qualitative calibration targets were selected to evaluate progress during calibration of the GSA Model. Time-varying heads at well locations throughout the greater physical subbasin served as quantitative calibration targets. Calibration involved adjusting Kh, Kv, storativity, RIV and DRN Package conductance, and other boundary-condition parameters within reasonable ranges until there was adequate consistency between modeled and calibration target values. Calibration summary statistics were computed for head targets to provide a quantitative measure of the GSA Model's ability to replicate head target values. Head calibration was evaluated using the following summary statistics:

- Residual, computed as the modeled head value minus the target (i.e., measured) head value
- Mean residual (MR), computed as the sum of all residuals divided by the number of observations
- Root mean squared residual (RMSR), computed as the square root of the mean of all squared residuals
- RMSR divided by the range of target head values (RMSR/Range)
- Coefficient of determination (R^2), computed as the square of the correlation coefficient

During the quantitative calibration effort, Jacobs executed work with the following general goals:

- Minimize global bias in heads (e.g., all heads being too high or too low as compared with the target heads)
- Minimize the spatial bias of residuals in key subareas of the model domain
- Minimize residuals, MR, RMSR, and RMSR/Range values
- Strive for R^2 values as close to 1.00 as possible

In addition to calibrating to transient heads, qualitative targets were also used to aid in the calibration process. Calibration summary statistics were not computed for qualitative calibration targets.
The qualitative targets used for the modeling effort are as follows:

- General groundwater flow patterns throughout the model domain
- Estimates of leakage from TID's main canals
- Tulelake Sump water balance closure calculated based on estimated and simulated Tulelake Sump inflows and outflows

Targets classified as "qualitative" should not be interpreted as being unimportant. The main distinction is that summary statistics are not computed for qualitative targets, because doing so is not a requirement nor is it typical for groundwater flow model documentation. Figure 4-1 shows the head calibration target locations.

4.2 Calibration Process

The calibration process focused on defining FMP parameter values, surface and subsurface parameter distributions, and boundary-condition values until there was a reasonably close match to both quantitative and qualitative targets. The main parameters adjusted during the calibration process were the Kh and Kv values within and outside of the Subbasin, TID main canals conductance, and FMP parameter values. Parameter values were adjusted throughout the calibration process to provide goodness of fit for the calibration targets as previously discussed.

The product resulting from this calibration process was an integrated groundwater/surface-water flow model that incorporates important aspects of the hydrogeologic conceptual model and the professional judgment of engineers and scientists familiar with the study area. The following section describes the results of the calibration effort.

4.3 Calibration Results

The following subsections describe the calibration results for time-varying groundwater levels, general groundwater flow patterns, TID main canals leakage, and the Tulelake Sump water balance. Calibrated values for key parameters and boundary conditions are also presented.

4.3.1 Groundwater Levels

Figure 4-2 presents the modeled versus target (i.e., measured) groundwater levels for all target locations within the model domain to evaluate potential global biases and the overall ability of the GSA Model to replicate historical groundwater elevations. In general, points trend along the one-to-one correlation line with some points falling above and below the line. This highlights that the GSP Model does not contain a global bias where all modeled groundwater levels are either always above or always below this line. Global calibration statistics for the data presented on Figure 4-2 are listed in Table 4-1. The model-wide data are reasonably aligned with industry standards for adequate model calibration (e.g., small MR with an RMSR/Range < 10 percent with an R^2 close to 1).

Table 4-1. Calibration Summary Statistics for Groundwater Elevations in Model Domain

Global Calibration Statistics	Value	Unit
Mean Residual (MR)	4.8	feet
Root Mean Squared Residual (RMSR)	21.7	feet
Range of Measured Values (Range)	187.7	feet
RMSR/Range	11.6	percent
Coefficient of Determination (R^2)	0.20	unitless
Number of Values	9,129	unitless

Note:

Residual is computed by subtracting the target (i.e., measured) groundwater level from the modeled groundwater level.

Although there is no indication of global bias in modeled groundwater elevations, there is an indication of some degree of spatial bias. For example, there is a cluster of points in the x-axis range of 4,100 to 4,150 feet above the NAVD88 on Figure 4-2 where the model tends to underestimate groundwater levels. These data are associated with target well locations in Malin and Shasta View Irrigation Districts in Oregon where details regarding the surface-water distribution system and supplies and distribution of groundwater pumping are more uncertain. Figure 4-3 and Table 4-2 present comparison of measured and simulated

groundwater elevations and associated calibration statistics for target locations within the Subbasin. As shown on Figure 4-3, there is a deeper target well (Layer 5) where the simulated groundwater elevations remain relatively constant (i.e., the data plot as a relatively horizontal line). This target is located in the north-central portion of the Subbasin in the city of Tulelake. The relatively consistent simulated groundwater elevation at this target indicates that the model is simulating less decline over time as compared to the measured data. This is likely the result of additional groundwater production within the Subbasin that is not incorporated into the GSA Model. Despite this limited bias, the overall lower MR and RMSR demonstrate that the GSA Model is able to better replicate conditions within the Subbasin as compared to the model-wide degree of calibration when targets in Oregon are considered.

Figure 4-4 is provided to further evaluate spatial biases in modeled groundwater elevations by displaying a spatial distribution of MR values for each calibration target well. According to this figure, there is some spatial bias in the northwestern portion of the Subbasin and in Oregon where modeled heads tend to overestimate the target heads. As previously described, there is a higher degree of uncertainty with respect to agricultural operations in Oregon (surface-water deliveries and location/magnitude of groundwater pumping) that likely contribute to the MRs in this portion of the model domain. In the northwestern portion of the Subbasin, there are a set of target wells where the MR ranges from 10 feet to 25 feet. Despite these targets being near pumping well TID001 (albeit at shallower depths), the model does not replicate the decline in groundwater levels over time observed in the measured data. This suggests that there is additional pumping in this area that is not incorporated into the model. In other portions of the model domain, there is a mix of positive and negative residuals, indicating lack of spatial bias (Figure 4-4).

Table 4-2. Calibration Summary Statistics for Groundwater Elevations in Subbasin

Global Calibration Statistics	Value	Unit
Mean Residual (MR)	3.4	feet
Root Mean Squared Residual (RMSR)	14.9	feet
Range of Measured Values (Range)	114.4	feet
RMSR/Range	13.0	percent
Coefficient of Determination (R^2)	0.35	unitless
Number of Values	5,384	unitless

Note:

Residual is computed by subtracting the target (i.e., measured) groundwater level from the modeled groundwater level.

Figure 4-5 includes hydrograph comparisons of select transient modeled and target groundwater levels. In general, simulated groundwater levels follow similar trends to the target groundwater-level data. However, in some instances, the GSA Model either overestimates or underestimates groundwater levels. Additionally, depending on the layer from which the target well was screened in the GSA Model, the groundwater hydrograph may portray larger or smaller groundwater-level fluctuations as compared to groundwater-level target data. A full set of modeled and measured groundwater-level hydrographs for target wells is included in Attachment 1.

Figure 4-6 illustrates the modeled water table during May 2016, which contained above average annual precipitation (Figure 3-16). It is provided to illustrate general patterns of groundwater flow. Groundwater generally moves from north to south through the model domain, flattening out in the central portion of the Subbasin where agricultural groundwater pumping and the TID drains and sumps tend to flatten out the groundwater elevation gradients. Beyond the Subbasin to the south, flow generally continues toward the Southern lateral subsurface boundary. The overall groundwater flow pattern being illustrated on Figure 4-6 is reasonable based on the understanding of groundwater use in the Subbasin and local hydrogeologic characteristics.

4.3.2 Main Canals Leakage

Main canal conductance served as one of the calibration parameters for fine-tuning of the GSA Model by comparing simulated leakage from main canals with estimated values. Figure 4-7 presents a comparison of estimated and simulated main canal seepage. These data are presented as comparison of average monthly values, total annual volumes, and cumulative volume. Estimated canal seepage is based on H20Sys water budget estimates provided by TID. On average, total main canal leakage is estimated to be approximately 58 TAFY as compared to the 57 TAFY simulated by the GSA Model. The annual modeled main canal leakage is generally consistent with the estimated main canal leakage; however, the model tends to underestimate leakage in the earlier and later portions of the historical simulation period (WYs 2002 through 2008 and WYs 2024 and 2025) and generally tends to overestimate canal leakage during the remainder of the historical simulation period (WYs 2010 through 2023). Additionally, on an average monthly basis, the GSA Model tends to overestimate main canal leakage during non-irrigation months (November through March) and underestimate leakage during the agricultural season (April through September). Due to the simplistic implementation of canal wetting and drying in the GSA Model, the model is not quite able to capture the year-to-year variability that is likely driven by the amount of flow through the system in any given year. The GSA Model likely overestimates the main canal stage in some years and underestimates stage in others, causing the resulting leakage estimates to over or underestimate as compared to the estimated main canal leakage. Because canal leakage is estimated, the performance of the GSA Model in simulating canal leakage is deemed adequate. Further study of TID conveyance systems could better characterize the amount of leakage that occurs from these canals to improve estimates of main canal leakage throughout the Subbasin.

4.3.3 Tulelake Sumps Water Balance

Considering the complexities of the TID conveyance system operations, including the operations of the Tulelake Sumps to meet regulatory requirements and for use as storage for recirculation of irrigation water, an external Tulelake Sump water balance was developed as a means to calibrate the volume of water discharging to drains in the GSA Model. Figure 4-8 presents the components of the Tulelake Sump water balance considered as part of this effort. Ultimately, water leaving the subsurface through drains is either recirculated directly from the drains for irrigation or flows into the Tulelake Sumps. Depending on water surface elevation conditions, water is pulled from the Tulelake Sump from a series of pumps (D-Plant, R, 11, and 12) or flows by gravity into the Q and R canal systems to the south (Figure 4-8). Pumps R, 11, and 12 recirculate water from the Tulelake Sumps back into canals for irrigation purposes. However, water is removed through D-Plant pumping facility to pump water through Sheepy Ridge to the west of the Subbasin to supplement refuge and irrigation supplies in Klamath Project areas to the west. Estimates of water recirculated through Pumps R, 11, and 12 were incorporated in the Tulelake Sump water balance based on H20Sys water balance estimates provided by TID. Pumping through D-Plant was continually monitored throughout the historical past, providing monthly estimates of the volume of water removed from the system to support the Tulelake Sump water balance. The records for D-Plant pumping provide a key piece of observed data for the surface-water budget that helps provide confidence in the GSA Model's representation of the system. D-Plant pumping represents the summation of flows out of the Subbasin that is typically only estimated in most Subbasin water budgets.

Considering the Tulelake Sumps are open water bodies, precipitation and evaporation from these water bodies were also considered as part of the Tulelake Sump water balance. An open water evaporation estimate for the Klamath Region was used based on a study by Risley and Gannett (2006) to provide a monthly estimate of evaporation from the Tulelake Sumps. Based on these estimates, the open water evaporation was estimated to be approximately 49 inches per year. Given that the Tulelake Sumps cover approximately 13,000 acres, this evaporation rate equates to a total annual evaporation of approximately 53 TAFY. This annual estimate of open water evaporation serves as an outflow from the Tulelake Sumps water balance. For precipitation, annual GSA Model average precipitation was used in conjunction with the Tulelake Sump area to provide an estimate of annual precipitation falling directly on the Tulelake Sumps equal to approximately 10 TAFY on average.

Figure 4-9 presents the time series annual sump water balance. The data driving this water balance are a combination of GSA Model simulated values, external calculations, and water balance estimates from the H20Sys spreadsheets provided by TID. The primary driver of inflows to the Tulelake Sumps is the drain inflow. To maintain water levels in the sumps, the drain inflow is balanced through recirculation of water through pumps and canal headworks, and loss to groundwater. The largest outflow from the Tulelake Sumps was D-Plant pumping between WYs 2000 through 2009, which average approximately 57 TAFY during this period. From WYs 2010 through 2025, D-Plant pumping was used to a lesser extent, averaging approximately 16 TAFY of water removed through D-Plant pumping. Groundwater recharge from the Tulelake Sumps is relatively stable throughout the historical period, except in WY 2022, when groundwater recharge from the Tulelake Sumps went to zero because the Tulelake Sumps were dry. Based on this configuration of the Tulelake Sump water balance, there is some imbalance to the water budget; however, the overall error is a relatively small percentage of the total exchange of water through this system. Such an imbalance may result from TID operations not adequately captured at the monthly scale of the estimates and GSA Model simulated values as shown. The primary goal was to reduce the imbalance as much as possible while maintaining adequate calibration results and metrics as previously discussed.

4.3.4 Surface Parameters

The primary surface parameters modified during the calibration process were the conductance values associated with the TID main canals as simulated through the RIV Package and conductance values associated with the TID drain system as simulated through the DRN Package. Calibrated conductance values in the RIV Package ranged from 50 to 10,000 square feet per day. Main canal conductance values were modified across the district to better match estimates of TID main canal leakage. Calibrated values were generally toward the lower range (less permeable) for the M-canal system and toward the higher end of the range (more permeable) for the D-canal system. The final calibrated conductance value for the TID drain system was a uniform value of 6,250 square feet per day across the network.

4.3.5 Subsurface Parameters

Initial distributions of hydraulic conductivity were adapted from the Klamath River Valley Groundwater Basin model as discussed under Section 3.4.1. Through the calibration process of the GSA Model, hydraulic conductivity distribution and parameter values were modified to meet the previously discussed calibration targets. Figures 4-10 through 4-12 present the final calibrated hydraulic conductivity distribution for each of the six layers incorporated in the GSA Model. Table 4-3 presents the calibrated subsurface parameter values for each model layer and corresponding lithologic unit within the layer.

Table 4-3. Calibrated Subsurface Parameters

Model Layer	Unit	Hydraulic Conductivity (ft/day)	Vertical Anisotropy (Kh:Kv)	Specific Storage
1	Qs	1 to 100	100 to 1,000	2.40E-03
	Qv	1 to 100	100	2.40E-03
	Tve	1 to 101	100 to 1,054	2.40E-03
	Tvw	1 to 100	100 to 1,000	2.40E-03
	Tso	1 to 100	100 to 1,000	2.40E-03
2	Tso	1 to 25	100 to 1,000	4.40E-05
	Tsv	1 to 25	100 to 1,000	4.40E-05
	Tsy	1 to 25	100 to 1,000	4.40E-05
	Tve	1 to 25	100 to 1,000	4.40E-05
	Tvw	0.9 to 25	100 to 1,040	4.40E-05
3	Tso	1 to 25	100 to 1,000	4.40E-05
	Tsv	1 to 25	100 to 1,000	4.40E-05
	Tsy	1 to 25	100 to 1,000	4.40E-05
	Tve	1 to 25	100 to 1,000	4.40E-05
	Tvw	0.9 to 25	100 to 1,040	4.40E-05
4	Tsv	1 to 2.5	10 to 1,000	1.30E-05 to 1.00 E-04
	Tve	1 to 2.5	10 to 1,000	1.70E-05 to 1.00 E-04
	Tvw	1 to 2.5	10 to 1,000	1.70E-05
5	Tsv	1 to 2.5	10 to 1,000	1.30E-05 to 1.00 E-04
	Tve	1 to 2.5	10 to 1,000	1.70E-05 to 1.00 E-04
	Tvw	1 to 2.5	10 to 1,000	1.70E-05
6	Tsv	1 to 2.5	10 to 1,000	1.00E-05
	Tve	1 to 2.5	10 to 1,000	1.00E-05
	Tvw	1 to 2.5	10 to 1,000	1.00E-05

Notes:

Vertical anisotropy represents the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity.

Specific yield is specified as 10 percent for Layer 1; Layers 1 through 4 do not have a specific yield as these layers are simulated as confined.

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

4.3.6 Numerical Mass Balance

It is important to review the numerical mass balance of model simulations to ensure that good mathematical closure is achieved. The percent discrepancy in the mass balance for each stress period ranged from -0.034 to 0.059 percent in the calibration simulation. The cumulative percent discrepancy in the numerical mass balance was 0.045 percent in the calibration simulation. Thus, the transient historical model achieved excellent numerical mass balances associated with the water budgets described in the following sections.

4.4 Historical and Current Water Budgets

GSP Regulations Section 354.18 requires the GSA to develop historical, current, and projected water budgets for the Subbasin. The historical water budget evaluates the availability and reliability of past surface-water supplies and agricultural demands. The 26-year hydrologic period of WYs 2000 through 2025 was selected for developing the historical water budget to include a period of representative hydrology, while capturing recent Subbasin operations. The current water budget evaluates the availability and reliability of more recent surface-water supplies and agricultural demands. WYs 2018 through 2025 were selected for developing the current water budget representing recent hydrology and Subbasin operations.

The water budgets described herein have been developed in accordance with the general guidelines provided in DWR's Water Budget BMP (DWR, 2016b) to help quantify the volumetric rate of water entering and leaving the Subbasin. Water enters and leaves the Subbasin naturally, such as through precipitation and streamflow, and through human activities, such as pumping and groundwater recharge from irrigation. Separate historical, current, and projected water budgets have been developed for two different "systems," including the land system and groundwater system. Table 4-4 lists the water budget components for each of these systems.

Table 4-4. Land and Groundwater Systems Water Budget Components

Land System Inflow Components	Land System Outflow Components
Precipitation	Evapotranspiration of Precipitation
Applied Water from TID Deliveries	Evapotranspiration of Applied Water
Applied Groundwater from Private Agricultural Pumping	Runoff to Streams/Canals
Shallow Groundwater into the Rootzone	Groundwater Recharge from Precipitation and Applied Water
	Shallow Groundwater Evapotranspiration
Groundwater System Inflow Components	**Groundwater System Outflow Components**
Groundwater Recharge from Precipitation and Applied Water	Irrigation and M&I Groundwater Pumping
Canal Laterals Leakage	Private Groundwater Pumping
Tulelake Sumps Leakage	Groundwater Discharge to Drains
Main Canals and Lost River Leakage	Shallow Groundwater Evapotranspiration
Subsurface Flow into Subbasin	Groundwater Discharge to Tulelake Sumps
	Groundwater Discharge to Main Canals and Lost River
	Subsurface Flow Out of Subbasin

M&I = municipal and industrial

4.4.1 Land System

Table 4-5 presents averages of the individual Subbasin components of the historical and current land system water budgets. Figure 4-13 presents the annual time series of each Subbasin component of the historical and current land system water budgets. Tabulated water budget values presented herein are reported to the nearest whole number, in TAF, from the GSA Model. This has been done out of convenience. It is not the intention of the authors to imply that the values are accurate to the nearest TAF.

Table 4-5. Historical and Current Average Annual Land System Budget

Land System Budget Term	Historical Average Annual Flow (TAFY) WYs 2000–2025	Current Average Annual Flow (TAFY) WYs 2018–2025
Inflows		
Precipitation	85	79
Applied Water from TID Deliveries	79	65
Applied Groundwater from Private Agricultural Pumping	53	61
Shallow Groundwater into the Rootzone	2	2
Total Inflow	219	207
Outflows		
Runoff to Streams/Canals	10	9
Evapotranspiration of Precipitation	36	36
Evapotranspiration of Shallow Groundwater	2	2
Evapotranspiration of Applied Water	113	108
Groundwater Recharge from Precipitation and Applied Water	58	52
Total Outflow	219	207

According to the GSA Model, the Subbasin experienced an average of approximately 200 TAFY of land inflows and outflows during the 26-year historical period. Primary inflows to the Subbasin land system water budget are applied water from TID deliveries and precipitation; whereas, the primary outflows from the Subbasin land system water budget are ET of applied water and groundwater recharge from precipitation and applied water. The hierarchy of inflow and outflows under current conditions is the same as that under the historical period; however, the total inflows and outflows under current conditions are approximately 12 TAFY lower than the historical condition average.

4.4.2 Groundwater System

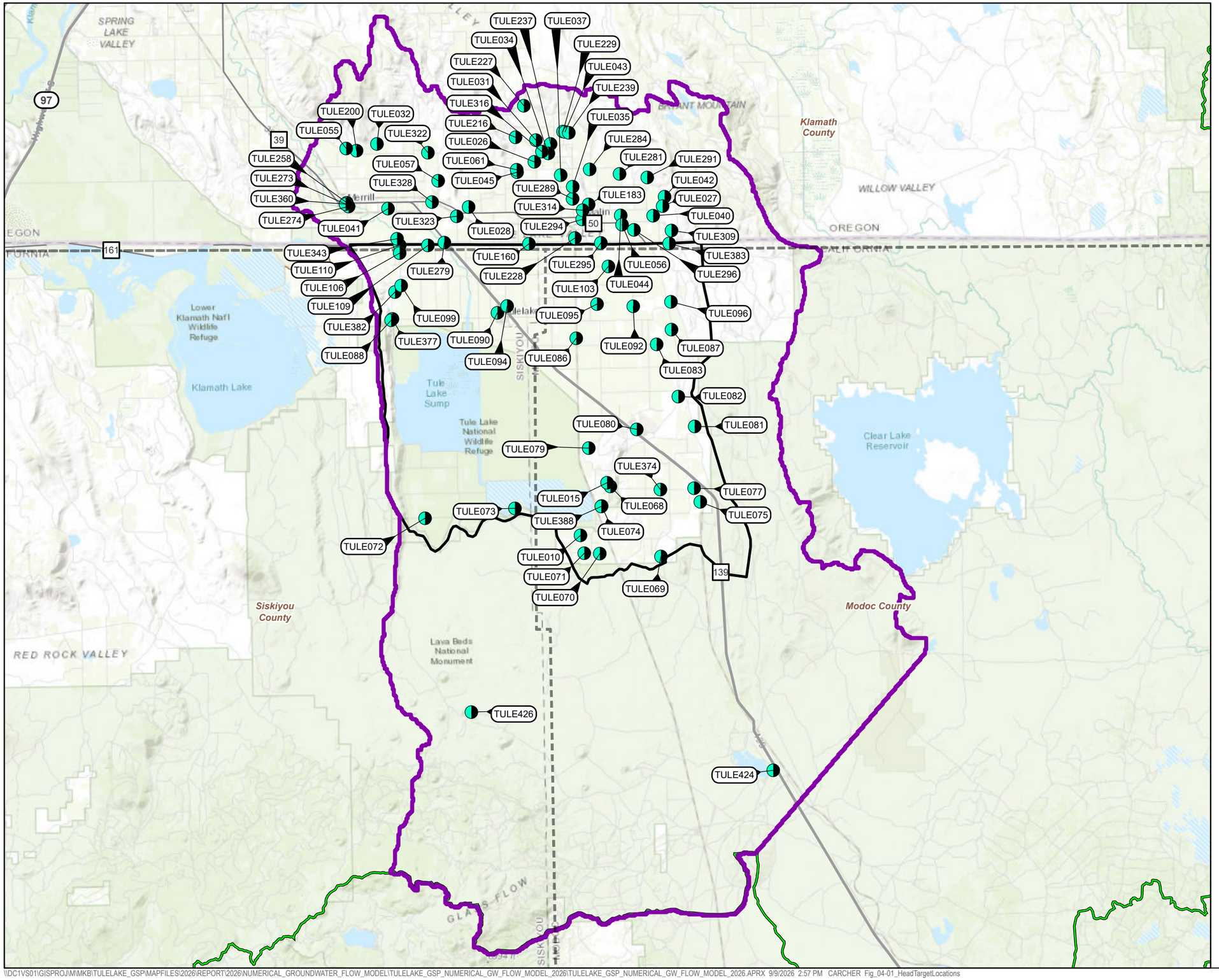
Table 4-6 presents averages of the individual Subbasin components of the historical and current groundwater system water budgets. Figure 4-14 presents the annual time series of each Subbasin component of the historical and current groundwater system water budgets.

According to the GSA Model, the Subbasin experienced an average of approximately 203 TAFY of groundwater inflows during the 26-year historical period. Primary inflows to the Subbasin groundwater system water budget are groundwater recharge from main canals and Lost River, groundwater recharge from precipitation and applied water, and groundwater recharge from canal laterals. Slightly higher groundwater recharge from main canals and the Lost River in WYs 2023 through 2025 resulted from the additional Lost River flows supplied to the Subbasin for groundwater recharge purposes (Figure 4-14). Groundwater outflows from the Subbasin averaged approximately 206 TAFY, with the largest outflow components being groundwater discharge to drains and irrigation, and M&I groundwater pumping. The hierarchy of inflow and outflows under current conditions is the same as that under the historical period.

Over the 26-year historical period, the change in groundwater storage declined by approximately 3 TAFY, which is approximately 1.5 percent of the average total inflows and outflows. Under current conditions, the change in stored groundwater was approximately 7 TAFY. The relatively small decline in groundwater stored under the historical period is likely within the uncertainty of the estimates of the water budget. Thus, the estimated change in groundwater storage is within the potential error of groundwater budget estimates, meaning small changes to individual water budget estimates could potentially result in no change in groundwater storage over time.

Table 4-6. Historical and Current Average Annual Groundwater System Budget

Groundwater Budget Term	Historical Average Annual Flow (TAFY) WYs 2000–2025	Current Annual Flow (TAFY) WYs 2018–2025
Inflows		
Groundwater Recharge from Precipitation and Applied Water	58	52
Groundwater Recharge from Canal Laterals	47	49
Groundwater Recharge from Tulelake Sumps	10	9
Groundwater Recharge from Main Canals and Lost River	71	71
Subsurface Flow from Surrounding Area	17	17
Total Inflow	203	198
Outflows		
Irrigation and M&I Groundwater Pumping	8	11
Private Groundwater Pumping	50	57
Total Subbasin Groundwater Pumping	58	68
Groundwater Discharge to Drains	137	120
Shallow Groundwater Evapotranspiration	2	2
Groundwater Discharge to Tulelake Sumps	0	0
Groundwater Discharge to Main Canals and Lost Rivers	0	0
Subsurface Outflow to Surrounding Area	10	13
Total Outflow	206	203
Change in Groundwater Storage	-3	-5



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World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

Figure 4-1
Calibration Target Locations
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

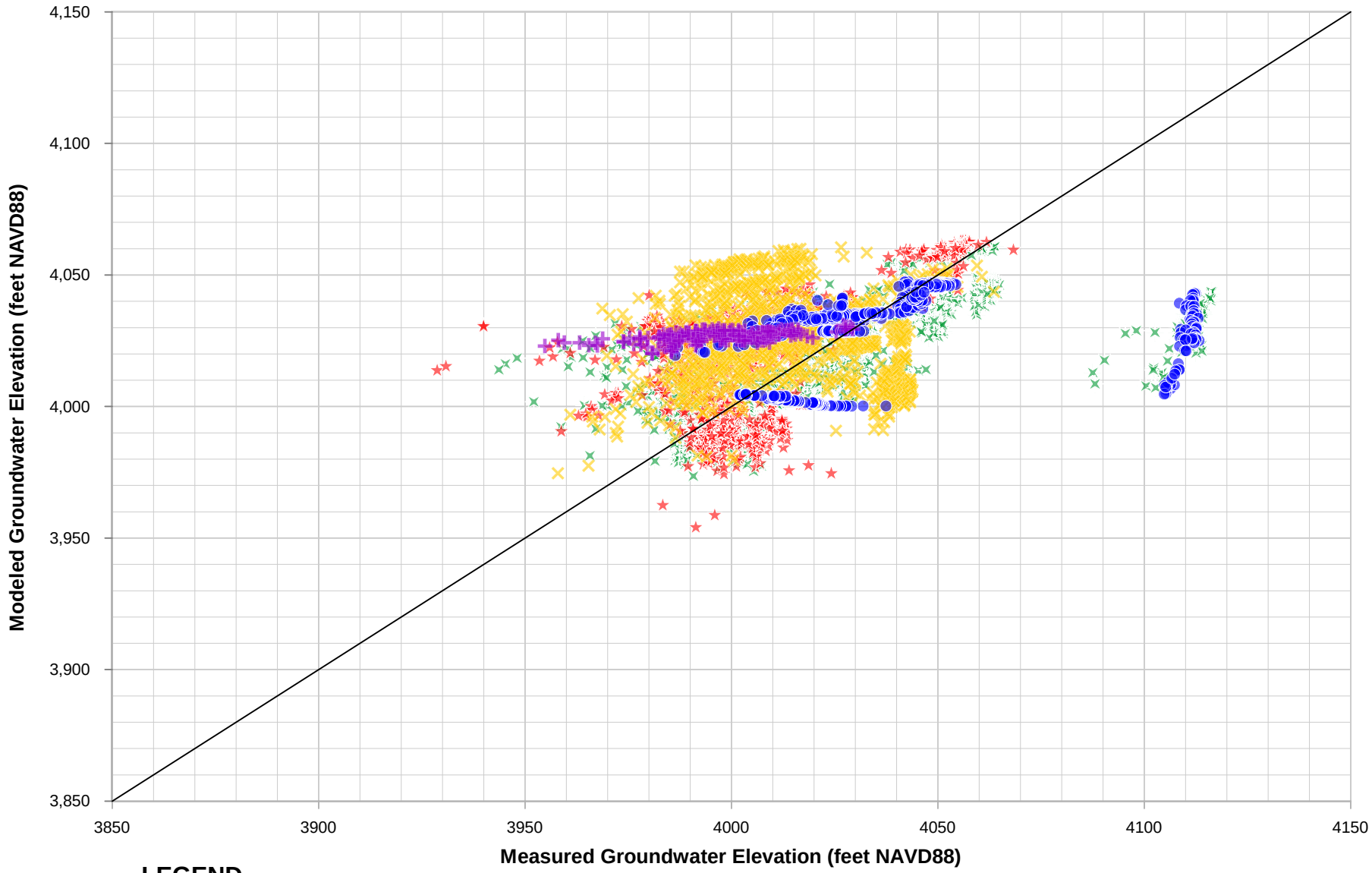
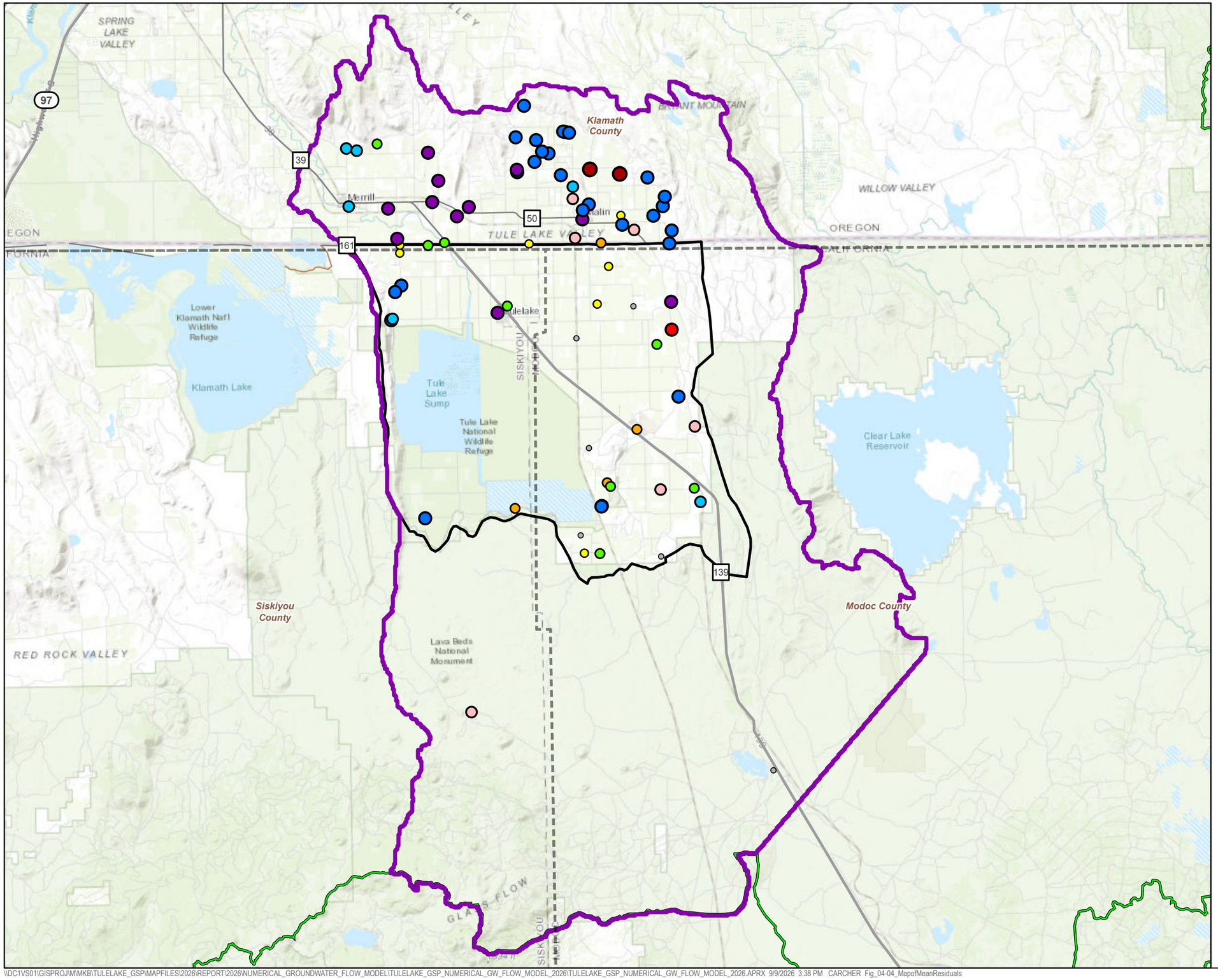
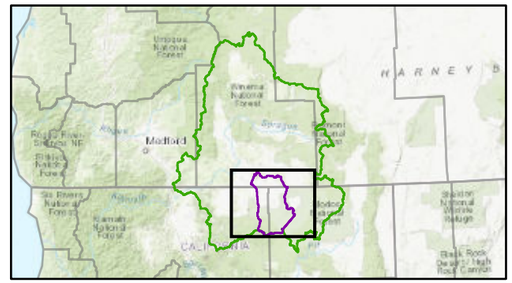


Figure 4-2
Modeled Versus Target Groundwater Elevations - Model Domain
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin



Figure 4-3
Modeled Versus Target Groundwater Elevations - Subbasin
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries

Mean Residual (feet)

- 25 to 52.5
- 10 to 25
- 5 to 10
- 1 to 5
- -1 to 1
- -1 to -5
- -5 to -10
- -10 to -25
- -25 to -50
- -50 to -83

Note:

The residual is computed by subtracting the target (measured) groundwater elevation from the modeled groundwater elevation. The mean residual values represent the average of the residuals from all measured times at a given target well during the calibration period.

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World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

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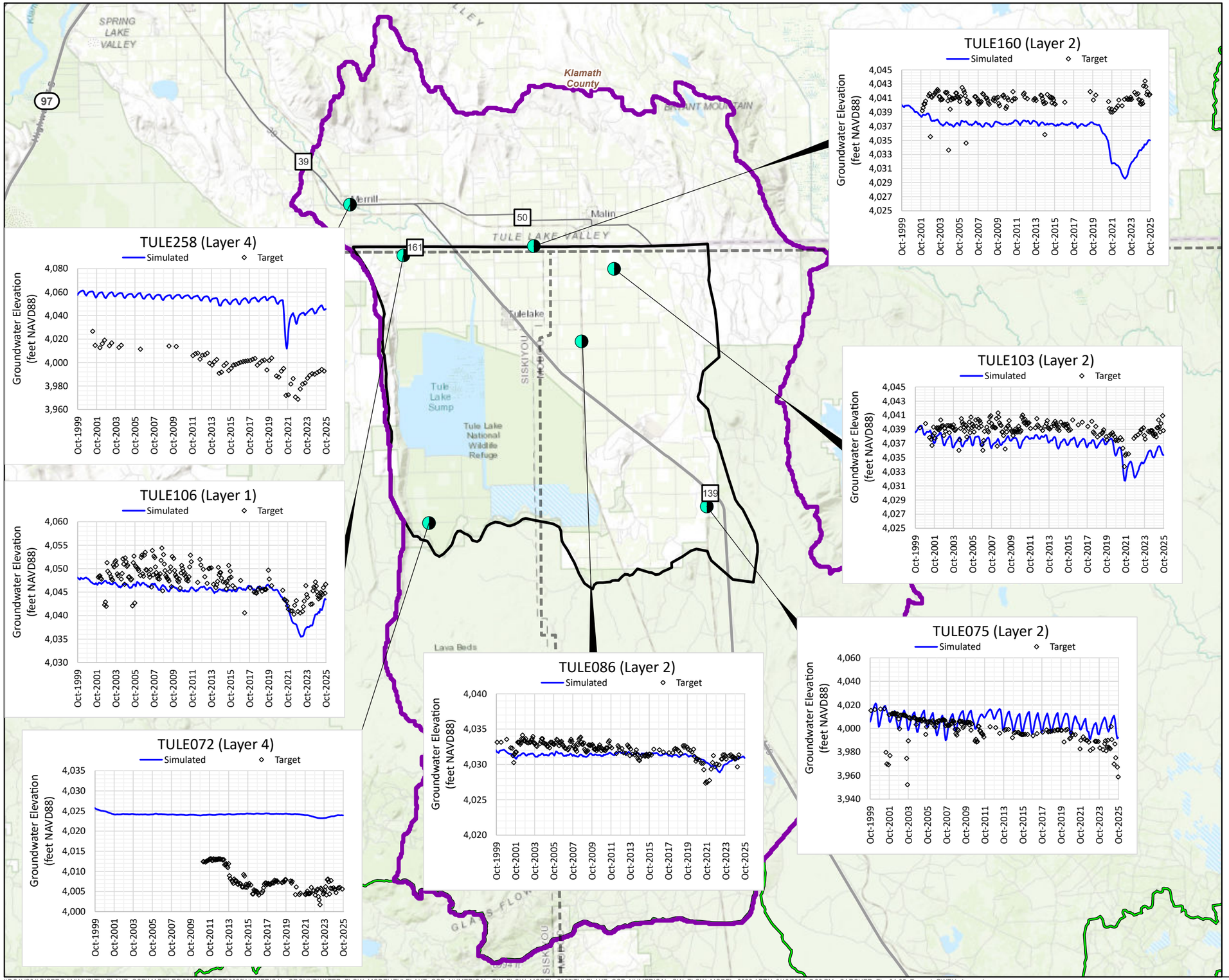
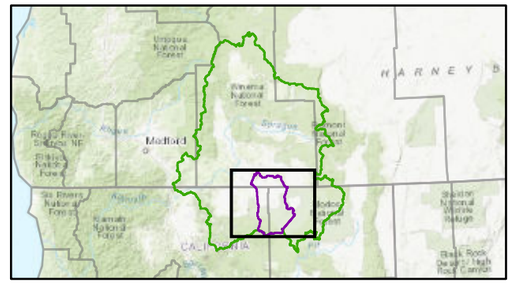
Figure 4-4
Map of Mean Residuals
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Head Target Location

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

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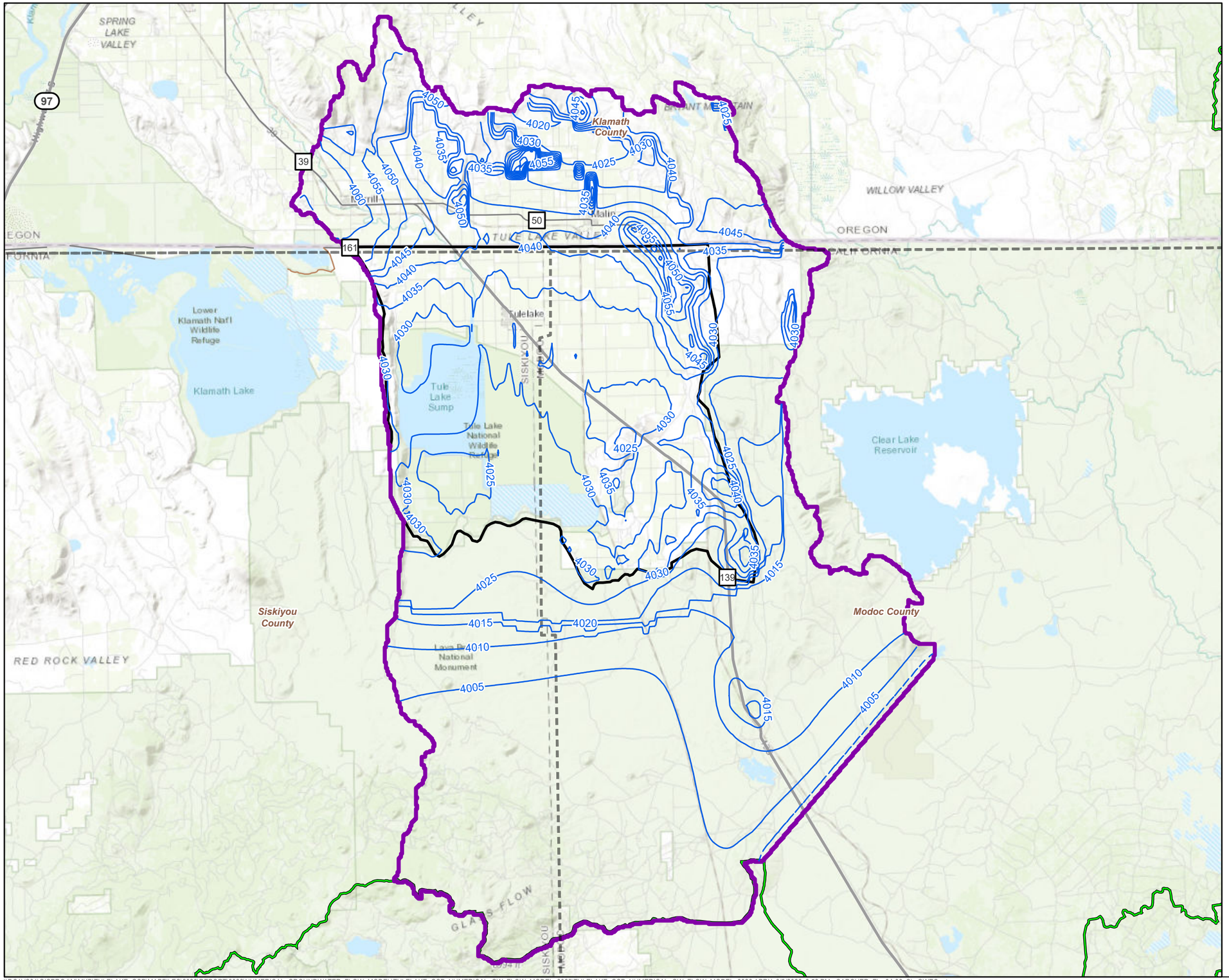
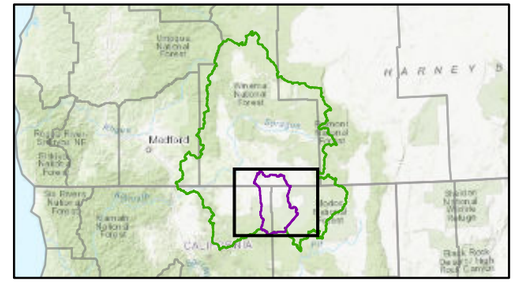
Figure 4-5
Modeled Versus Target Groundwater Elevation Hydrographs
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Modeled Water-Table-Elevation Contour (5 foot)

Notes:
Contours represent May 2016 conditions.
NAVD88 = North American vertical Datum of 1988

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

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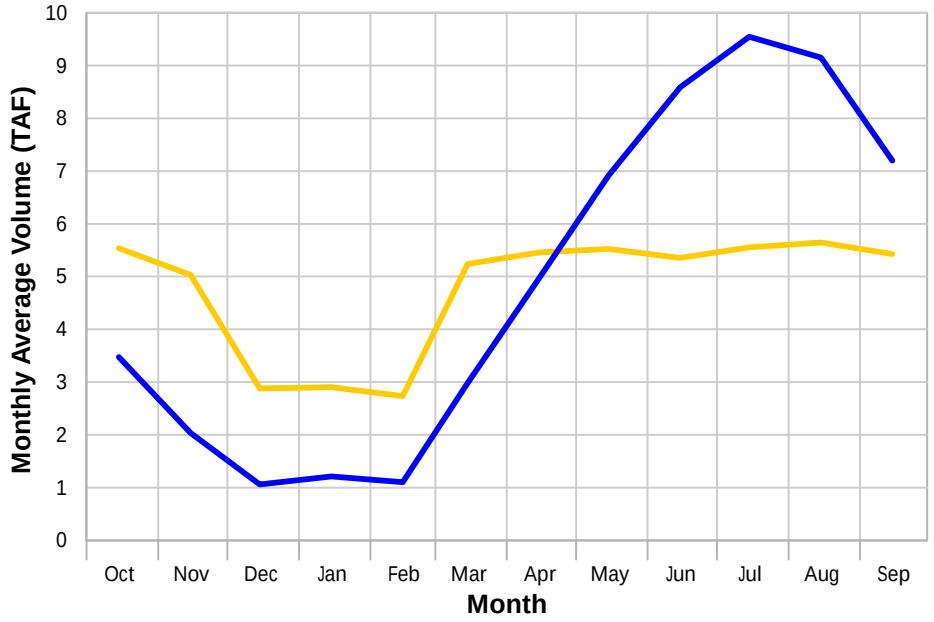
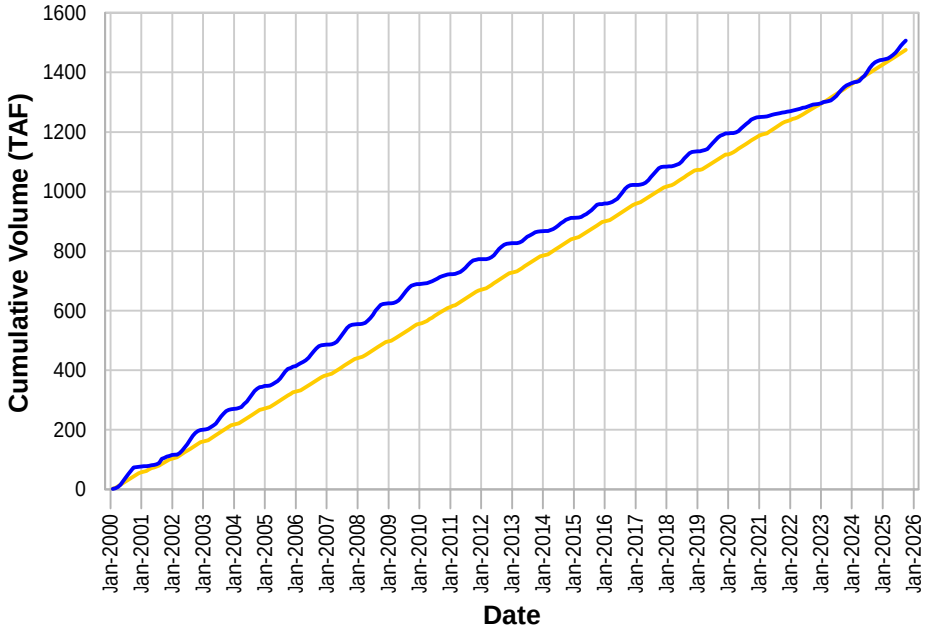
Figure 4-6
Modeled Water Table During a Normal Year
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs





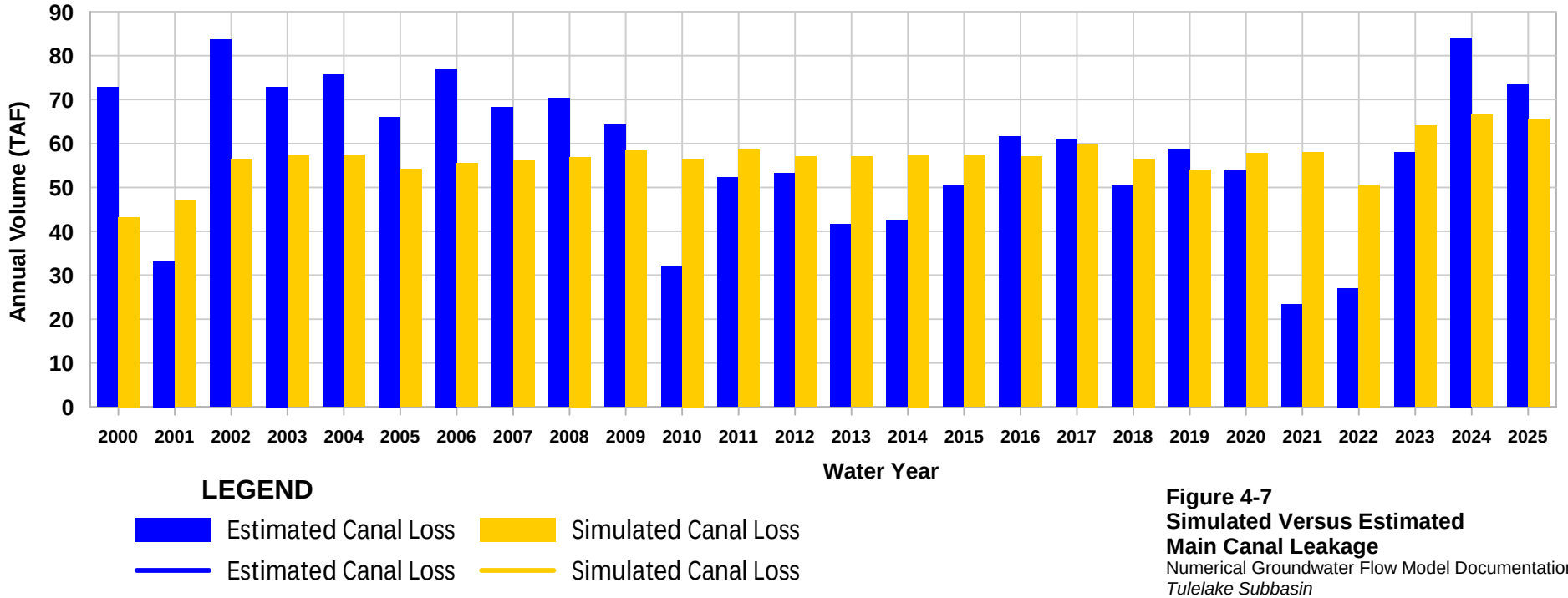
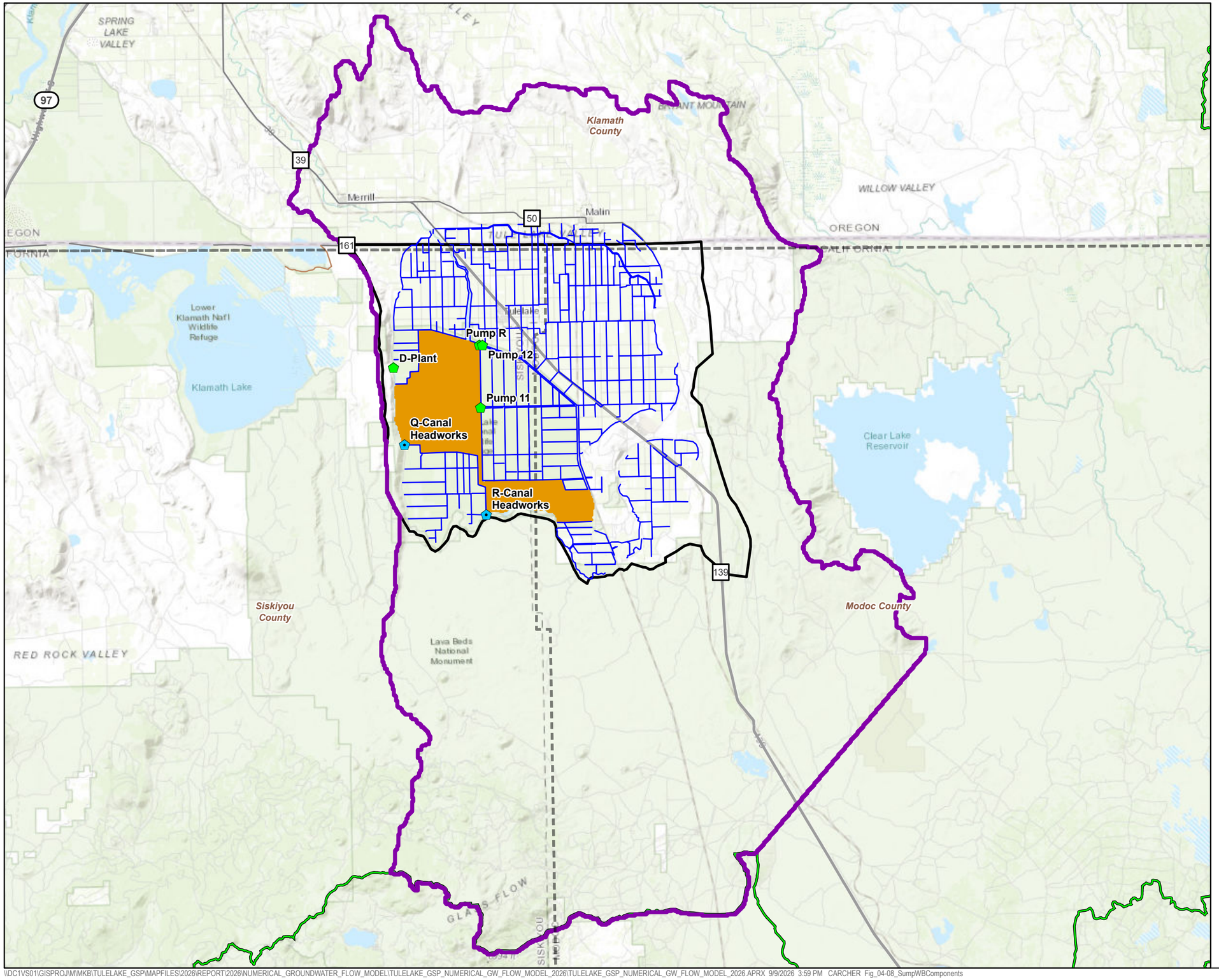
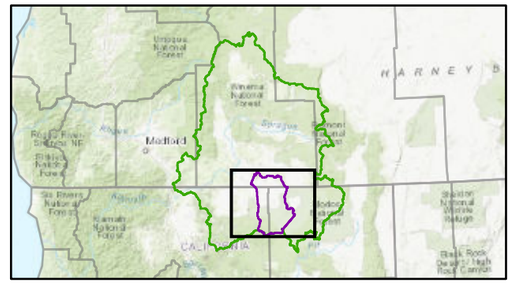


Figure 4-7
Simulated Versus Estimated Main Canal Leakage
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- TID Pumps
- Canal Headworks
- TID Drains
- Areal Extent of Gain/Loss from Groundwater, Precipitation, & Open Water Evaporation

Notes:
TID = Tulelake Irrigation District

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

Figure 4-8
Tulelake Sump Water Balance Components
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 9/9/2026 3:59 PM CARCHER Fig_04-08_SumpWBComponents

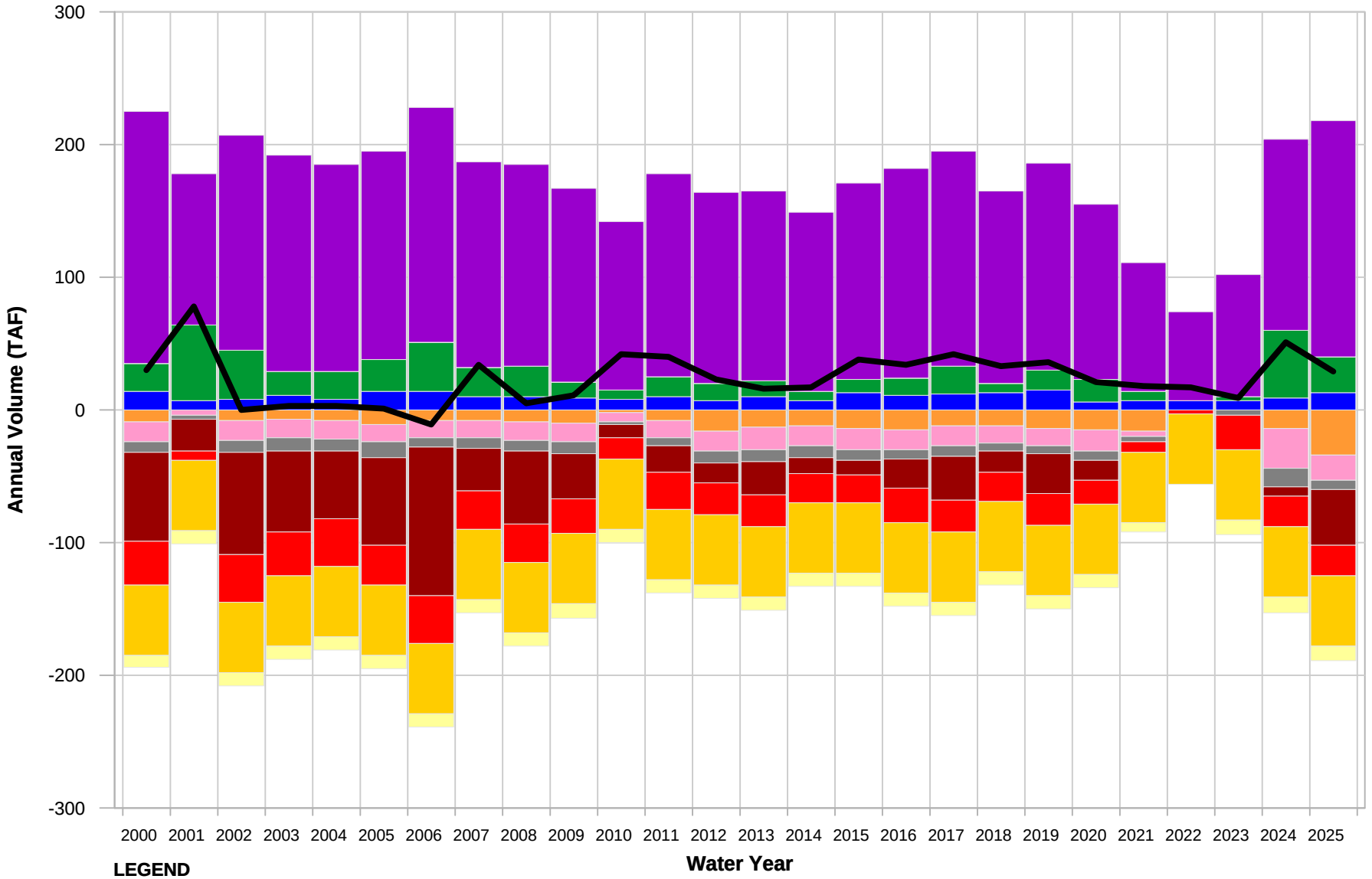
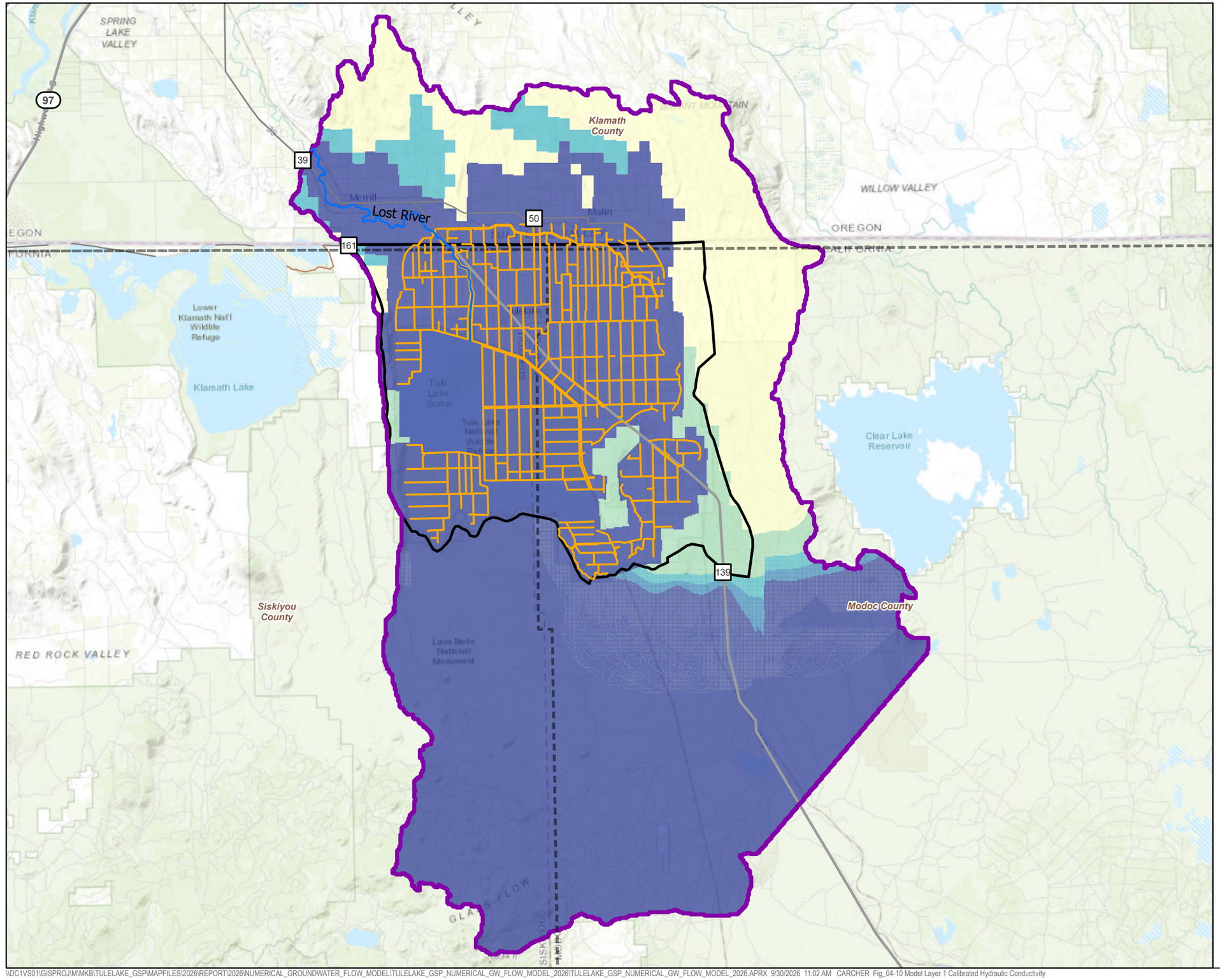


Figure 4-9
Annual Sump Water Balance
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin



LEGEND

- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- TID Drains
- Lost River

Hydraulic Conductivity (feet per day)

- 0.9 to 2.5
- 2.5 to 10
- 10 to 25
- 25 to 50
- 50 to 101

Notes:
TID = Tulelake Irrigation District

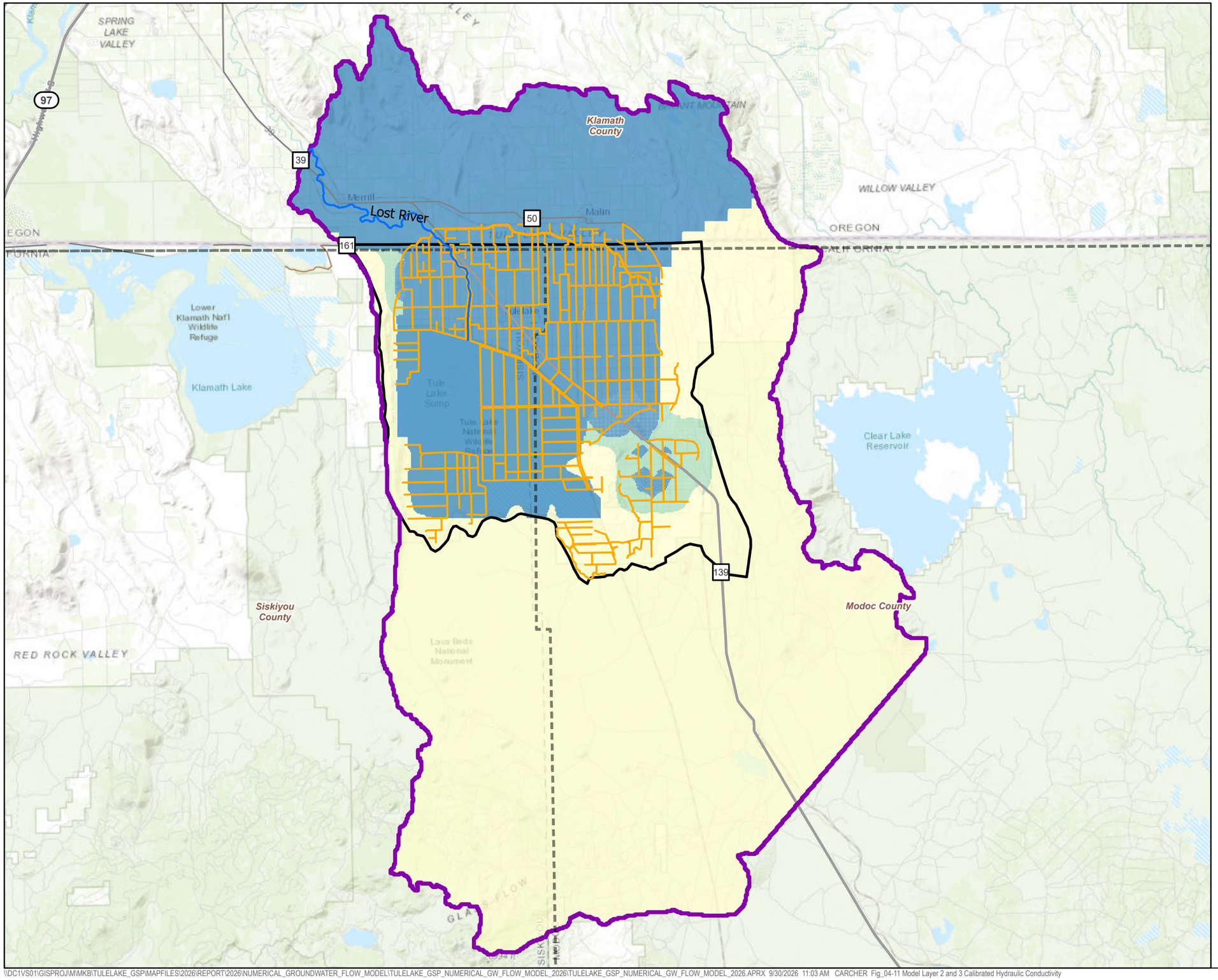
Service Layer Credits: USA Counties - Generalized: Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS)
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

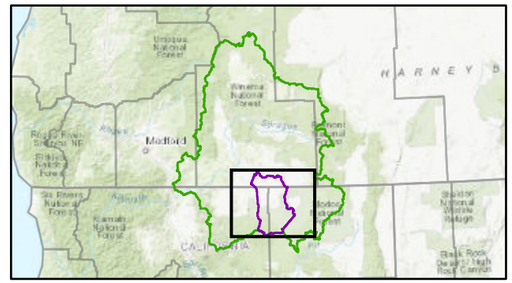
0 4 8 Miles

N

FIGURE 4-10
Model Layer 1 Calibrated Hydraulic Conductivity
Numerical Groundwater Flow Model Documentation
Tulelake Groundwater Subbasin

Jacobs





LEGEND

- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- TID Drains
- Lost River

Hydraulic Conductivity (feet per day)

- 0.9 to 2.5
- 2.5 to 10
- 10 to 25
- 25 to 50
- 50 to 101

Notes:
TID = Tulelake Irrigation District

Service Layer Credits: USA Counties - Generalized: Sources: Esri; U.S. Department of Commerce, Census Bureau; U.S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Geodetic Survey (NGS)
World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

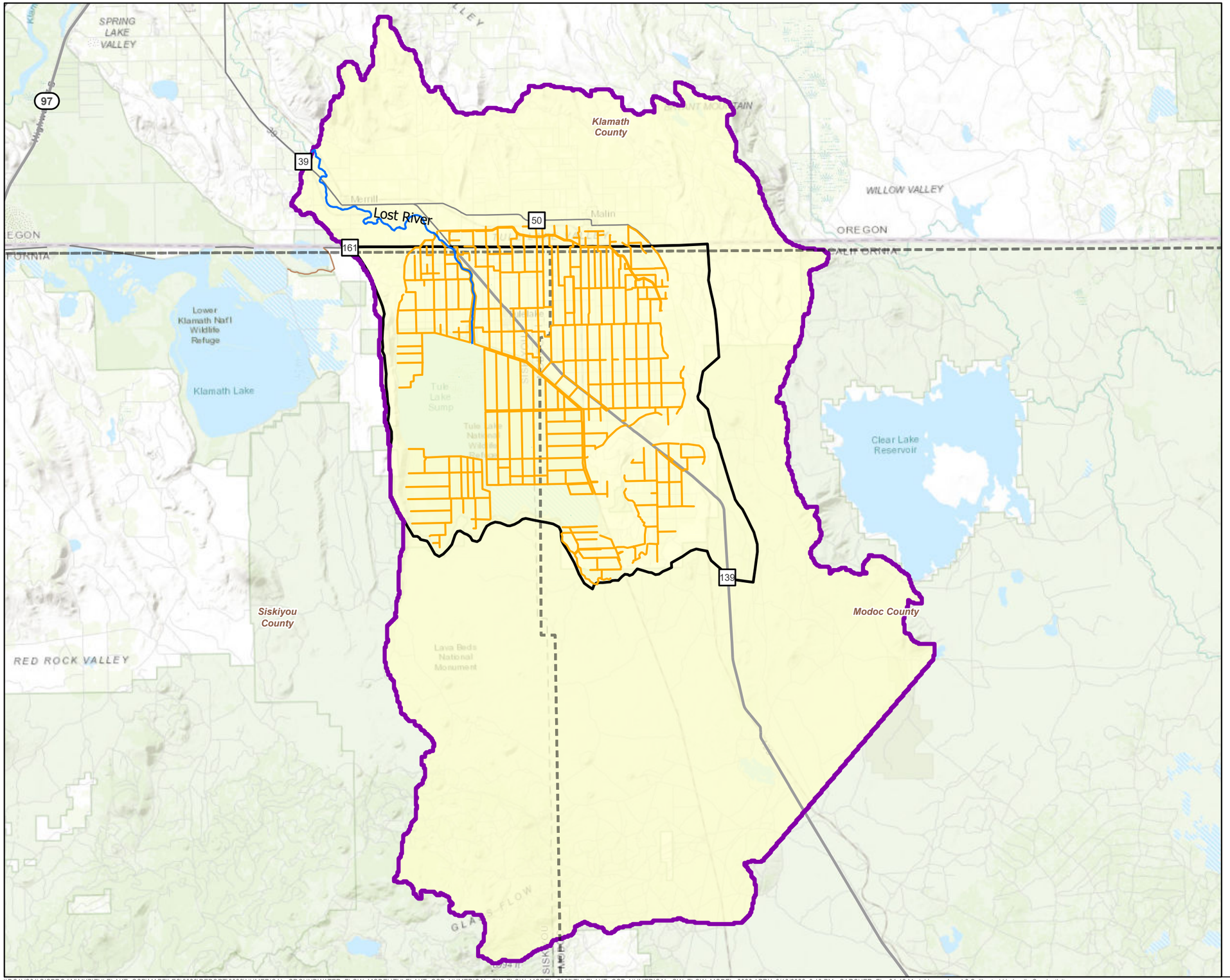
0 4 8 Miles

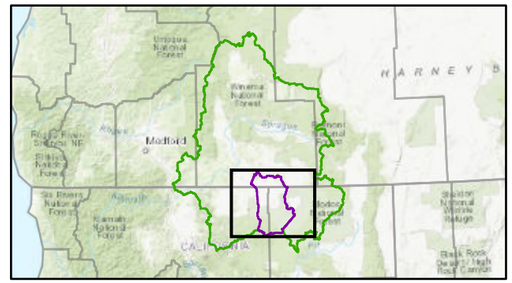
N

FIGURE 4-11
Model Layer 2 and 3 Calibrated Hydraulic Conductivity
Numerical Groundwater Flow Model Documentation
Tulelake Groundwater Subbasin

Jacobs

\\DC1VS01\GISPROJ\M\MKB\TULELAKE_GSP\MAPFILES\2026\REPORT\2026\NUMERICAL_GROUNDWATER_FLOW_MODEL\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026\TULELAKE_GSP_NUMERICAL_GW_FLOW_MODEL_2026.APRX 9/30/2026 11:03 AM CARCHER Fig_04-11 Model Layer 2 and 3 Calibrated Hydraulic Conductivity





LEGEND

- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- TID Drains
- Lost River

Hydraulic Conductivity (feet per day)

- 0.9 to 2.5
- 2.5 to 10
- 10 to 25
- 25 to 50
- 50 to 101

Notes:
TID = Tulelake Irrigation District

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

0 4 8 Miles

N

Figure 4-12
Model Layer 4 and 6 Calibrated Hydraulic Conductivity
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

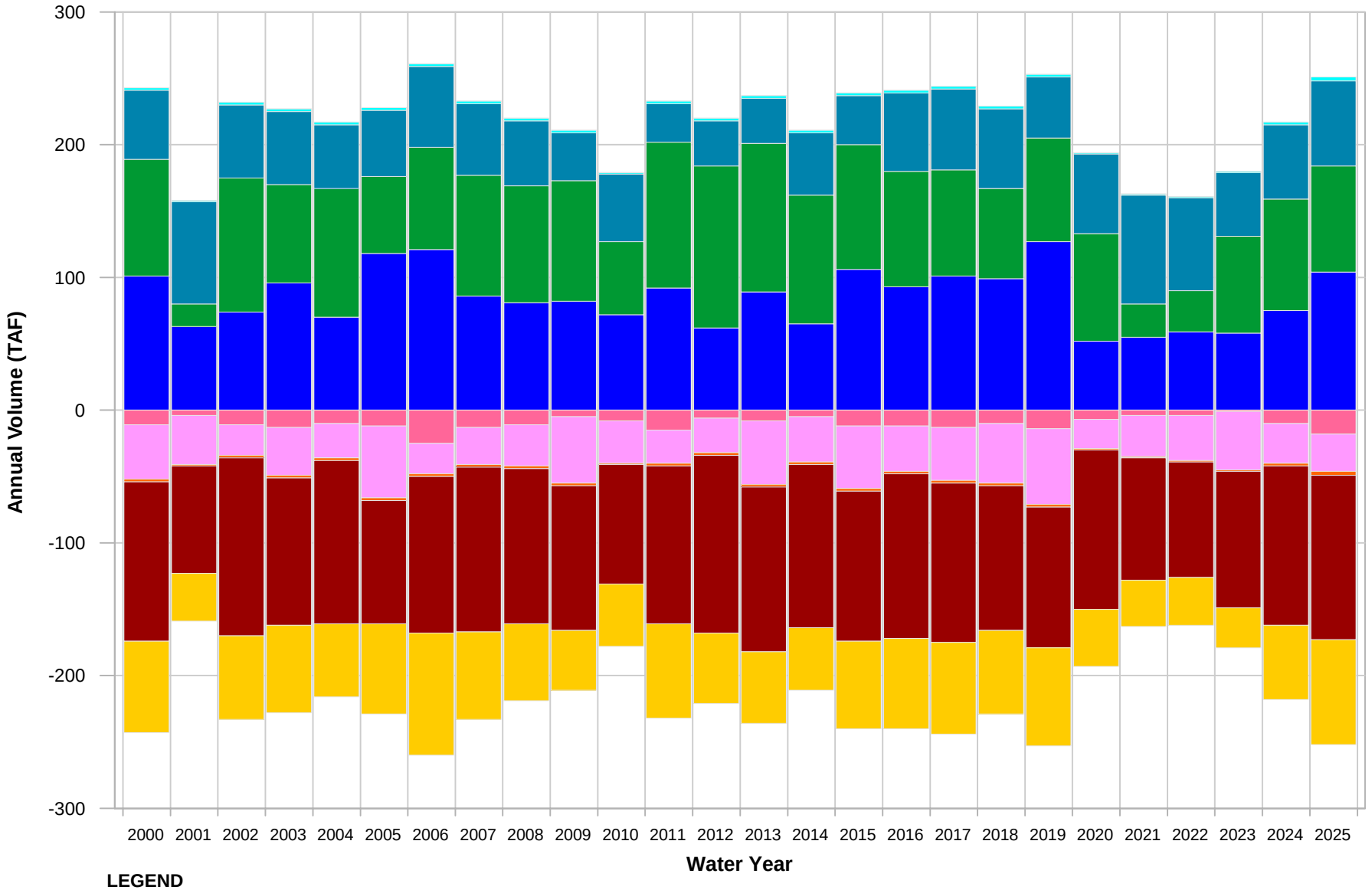


Figure 4-13
Historical Annual Land System Water Balance
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

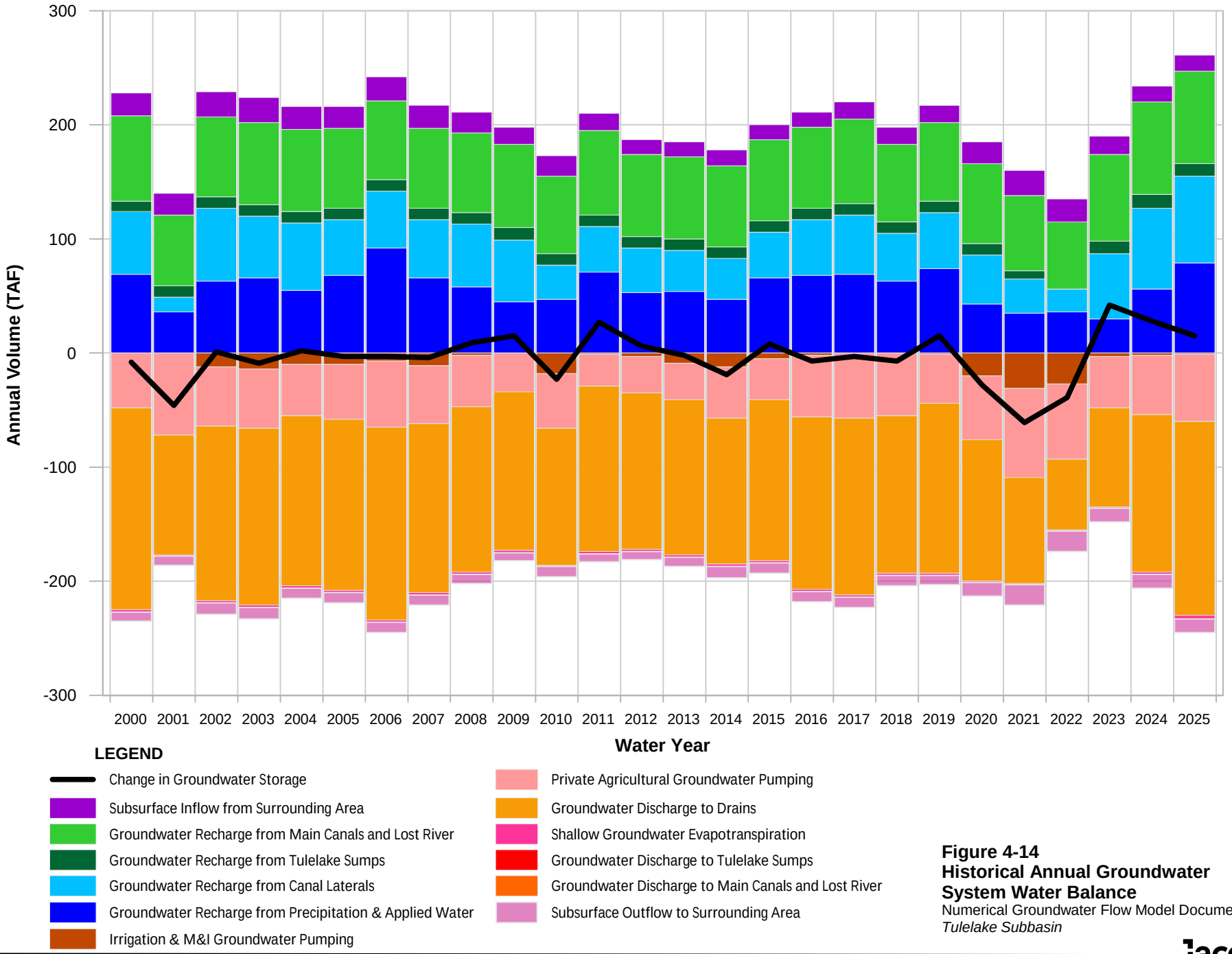


Figure 4-14
Historical Annual Groundwater System Water Balance
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

5. Model Projections

Although it is impossible to predict future hydrology with certainty, the GSA Model is the best available tool to forecast the response of the Subbasin to potential future conditions. Application of this tool as described in this section is intended to provide projected water budgets under assumed climate conditions to support development of the Subbasin GSP.

5.1 Assumed Future Conditions

GSP Regulations Section 354.18 requires the GSA to develop historical, current, and projected water budgets for the Basin. Section 4.4 discusses the historical and current water budgets. To develop the projected water budget, certain boundary conditions needed to be modified from the calibration version of the model, which was used to evaluate historical conditions, to convert it into a projection tool configured to simulate assumed future climatic conditions.

As part of the GSP development effort, two projected simulation runs were developed using the GSA Model representing future baseline conditions and future baseline conditions with assumptions of projected climate change. The following sections describe the process of converting the historical model into a projection model for the future baseline and future baseline with climate change conditions.

5.1.1 Climate Change

One requirement of the projected water budget is to account for climate change. Projected climate conditions were adapted from the DWR-provided data and tools representing future climate change scenarios. As described in the Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development (DWR, 2018), a time-period analysis was incorporated in the GSA Model to translate historical variability to conditions representative of the climate change trends established in the 2070 Drier Extreme Warming (DEW) climate change scenario.

From the DWR climate change scenario, historical ET_0 and precipitation values were adjusted to reflect projected changes in temperature and precipitation under the DWR 2070 DEW climate change scenario. Figure 5-1 presents annual precipitation under historical and 2070 DEW climate change adjusted conditions. Under projected conditions, historical annual precipitation is projected to decrease from an average of 9.6 inches to an average of 8.0 inches. Figure 5-2 presents annual ET_0 under historical and 2070 DEW climate change adjusted conditions. Under 2070 climate conditions, ET_0 is projected to increase as compared to historical conditions by approximately 6.6 inches per year. To develop the 46-year future period covering WYs 2026 through 2071, historical precipitation and ET_0 adjusted for 2070 climate conditions were repeated to cover the project simulation period.

5.1.2 Surface-Water Availability

As discussed in previous sections, surface water for irrigation plays a large role in the operations of the TID system. Historical Klamath Project operations were used to develop a set of surface-water conditions that reflect historical hydrologic conditions, which were then compared to predictions of surface-water supply based on the Klamath Basin Planning Model (KBPM). The KBPM was developed by the Bureau of Reclamation and is the accepted model for performing planning-level analyses of the Klamath Project.

Based on the KBPM, projected annual surface-water availability at Anderson-Rose Dam was estimated representing the total surface-water availability for conveyance into the TID system. Total surface-water availability was combined with TID groundwater pumping volumes to represent total supply for TID. Figure 5-3 presents historical and projected total supply for TID for the historical and projected simulation periods. In general, supplies are projected to be close to historical conditions with some increases and decreases in certain years as compared to historical conditions. For the historical simulation period, historical supply averaged approximately 94 TAFY as compared to 107 TAFY under projected conditions.

Total TID supply was then split into estimates of surface-water deliveries by TID canal system and canal lateral leakage. Historical canal lateral leakage estimates were subtracted from the total TID supply to create an estimate of surface-water deliveries, assuming canal lateral leakage would occur in a manner similar to historical conditions. Figure 5-4 presents the historical versus projected annual TID water deliveries. Projected water deliveries are generally within the range of historical values with an average volume of water delivered at approximately 22 to 98 TAFY under projected conditions as compared to a range of 13 to 122 TAFY under historical conditions. Estimated surface-water deliveries were incorporated for the projected simulation period as NRDs as described under Section 3.7.1.3. Figure 5-5 presents the historical and projected total canal lateral leakage. Projected canal lateral leakage is generally within the range of historical values with an average canal lateral leakage of approximately 47 TAFY under projected conditions as compared to the 49 TAFY historical average. Projected canal lateral leakage was distributed evenly across each canal system and prescribed as a volumetric flux for the projected period as described under Section 3.7.1.7.

Additional sources of supply into TID canals and drains come from operational spills from upgradient irrigation districts and through recirculation of Tulelake Sump and drain water within TID. Limited information is available regarding the quantity of water entering TID's canals and drains. For the purposes of the projected simulations, spills into TID were assumed to be fixed under historical conditions. As such, any changes in surface-water conditions are based solely on the projected volume of water available as part of TID's Klamath Project supply.

5.1.3 Groundwater Pumping

Considering the availability of surface water in the Subbasin is projected to be similar to historical conditions, historical groundwater pumping rates per well were repeated based on repetition of pumping rates from WYs 2000 through 2025 to cover the full projected period (Figure 5-6). Groundwater pumping well locations and construction information are assumed to be unchanged from historical conditions. Projected private agricultural groundwater pumping is calculated in the same manner as it was during the historical period where the FMP package estimates groundwater pumping requirements based on consumptive use minus the availability of precipitation, shallow groundwater, and surface water supplies to meet the consumptive use.

5.1.4 Tulelake Sumps Water Levels

Operations of the Tulelake Sumps are assumed to be consistent with historical conditions, except for when the Tulelake Sumps went dry. In the future, the Klamath Project is projected to operate in a manner that will provide additional flows to the Tulelake Sumps to maintain the water surface elevations in these sumps year-round. Thus, monthly historical Tulelake Sump water surface elevations were repeated to cover the future simulation period, and the period when the Tulelake Sumps went dry were filled in with monthly average water surface elevation values (Figure 5-7).

5.1.5 Lateral Subsurface Boundaries

Lateral subsurface boundaries in the GSA Model represent transient groundwater elevation conditions requiring a full time series of conditions under future conditions. Considering the uncertainty in groundwater elevations into the future, the historical time series associated with the boundary-condition locations presented on Figure 3-23 are repeated to cover the entire projected simulation period.

5.2 Model Setup for Projection Scenarios

For the future baseline simulation, the GSA Model was configured to run the historical and projected simulation periods as one continuous simulation. Simulating the historical and projected periods as a continuous simulation ensures that there are no discontinuities in Subbasin conditions between the end of the historical period and the start of the projection period. Table 5-1 presents a comparison of the assumptions associated with the historical and projection simulations.

Table 5-1. Overview of Assumptions for the Historical and Projection Periods

Simulation Item	Assumption/Basis for Historical Simulation Periods	Assumption/Basis for Projection Simulation Periods
Hydrologic Period	▪ Historical: WYs 1999 through 2025. ▪ Monthly time intervals.	▪ WYs 2026 through 2071 as represented by a repeating pattern of historical conditions (WYs 2000 through 2022). ▪ Monthly time intervals.
Precipitation	▪ Downscaled PRISM (PRISM Group, 2020) precipitation dataset, as processed using the BCM (Flint et al., 2013).	▪ Repeating pattern of historical precipitation for projection baseline. ▪ Climate change adjustment factors applied to projection baseline based on the DWR 2070 DEW climate scenario (DWR, 2020).
Reference Evapotranspiration	▪ ET_0 is computed using the BCM (Flint et al., 2013) based on air temperature projections. ▪ Klamath Region AgriMet stations: Klamath Falls and Worden used to correct BCM ET_0.	▪ Repeating pattern of historical ET_0 for future baseline conditions. ▪ Repeating pattern of historical ET_0 adjusted to reflect DWR 2070 DEW climate change scenario.
Crop Coefficients	▪ Monthly crop coefficients developed based on AgriMet station data.	▪ Same as historical.
Land Use/Cropping	▪ 2008, 2010, 2019, 2022, and 2024 TID reported crop acreages with 2008 and 2019 representative of average cropping conditions and 2010, 2019, 2022, and 2025 representative of years when varying degrees of crop idling occurred.	▪ Repeating pattern of 2008, 2010, 2019, 2022, and 2024 land use conditions based on historical designation.
Surface-Water Availability	▪ Based on water balance estimates from TID's H20Sys for WYs 2000 through 2025; WYs 1998 and 1999 filled in with average conditions.	▪ Historical conditions with modified conditions representing future conditions. ▪ Repeating pattern of projected historical conditions.
Well Infrastructure	▪ Input from TID, Water User Mitigation Program, and Oregon Water Resources Department.	▪ Same as historical.

Simulation Item	Assumption/Basis for Historical Simulation Periods	Assumption/Basis for Projection Simulation Periods
Tulelake Sumps Water Elevation	▪ Historical measured daily water surface elevation averaged on a monthly interval.	▪ Repeating pattern of historical monthly average water surface elevations (WYs 2000 through 2022). ▪ Tulelake Sumps assumed to not run dry again in the future. Period of repeated historical period when Tulelake Sumps assumed to be dry were set to monthly average elevations from historical period.
Subsurface Lateral Flow	▪ Based on historical measured water levels in the vicinity of each subsurface lateral boundary location.	▪ Repeating pattern of historical monthly groundwater elevations.

5.3 Projected Groundwater Levels

Figure 5-8 includes hydrograph comparisons of transient modeled and target groundwater levels for the future baseline and future baseline with 2070 DEW climate scenario conditions. Simulated groundwater levels are presented from the start of the historical calibration period (WY 2000) through the end of the projected period (WY 2071). The horizontal and vertical axes on the hydrographs presented on Figure 5-8 have been standardized to facilitate making comparisons among the hydrographs. In general, simulated groundwater levels tend to decline through the historical simulation period and level off through the end of the project simulation period. Overall, there are minor changes in the future baseline as compared to the future baseline with climate change scenario except for a number of wells that portray lower groundwater levels under the future baseline with 2070 DEW climate as compared to future baseline conditions. A full set of modeled and measured groundwater-level hydrographs extending through the projection period is included in Attachment 2.

5.4 Projected Water Budgets

GSP Regulations Section 354.18 requires the GSA to develop historical, current, and projected water budgets for the Subbasin. Section 4.4 discusses the historical and current water budgets. The following sections discuss the average annual water budgets. Full historical and future water budget datasets (with and without climate change) are included in Attachments 3 through 7.

5.4.1 Land System

Table 5-2 presents averages of the individual Subbasin components of the historical, future baseline, and future baseline with 2070 DEW climate conditions land system water budgets. Figure 5-9 presents the annual time series of each Subbasin component of the historical and future baseline land system water budgets. In general, the hierarchy of inflows and outflows from the land system are consistent under historical and future conditions; however, there is a shift in the source of water used for irrigation in the Subbasin due to surface-water availability in the future leading to a higher reliance on groundwater. Additionally, a higher reliance on groundwater pumping for irrigation is observed under future baseline with 2070 DEW climate change conditions due to a reduction in available precipitation.

Table 5-2. Average Annual Historical and Projected Land System Water Budgets

Land System Budget Term	Historical Average Annual Flow (TAFY) WYs 2000–2025	Future Baseline Average Annual Flow (TAFY) WYs 2026–2071	Future Baseline with 2070 DEW Climate Conditions Average Annual Flow (TAFY) WYs 2026–2071
Inflows			
Precipitation	85	85	75
Applied Water from TID Deliveries	79	46	46
Applied Groundwater from Private Agricultural Pumping	53	67	77
Shallow Groundwater into the Rootzone	2	1	1
Total Inflow	219	199	199
Outflows			
Runoff to Streams/Canals	10	10	9
Evapotranspiration of Precipitation	36	36	31
Evapotranspiration of Shallow Groundwater	2	1	1
Evapotranspiration of Applied Water	113	96	105
Groundwater Recharge from Precipitation and Applied Water	58	56	53
Total Outflow	219	199	199

5.4.2 Groundwater System

Table 5-3 presents averages of the individual Subbasin components of the historical, future baseline, and future baseline with 2070 DEW climate conditions groundwater system water budgets. Figure 5-10 presents the annual time series of each Subbasin component of the historical and future baseline groundwater system water budgets. In general, the hierarchy of inflows and outflows from the groundwater system are consistent under historical and future conditions. This is expected because the projected boundary conditions reflect a repeating pattern of historical conditions. However, minor changes are observed under future baseline and future baseline with 2070 DEW climate change conditions for groundwater recharge from precipitation and applied water, which results from reductions in projected precipitation under the 2070 DEW climate change condition. Overall, the changes in climate tend to result in slightly less total inflow and outflow as compared to historical and future baseline conditions. Groundwater pumping is projected to increase from historical conductions under future baseline and future baseline with 2070 DEW climate conditions. The higher reliance on groundwater in the future results from the repeated historical period having a higher reliance on groundwater and is increased under the future baseline with 2070 DEW climate conditions due to a decrease in precipitation and increase in ET resulting in higher crop demands. Groundwater discharge to drains is expected to decrease under future baseline and future baseline with 2070 DEW climate conditions due to groundwater levels generally being lower, resulting in less connectivity between the drains and the underlying water table.

Like historical conditions, the annual average change in groundwater storage under future baseline with 2070 DEW climate conditions resulted in a small negative value, indicating a slight decrease in groundwater storage over the projected period. However, the groundwater storage declines observed indicate that the Subbasin is generally stable, reflecting sustainable conditions.

Table 5-3. Average Annual Historical and Projected Groundwater Water Budgets

Groundwater Budget Term	Historical Average Annual Flow (TAFY) WYs 2000–2025	Future Baseline Average Annual Flow (TAFY) WYs 2026–2071	Future Baseline with 2070 DEW Climate Conditions Average Annual Flow (TAFY) WYs 2026–2071
Inflows			
Groundwater Recharge from Precipitation and Applied Water	58	56	53
Groundwater Recharge from Canal Laterals	47	44	44
Groundwater Recharge from Tulelake Sumps	10	11	12
Groundwater Recharge from Main Canals and Lost River	71	73	73
Subsurface Inflow from Surrounding Area	17	17	16
Total Inflow	203	201	198
Outflows			
Irrigation and M&I Groundwater Pumping	8	8	8
Private Groundwater Pumping	50	63	72
Total Subbasin Groundwater Pumping	58	71	80
Groundwater Discharge to Drains	137	117	102
Shallow Groundwater Evapotranspiration	2	1	1
Groundwater Discharge to Tulelake Sumps	0	0	0
Groundwater Discharge to Main Canals and Lost Rivers	0	0	0
Subsurface Outflow to Surrounding Area	10	12	18
Total Outflow	206	201	201
Change in Groundwater Storage	-3	0	-3

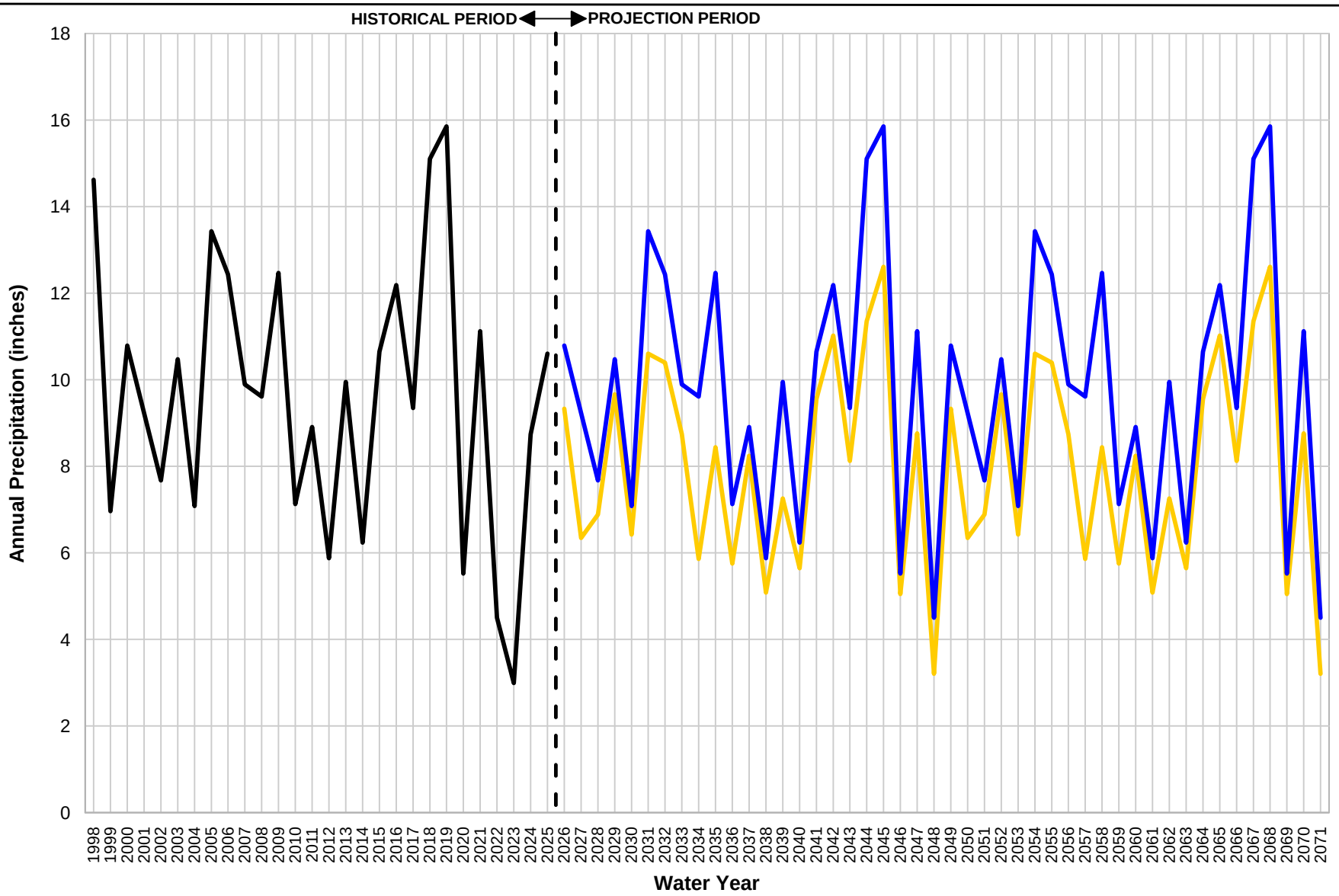


Figure 5-1
Historical Versus 2070 Climate Change Adjusted Precipitation
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

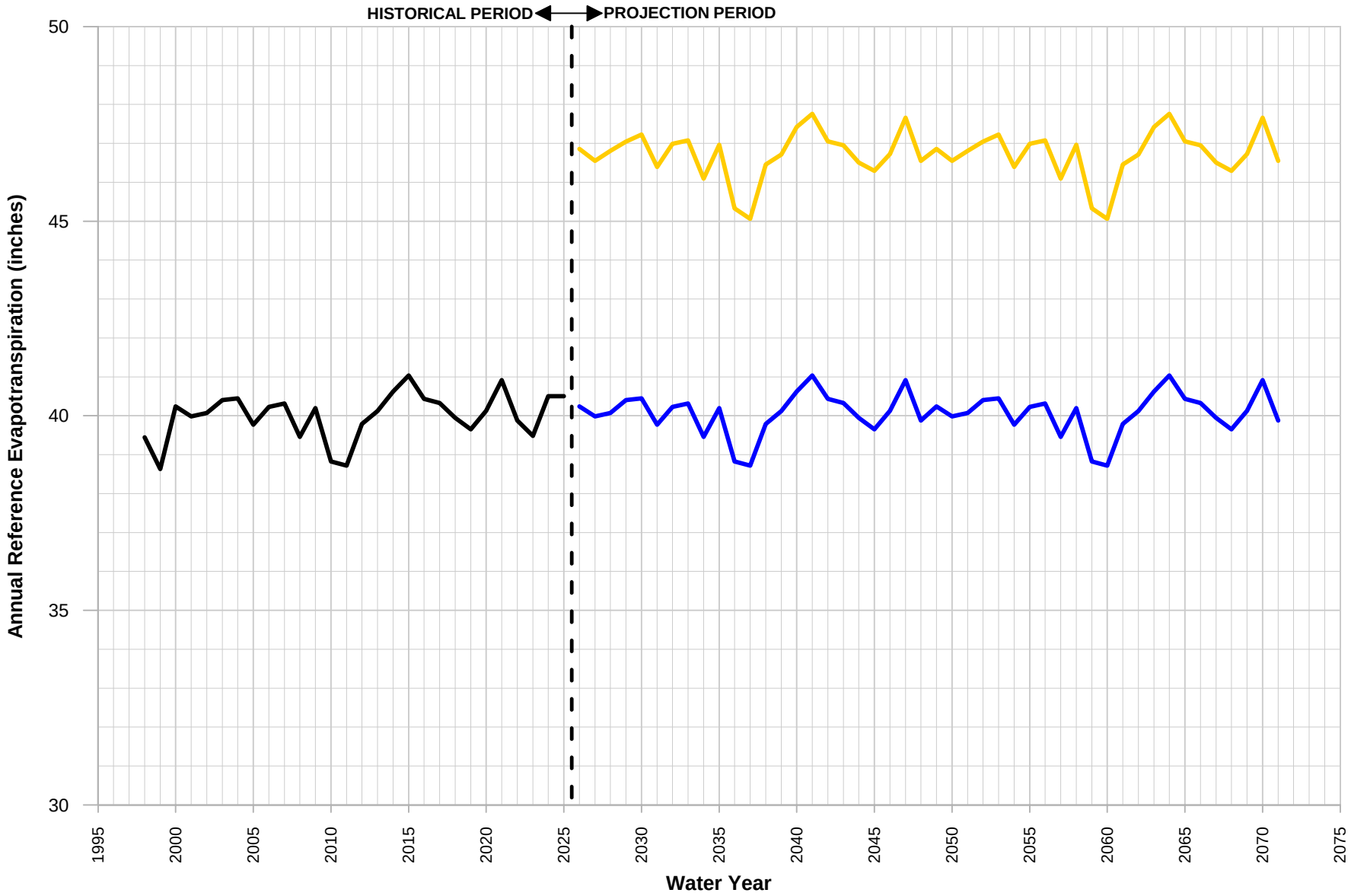
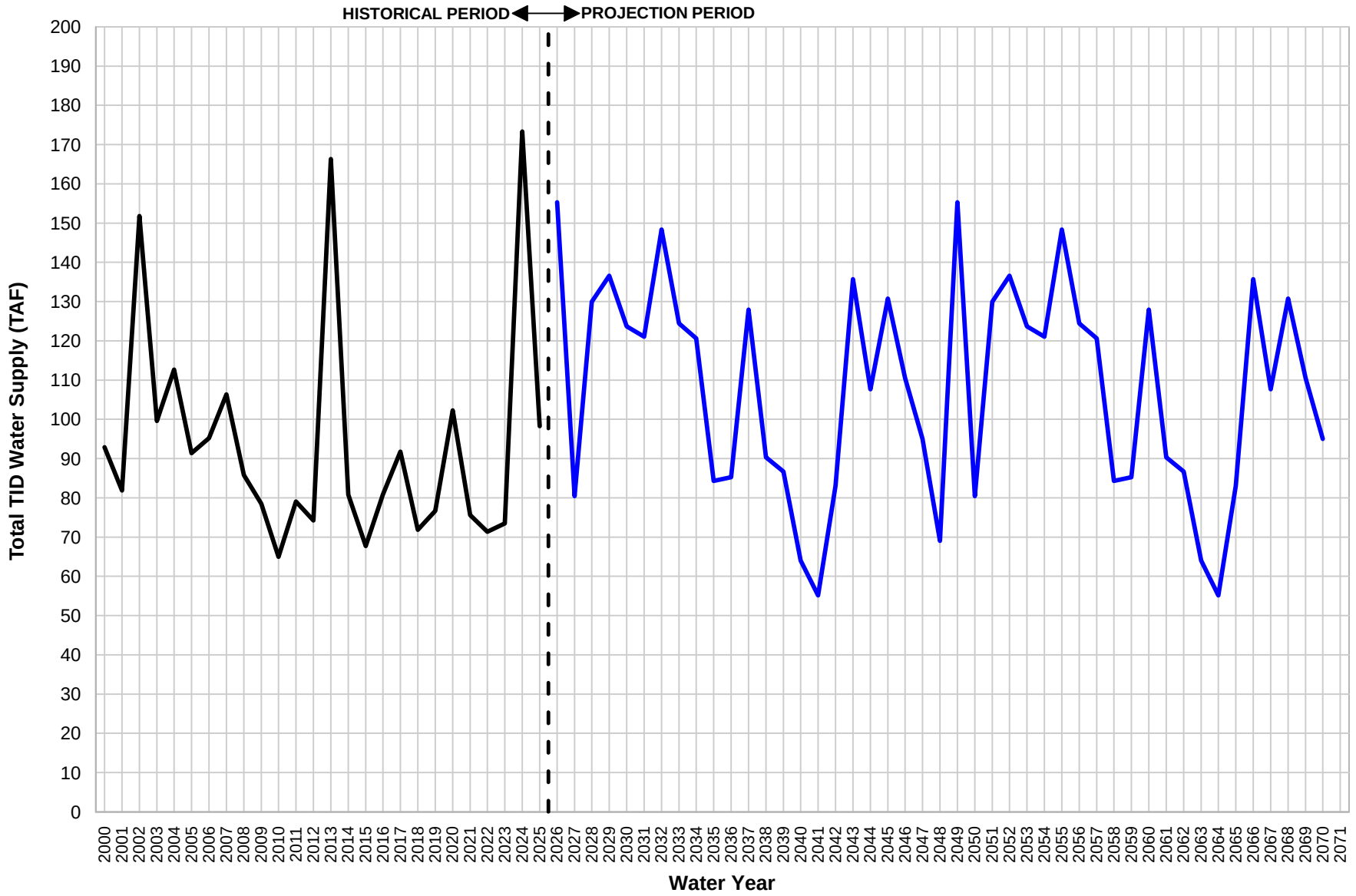


Figure 5-2
Historical Versus 2070 Climate Change Adjusted Reference Evapotranspiration
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin



Notes:
TID Water Supply = Station 48 Diversions + Lost River Spills at Anderson Rose Dam + TID Groundwater Supply.

Figure 5-3
Historical and Projected TID Total Supply
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

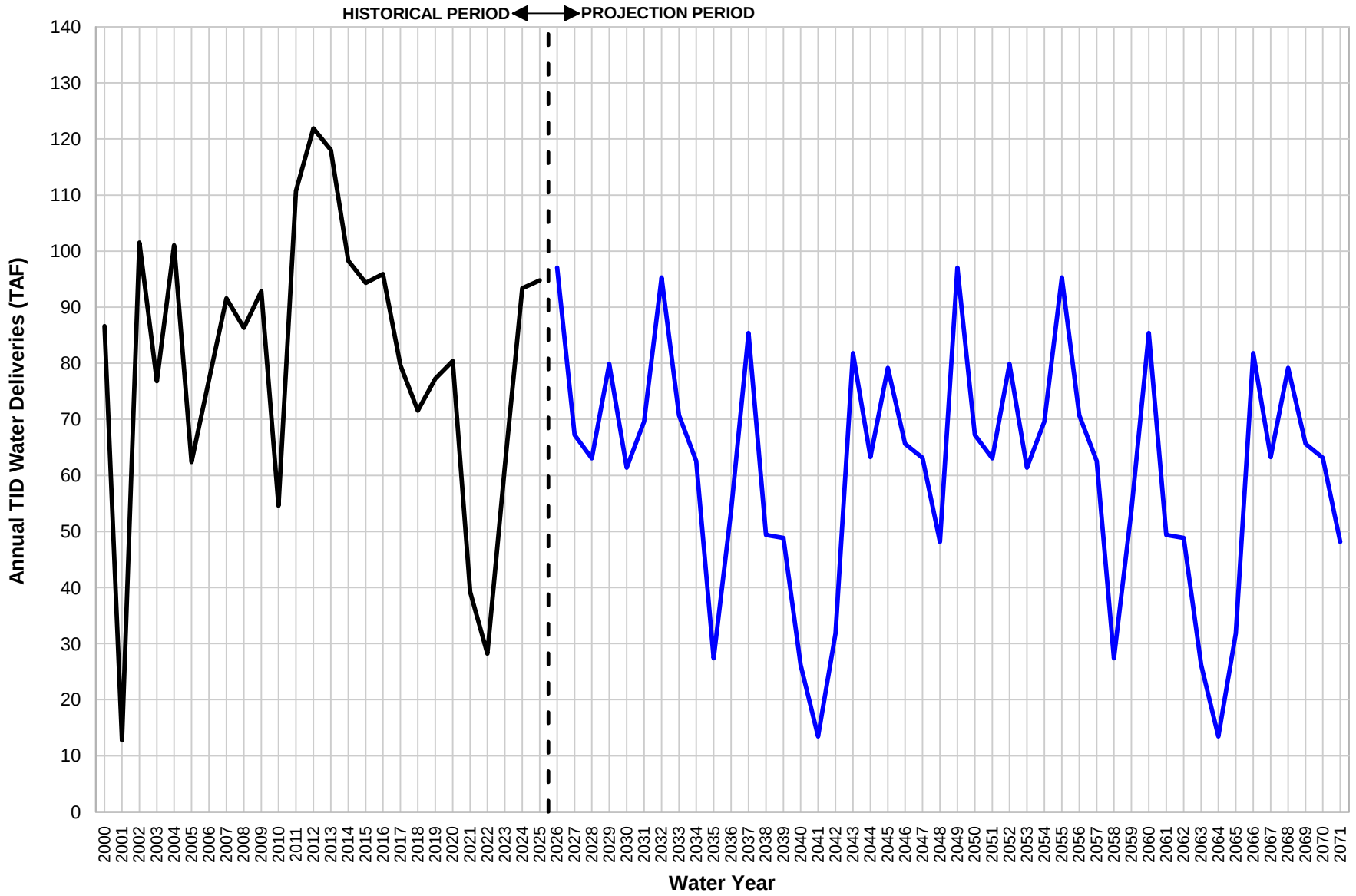


Figure 5-4
Historical and Projected Annual TID Water Deliveries
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

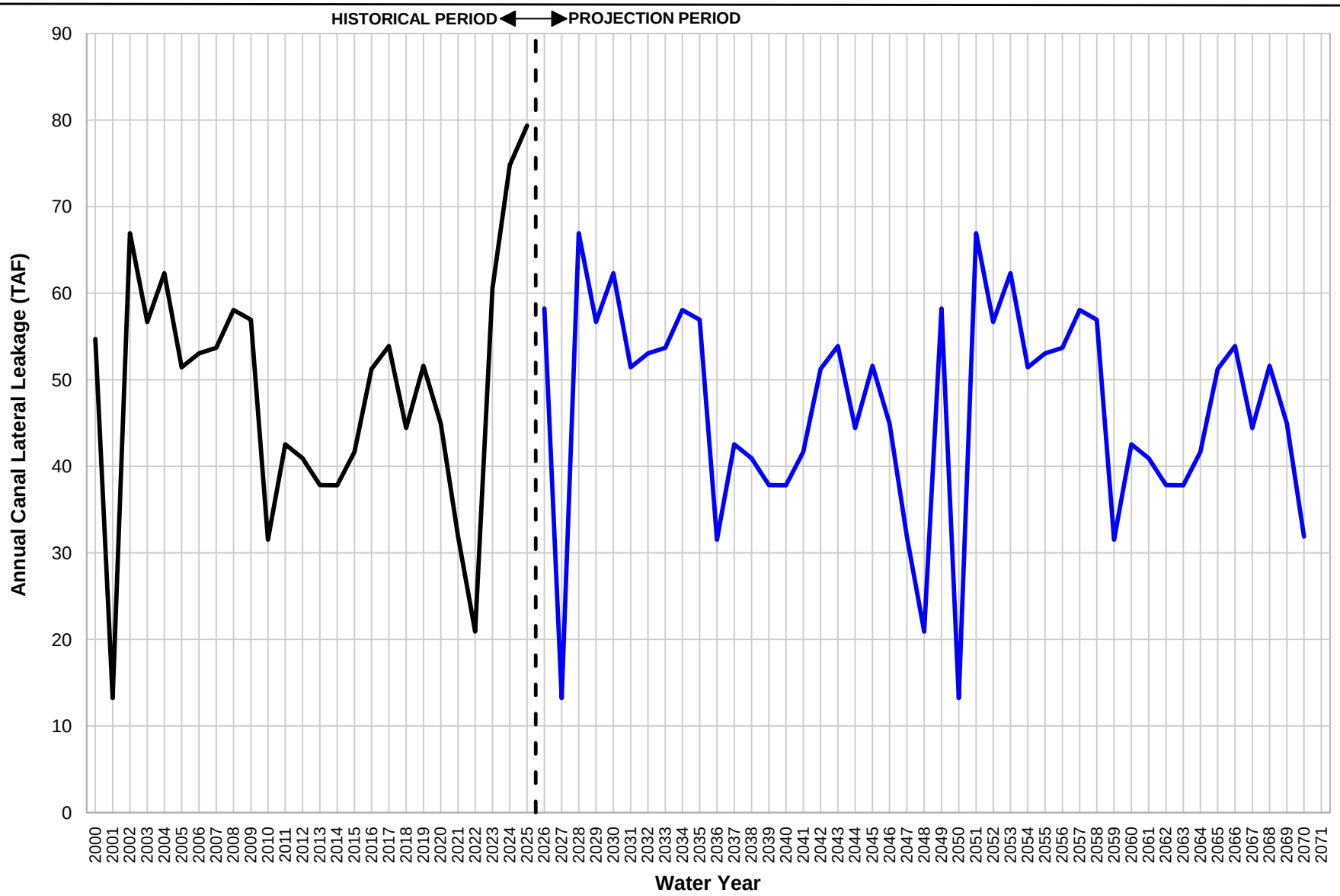


Figure 5-5
Historical and Projected Canal Lateral Leakage
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

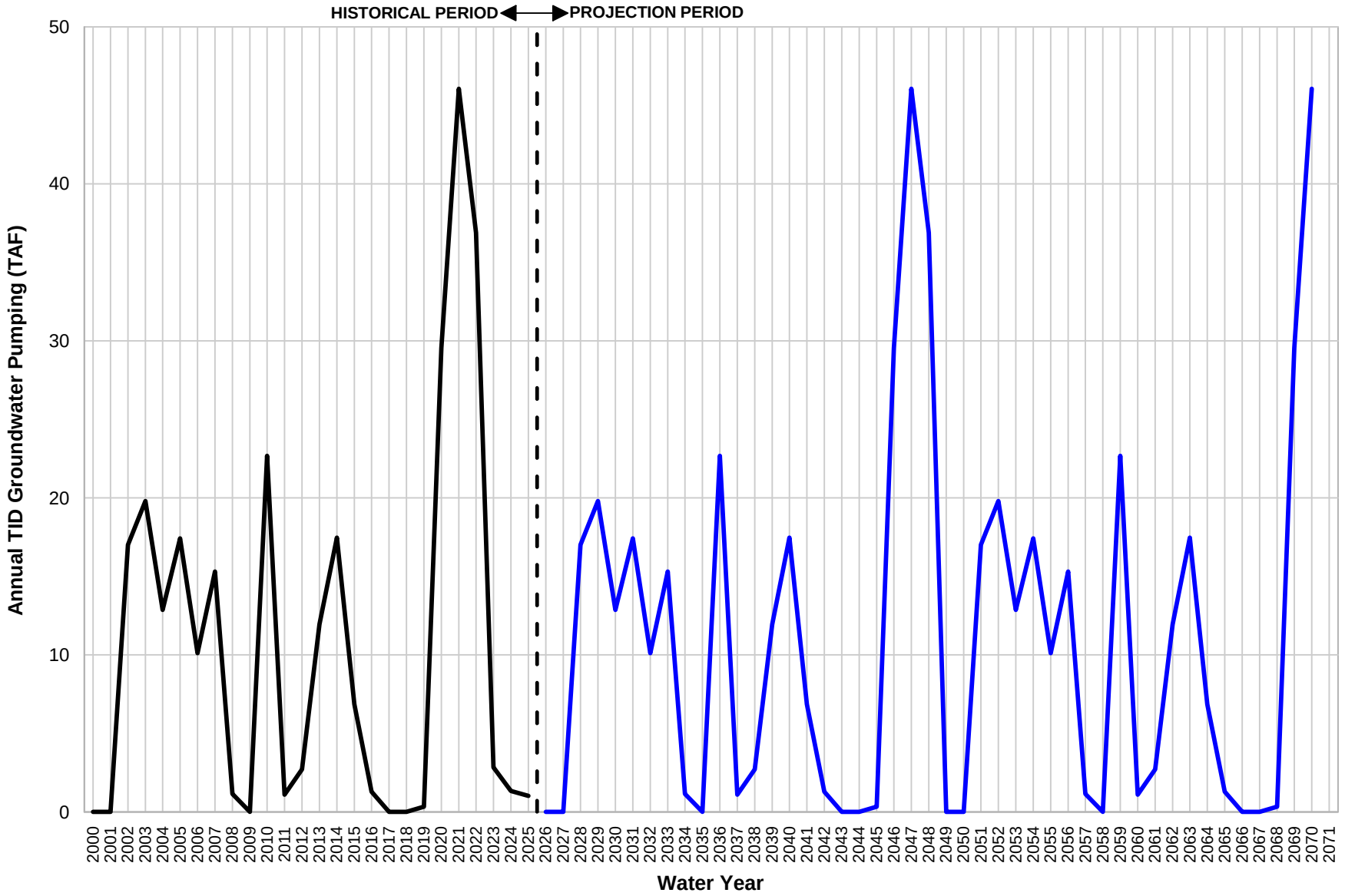


Figure 5-6
Historical and Projected TID Groundwater Pumping
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

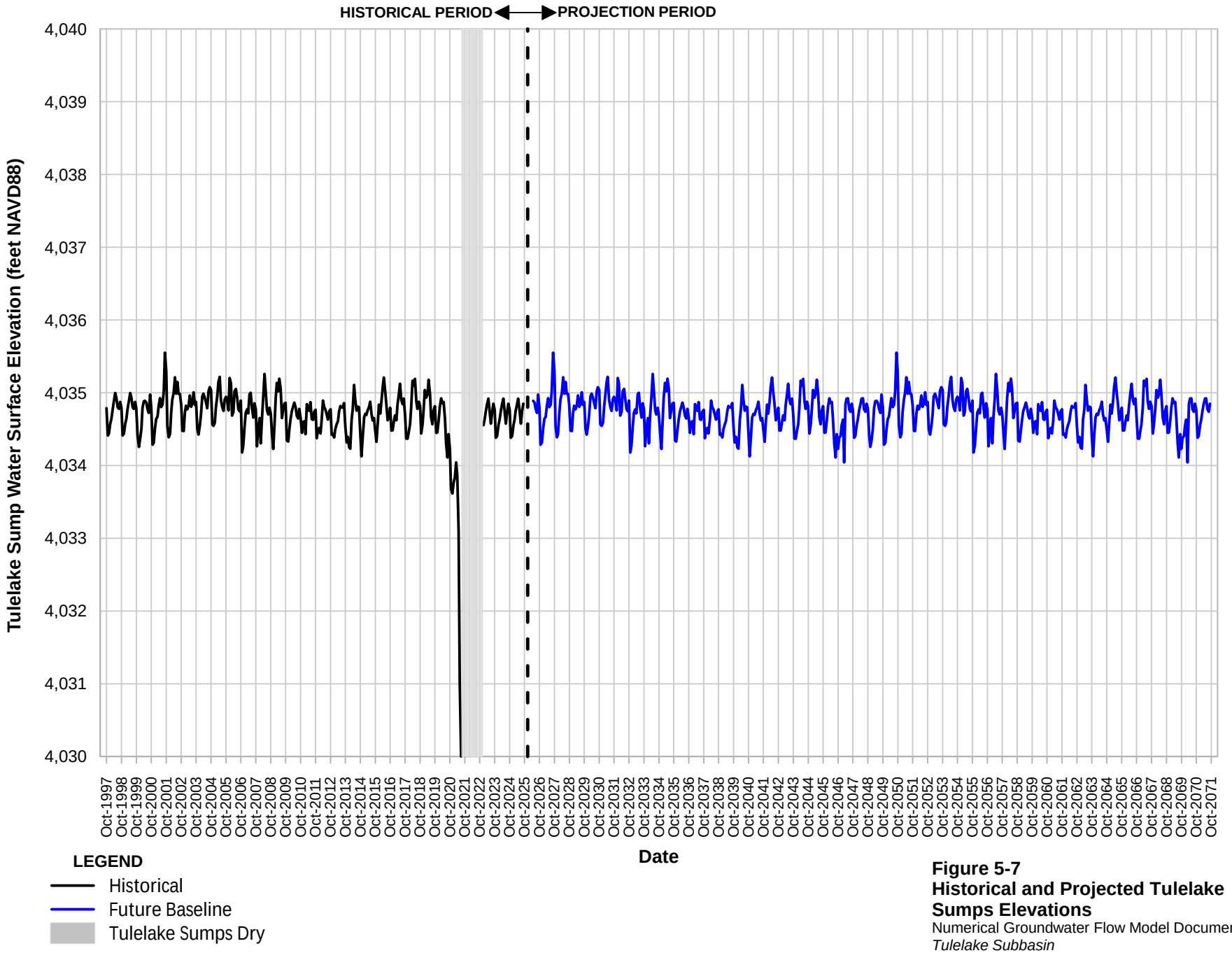
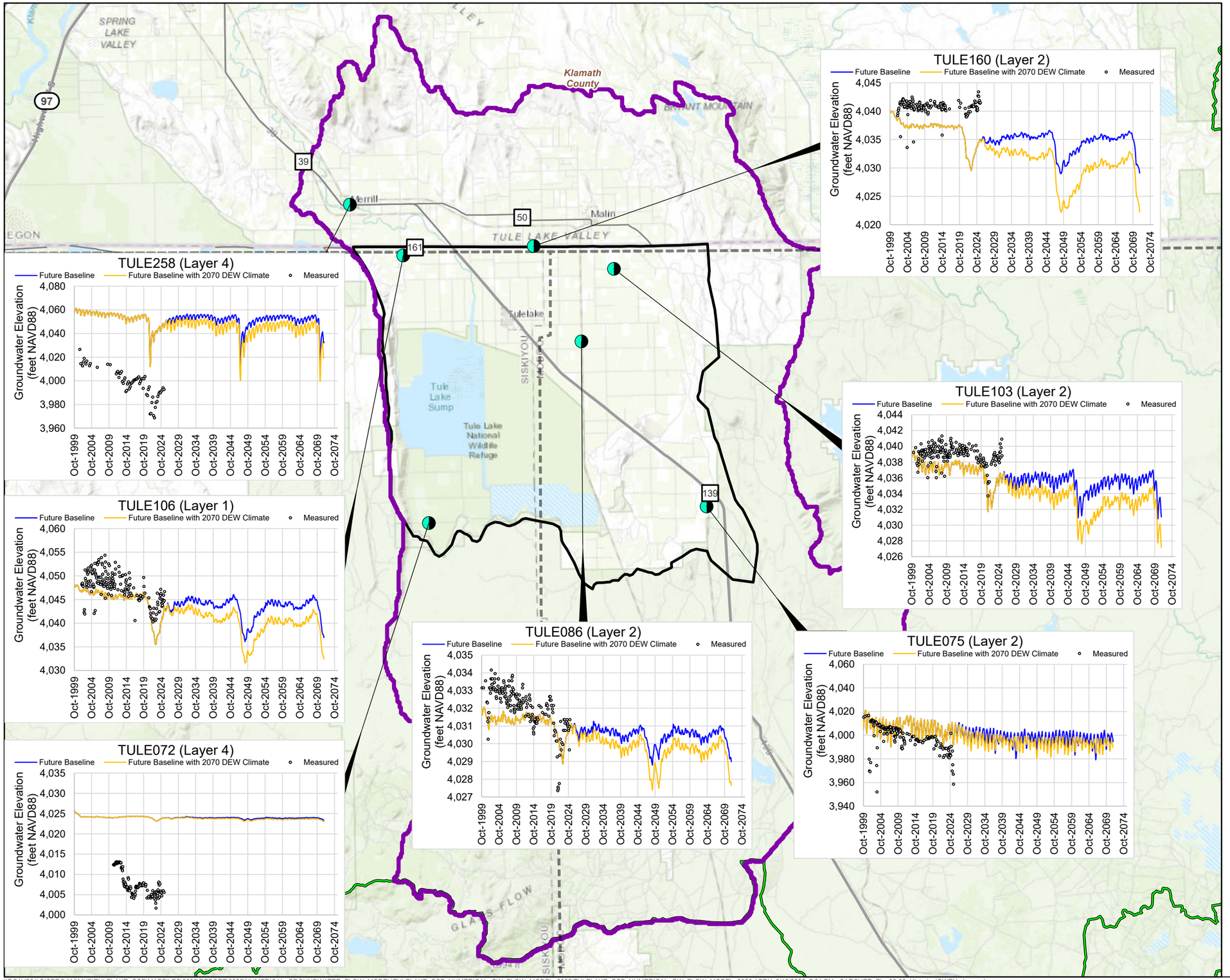
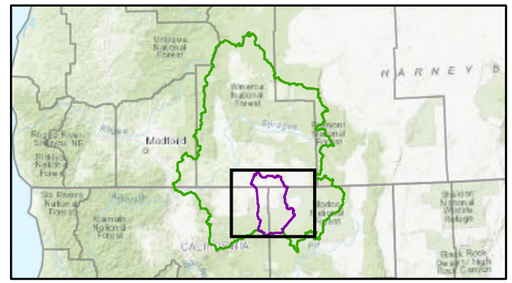


Figure 5-7
Historical and Projected Tulelake Sumps Elevations
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin





LEGEND

- Upper Klamath Basin
- Bulletin 118 Subbasin Boundary
- Model Domain Boundary
- County Boundaries
- Head Target Location

Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS
World_Topo_Map: Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
World Hillshade: Esri, NASA, NGA, USGS

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Figure 5-8
Historical and Projected Groundwater Elevation Hydrographs
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

Jacobs

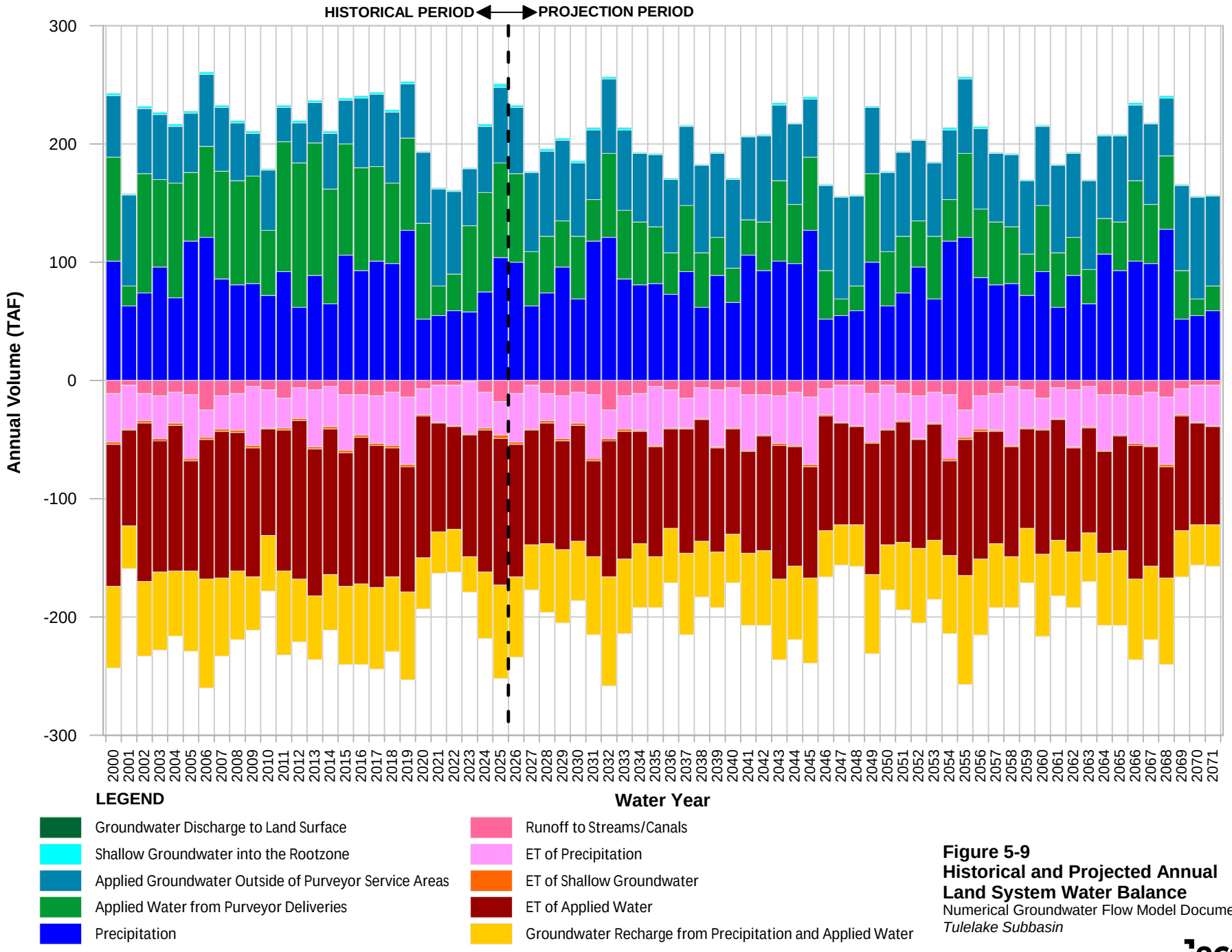

Figure 5-9
Historical and Projected Annual Land System Water Balance
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

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Jacobs

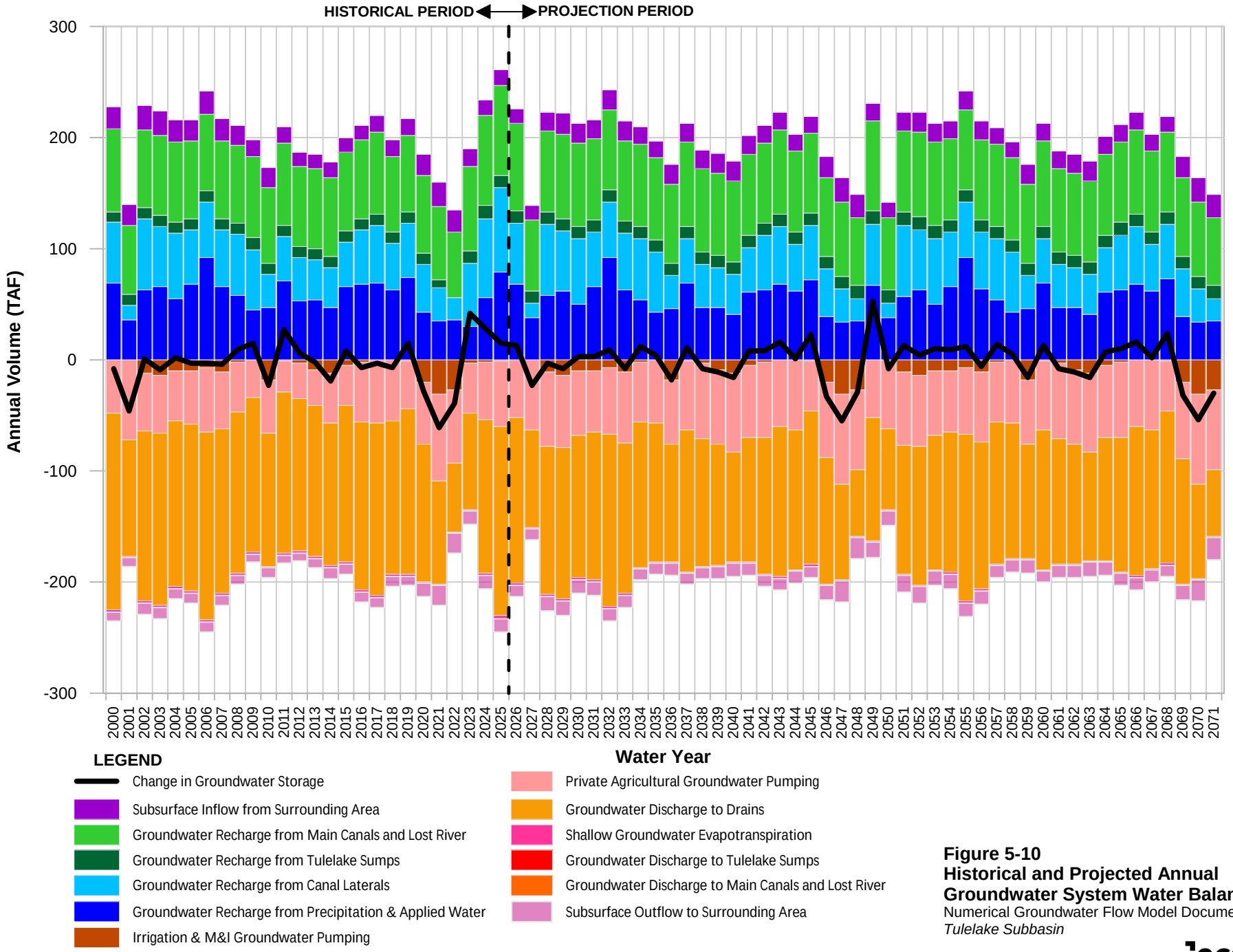

Figure 5-10
Historical and Projected Annual Groundwater System Water Balance
Numerical Groundwater Flow Model Documentation
Tulelake Subbasin

6. Conclusions and Recommendations

Jacobs has developed an integrated groundwater/surface-water flow model (called the GSA Model) of an area encompassing the Subbasin in Modoc and Siskiyou Counties, California. This report was prepared by Jacobs to support the GSAs in the preparation of the GSP. This model integrates the 3D groundwater and surface-water systems, land surface processes, and operations. The model was constructed and calibrated to simulate groundwater and surface-water flow conditions within a 610-square-mile area encompassing the Subbasin using the USGS OneWater code (Boyce et al., 2020) and the USGS BCM (Flint et al., 2013; Flint and Flint, 2014). The calibration version of the GSA Model simulates historical hydrologic conditions from October 1997 through September 2025, whereas the projection version of the GSA Model simulates future hydrologic conditions from October 2025 through September 2071. The climate change projections are based on DWR's 2070 DEW climate change scenario (DWR, 2018). All versions of the model include monthly stress periods to adequately simulate seasonal hydrologic processes.

The historical and projected groundwater systems all indicate that the Subbasin is relatively in balance where the annual average change in storage ranges from a decrease of 3 TAFY under historical conditions and projected conditions. Projected hydrographs indicate that the Subbasin is likely converging on a new equilibrium where water levels are generally stable over the SGMA implementation period.

Now that the GSA Model has been developed to support the GSAs in the preparation of the GSP, it could also be used during the implementation of the GSP to aid in the following:

- Help prioritize and refine the monitoring well network used to demonstrate whether the Subbasin is being managed sustainably
- Forecast potential outcomes to potential conditions or actions not evaluated herein
- Test hypotheses about interrelationships among different hydrologic processes of interest
- Support the GSA with decisions related to managing their water supply portfolios resulting in capital investments for projects and management actions, if necessary
- Provide technical graphics to support public outreach efforts
- Aid in the development of annual SGMA-related reports to DWR, as needed
- Support constructive dispute resolution on the basis of objective scientific analyses, if necessary

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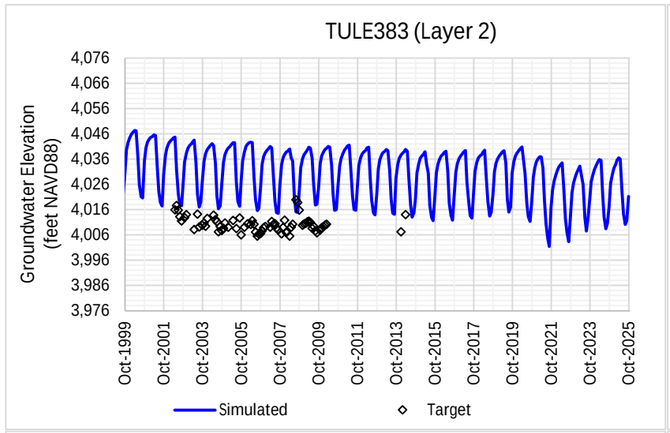
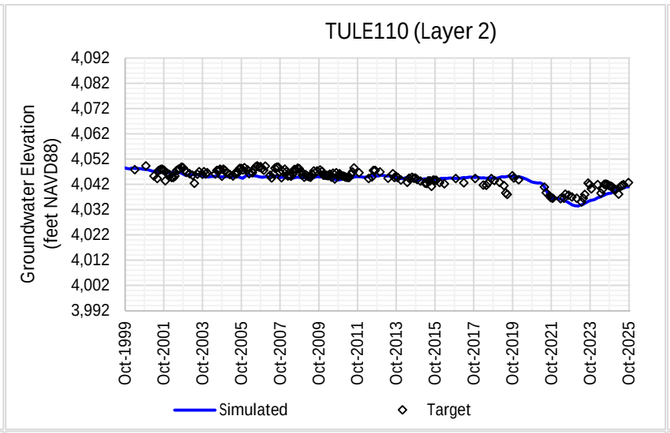
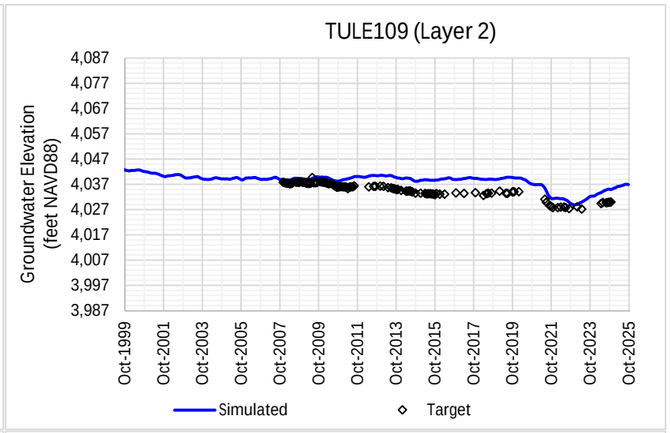
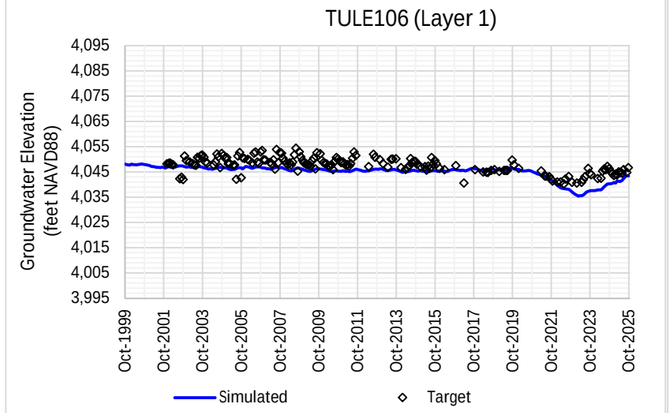
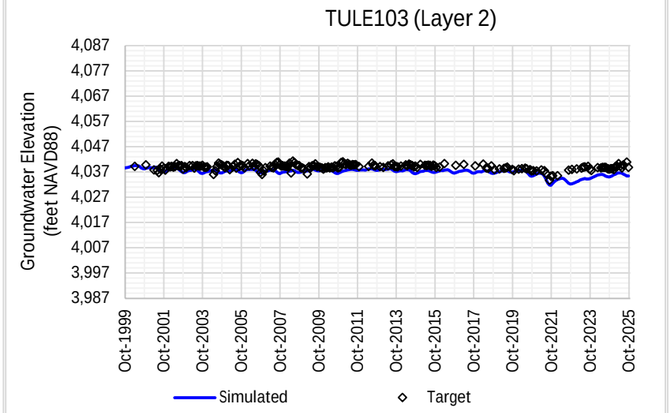
Attachment 1
Modeled Versus Target Groundwater Elevation Hydrographs

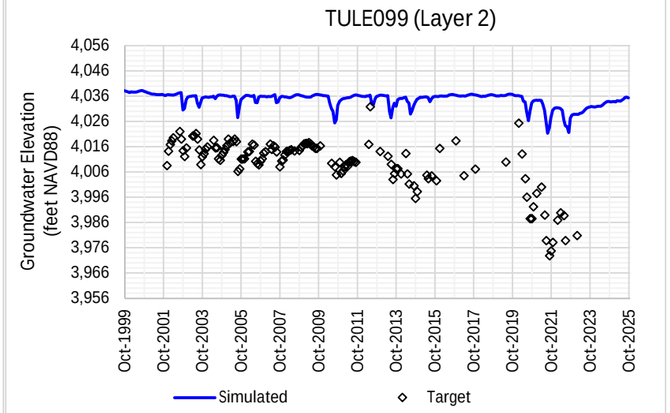


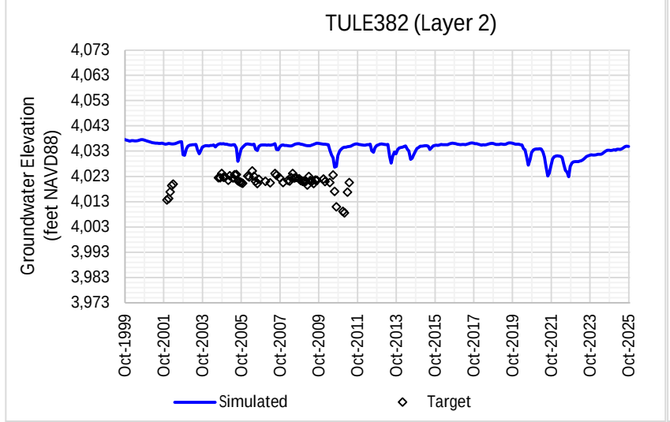


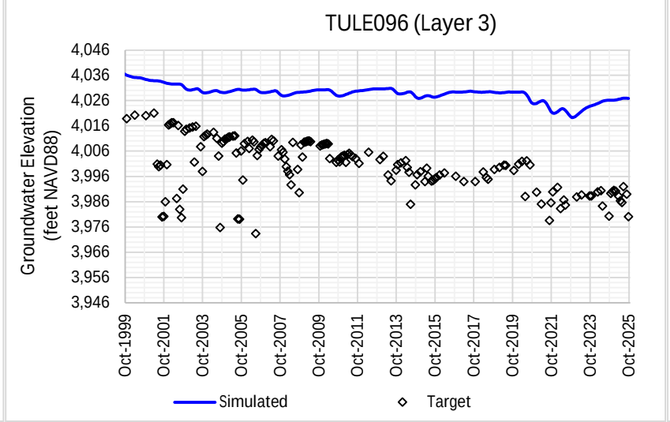


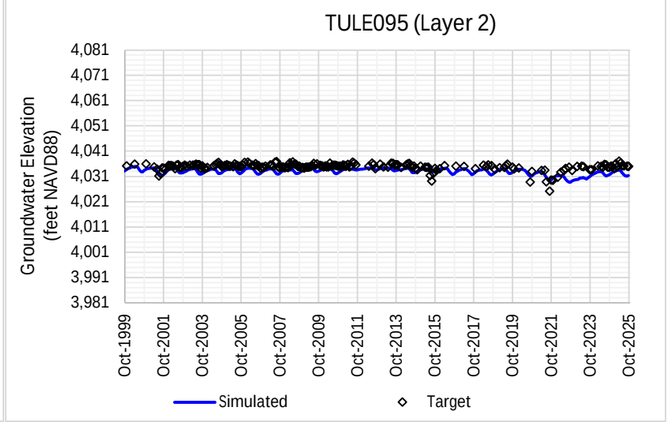






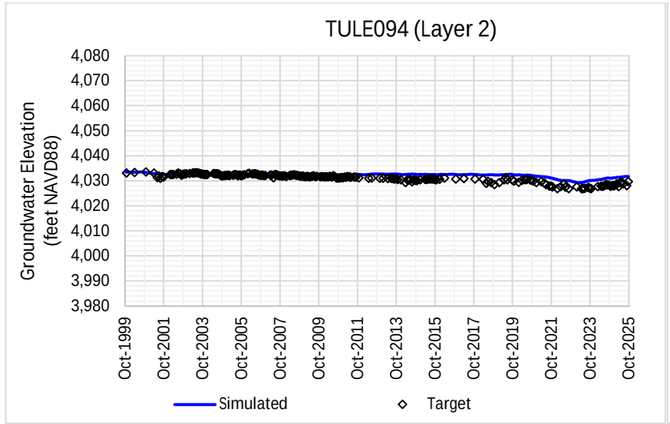


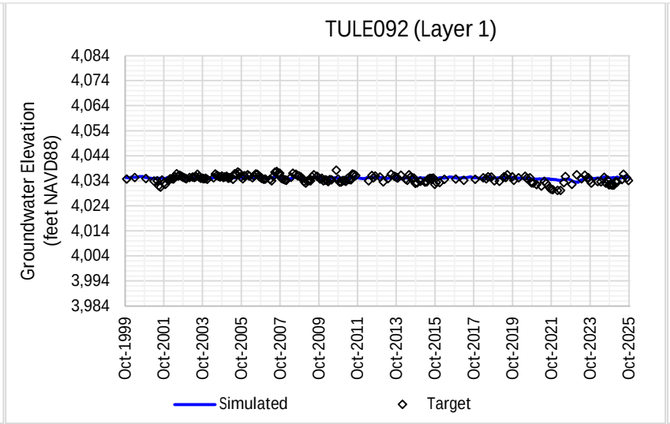


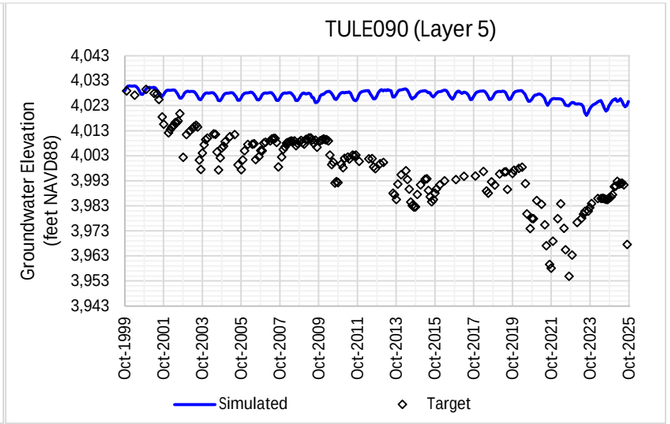


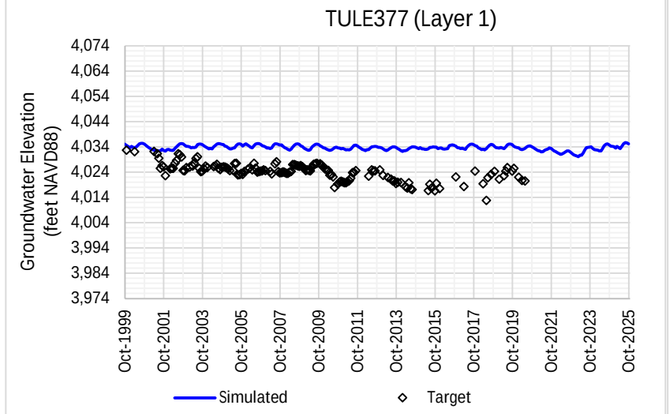
NAVD88 = North American Vertical Datum of 1988

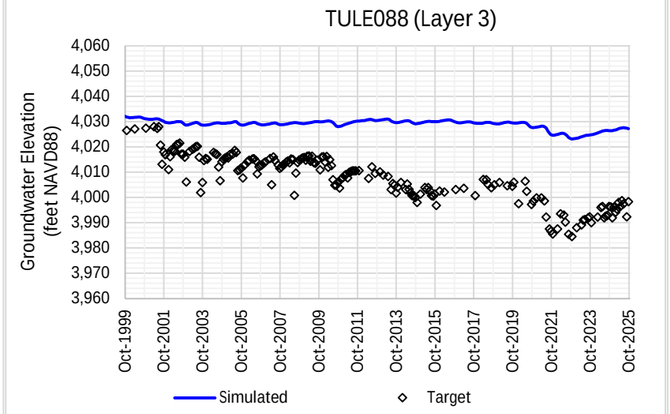
Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

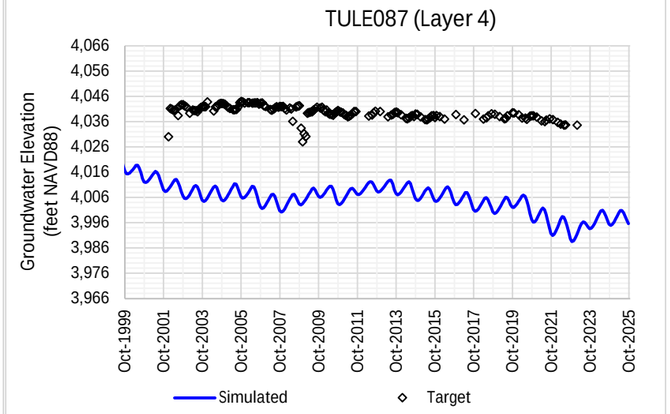


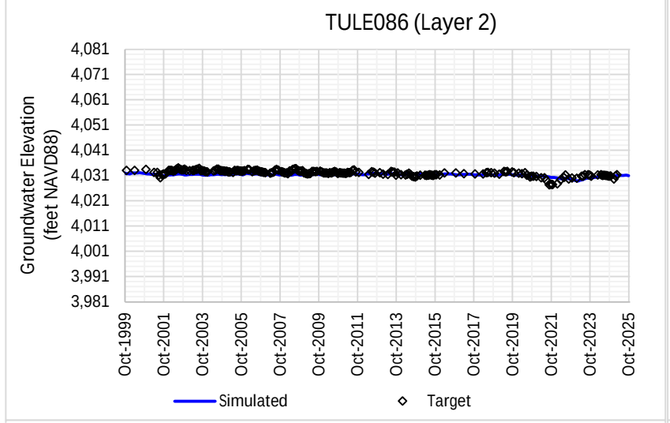


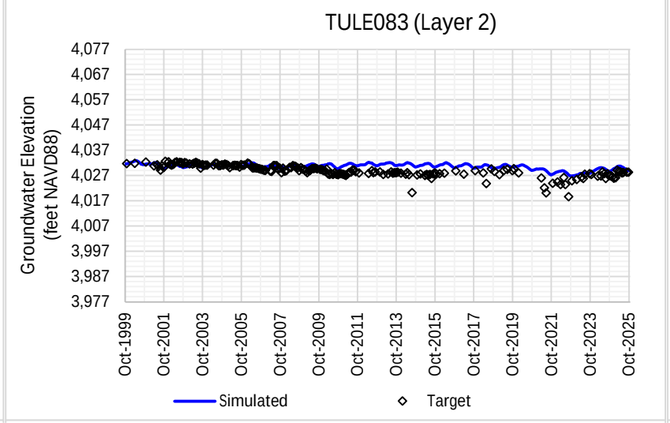


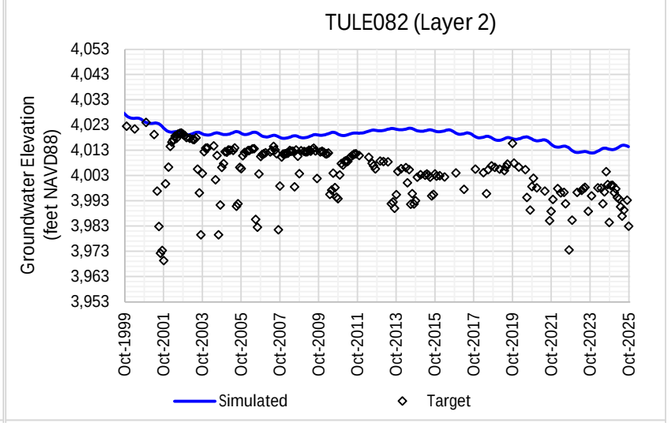












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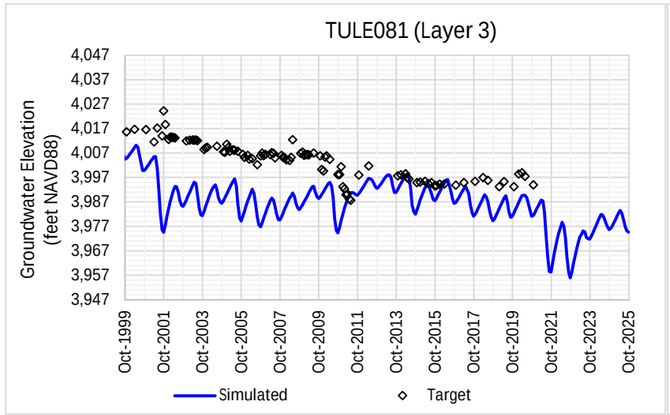
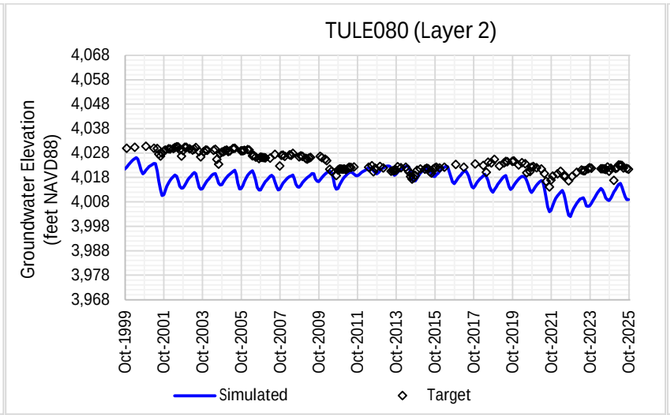
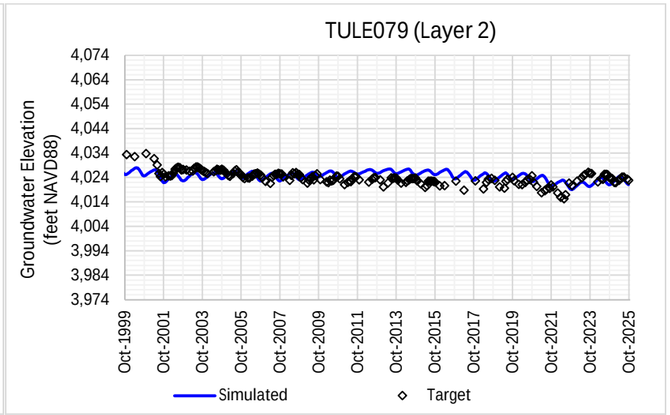
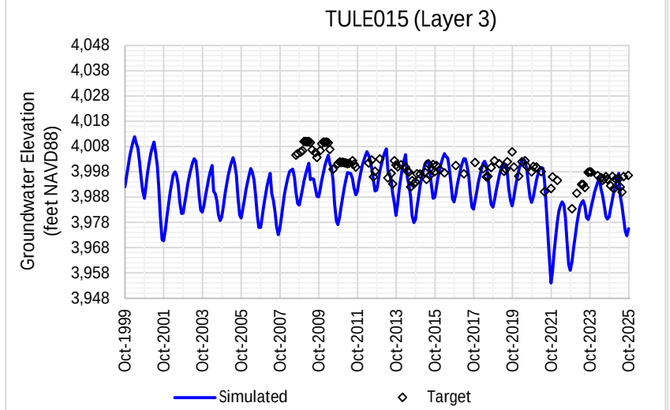
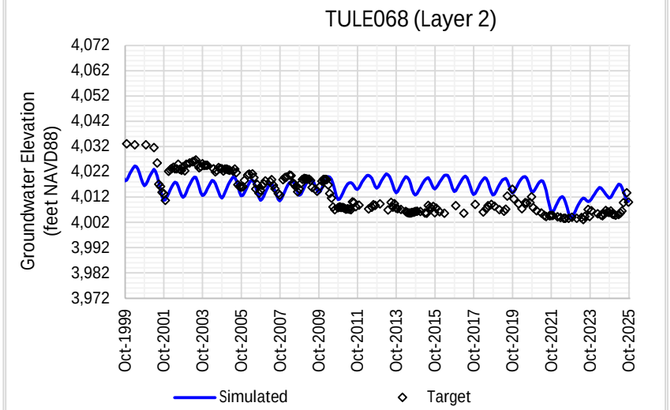
Modeled versus Measured
Groundwater Elevation Hydrographs

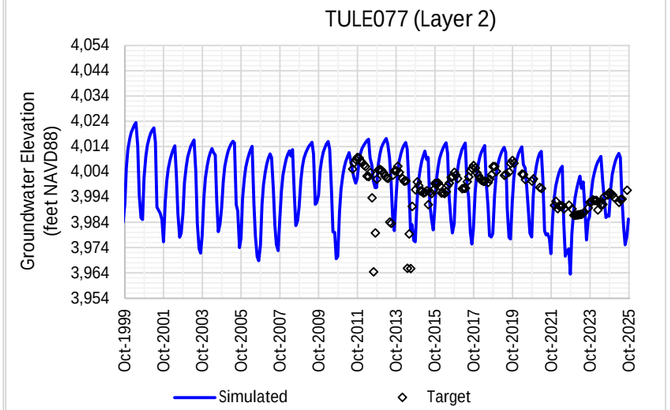


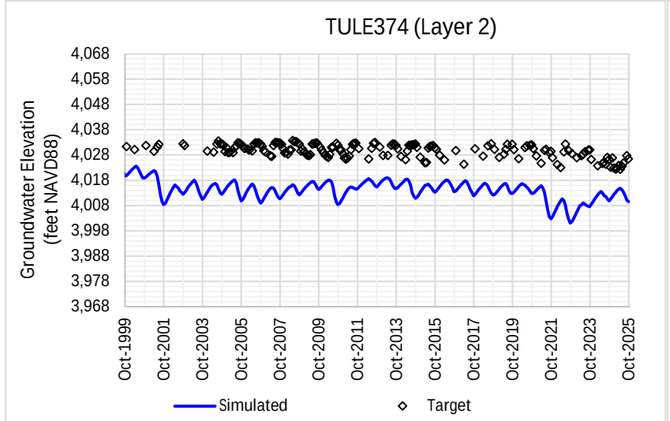


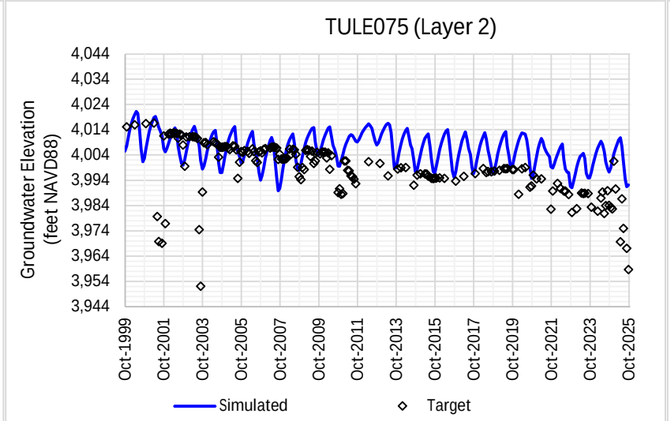


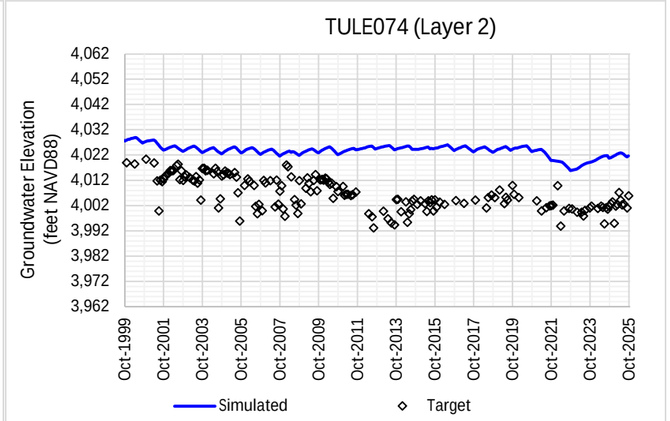












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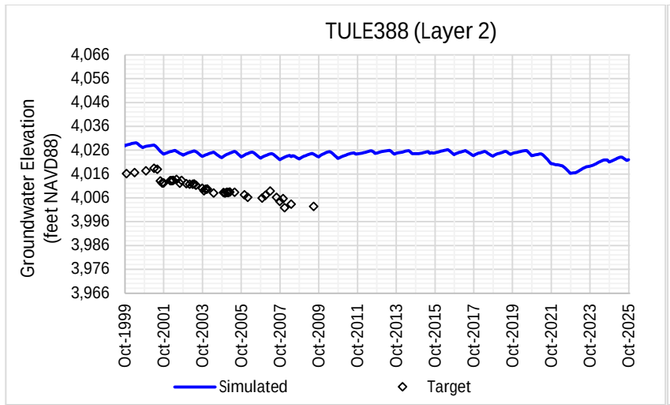
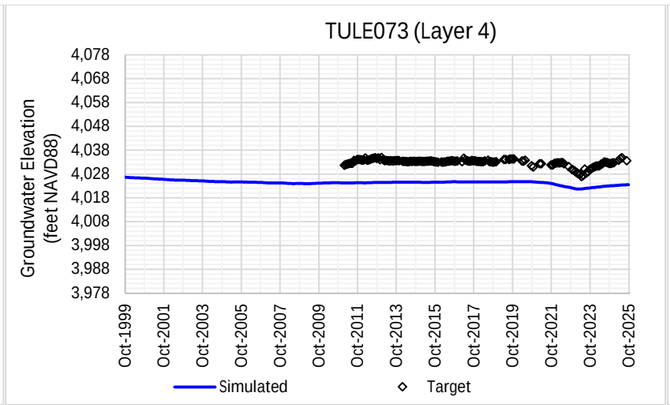
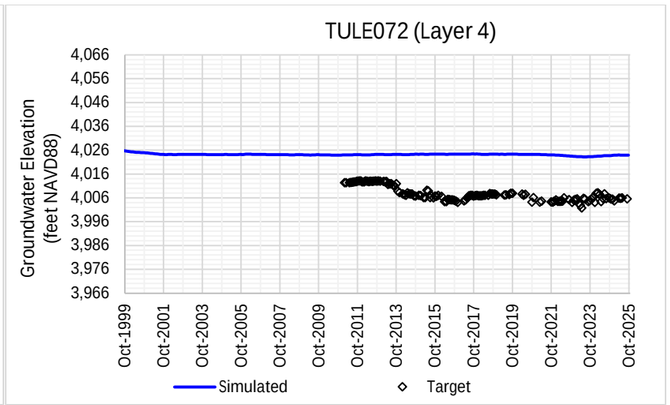
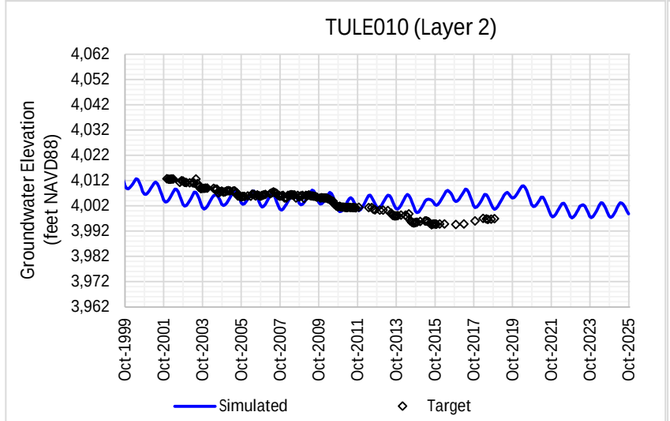
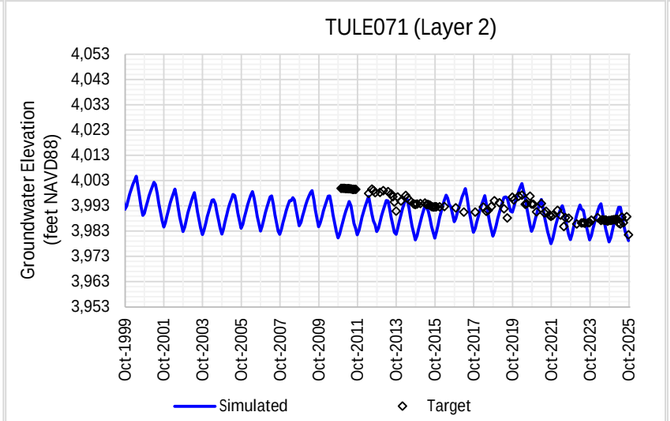
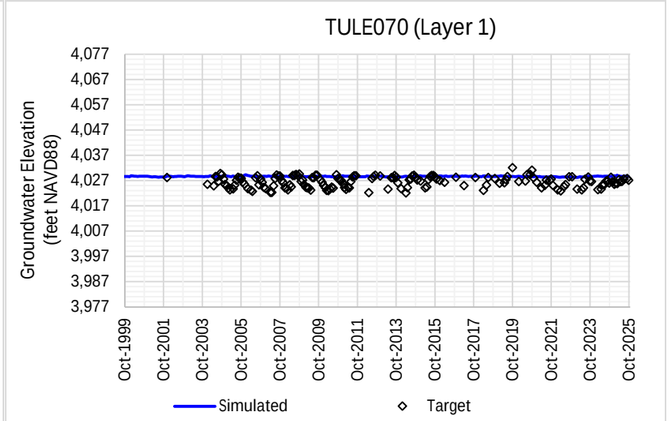


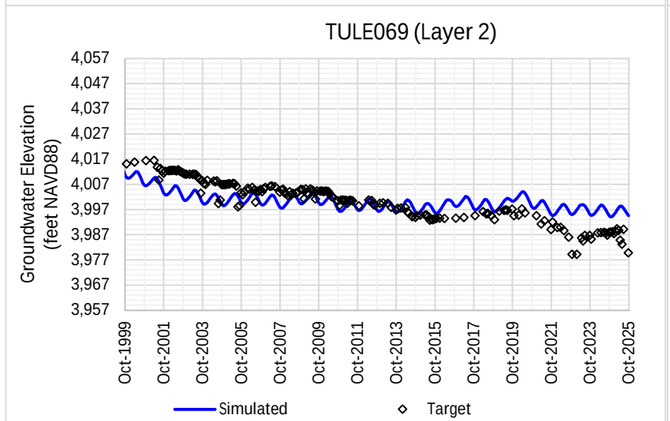


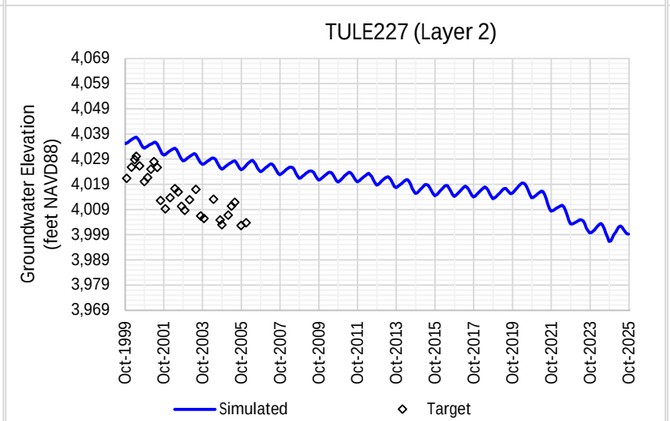


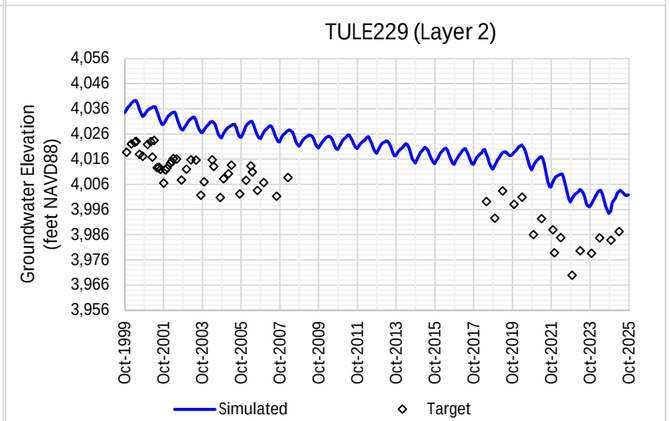






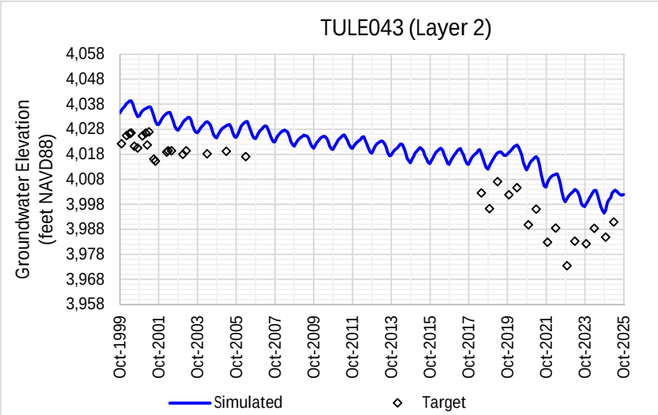


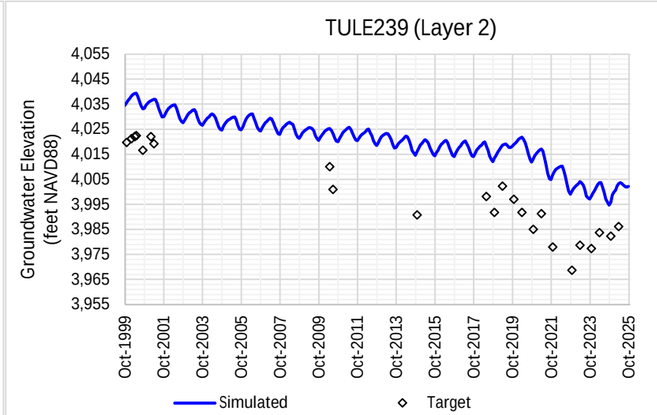


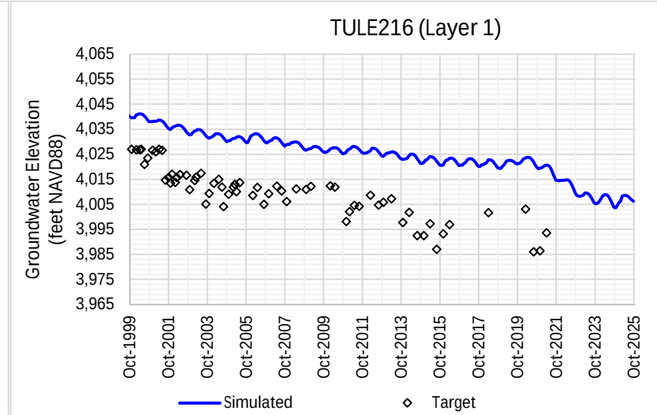


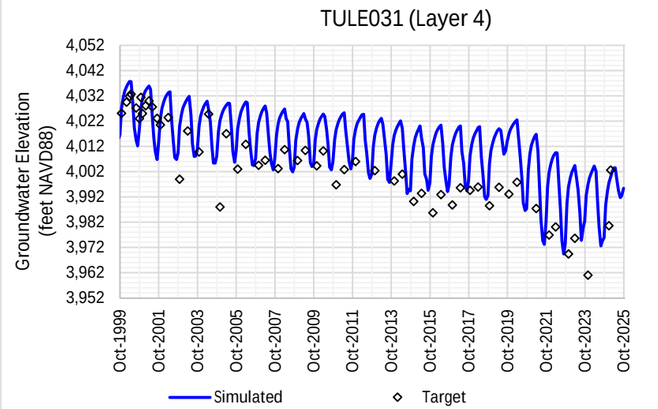
NAVD88 = North American Vertical Datum of 1988

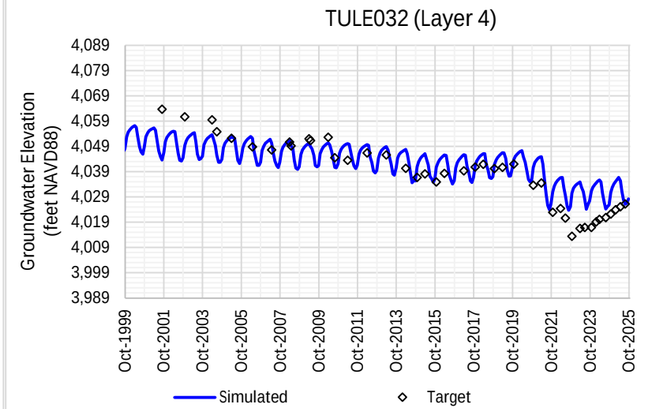
Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

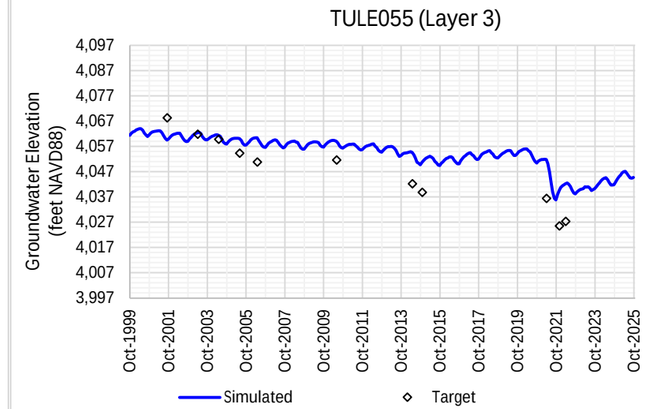


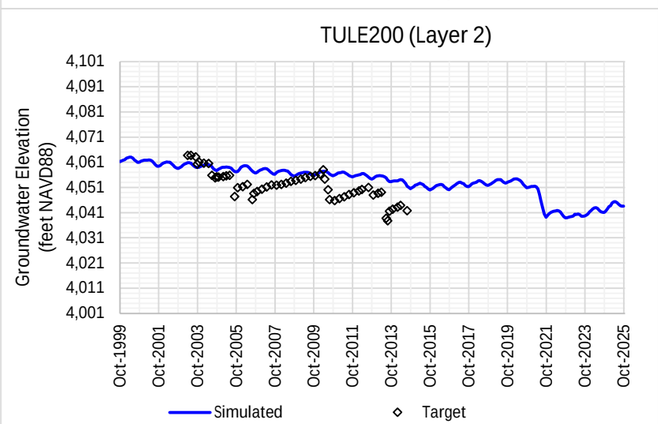


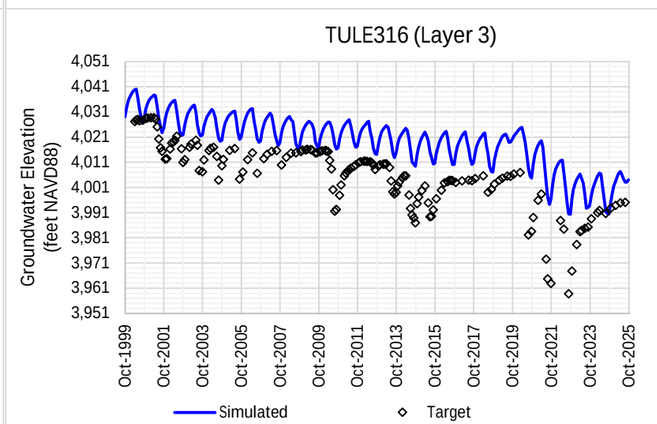


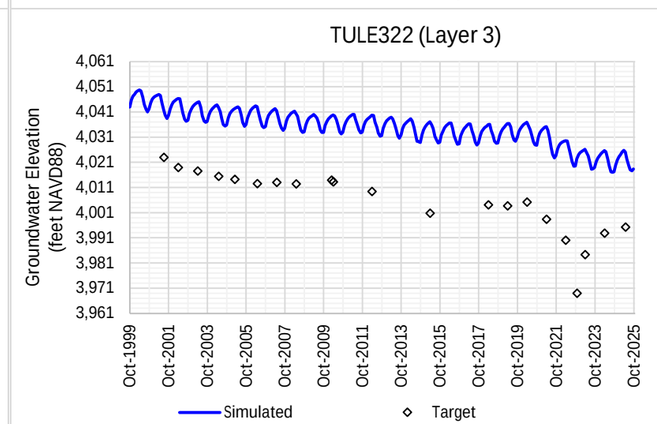




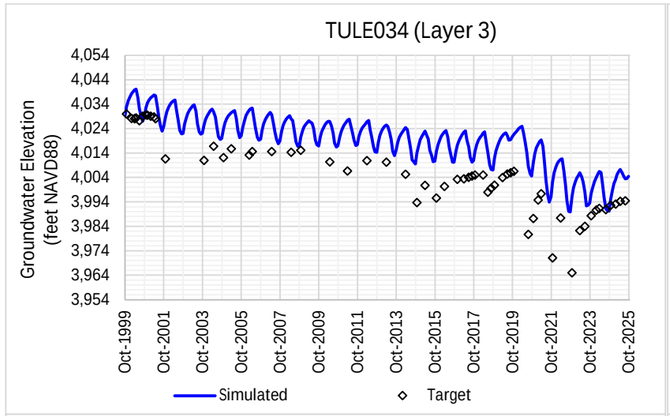


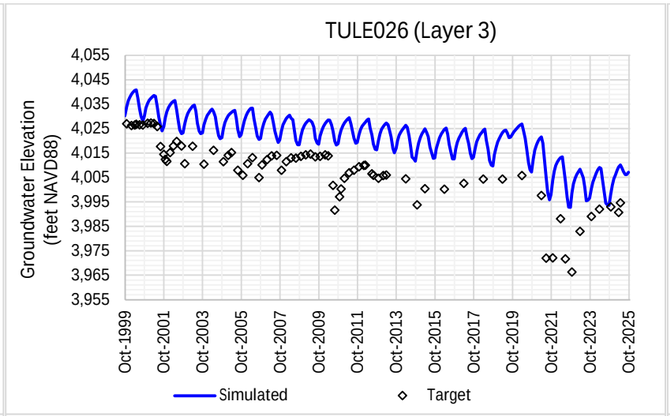


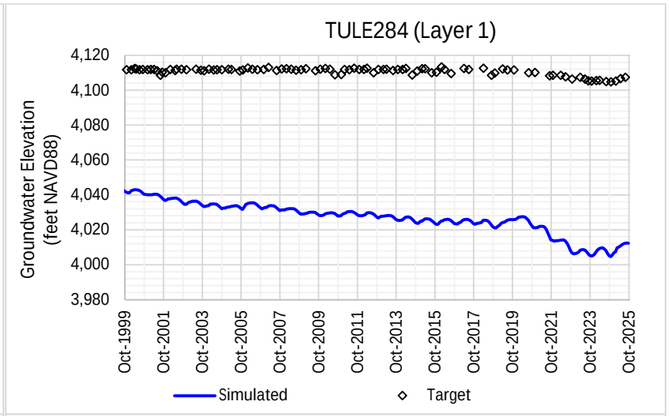


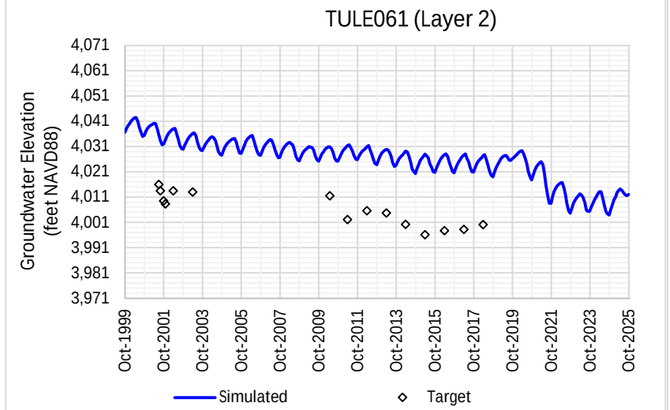


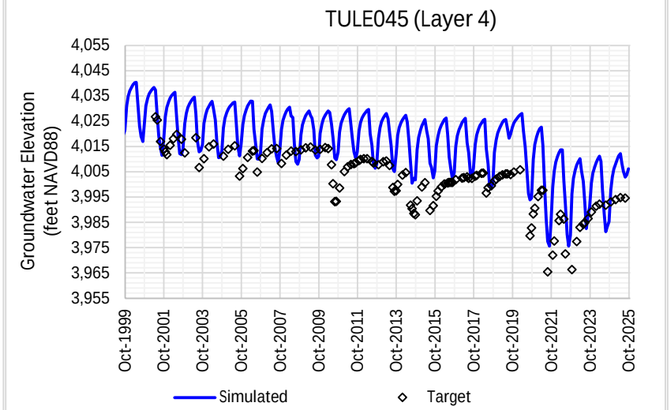
NAVD88 = North American Vertical Datum of 1988

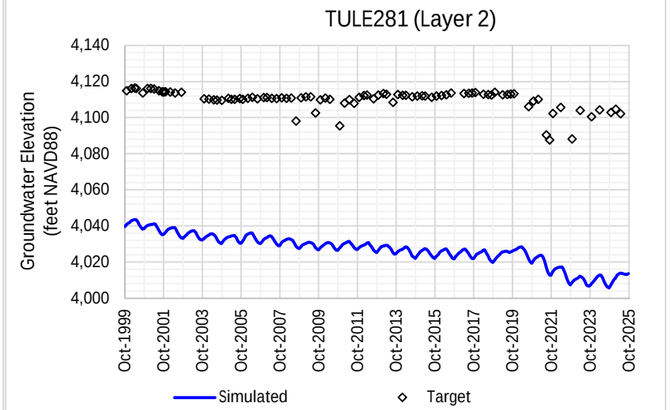


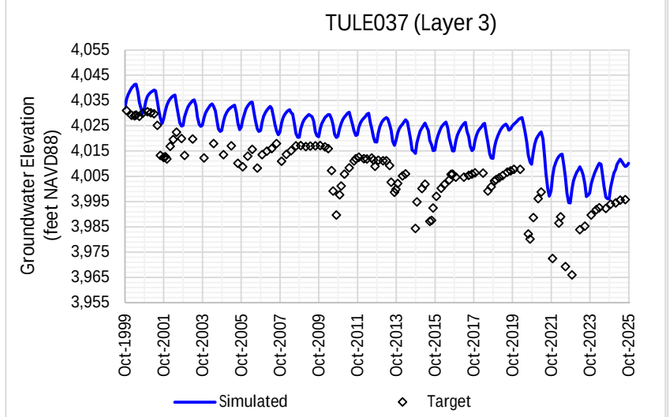


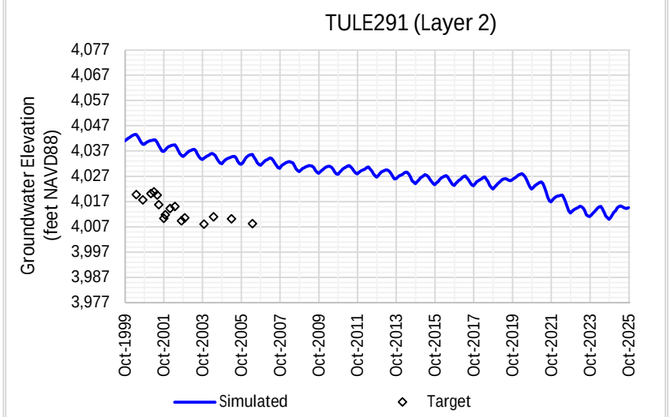


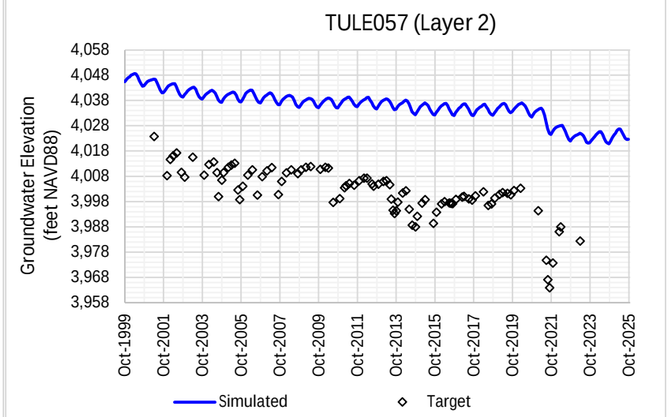






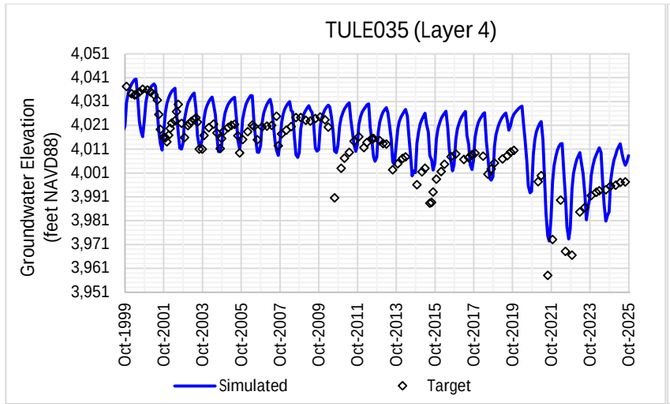


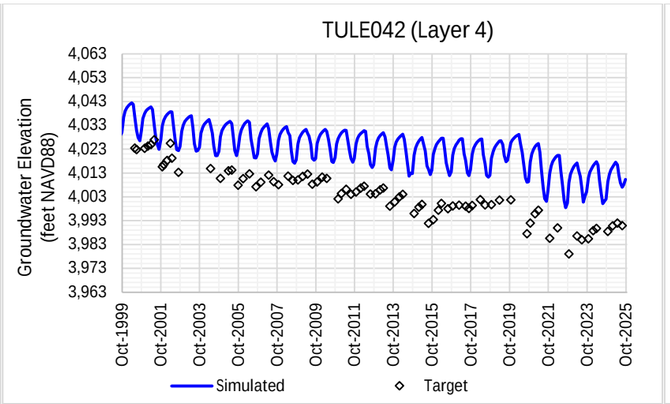


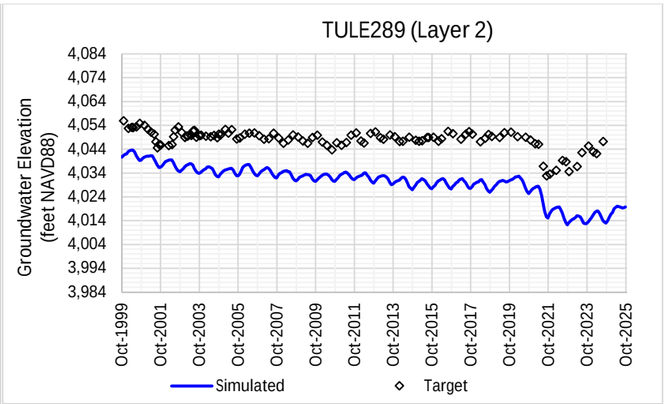


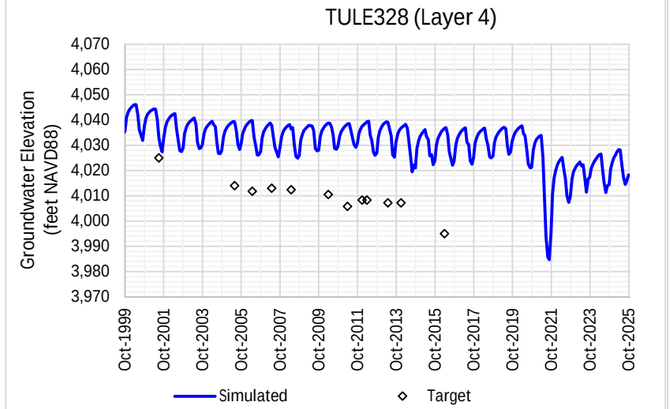
NAVD88 = North American Vertical Datum of 1988

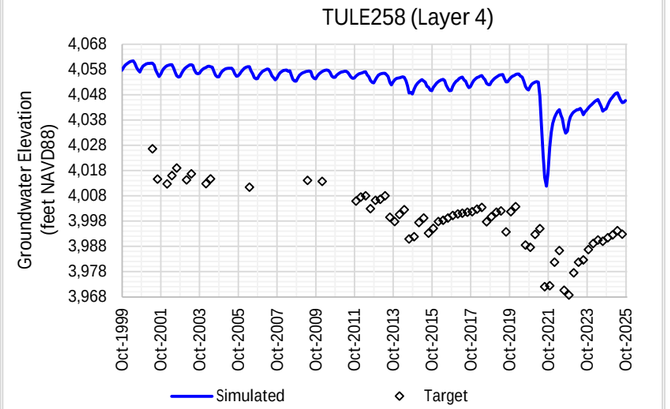
Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

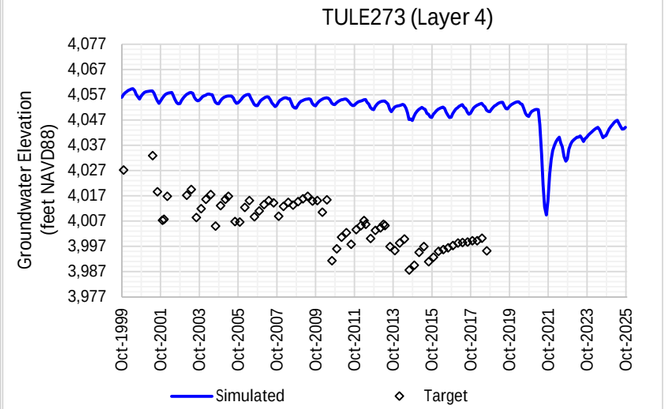


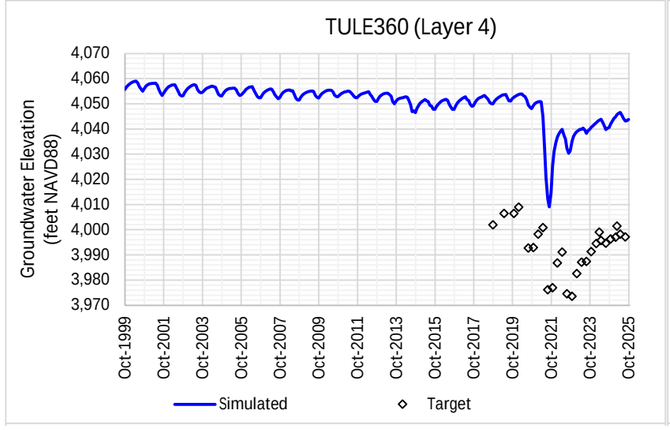


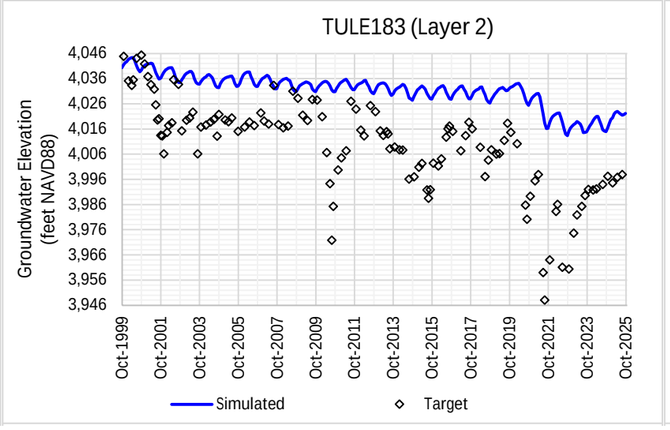


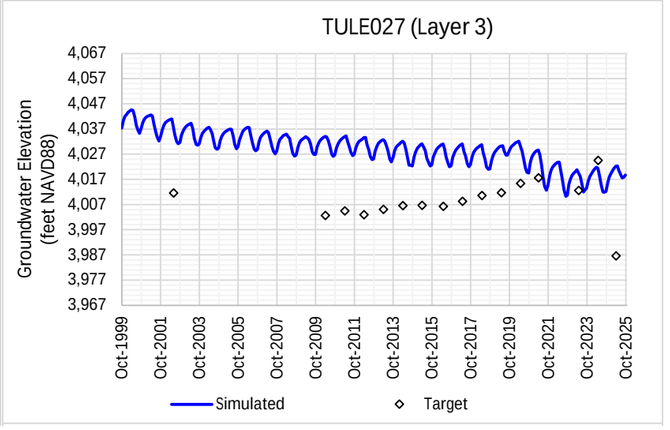






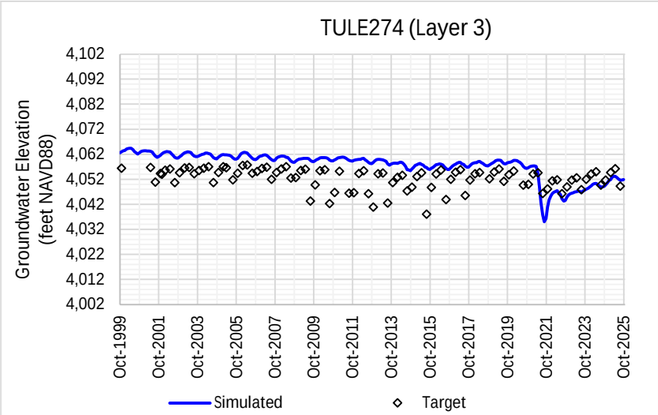


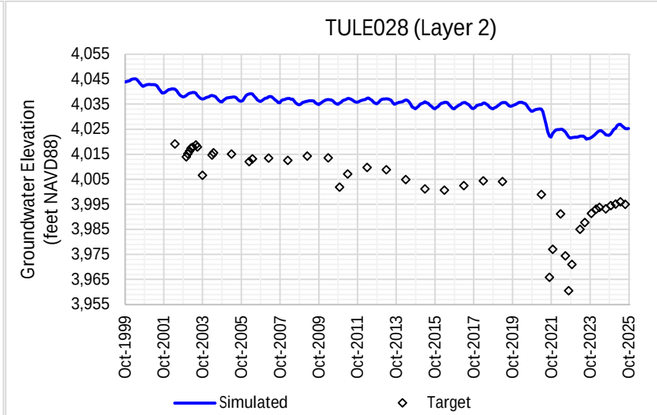


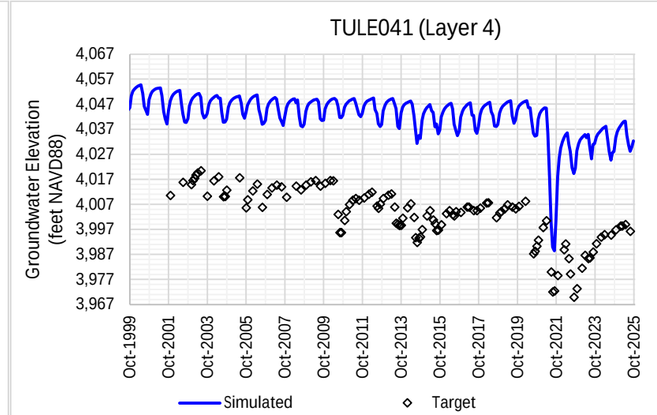


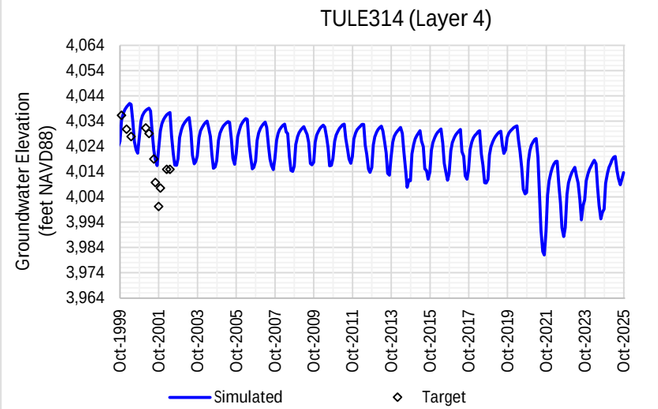
NAVD88 = North American Vertical Datum of 1988

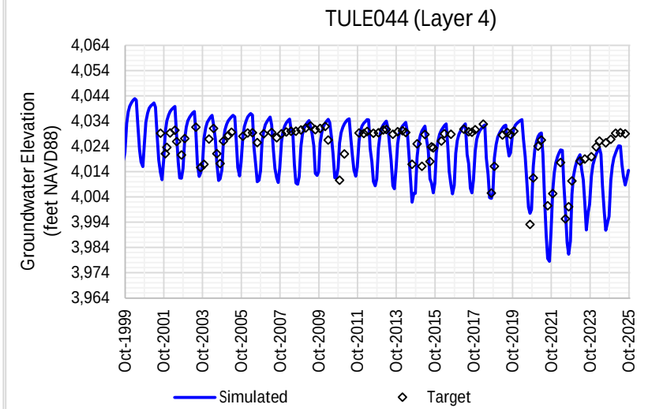
Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

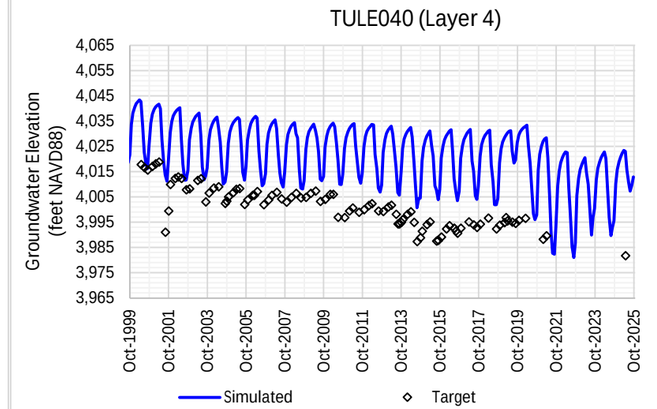


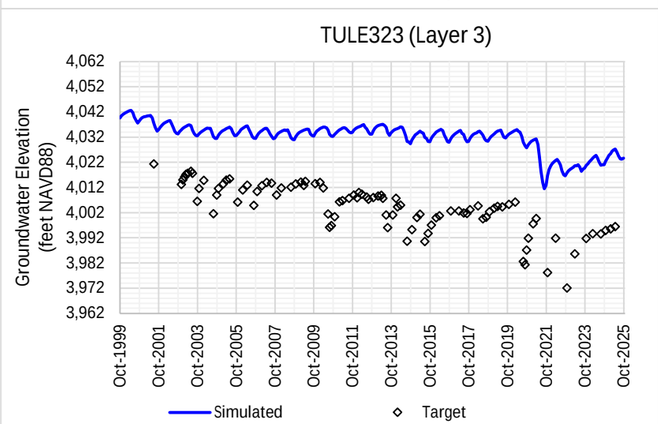


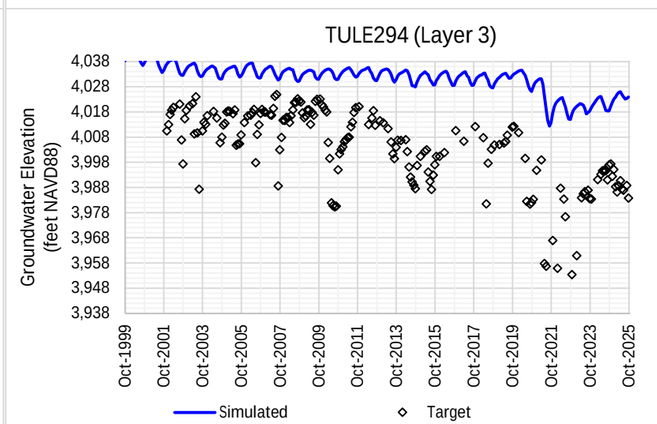


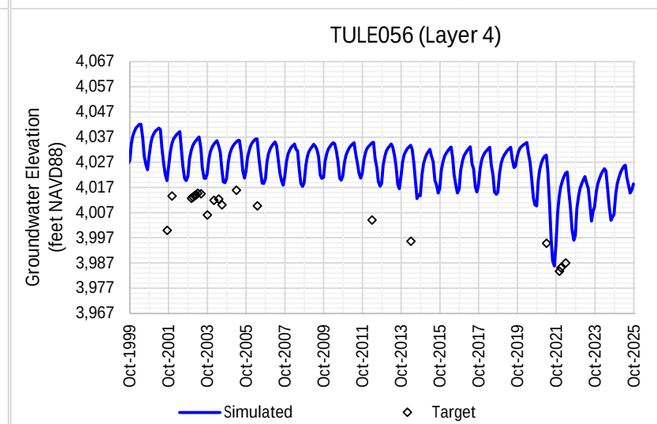






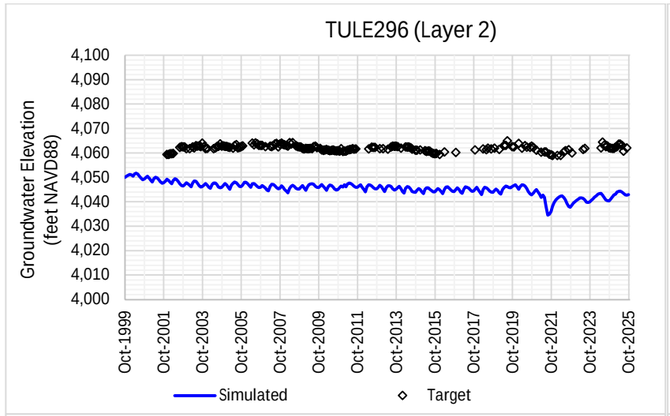


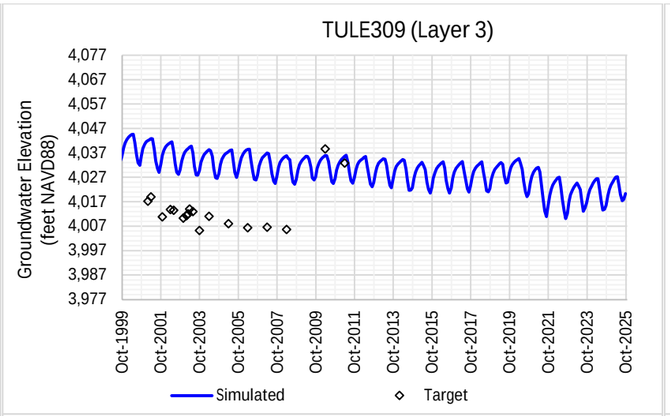


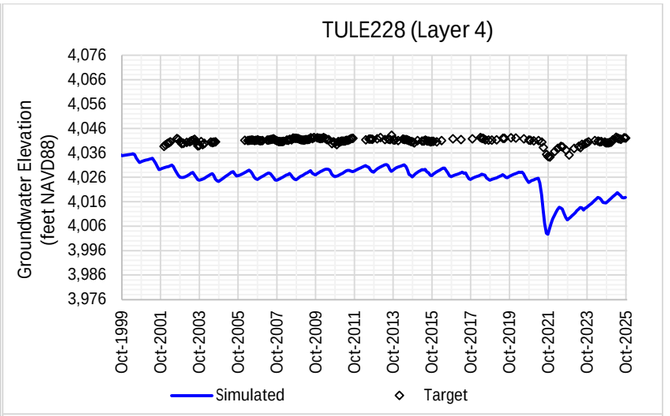


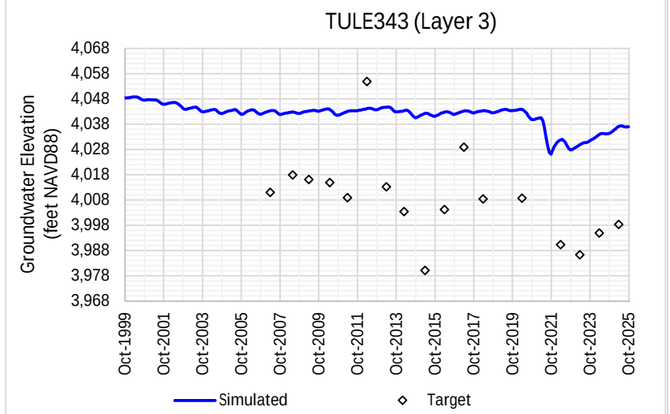
NAVD88 = North American Vertical Datum of 1988

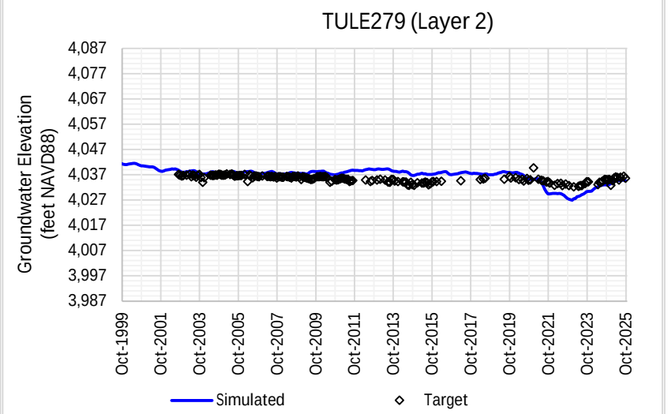
Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

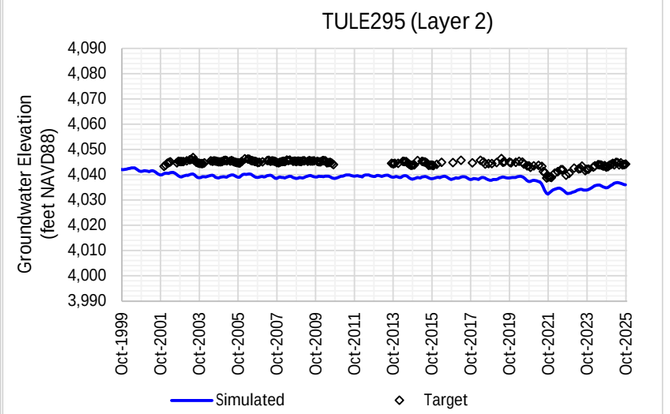


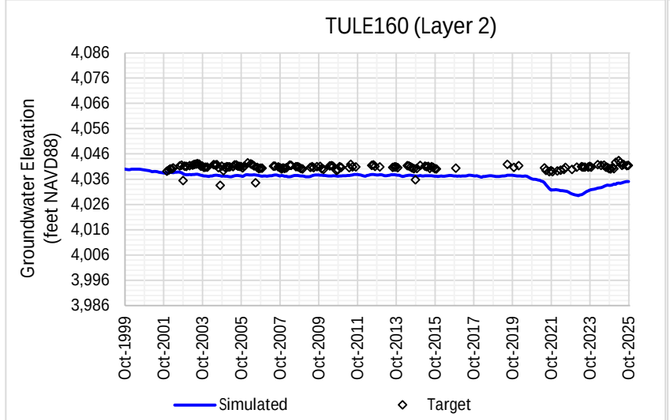


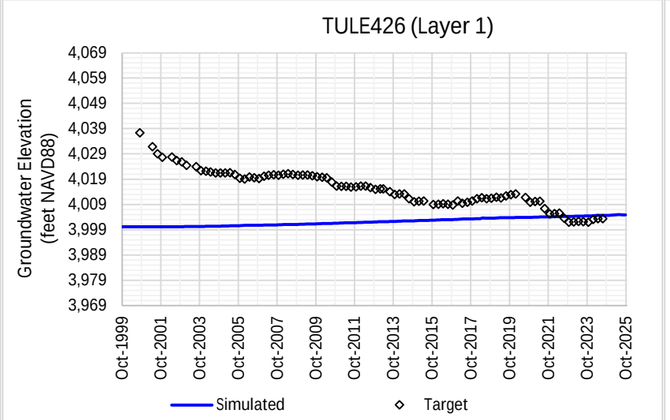


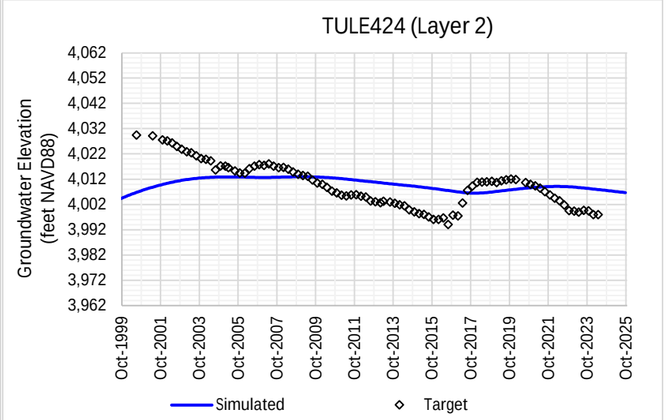








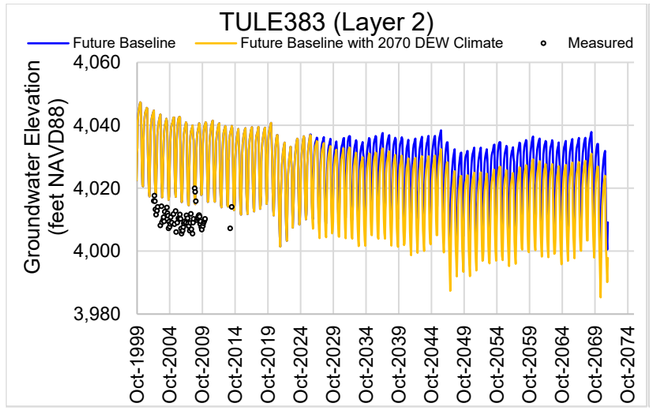


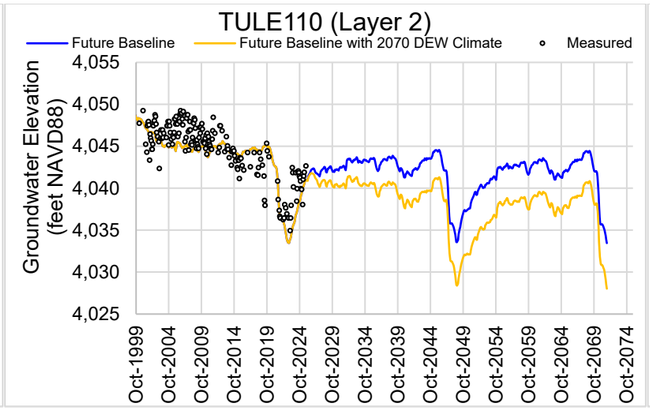


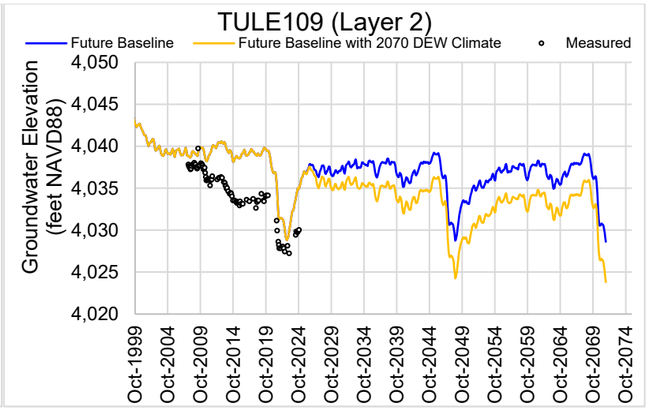
NAVD88 = North American Vertical Datum of 1988

Attachment 1
Modeled versus Measured
Groundwater Elevation Hydrographs

Attachment 2
Historical and Future Projected Groundwater Elevation Hydrographs


TULE383 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE110 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,055
4,050
4,045
4,040
4,035
4,030
4,025
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE109 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,050
4,045
4,040
4,035
4,030
4,025
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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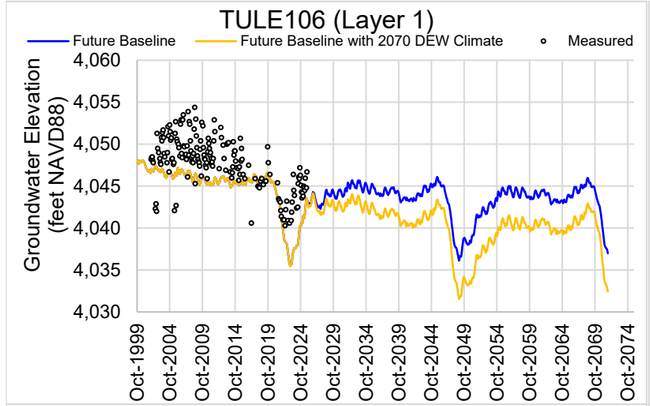
Oct-2064
Oct-2069
Oct-2074


TULE106 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,055
4,050
4,045
4,040
4,035
4,030
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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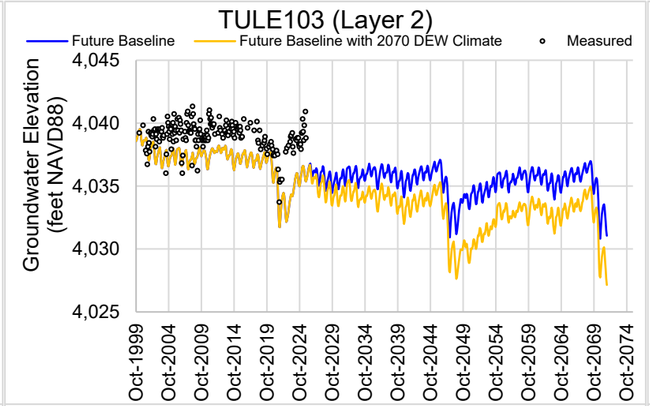
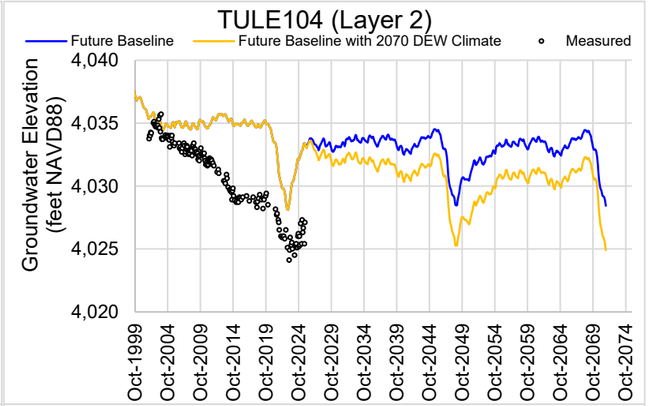
Oct-2064
Oct-2069
Oct-2074


TULE103 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,045
4,040
4,035
4,030
4,025
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE104 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,035
4,030
4,025
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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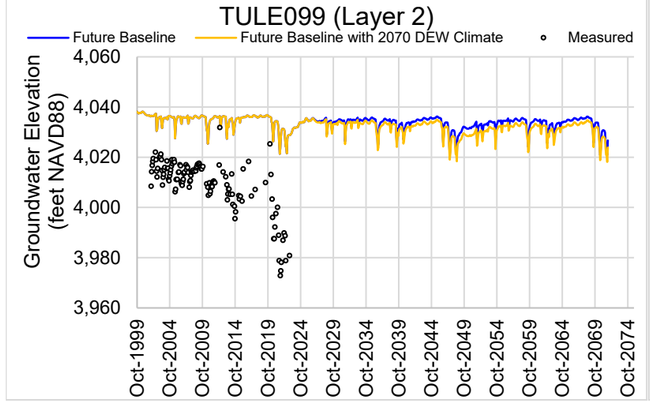
Oct-2074


TULE099 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2049
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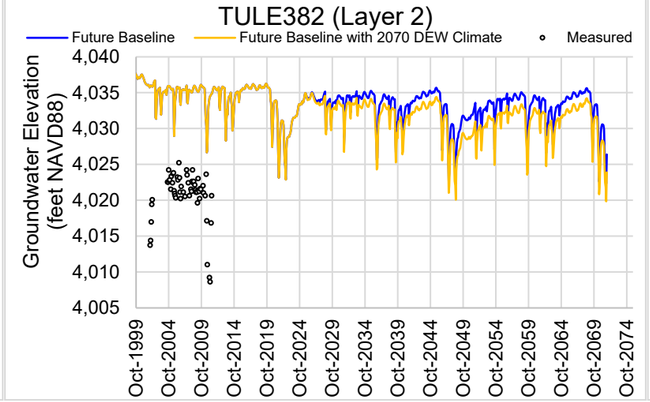
Oct-2074


TULE382 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,035
4,030
4,025
4,020
4,015
4,010
4,005
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2059
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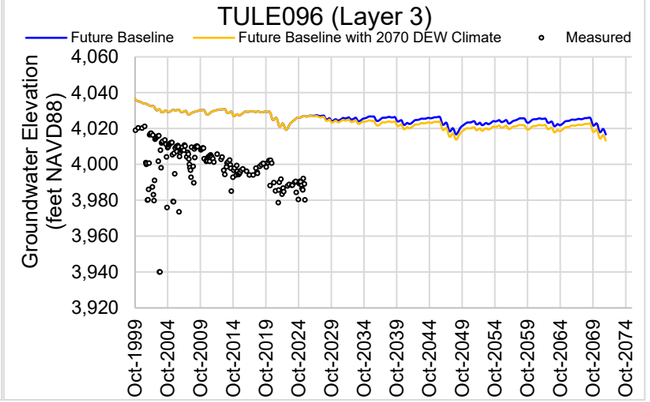
Oct-2074


TULE096 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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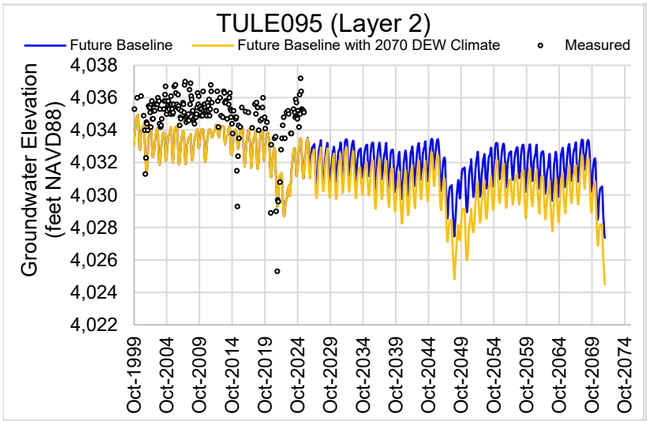
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE095 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,038
4,036
4,034
4,032
4,030
4,028
4,026
4,024
4,022
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2039
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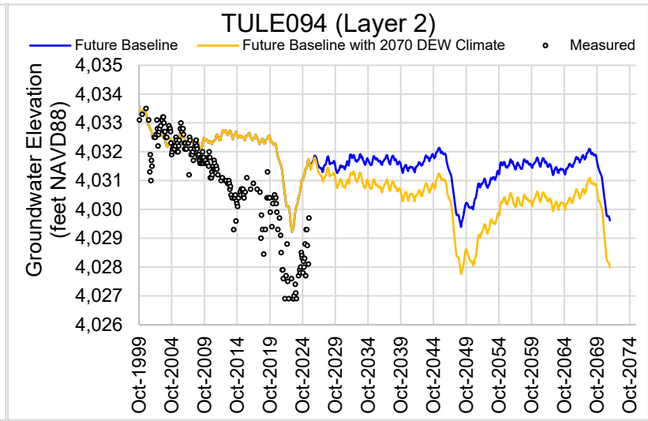
Oct-2064
Oct-2069
Oct-2074


TULE094 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,035
4,034
4,033
4,032
4,031
4,030
4,029
4,028
4,027
4,026
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2039
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Oct-2049
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Oct-2059
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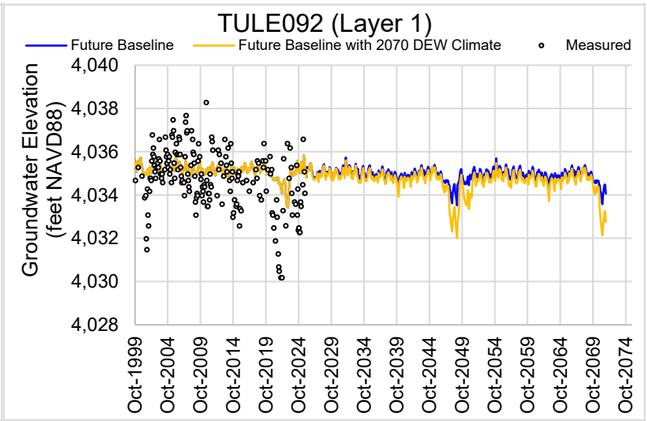
Oct-2069
Oct-2074


TULE092 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,038
4,036
4,034
4,032
4,030
4,028
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2039
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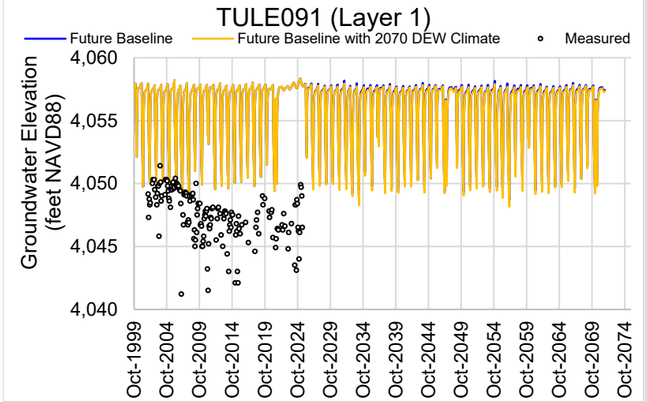
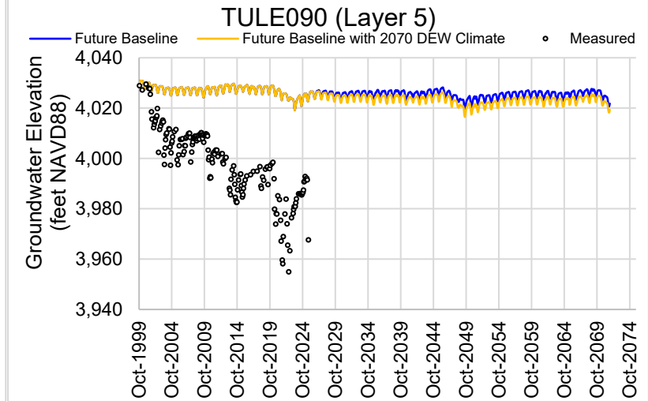
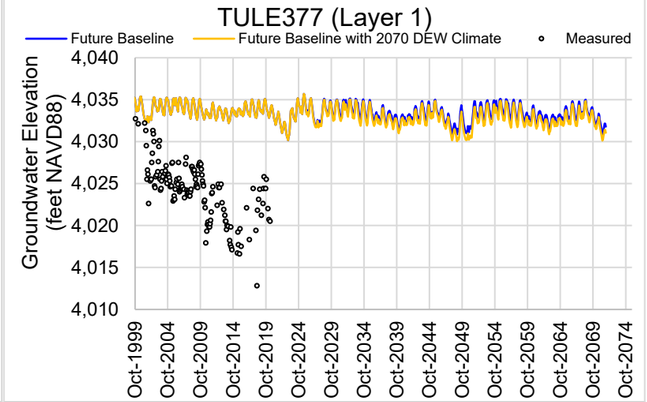
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE091 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,055
4,050
4,045
4,040
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE090 (Layer 5)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE377 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,035
4,030
4,025
4,020
4,015
4,010
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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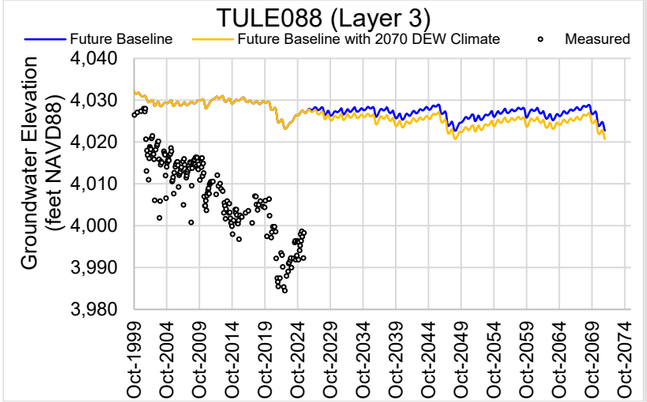
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE088 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
Oct-2044
Oct-2049
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Oct-2059
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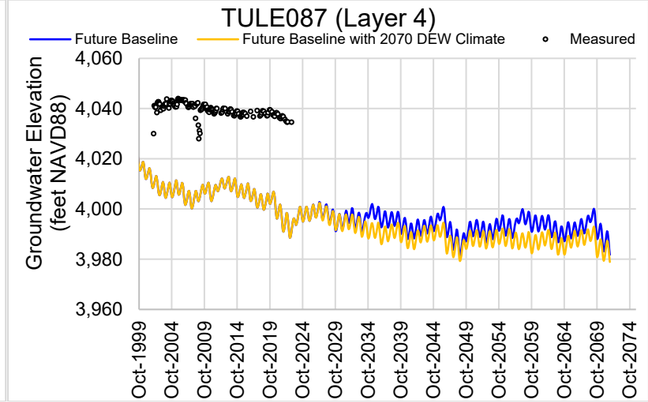
Oct-2069
Oct-2074


TULE087 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2044
Oct-2049
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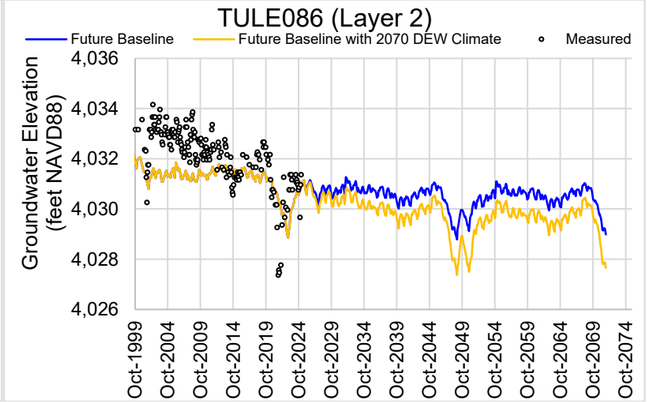
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE086 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,036
4,034
4,032
4,030
4,028
4,026
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
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Oct-2059
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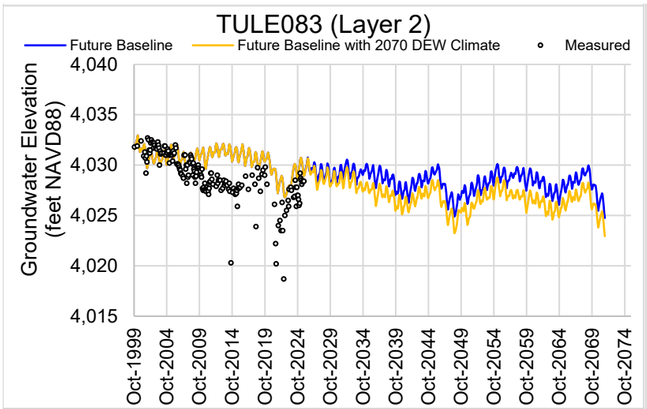
Oct-2069
Oct-2074


TULE083 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,035
4,030
4,025
4,020
4,015
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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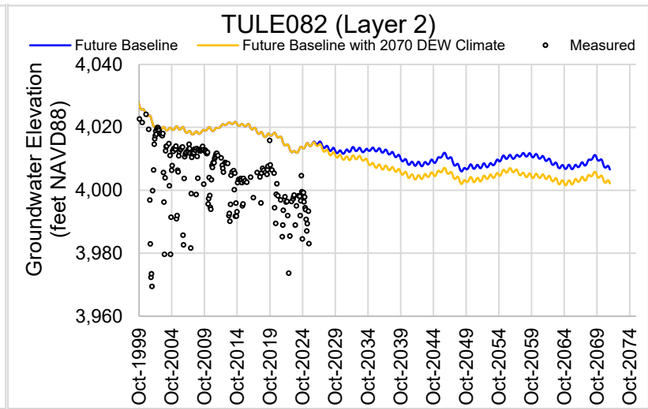
Oct-2074


TULE082 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
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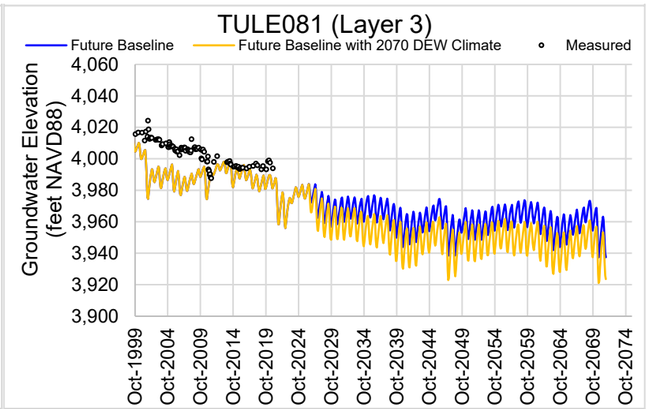
Oct-2074


TULE081 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
3,900
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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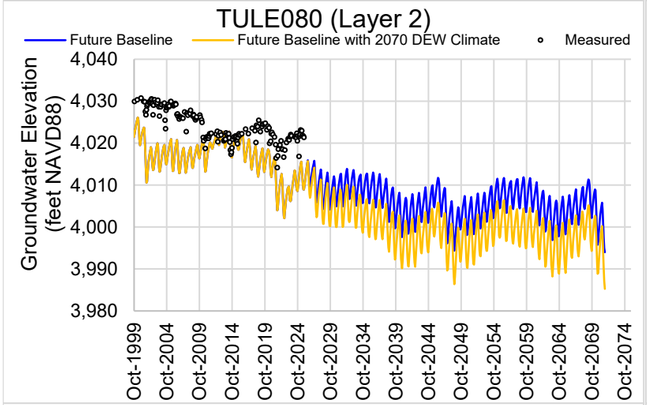
Oct-2074


TULE080 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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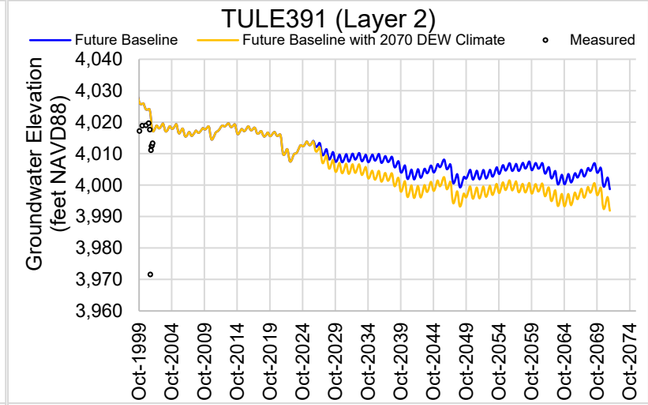
TULE391 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
3,970
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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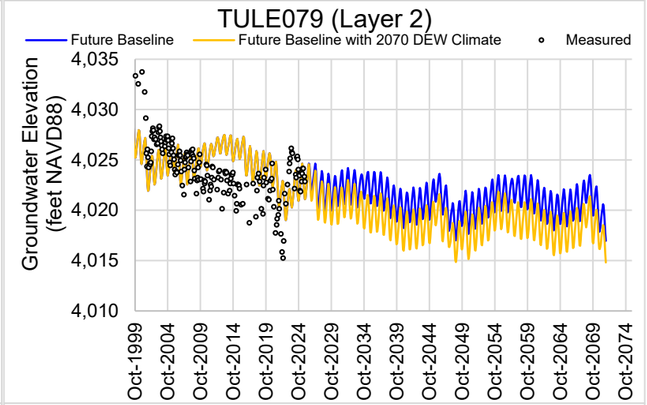
TULE079 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,035
4,030
4,025
4,020
4,015
4,010
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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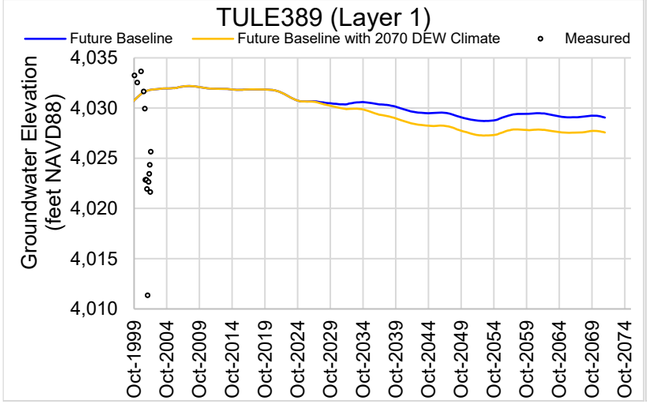
Oct-2074


TULE389 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,035
4,030
4,025
4,020
4,015
4,010
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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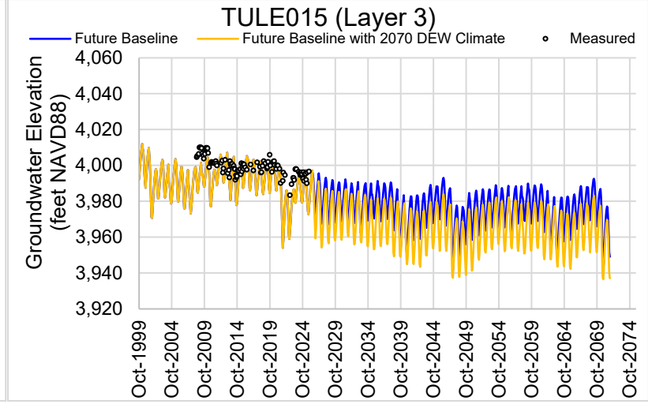
TULE015 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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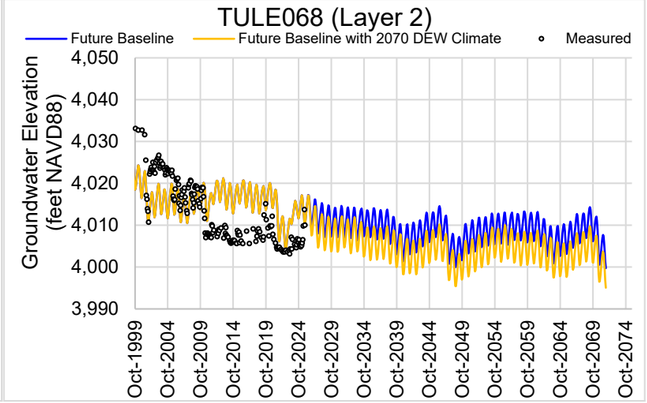
TULE068 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,050
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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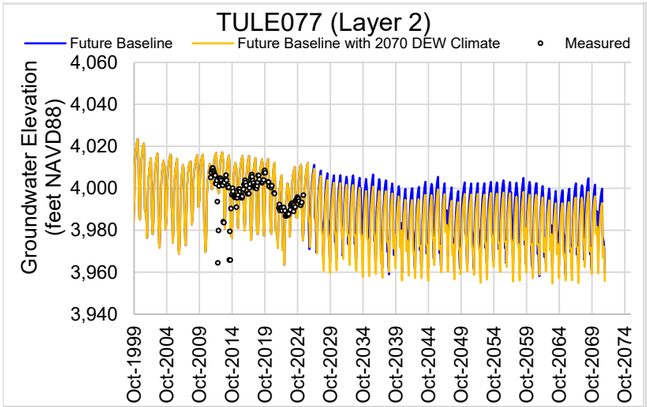
TULE077 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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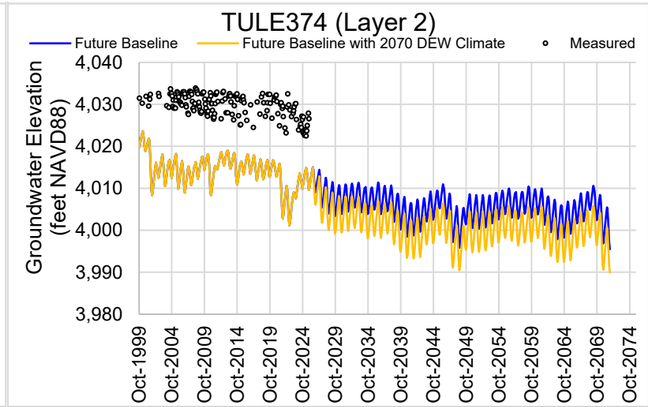
Oct-2069
Oct-2074


TULE374 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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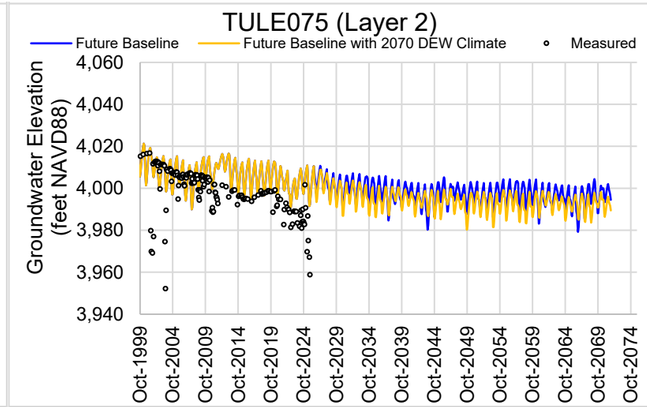
Oct-2074


TULE075 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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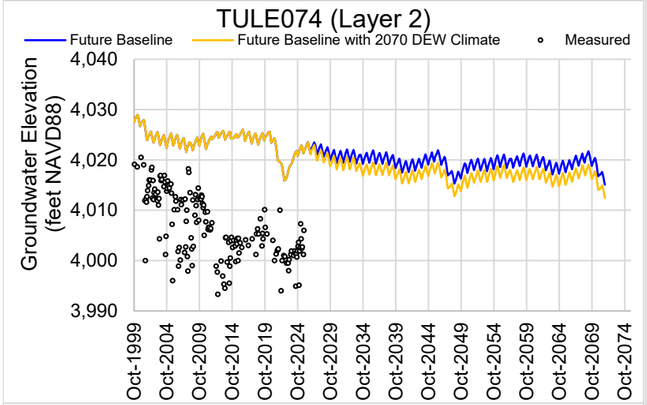
Oct-2069
Oct-2074


TULE074 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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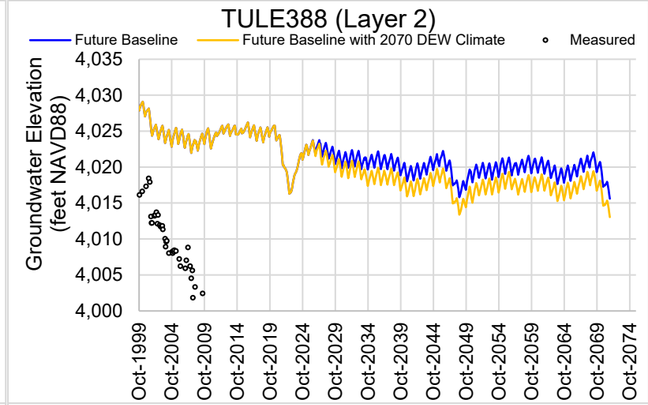
Oct-2074


TULE388 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,035
4,030
4,025
4,020
4,015
4,010
4,005
4,000
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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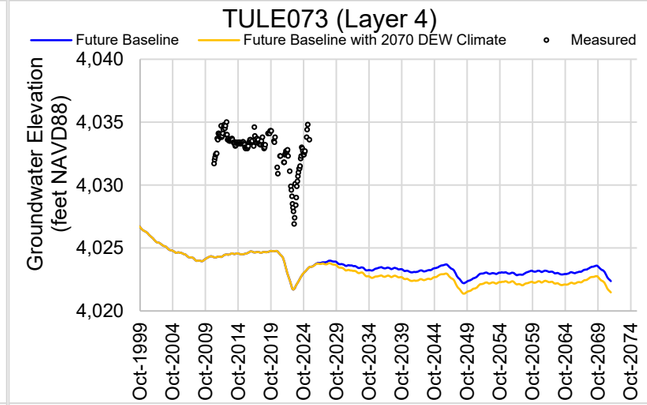
Oct-2074


TULE073 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,035
4,030
4,025
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2049
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Oct-2059
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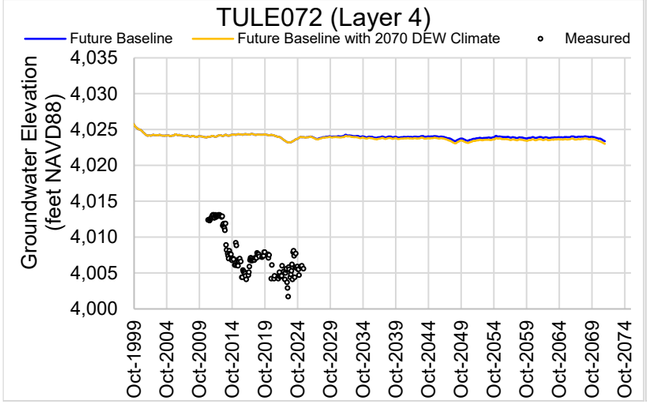
Oct-2074


TULE072 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,035
4,030
4,025
4,020
4,015
4,010
4,005
4,000
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
Oct-2044
Oct-2049
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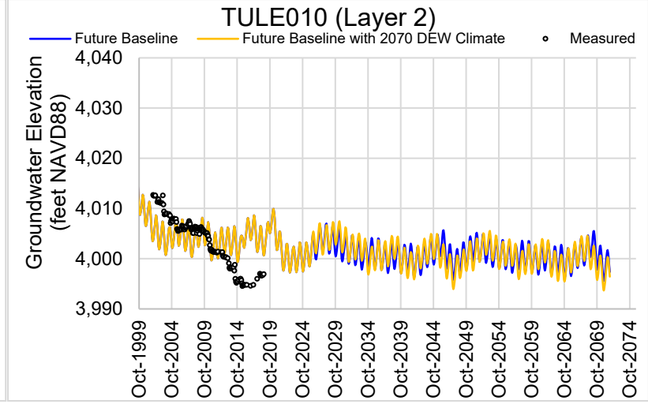
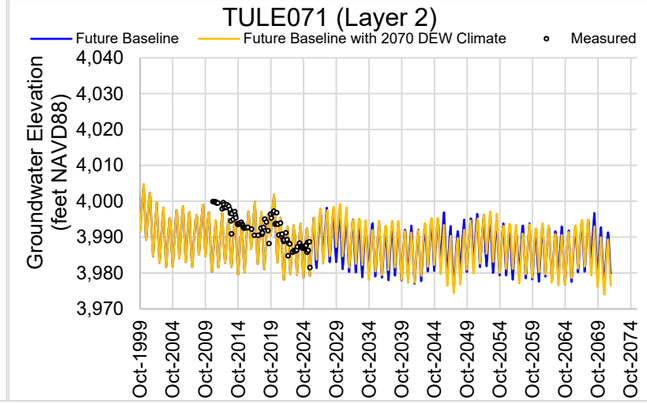
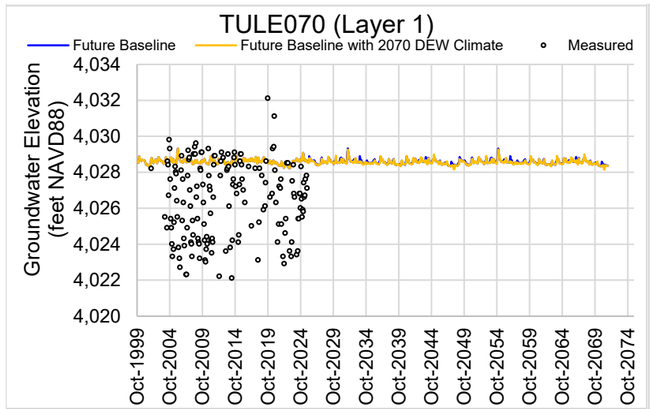
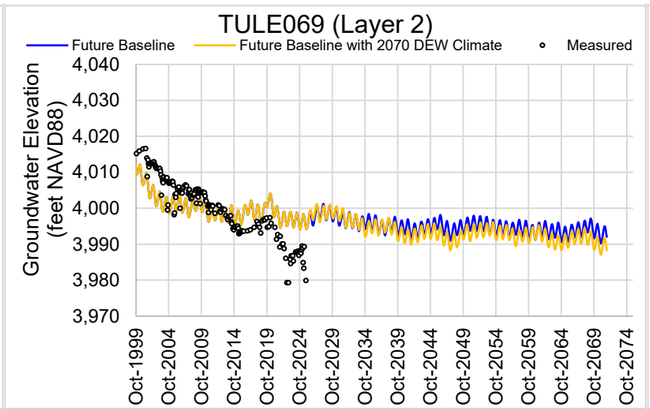
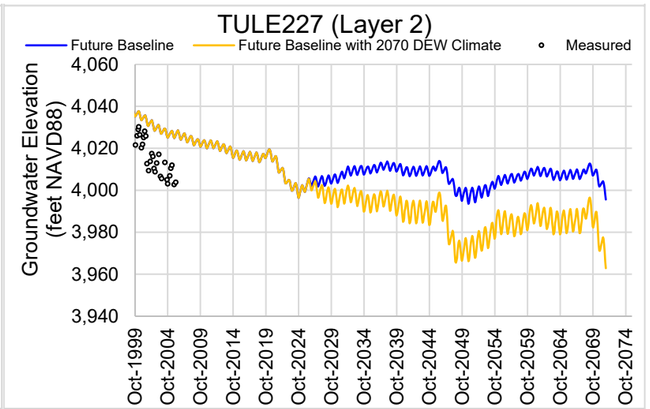
Oct-2074

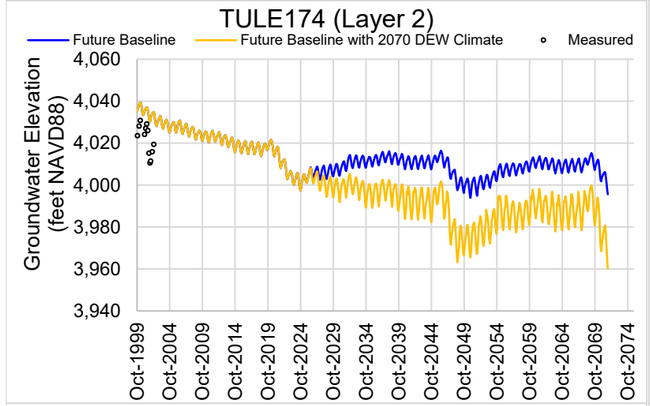

TULE010 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

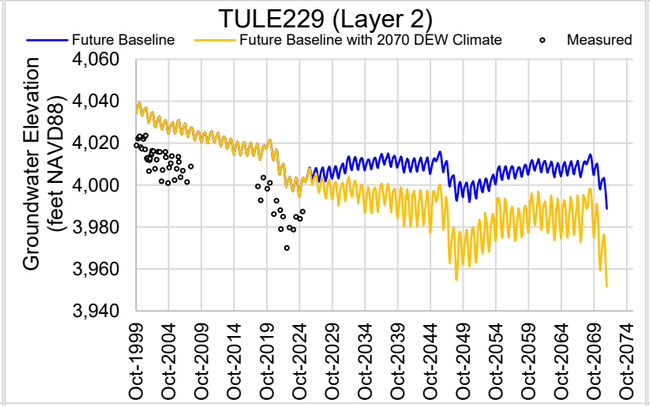

TULE071 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
3,970
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

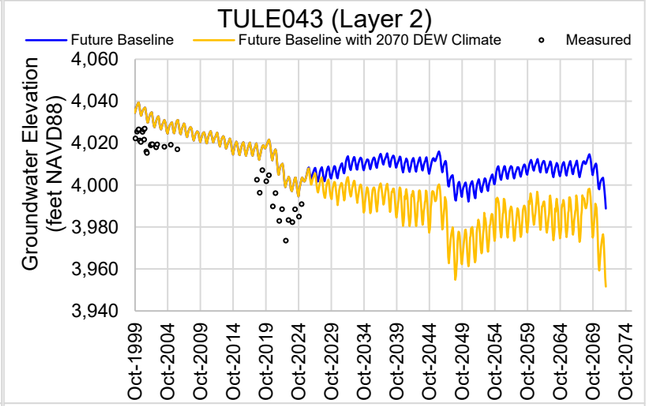

TULE070 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,034
4,032
4,030
4,028
4,026
4,024
4,022
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

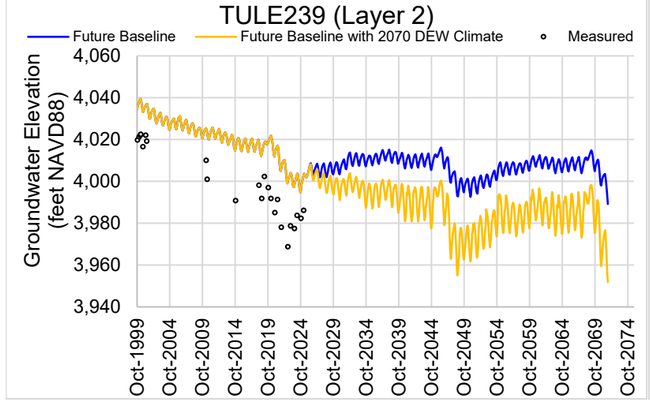

TULE069 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
3,980
3,970
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

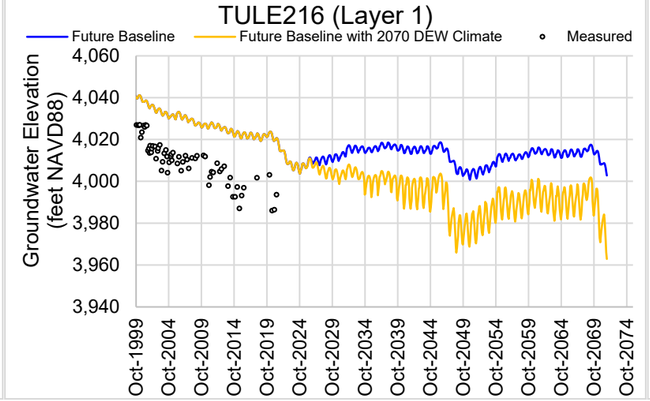

TULE227 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

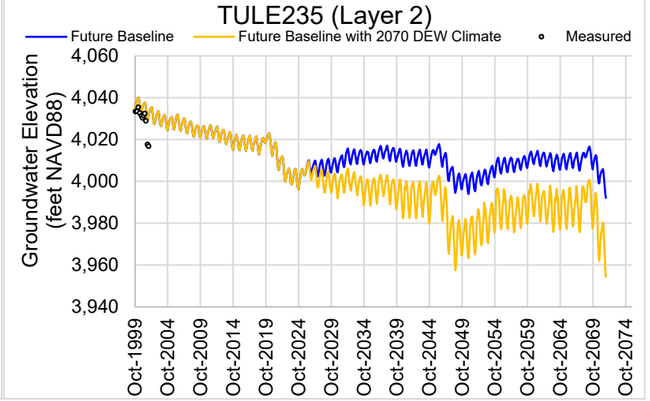

TULE174 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

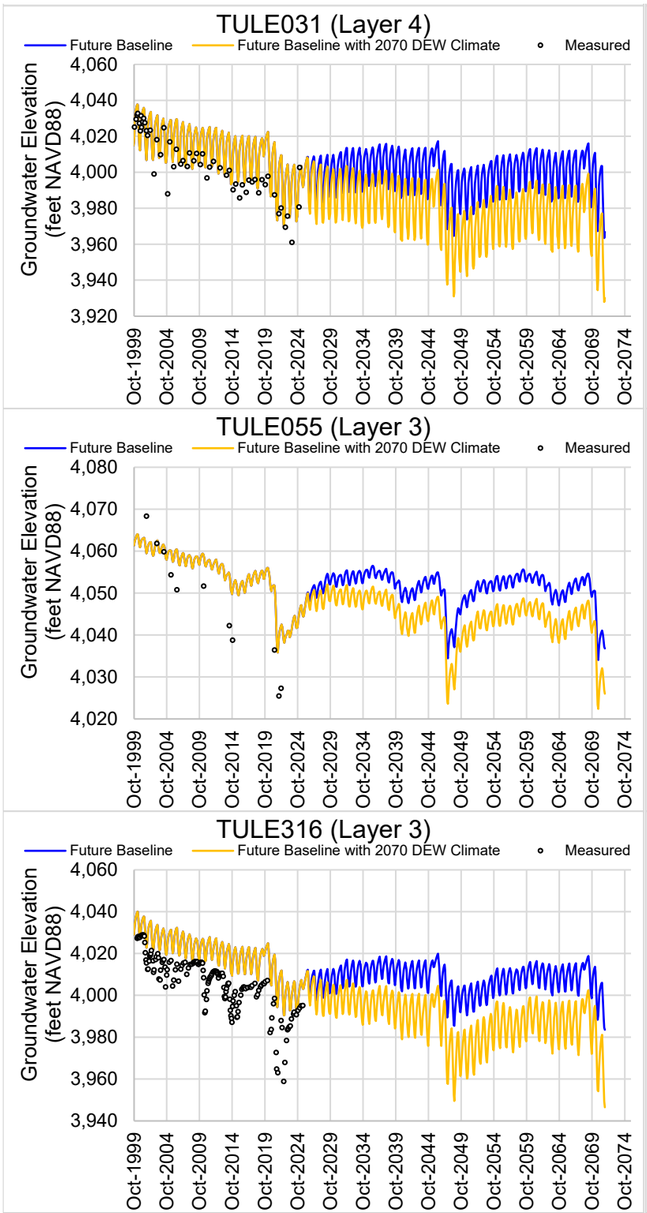

TULE229 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

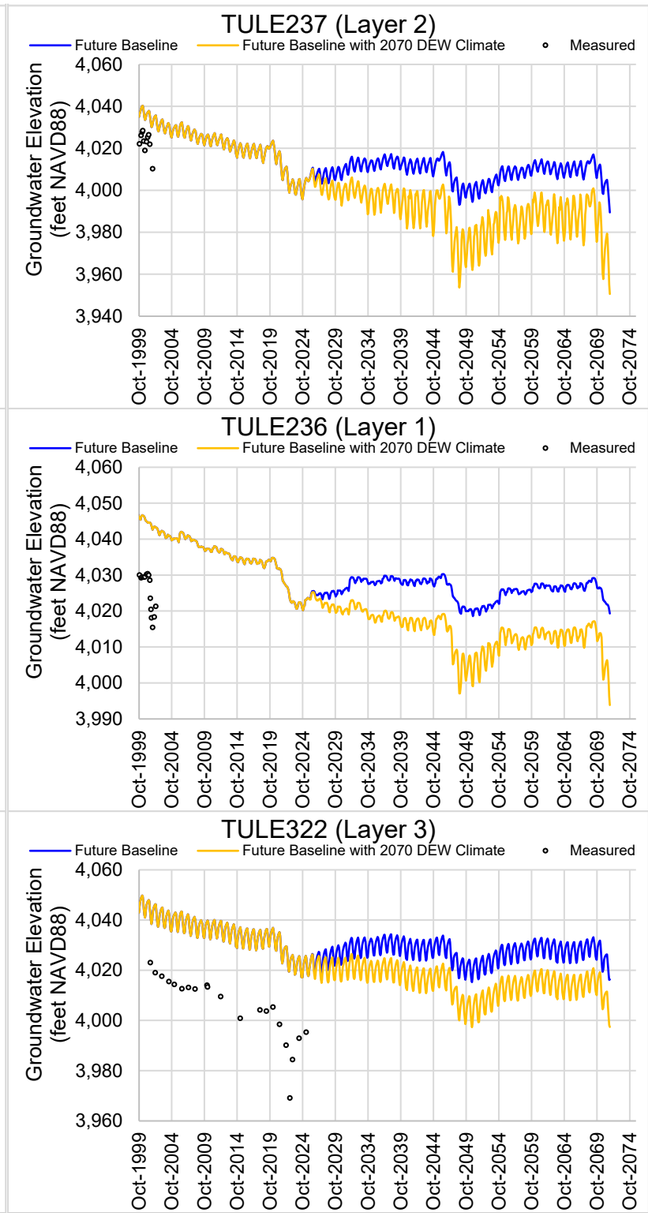

TULE043 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

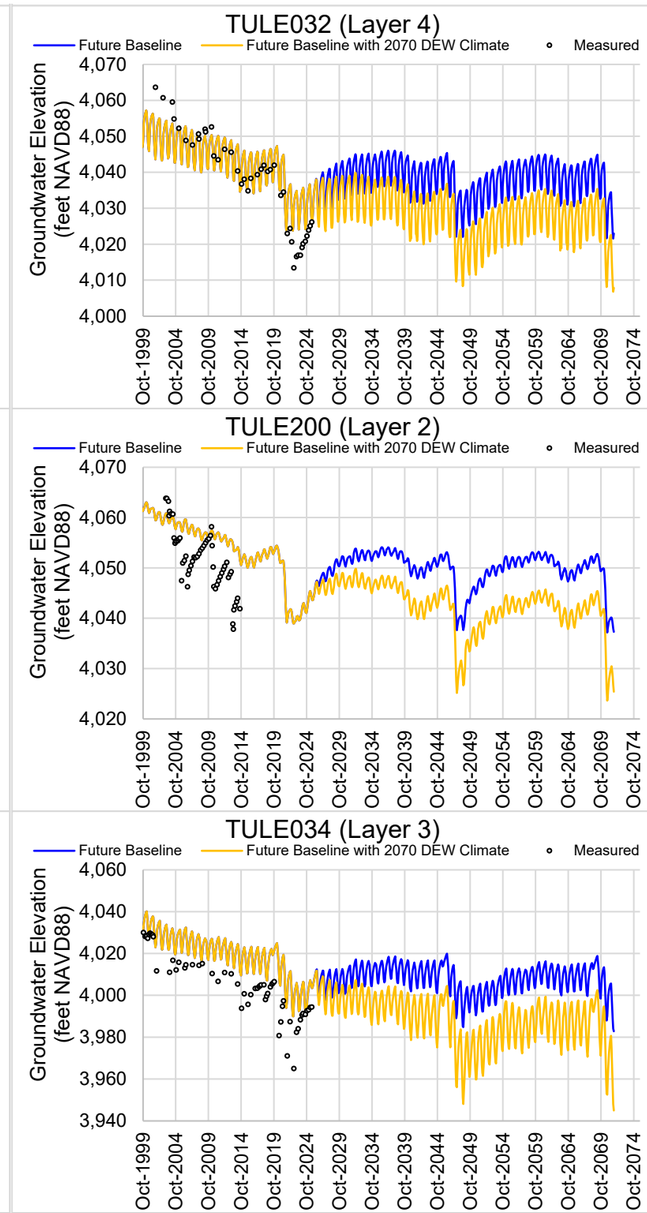

TULE239 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE216 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE235 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE031 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE237 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE032 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,070
4,060
4,050
4,040
4,030
4,020
4,010
4,000
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE055 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,070
4,060
4,050
4,040
4,030
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE236 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,050
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE200 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,070
4,060
4,050
4,040
4,030
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE316 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE322 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE034 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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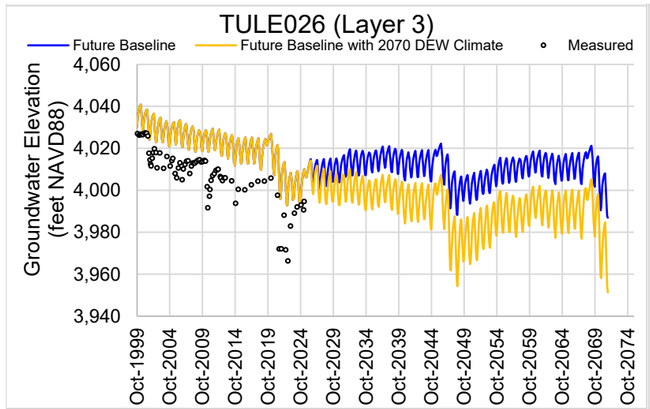
Oct-2074


TULE026 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
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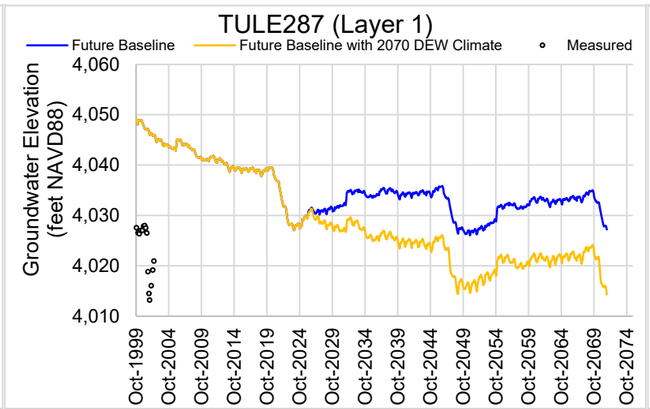
Oct-2074


TULE287 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,050
4,040
4,030
4,020
4,010
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
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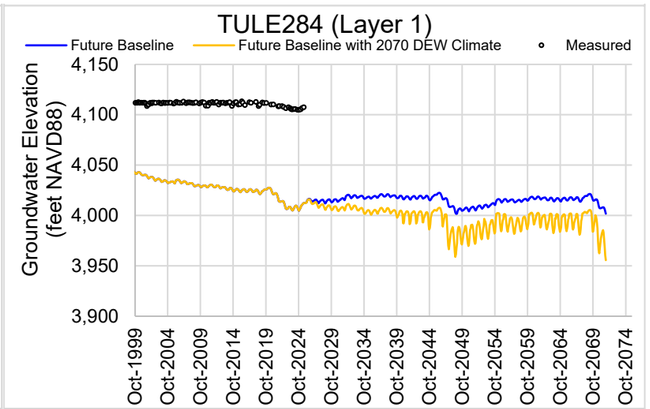
Oct-2069
Oct-2074


TULE284 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,150
4,100
4,050
4,000
3,950
3,900
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2059
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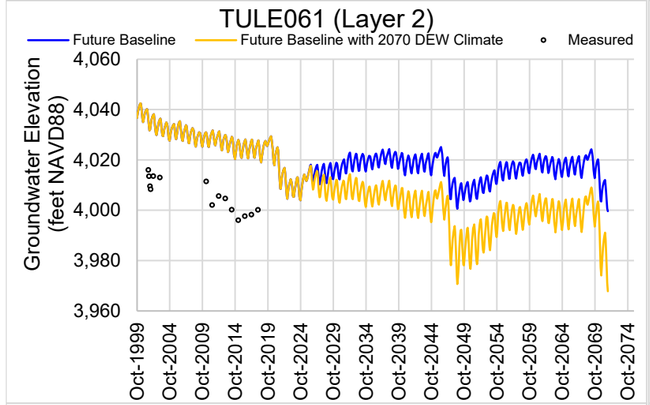
Oct-2069
Oct-2074


TULE061 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
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Oct-2054
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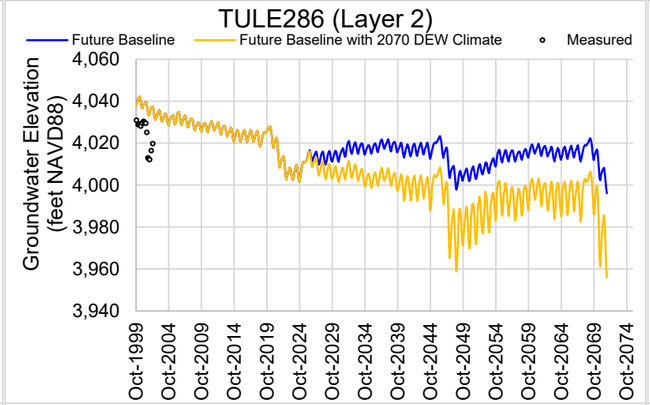
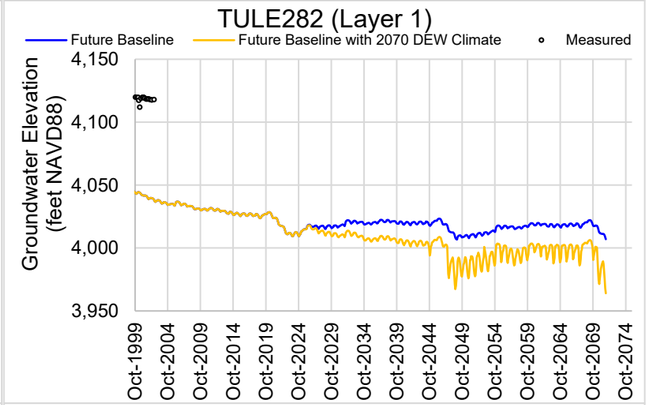
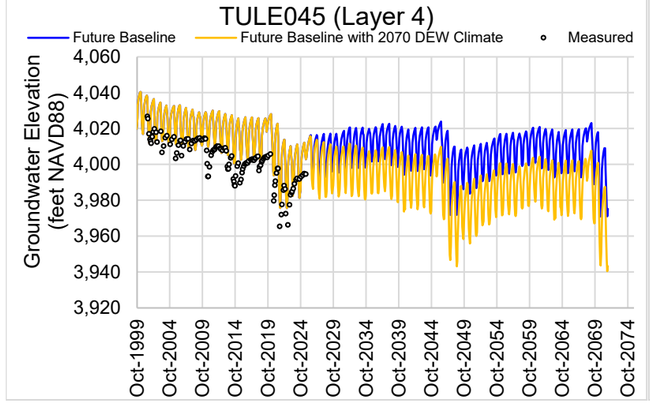
Oct-2069
Oct-2074


TULE286 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE282 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,150
4,100
4,050
4,000
3,950
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE045 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2039
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Oct-2049
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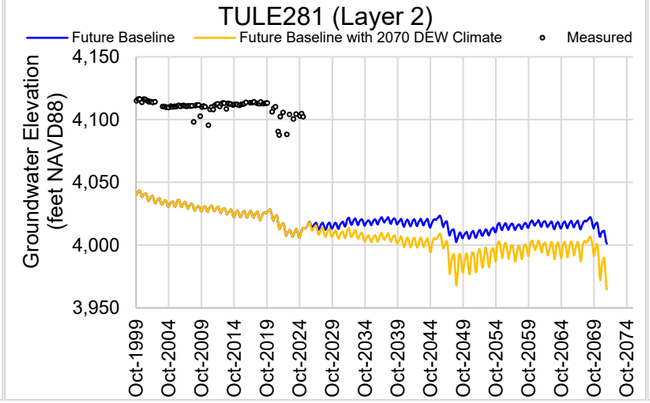
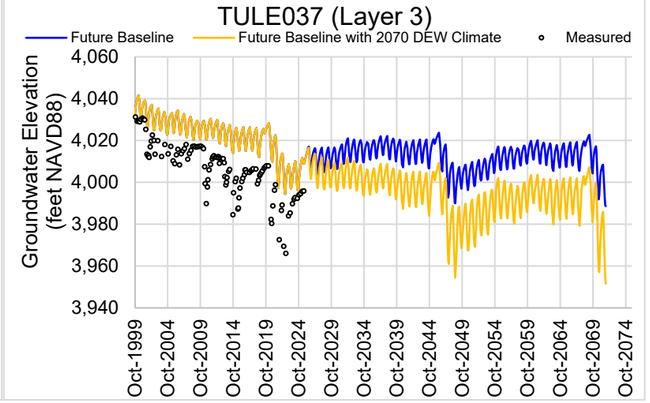
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE281 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,150
4,100
4,050
4,000
3,950
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE037 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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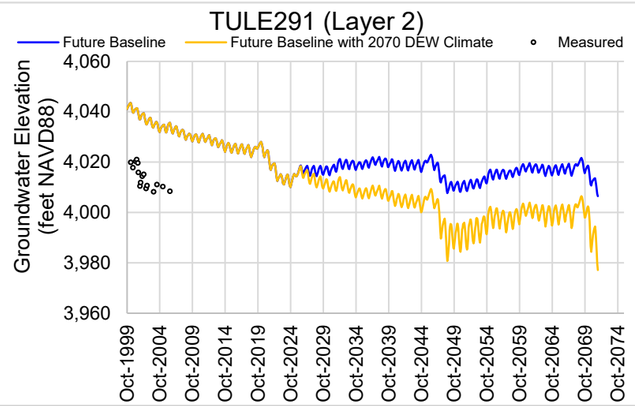
Oct-2069
Oct-2074


TULE291 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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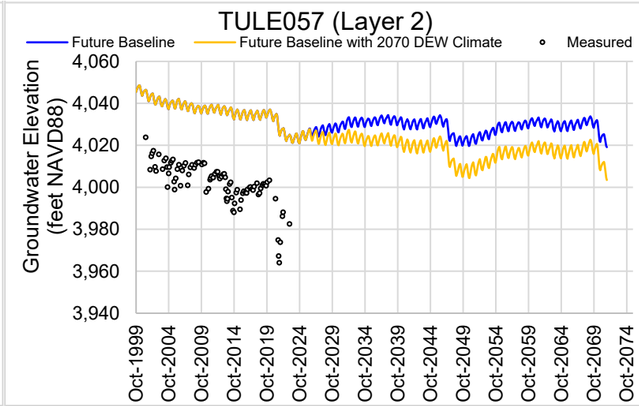
Oct-2074


TULE057 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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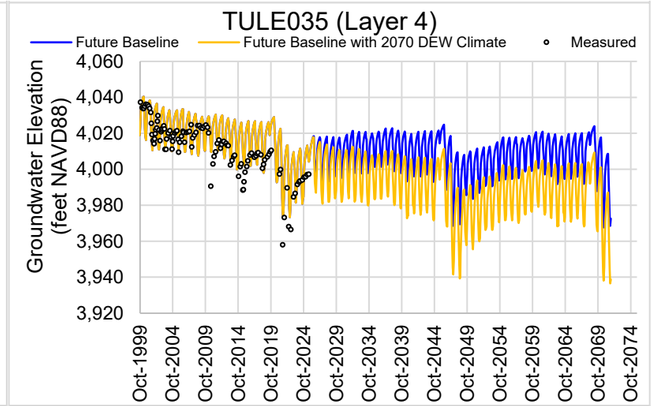
Oct-2069
Oct-2074


TULE035 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2049
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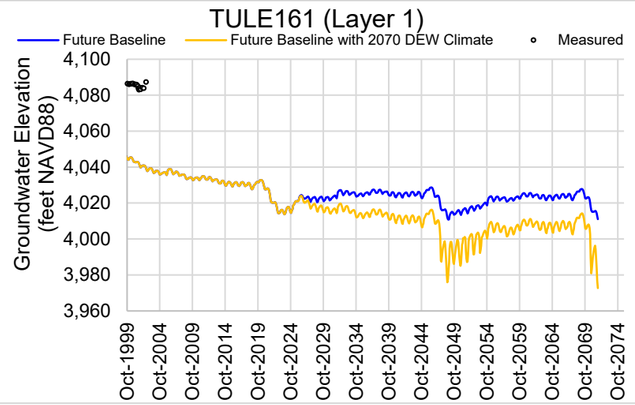
Oct-2069
Oct-2074


TULE161 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2044
Oct-2049
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Oct-2059
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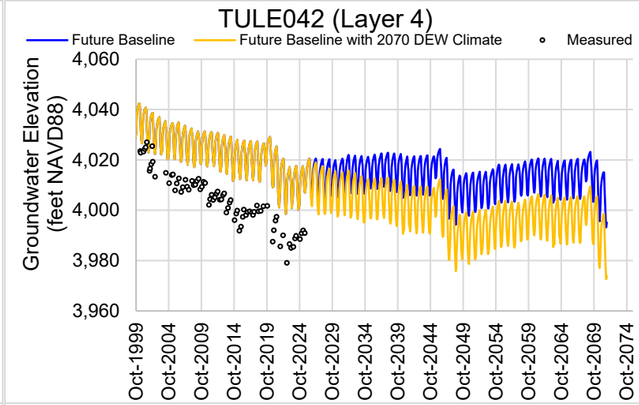
Oct-2069
Oct-2074


TULE042 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
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Oct-2049
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Oct-2059
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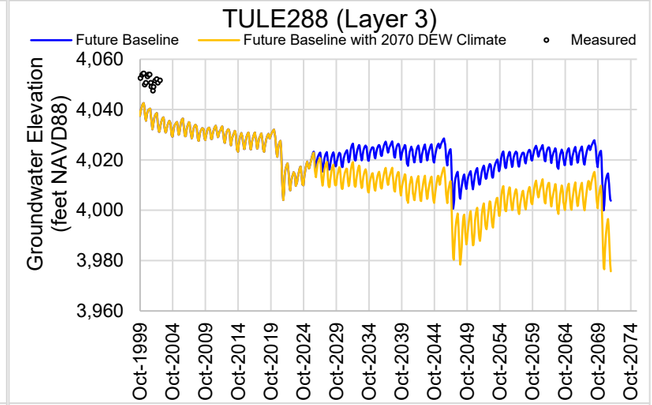
Oct-2069
Oct-2074


TULE288 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2059
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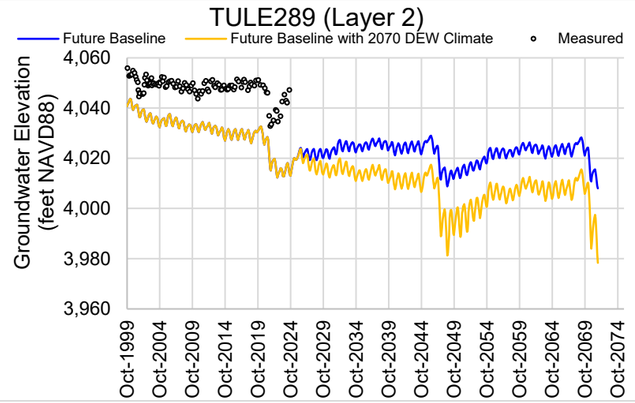
Oct-2069
Oct-2074


TULE289 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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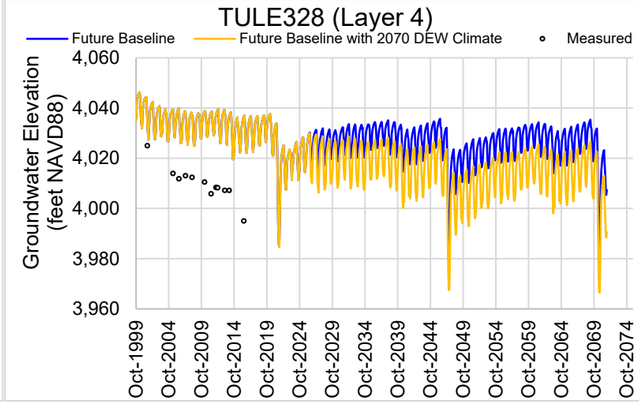
Oct-2069
Oct-2074


TULE328 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2039
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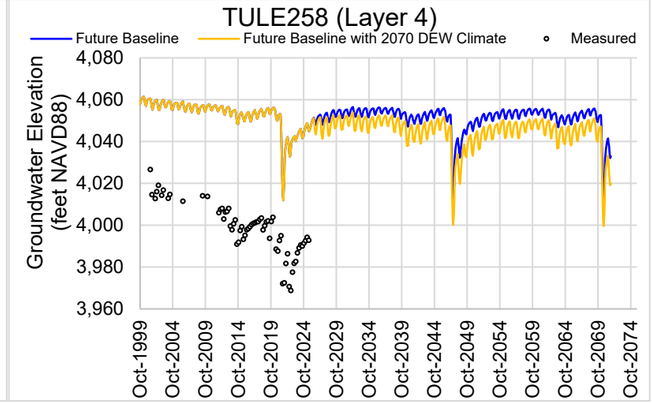
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE258 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2039
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Oct-2049
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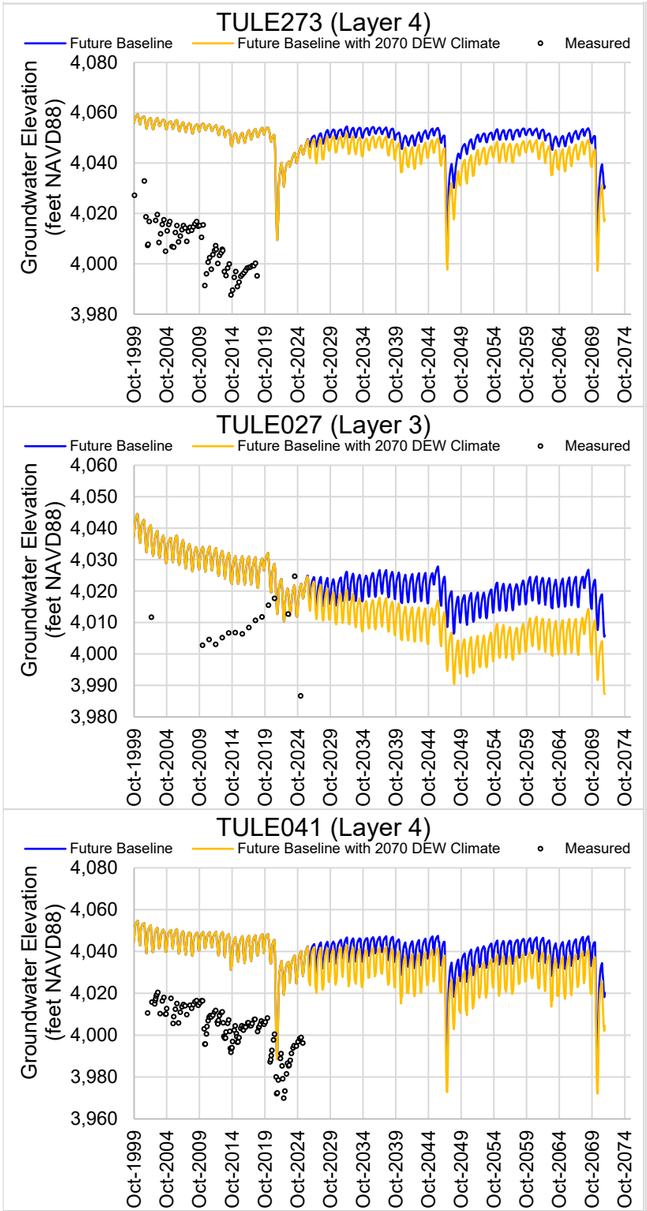
Oct-2069
Oct-2074


TULE273 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,060
4,040
4,020
4,000
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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Oct-2044
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Oct-2059
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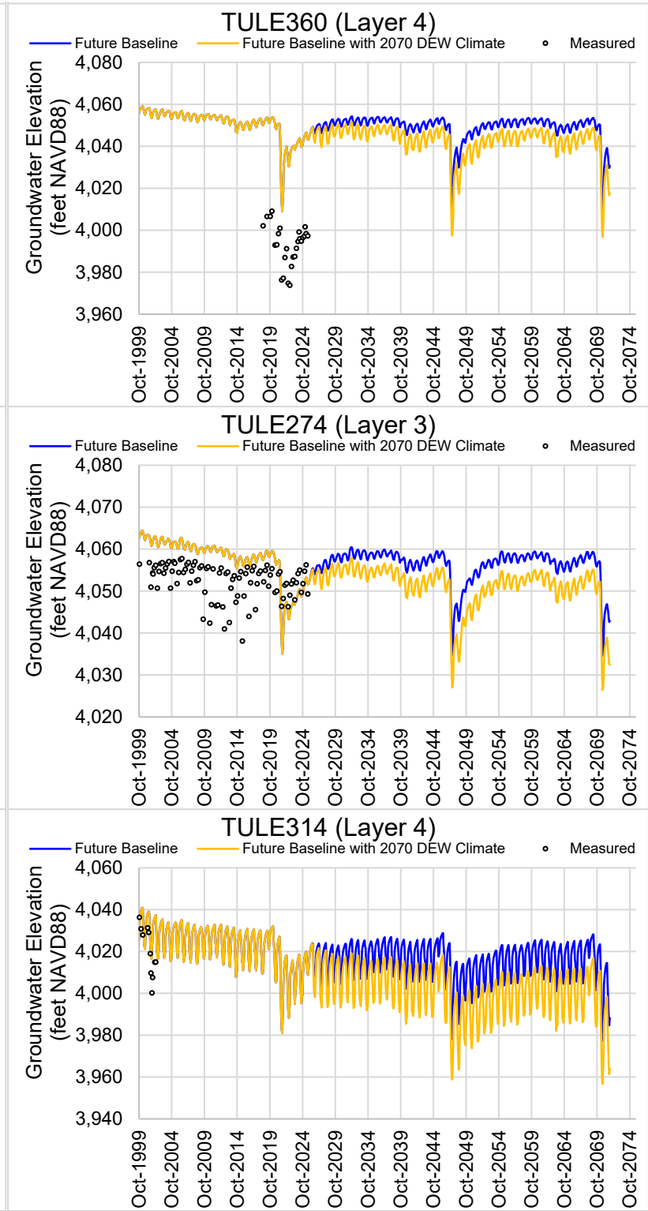
Oct-2069
Oct-2074


TULE360 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2044
Oct-2049
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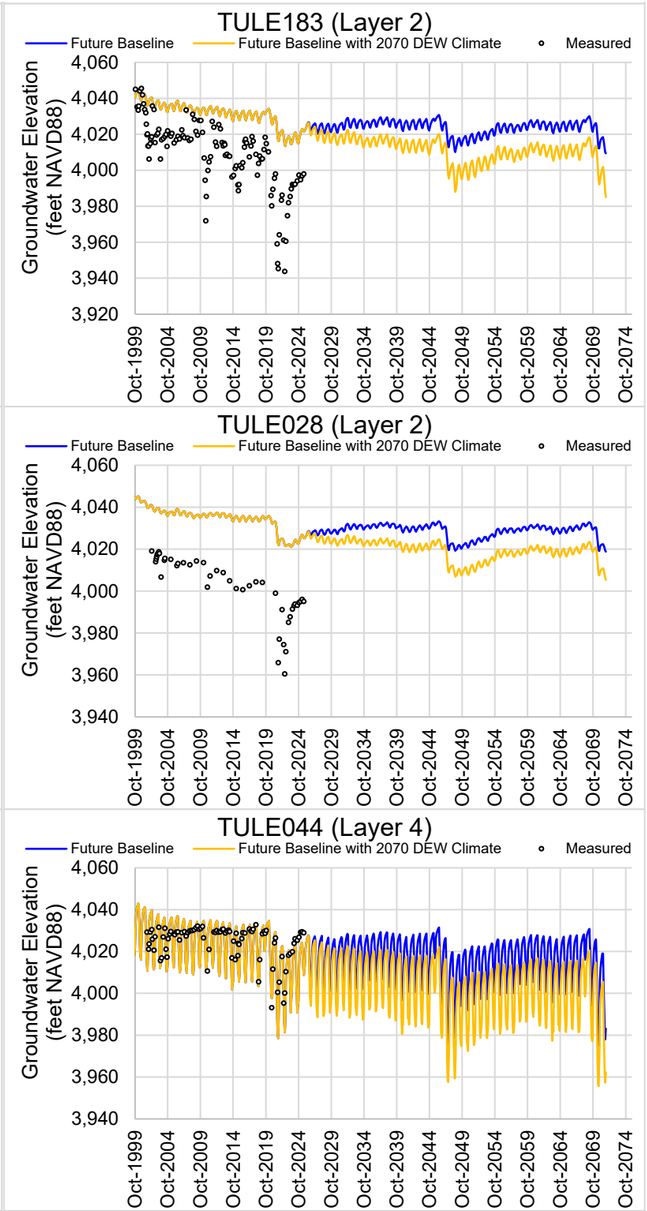
Oct-2059
Oct-2064
Oct-2069
Oct-2074


TULE183 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE027 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,050
4,040
4,030
4,020
4,010
4,000
3,990
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE274 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,070
4,060
4,050
4,040
4,030
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE028 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE041 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE314 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

TULE044 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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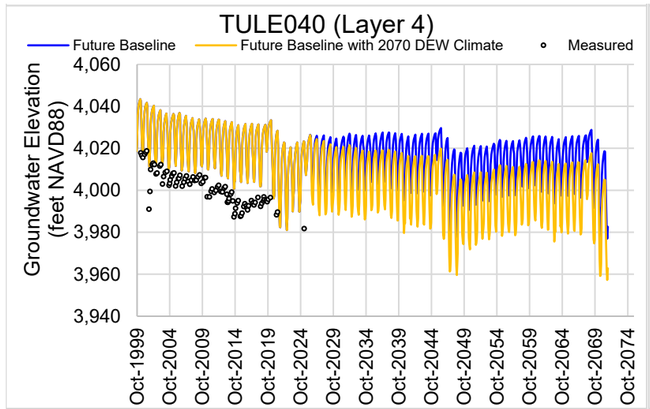
Oct-2074


TULE040 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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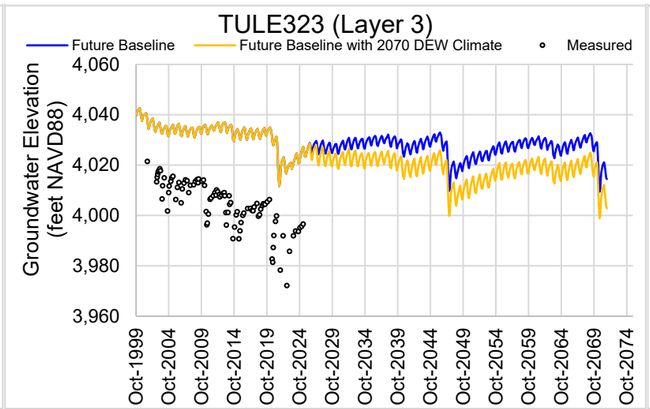
TULE323 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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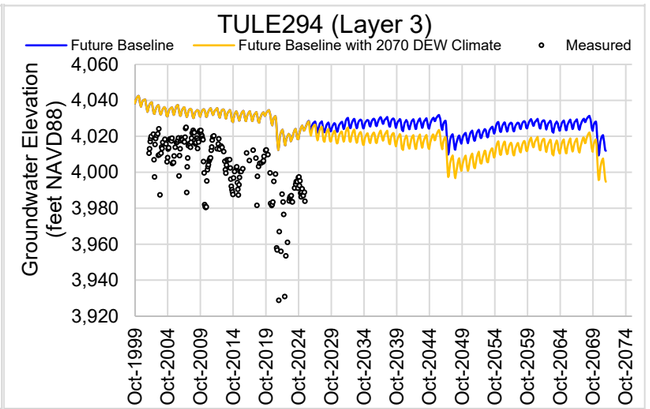
TULE294 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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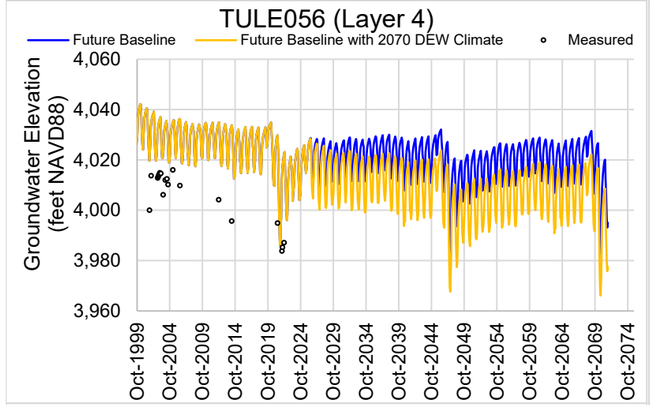
Oct-2074


TULE056 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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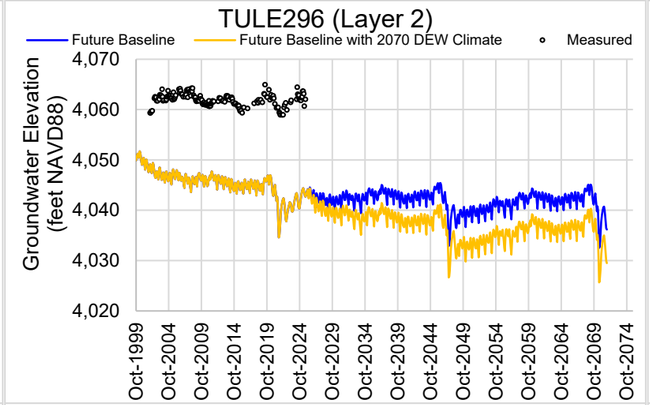
TULE296 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,070
4,060
4,050
4,040
4,030
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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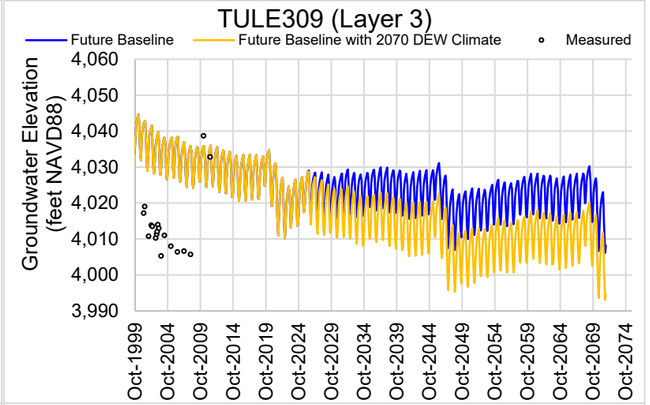
Oct-2074


TULE309 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,050
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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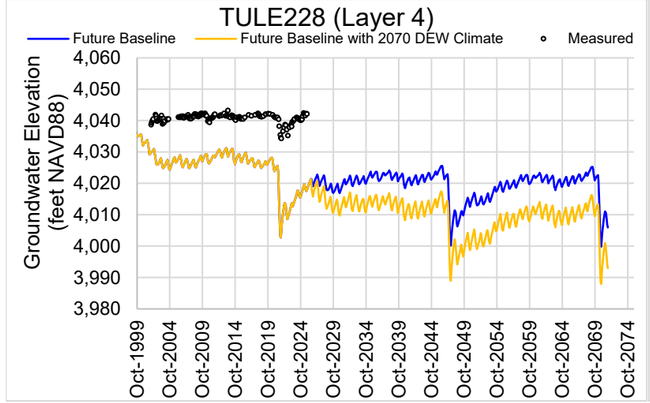
Oct-2074


TULE228 (Layer 4)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,060
4,050
4,040
4,030
4,020
4,010
4,000
3,990
3,980
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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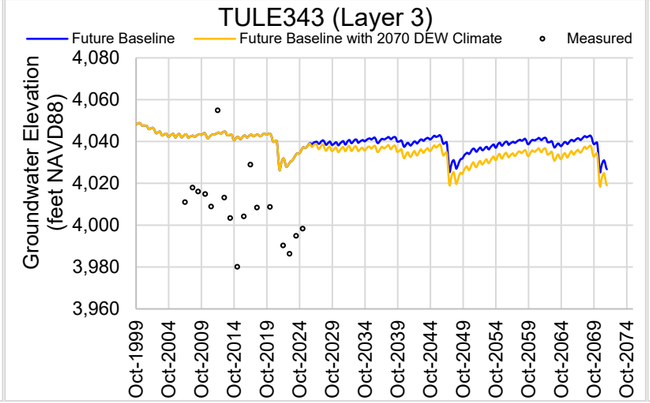
Oct-2069
Oct-2074


TULE343 (Layer 3)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,080
4,060
4,040
4,020
4,000
3,980
3,960
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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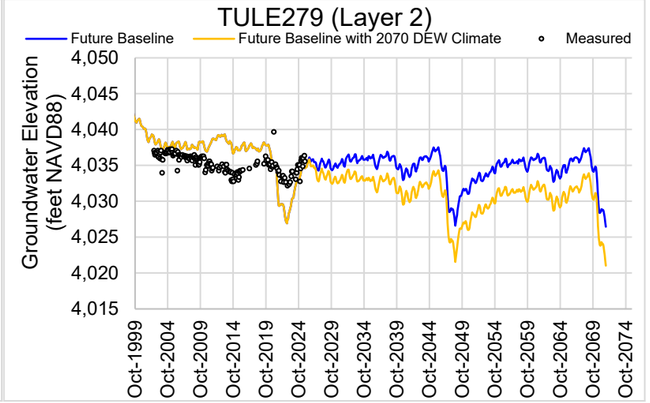
Oct-2074


TULE279 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,050
4,045
4,040
4,035
4,030
4,025
4,020
4,015
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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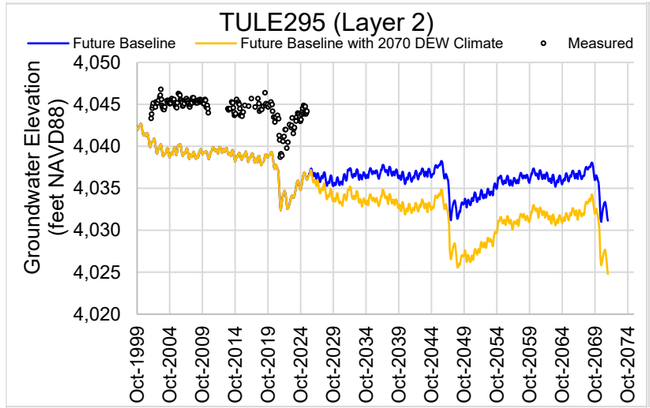
Oct-2074


TULE295 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,050
4,045
4,040
4,035
4,030
4,025
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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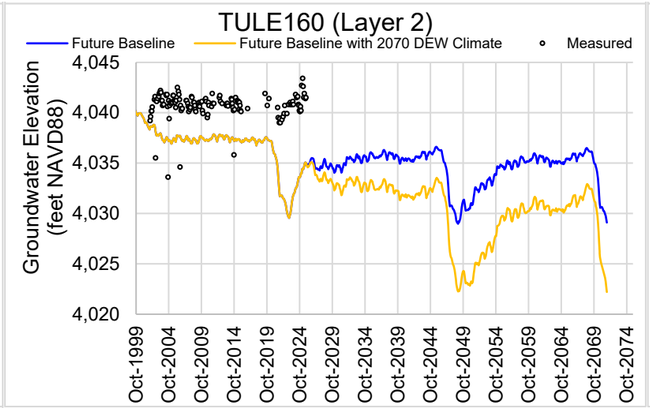
Oct-2069
Oct-2074


TULE160 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,045
4,040
4,035
4,030
4,025
4,020
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
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Oct-2059
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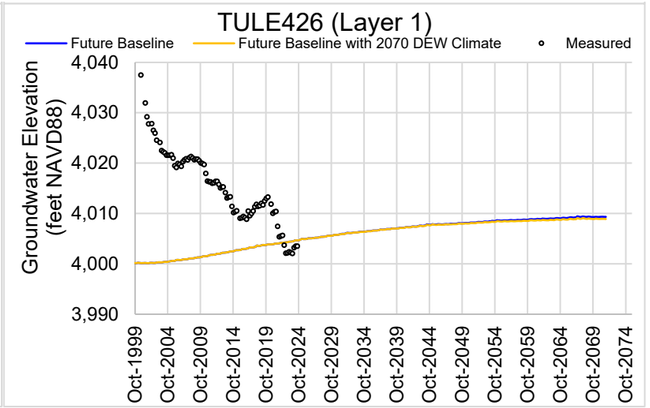
Oct-2069
Oct-2074


TULE426 (Layer 1)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
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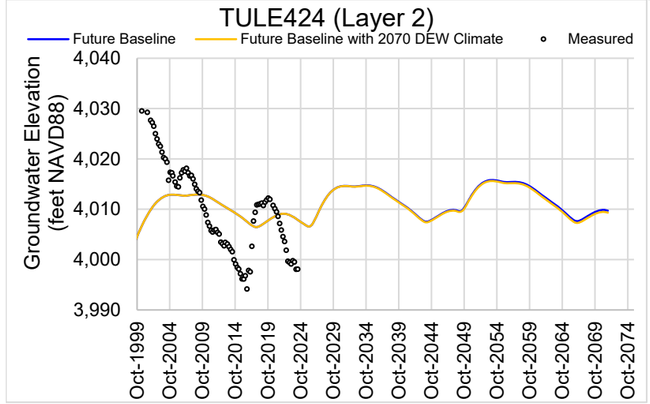
Oct-2069
Oct-2074


TULE424 (Layer 2)
Future Baseline
Future Baseline with 2070 DEW Climate
Measured
Groundwater Elevation (feet NAVD88)
4,040
4,030
4,020
4,010
4,000
3,990
Oct-1999
Oct-2004
Oct-2009
Oct-2014
Oct-2019
Oct-2024
Oct-2029
Oct-2034
Oct-2039
Oct-2044
Oct-2049
Oct-2054
Oct-2059
Oct-2064
Oct-2069
Oct-2074

Attachment 3
Tulelake Subbasin Land System Annual Water Budget (Historical and Future Baseline)

	Land System Inflows (TAF)					Land System Outflows (TAF)					
Water Year	Precipitation	Applied Water from TID Deliveries	Applied Groundwater from Private Agricultural Pumping	Shallow Groundwater into the Rootzone	Total Inflow	Runoff to Streams/Canals	ET of Precipitation	ET of Shallow Groundwater	ET of Applied Water	Groundwater Recharge from Precipitation and Applied Water	Total Outflow
2000	101	88	52	2	243	11	41	2	120	69	243
2001	63	17	77	1	158	4	37	1	81	36	159
2002	74	101	55	2	232	11	23	2	134	63	233
2003	96	74	55	2	227	13	36	2	111	66	228
2004	70	97	48	2	217	10	26	2	123	55	216
2005	118	58	50	2	228	12	54	2	93	68	229
2006	121	77	61	2	261	25	23	2	118	92	260
2007	86	91	54	2	233	13	28	2	124	66	233
2008	81	88	49	2	220	11	31	2	117	58	219
2009	82	91	36	2	211	5	50	2	109	45	211
2010	72	55	51	1	179	8	32	1	90	47	178
2011	92	110	29	2	233	15	25	2	119	71	232
2012	62	122	34	2	220	6	26	2	134	53	221
2013	89	112	34	2	237	8	48	2	124	54	236
2014	65	97	47	2	211	5	34	2	123	47	211
2015	106	94	37	2	239	12	47	2	113	66	240
2016	93	87	59	2	241	12	34	2	124	68	240
2017	101	80	61	2	244	13	40	2	120	69	244
2018	99	68	60	2	229	10	45	2	109	63	229
2019	127	78	46	2	253	14	57	2	106	74	253
2020	52	81	60	1	194	7	22	1	120	43	193
2021	55	25	82	1	163	4	31	1	92	35	163
2022	59	31	70	1	161	4	34	1	87	36	162
2023	58	73	48	1	180	1	44	1	103	30	179
2024	75	84	56	2	217	10	30	2	120	56	218
2025	104	80	64	3	251	18	28	3	124	79	252
2026	100	75	56	2	233	11	41	2	112	68	234
2027	63	46	67	1	177	4	37	1	97	38	177
2028	74	48	72	2	196	11	23	2	102	58	196
2029	96	39	68	2	205	13	36	2	92	62	205
2030	69	53	62	2	186	10	26	2	98	50	186
2031	118	35	59	2	214	12	54	2	81	66	215
2032	121	71	63	2	257	25	24	2	115	92	258
2033	86	58	68	2	214	13	28	2	108	63	214
2034	81	53	58	1	193	11	31	1	95	54	192
2035	82	48	61	1	192	5	50	1	93	43	192
2036	73	35	62	1	171	8	32	1	84	46	171
2037	92	56	67	1	216	15	25	1	105	69	215
2038	62	46	74	1	183	6	26	1	103	47	183
2039	89	32	71	1	193	8	48	1	88	47	192
2040	66	29	75	1	171	6	34	1	89	41	171
2041	106	30	70	1	207	12	47	1	86	61	207

	Land System Inflows (TAF)					Land System Outflows (TAF)					
Water Year	Precipitation	Applied Water from TID Deliveries	Applied Groundwater from Private Agricultural Pumping	Shallow Groundwater into the Rootzone	Total Inflow	Runoff to Streams/Canals	ET of Precipitation	ET of Shallow Groundwater	ET of Applied Water	Groundwater Recharge from Precipitation and Applied Water	Total Outflow
2042	93	41	73	1	208	12	34	1	97	63	207
2043	101	68	64	2	235	13	40	2	113	68	236
2044	99	50	68	1	218	10	45	1	101	62	219
2045	127	62	49	2	240	14	57	2	94	72	239
2046	52	41	72	1	166	7	22	1	97	39	166
2047	55	14	86	1	156	4	31	1	86	34	156
2048	59	21	76	1	157	4	34	1	83	35	157
2049	100	75	56	1	232	11	41	1	111	67	231
2050	63	46	67	1	177	4	37	1	97	38	177
2051	74	48	71	1	194	11	23	1	102	57	194
2052	96	39	68	1	204	13	36	1	92	63	205
2053	69	53	62	1	185	10	26	1	98	50	185
2054	118	35	59	2	214	12	54	2	80	66	214
2055	121	71	63	2	257	25	23	2	115	92	257
2056	87	58	68	2	215	13	28	2	108	64	215
2057	81	53	58	1	193	11	31	1	95	54	192
2058	82	48	61	1	192	5	50	1	93	43	192
2059	72	35	62	1	170	8	32	1	84	46	171
2060	92	56	67	1	216	15	26	1	105	69	216
2061	62	46	74	1	183	6	26	1	102	47	182
2062	89	32	71	1	193	8	48	1	88	47	192
2063	65	29	75	1	170	5	34	1	89	41	170
2064	107	30	70	1	208	12	47	1	86	61	207
2065	93	41	73	1	208	12	34	1	97	63	207
2066	101	68	64	2	235	13	40	2	113	68	236
2067	99	50	68	1	218	10	45	1	101	62	219
2068	128	62	49	2	241	14	57	2	94	73	240
2069	52	41	72	1	166	7	22	1	97	39	166
2070	55	14	86	1	156	4	31	1	86	34	156
2071	59	21	76	1	157	4	34	1	83	35	157
Historical Average (2000-2025)	85	79	53	2	219	10	36	2	113	58	219
Current Average (2018-2025)	79	65	61	2	207	9	36	2	108	52	207
Projected Average (2025-2074)	85	46	67	1	199	10	36	1	96	56	199

Notes:
TAF = thousand acre-feet
ET = evapotranspiration
TID = Tulelake Irrigation District

Attachment 4
Tulelake Subbasin Land System Annual Water Budget (Historical and Future Baseline with Climate Change)

	Land System Inflows (TAF)					Land System Outflows (TAF)					
Water Year	Precipitation	Applied Water from Purveyor Deliveries	Applied Groundwater Outside of Purveyor Service Areas	Shallow Groundwater into the Rootzone	Total Inflow	Runoff from Farm	ET of Precipitation	ET of Shallow Groundwater	ET of Applied Water	Groundwater Recharge from Precipitation and Applied Water	Total Outflow
2000	101	88	52	2	243	11	41	2	120	69	243
2001	63	17	77	1	158	4	37	1	81	36	159
2002	74	101	55	2	232	11	23	2	134	63	233
2003	96	74	55	2	227	13	36	2	111	66	228
2004	70	97	48	2	217	10	26	2	123	55	216
2005	118	58	50	2	228	12	54	2	93	68	229
2006	121	77	61	2	261	25	23	2	118	92	260
2007	86	91	54	2	233	13	28	2	124	66	233
2008	81	88	49	2	220	11	31	2	117	58	219
2009	82	91	36	2	211	5	50	2	109	45	211
2010	72	55	51	1	179	8	32	1	90	47	178
2011	92	110	29	2	233	15	25	2	119	71	232
2012	62	122	34	2	220	6	26	2	134	53	221
2013	89	112	34	2	237	8	48	2	124	54	236
2014	65	97	47	2	211	5	34	2	123	47	211
2015	106	94	37	2	239	12	47	2	113	66	240
2016	93	87	59	2	241	12	34	2	124	68	240
2017	101	80	61	2	244	13	40	2	120	69	244
2018	99	68	60	2	229	10	45	2	109	63	229
2019	127	78	46	2	253	14	57	2	106	74	253
2020	52	81	60	1	194	7	22	1	120	43	193
2021	55	25	82	1	163	4	31	1	92	35	163
2022	59	31	70	1	161	4	34	1	87	36	162
2023	58	73	48	1	180	1	44	1	103	30	179
2024	75	84	56	2	217	10	30	2	120	56	218
2025	104	80	64	3	251	18	28	3	124	79	252
2026	89	76	66	2	233	10	36	2	121	64	233
2027	50	47	78	1	176	2	30	1	107	35	175
2028	69	48	78	2	197	9	23	2	108	55	197
2029	90	40	76	2	208	12	33	2	99	62	208
2030	63	54	73	2	192	9	21	2	109	51	192
2031	97	36	67	2	202	8	47	2	88	57	202
2032	112	72	72	2	258	23	22	2	123	88	258
2033	78	58	77	2	215	11	27	2	116	60	216
2034	51	53	78	1	183	5	22	1	112	43	183
2035	63	48	75	1	187	3	37	1	106	40	187
2036	61	36	71	1	169	6	29	1	92	42	170
2037	86	56	77	1	220	15	22	1	114	68	220
2038	56	46	82	1	185	5	24	1	110	46	186
2039	74	33	79	1	187	6	40	1	96	44	187
2040	66	29	85	1	181	6	32	1	98	44	181
2041	97	31	79	1	208	12	40	1	94	61	208

	Land System Inflows (TAF)					Land System Outflows (TAF)					
Water Year	Precipitation	Applied Water from Purveyor Deliveries	Applied Groundwater Outside of Purveyor Service Areas	Shallow Groundwater into the Rootzone	Total Inflow	Runoff from Farm	ET of Precipitation	ET of Shallow Groundwater	ET of Applied Water	Groundwater Recharge from Precipitation and Applied Water	Total Outflow
2042	82	41	82	1	206	12	26	1	105	62	206
2043	94	68	77	2	241	13	35	2	124	68	242
2044	82	51	77	1	211	6	40	1	109	54	210
2045	123	62	62	2	249	16	50	2	107	75	250
2046	41	42	84	1	168	6	13	1	107	39	166
2047	52	14	89	1	156	5	26	1	88	35	155
2048	44	21	81	1	147	2	29	1	88	28	148
2049	89	76	66	1	232	10	36	1	121	64	232
2050	50	47	77	1	175	2	30	1	106	35	174
2051	68	48	77	1	194	9	23	1	108	54	195
2052	90	40	75	1	206	12	33	1	98	62	206
2053	63	54	73	1	191	9	21	1	109	51	191
2054	97	36	67	2	202	8	47	2	88	57	202
2055	111	72	72	2	257	23	22	2	123	88	258
2056	79	58	77	2	216	11	27	2	116	60	216
2057	51	53	78	1	183	5	22	1	112	43	183
2058	63	48	75	1	187	3	37	1	106	40	187
2059	61	36	71	1	169	6	29	1	92	42	170
2060	86	56	77	1	220	15	22	1	114	68	220
2061	56	46	82	1	185	5	24	1	110	46	186
2062	74	33	79	1	187	6	40	1	96	44	187
2063	66	29	85	1	181	6	32	1	98	44	181
2064	98	31	79	1	209	13	40	1	94	61	209
2065	82	41	82	1	206	12	26	1	105	62	206
2066	94	68	77	2	241	13	35	2	124	68	242
2067	81	51	77	1	210	6	40	1	109	54	210
2068	124	62	62	2	250	16	50	2	107	76	251
2069	41	42	84	1	168	6	14	1	107	39	167
2070	52	14	89	1	156	5	26	1	88	35	155
2071	44	21	81	1	147	2	29	1	88	28	148

Historical Average (2000-2025)	85	79	53	2	219	10	36	2	113	58	219
Current Average (2018-2025)	79	65	61	2	207	9	36	2	108	52	207
Projected Average (2026-2071)	75	46	77	1	199	9	31	1	105	53	199

Notes:
TAF = thousand acre-feet
ET = evapotranspiration

Attachment 5
Tulelake Subbasin Groundwater System Annual Water Budget (Historical and Future Baseline)

	Groundwater System Inflows (TAF)						Groundwater System Outflows (TAF)								Change in Groundwater Storage (TAF)
Water Year	Groundwater Recharge from Precipitation & Applied Water	Groundwater Recharge from Canal Laterals	Groundwater Recharge from Tulelake Sumps	Groundwater Recharge from Main Canals and Lost River	Subsurface Inflow from Surrounding Area	Total Inflow	Irrigation & M&I Groundwater Pumping	Private Agricultural Groundwater Pumping	Groundwater Discharge to Drains	Shallow Groundwater ET	Groundwater Discharge to Tulelake Sumps	Groundwater Discharge to Main Canals and Lost River	Subsurface Outflow to Surrounding Area	Total Outflow	
2000	69	55	9	75	20	228.0	0	48	177	2	0	0	8	235	-7
2001	36	13	10	62	19	140	0	72	105	1	0	0	8	186	-46
2002	63	64	10	70	22	229	12	52	153	2	0	0	10	229	0
2003	66	54	10	72	22	224	14	52	155	2	0	0	10	233	-9
2004	55	59	10	72	20	216	10	45	149	2	0	0	9	215	1
2005	68	49	10	70	19	216	10	48	150	2	0	0	9	219	-3
2006	92	50	10	69	21	242	7	58	169	2	0	0	9	245	-3
2007	66	51	10	70	20	217	11	51	148	2	0	0	9	221	-4
2008	58	55	10	70	18	211	2	45	145	2	0	0	8	202	9
2009	45	54	11	73	15	198	0	34	139	2	0	0	7	182	16
2010	47	30	10	68	18	173	18	48	120	1	0	0	9	196	-23
2011	71	40	10	74	15	210	1	28	145	2	0	0	7	183	27
2012	53	39	10	72	13	187	3	32	137	2	0	0	7	181	6
2013	54	36	10	72	13	185	9	32	136	2	0	0	8	187	-2
2014	47	36	10	71	14	178	12	45	128	2	0	0	10	197	-19
2015	66	40	10	71	13	200	5	36	141	2	0	0	9	193	7
2016	68	49	10	71	13	211	2	54	151	2	0	0	9	218	-7
2017	69	52	10	74	15	220	0	57	155	2	0	0	9	223	-3
2018	63	42	10	68	15	198	0	55	138	2	0	0	9	204	-6
2019	74	49	10	69	15	217	1	43	149	2	0	0	8	203	14
2020	43	43	10	70	19	185	20	56	124	1	0	0	12	213	-28
2021	35	30	7	66	22	160	31	78	93	1	0	0	18	221	-61
2022	36	20	0	59	20	135	27	66	62	1	0	0	18	174	-39
2023	30	57	11	76	16	190	3	45	87	1	0	0	12	148	42
2024	56	71	12	81	14	234	2	52	138	2	0	0	12	206	28
2025	79	76	11	81	14	261	1	59	170	3	0	0	12	245	16
2026	68	55	11	79	13	226	0	52	149	2	0	0	10	213	13
2027	38	13	11	64	13	139	0	63	88	1	0	0	10	162	-23
2028	58	64	11	73	17	223	11	67	133	2	0	0	13	226	-3
2029	62	54	11	76	19	222	14	65	136	2	0	0	13	230	-8
2030	50	59	11	75	18	213	10	58	128	2	0	0	12	210	3
2031	66	49	11	73	17	216	10	55	133	2	0	0	12	212	4
2032	92	50	11	72	18	243	7	60	155	2	0	0	11	235	8
2033	63	51	11	72	18	215	11	64	135	2	0	0	11	223	-8
2034	54	55	11	74	16	210	2	54	131	1	0	0	10	198	12
2035	43	54	11	74	15	197	0	57	125	1	0	0	10	193	4
2036	46	30	11	71	18	176	18	58	106	1	0	0	11	194	-18
2037	69	40	11	76	17	213	1	62	128	1	0	0	10	202	11
2038	47	39	11	75	17	189	3	68	115	1	0	0	10	197	-8
2039	47	36	11	74	18	186	9	67	109	1	0	0	11	197	-11
2040	41	36	11	73	18	179	12	71	99	1	0	0	12	195	-16
2041	61	40	11	73	17	202	5	65	112	1	0	0	11	194	8
2042	63	49	11	72	16	211	2	68	123	1	0	0	10	204	7
2043	68	52	11	76	16	223	0	60	135	2	0	0	10	207	16
2044	62	42	11	73	15	203	0	63	126	1	0	0	11	201	2
2045	72	49	11	72	15	219	1	45	138	2	0	0	10	196	23
2046	39	43	11	71	19	183	20	68	114	1	0	0	13	216	-33
2047	34	30	11	67	22	164	31	81	86	1	0	0	19	218	-54
2048	35	20	12	61	21	149	27	72	60	1	0	0	19	179	-30
2049	67	55	12	81	16	231	0	52	111	1	0	0	14	178	53
2050	38	13	12	65	14	142	0	62	73	1	0	0	13	149	-7
2051	57	64	12	73	17	223	11	66	116	1	0	0	15	209	14
2052	63	54	12	76	18	223	14	64	125	1	0	0	15	219	4
2053	50	59	12	75	17	213	10	58	121	1	0	0	13	203	10
2054	66	49	11	73	16	215	10	55	126	2	0	0	13	206	9
2055	92	50	11	72	17	242	7	60	150	2	0	0	12	231	11
2056	64	51	11	72	17	215	11	63	132	2	0	0	12	220	-5
2057	54	55	11	74	15	209	2	54	128	1	0	0	11	196	13
2058	43	54	11	74	14	196	0	57	122	1	0	0	11	191	5
2059	46	30	11	71	18	176	18	58	103	1	0	0	12	192	-16

	Groundwater System Inflows (TAF)						Groundwater System Outflows (TAF)								Change in Groundwater Storage (TAF)
Water Year	Groundwater Recharge from Precipitation & Applied Water	Groundwater Recharge from Canal Laterals	Groundwater Recharge from Tulelake Sumps	Groundwater Recharge from Main Canals and Lost River	Subsurface Inflow from Surrounding Area	Total Inflow	Irrigation & M&I Groundwater Pumping	Private Agricultural Groundwater Pumping	Groundwater Discharge to Drains	Shallow Groundwater ET	Groundwater Discharge to Tulelake Sumps	Groundwater Discharge to Main Canals and Lost River	Subsurface Outflow to Surrounding Area	Total Outflow	
2060	69	40	11	77	16	213	1	62	126	1	0	0	10	200	13
2061	47	39	11	75	16	188	3	68	113	1	0	0	11	196	-8
2062	47	36	11	74	17	185	9	67	108	1	0	0	11	196	-11
2063	41	36	11	73	18	179	12	71	98	1	0	0	13	195	-16
2064	61	40	11	73	16	201	5	65	111	1	0	0	12	194	7
2065	63	49	12	72	16	212	2	68	121	1	0	0	11	203	9
2066	68	52	11	76	16	223	0	60	134	2	0	0	11	207	16
2067	62	42	11	73	15	203	0	63	125	1	0	0	11	200	3
2068	73	49	11	72	14	219	1	45	137	2	0	0	10	195	24
2069	39	43	11	71	19	183	20	69	113	1	0	0	13	216	-33
2070	34	30	11	67	22	164	31	81	85	1	0	0	19	217	-53
2071	35	20	12	61	21	149	27	72	60	1	0	0	20	180	-31
Historical Average (2000-2025)	58	47	10	71	17	203	8	50	137	2	0	0	10	207	-4
Current Average (2018-2025)	52	49	9	71	17	198	11	57	120	2	0	0	13	203	-5
Projected Average (2026-2071)	56	44	11	73	17	201	8	63	117	1	0	0	12	201	0

Notes:
TAF = thousand acre-feet
M&I = municipal and industrial
ET = evapotranspiration

Attachment 6
Tulelake Subbasin Groundwater System Annual Water Budget (Historical and Future Baseline with Climate Change)

	Groundwater System Inflows (TAF)						Groundwater System Outflows (TAF)								Change in Groundwater Storage (TAF)
Water Year	Groundwater Recharge from Precipitation & Applied Water	Groundwater Recharge from Canal Laterals	Groundwater Recharge from Tulelake Sumps	Groundwater Recharge from Main Canals and Lost River	Subsurface Inflow from Surrounding Area	Total Inflow	Irrigation & M&I Groundwater Pumping	Private Agricultural Groundwater Pumping	Groundwater Discharge to Drains	Shallow Groundwater ET	Groundwater Discharge to Tulelake Sumps	Groundwater Discharge to Main Canals and Lost River	Subsurface Outflow to Surrounding Area	Total Outflow	
2000	69	55	9	75	20	228.0	0	48	177	2	0	0	8	235	-7
2001	36	13	10	62	19	140	0	72	105	1	0	0	8	186	-46
2002	63	64	10	70	22	229	12	52	153	2	0	0	10	229	0
2003	66	54	10	72	22	224	14	52	155	2	0	0	10	233	-9
2004	55	59	10	72	20	216	10	45	149	2	0	0	9	215	1
2005	68	49	10	70	19	216	10	48	150	2	0	0	9	219	-3
2006	92	50	10	69	21	242	7	58	169	2	0	0	9	245	-3
2007	66	51	10	70	20	217	11	51	148	2	0	0	9	221	-4
2008	58	55	10	70	18	211	2	45	145	2	0	0	8	202	9
2009	45	54	11	73	15	198	0	34	139	2	0	0	7	182	16
2010	47	30	10	68	18	173	18	48	120	1	0	0	9	196	-23
2011	71	40	10	74	15	210	1	28	145	2	0	0	7	183	27
2012	53	39	10	72	13	187	3	32	137	2	0	0	7	181	6
2013	54	36	10	72	13	185	9	32	136	2	0	0	8	187	-2
2014	47	36	10	71	14	178	12	45	128	2	0	0	10	197	-19
2015	66	40	10	71	13	200	5	36	141	2	0	0	9	193	7
2016	68	49	10	71	13	211	2	54	151	2	0	0	9	218	-7
2017	69	52	10	74	15	220	0	57	155	2	0	0	9	223	-3
2018	63	42	10	68	15	198	0	55	138	2	0	0	9	204	-6
2019	74	49	10	69	15	217	1	43	149	2	0	0	8	203	14
2020	43	43	10	70	19	185	20	56	124	1	0	0	12	213	-28
2021	35	30	7	66	22	160	31	78	93	1	0	0	18	221	-61
2022	36	20	0	59	20	135	27	66	62	1	0	0	18	174	-39
2023	30	57	11	76	16	190	3	45	87	1	0	0	12	148	42
2024	56	71	12	81	14	234	2	52	138	2	0	0	12	206	28
2025	79	76	11	81	14	261	1	59	170	3	0	0	12	245	16
2026	64	55	11	79	14	223	0	61	145	2	0	0	11	219	4
2027	35	13	11	65	13	137	0	72	82	1	0	0	12	167	-30
2028	55	64	12	73	16	220	11	72	124	2	0	0	15	224	-4
2029	62	54	11	76	18	221	14	71	128	2	0	0	16	231	-10
2030	51	59	12	75	17	214	10	69	121	2	0	0	15	217	-3
2031	57	49	12	74	17	209	10	63	117	2	0	0	15	207	2
2032	88	50	11	73	17	239	7	68	141	2	0	0	14	232	7
2033	60	51	11	72	17	211	11	72	122	2	0	0	15	222	-11
2034	43	55	12	74	16	200	2	72	111	1	0	0	14	200	0
2035	40	54	12	75	15	196	0	70	109	1	0	0	15	195	1
2036	42	30	12	71	18	173	18	66	90	1	0	0	15	190	-17
2037	68	40	12	78	16	214	1	71	113	1	0	0	14	200	14
2038	46	39	12	76	15	188	3	76	101	1	0	0	14	195	-7
2039	44	36	12	76	16	184	9	75	95	1	0	0	16	196	-12
2040	44	36	12	73	17	182	12	80	89	1	0	0	17	199	-17
2041	61	40	12	73	16	202	5	74	99	1	0	0	17	196	6
2042	62	49	12	74	15	212	2	76	108	1	0	0	16	203	9
2043	68	52	12	78	15	225	0	71	120	2	0	0	16	209	16
2044	54	42	12	73	14	195	0	71	106	1	0	0	16	194	1
2045	75	49	12	72	14	222	1	58	124	2	0	0	15	200	22
2046	39	43	11	73	18	184	20	79	100	1	0	0	18	218	-34
2047	35	30	12	67	21	165	31	84	76	1	0	0	25	217	-52
2048	28	20	13	61	20	142	27	77	48	1	0	0	27	180	-38
2049	64	55	13	82	15	229	0	61	94	1	0	0	22	178	51
2050	35	13	13	66	13	140	0	71	61	1	0	0	20	153	-13
2051	54	64	13	74	16	221	11	72	96	1	0	0	22	202	19
2052	62	54	12	77	17	222	14	70	107	1	0	0	23	215	7
2053	51	59	12	76	16	214	10	68	105	1	0	0	21	205	9
2054	57	49	12	74	16	208	10	63	104	2	0	0	20	199	9

	Groundwater System Inflows (TAF)						Groundwater System Outflows (TAF)								Change in Groundwater Storage (TAF)
Water Year	Groundwater Recharge from Precipitation & Applied Water	Groundwater Recharge from Canal Laterals	Groundwater Recharge from Tulelake Sumps	Groundwater Recharge from Main Canals and Lost River	Subsurface Inflow from Surrounding Area	Total Inflow	Irrigation & M&I Groundwater Pumping	Private Agricultural Groundwater Pumping	Groundwater Discharge to Drains	Shallow Groundwater ET	Groundwater Discharge to Tulelake Sumps	Groundwater Discharge to Main Canals and Lost River	Subsurface Outflow to Surrounding Area	Total Outflow	
2055	88	50	12	73	16	239	7	68	128	2	0	0	19	224	15
2056	60	51	12	72	16	211	11	72	113	2	0	0	19	217	-6
2057	43	55	12	74	15	199	2	72	104	1	0	0	18	197	2
2058	40	54	12	76	14	196	0	69	103	1	0	0	18	191	5
2059	42	30	12	71	17	172	18	66	85	1	0	0	18	188	-16
2060	68	40	12	78	15	213	1	71	107	1	0	0	16	196	17
2061	46	39	12	76	15	188	3	76	97	1	0	0	17	194	-6
2062	44	36	12	76	16	184	9	74	91	1	0	0	18	193	-9
2063	44	36	12	73	16	181	12	80	85	1	0	0	19	197	-16
2064	61	40	12	74	15	202	5	74	96	1	0	0	18	194	8
2065	62	49	12	74	14	211	2	75	104	1	0	0	18	200	11
2066	68	52	12	78	14	224	0	71	117	2	0	0	18	208	16
2067	54	42	12	73	14	195	0	71	103	1	0	0	17	192	3
2068	76	49	12	73	13	223	1	58	122	2	0	0	16	199	24
2069	39	43	11	73	17	183	20	79	98	1	0	0	19	217	-34
2070	35	30	12	67	21	165	31	84	75	1	0	0	26	217	-52
2071	28	20	13	61	20	142	27	77	47	1	0	0	28	180	-38
Historical Average (2000-2025)	58	47	10	71	17	203	8	50	137	2	0	0	10	207	-4
Current Average (2018-2025)	52	49	9	71	17	198	11	57	120	2	0	0	13	203	-5
Projected Average (2026-2071)	53	44	12	73	16	198	8	72	102	1	0	0	18	201	-3

Notes:
TAF = thousand acre-feet
M&I = municipal and industrial
ET = evapotranspiration

Attachment 7
Tulelake Sumps Water Balance (Historical)

Water Year	Tulelake Sumps Inflows (TAF)					Tulelake Sumps Outflows (TAF)								Tulelake Sumps Imbalance (closure)
	Precipitation	Spills from Lost River	Groundwater Discharge to Sumps	Inflow from Drains	Total Inflow	Pump 11 Diversions	Q-Canal Headworks Diversions	R-Canal Headworks Diversions	D-Plant Pumping	Pumps R and 12 Diversions	Open-water Evaporation	Groundwater Recharge from Sumps	Total Outflow	
2000	14	21	0	190	225	9	15	8	67	33	53	9	194	31
2001	7	57	0	114	178	0	4	3	24	7	53	10	101	77
2002	8	37	0	162	207	8	15	9	77	36	53	10	208	-1
2003	11	18	0	163	192	7	14	10	61	33	53	10	188	4
2004	8	21	0	156	185	8	14	9	51	36	53	10	181	4
2005	14	24	0	157	195	11	13	12	66	30	53	10	195	0
2006	14	37	0	177	228	8	13	7	112	36	53	10	239	-11
2007	10	22	0	155	187	8	13	8	32	29	53	10	153	34
2008	10	23	0	152	185	9	14	8	55	29	53	10	178	7
2009	9	12	0	146	167	10	14	9	34	26	53	11	157	10
2010	8	7	0	127	142	2	7	2	10	16	53	10	100	42
2011	10	15	0	153	178	8	13	6	20	28	53	10	138	40
2012	7	13	0	144	164	16	15	9	15	24	53	10	142	22
2013	10	12	0	143	165	13	17	9	25	24	53	10	151	14
2014	7	7	0	135	149	12	15	9	12	22	53	10	133	16
2015	13	10	0	148	171	14	16	8	11	21	53	10	133	38
2016	11	13	0	158	182	15	15	7	22	26	53	10	148	34
2017	12	21	0	162	195	12	15	8	33	24	53	10	155	40
2018	13	7	0	145	165	12	13	6	16	22	53	10	132	33
2019	15	15	0	156	186	14	13	6	30	24	53	10	150	36
2020	6	17	0	132	155	15	16	7	15	18	53	10	134	21
2021	7	7	0	97	111	16	4	4	0	8	53	7	92	19
2022	7	0	0	67	74	0	0	0	0	3	53	0	56	18
2023	7	3	0	92	102	0	0	4	0	26	53	11	94	8
2024	9	51	0	144	204	14	30	14	7	23	53	12	153	51
2025	13	27	0	178	218	34	19	7	42	23	53	11	189	29
Historical Average (2000-2025)	10	19	0	144	173	11	13	7	32	24	53	10	150	23
Current Average (2018-2025)	10	16	0	126	152	13	12	6	14	18	53	9	125	27

Notes:
TAF = thousand acre-feet

Appendix M

MBK ENGINEERS
Water Resources ◆ Flood Control ◆ Water Rights

TECHNICAL MEMORANDUM

DATE: ~~June 14, 2024~~September 24, 2026

PREPARED BY: Chris Connor

REVIEWED BY: Angela Bezzone, P.E. and Kyle Knutson, P.E.

SUBJECT: Updated Methodology for Determination of Minimum Thresholds

Purpose

As documented in Appendix L of the Tule Lake Subbasin Groundwater Sustainability Plan (GSP) Amendment 1, the Groundwater Sustainability Agencies (GSAs) provided direction on the methodology used to establish minimum thresholds (MTs) for groundwater levels at each representative monitoring well. On January 18, 2024, the Department of Water Resources (DWR) transmitted a letter to the GSAs (Attachment A). The letter stated that the GSP was found to be "incomplete" and identified two corrective actions relative to the MTs, which are generally described below. Based upon the comments received in the DWR letter, the purpose of this technical memorandum is to provide an overview of the updated methodology to establish MTs for the GSP and describe how the corrective actions have been addressed.

Well Completion Report Review

During development of the GSP, well completion reports (WCR) for the Tule Lake Subbasin were downloaded from DWR's Well Completion Report Map Application (Application)[1] and reviewed using ESRI's ArcGIS mapping software. Due to the length of time between development of the GSP and this effort to revise the GSP, the WCRs were downloaded again to ensure that any new WCRs and any changes to WCRs were included. On ~~March 28, 2024~~September 23, 2026, ~~428~~ 448 WCRs[2] were downloaded and stored in a file geodatabase. Unless a WCR has coordinates, the Application assigns the WCR to the centroid of the associated Public Land Survey System section. There were ~~eight~~ nine instances where the centroid of a section was adjacent to, but outside of the Tule Lake Subbasin boundary. Due to the proximity of the centroid in these instances, it was assumed that the accompanying WCRs were likely related to wells within the Tule Lake Subbasin and therefore included in the analysis.

The well completion reports were first organized into the following Record Types:

1. 'Destruction' or 'Drill and Destroy' (30 of 448)
2. 'Modification or Repair' (5 of 448)

[1] https://gis.water.ca.gov/app/wcr/

[2] Records within the database did not always contain well completion reports. These records were not removed from the overall analysis, nor were they removed from the counts that follow in this memorandum.

DRAFT

3. 'New' (413 of 448)

Wells marked as 'Destruction' or 'Drill and Destroy' on the well completion report should no longer exist and are therefore not used in the analysis. Therefore, ~~is leaves~~ 418 well completion reports (448 less 30).

The remaining wells~~wells~~ were then organized into the following six categories based on the "B118WellUse" field as identified in the WCR download.

1. Domestic (157~~6~~ of 412~~8~~)
2. Irrigation (~~135~~ 144 of 412~~8~~)
3. ~~Public Supply (4 of 428)~~
3.
4. ~~Industrial, Other, or Unknown~~ (5~~43~~ of 412~~8~~)
4.
5. Monitoring (716~~2~~ of 412~~8~~)
   Other (37 of 418)
6.

~~5.~~ The 37 wells categorized as "Other" were further distinguished~~reviewed~~ into the following 3 categories based on the "PlannedUse" field as identified in the WCR download.~~Destroyed (28 of 428)~~

1. Other (29 of 37)
2. Test Well (4 of 37)
3. Vapor Extraction (3 of 37)

The four test wells and three vapor extraction wells are not used for water supply and are therefore not used in the analysis. This leaves 411 well completion reports (418 less 4 less 3), of which 29 are marked as "Other" in both the "B118WellUse" and "PlannedUse" fields as identified in the WCR download. Each of the 29 well completion reports was then reviewed to determine the applicability of the well to the analysis. Table 1 below~~he following table~~ summarizes~~hows~~ the results of the review.

Table 1. Summary of "Other" Well Completion Report Review

WCR Number	Note	Action
WCR1944-000255	H~~h~~andwritten note indicating that the well is capped and a hand-bored well was drilled 20' away. New well is 14' deep. On 6/30/2024, it was confirmed that this well is not in use.	Remove. See attachment E to this memorandum for updated well completion report.
WCR1944-000257	H~~h~~andwritten note indicating that the well is destroyed.	Remove from Analysis. Adjust B118 Well Use to "Destroyed"
WCR1945-000347	H~~h~~andwritten note indicating that the well is destroyed.	Remove from Analysis. Adjust B118 Well Use to "Destroyed"
WCR1957-001332	H~~h~~andwritten note indicating that the well is destroyed.	Remove from Analysis. Adjust B118 Well Use to "Destroyed"
WCR1958-000886	61 feet deep, no screen, marked as other.	Keep, adjust B118WellUse to "Domestic"
WCR1958-000887	-	Keep

WCR Number	Note	Action
WCR1959-001084	-	Keep
WCR1962-001268	-	Keep
WCR1964-001163	-	Keep
WCR1972-002316	-	Keep
WCR2001-009777	Note indicates well is being used for monitoring.	Keep, adjust B118WellUse to "Monitoring"
WCR2010-008680	-	Keep
WCR2013-008401	Sparging well	Remove from Analysis
WCR2013-008402	Sparging well	Remove from Analysis
WCR2013-008403	Sparging well	Remove from Analysis
WCR2013-008404	Sparging well	Remove from Analysis
WCR2013-008405	Sparging well	Remove from Analysis
WCR2013-008406	Sparging well	Remove from Analysis
WCR2013-008407	Sparging well	Remove from Analysis
WCR2013-008408	Sparging well	Remove from Analysis
WCR2014-007250	Well was deepened to 297 ft. Screened from 257 to 297 ft.	Keep, adjust completion depth to 297 ft., top of screen to 257 ft. and bottom of screen to 297 ft. Adjust B118Use to "Domestic"
WCR2014-005757	Sparging well	Remove from Analysis
WCR2014-007005	Well was deepened to 242 ft. Screened from 212 to 232 ft.	Keep, adjust completion depth to 242 ft., top of screen to 212 ft. and bottom of screen to 232 ft. Adjust B118Use to "Domestic"
WCR2014-007006	Well was deepened to 200 ft. No screen installed. Blank casing to 173 t.	Keep, adjust completion depth to 200 ft. Adjust B118Use to "Domestic"
WCR2014-005783	Sparging well	Remove from Analysis
WCR2014-005784	Sparging well	Remove from Analysis
WCR2014-005785	Sparging well	Remove from Analysis
WCR2014-005786	Sparging well	Remove from Analysis
WCR2014-005787	Sparging well	Remove from Analysis

Below is a summary of the observations and actions taken based on the review documented in Table 1 above~~In summary~~:

- 14 wells were removed from the analysis because they are used for sparging (14 of 29)
- 4 wells were removed from the analysis because they were destroyed (4 of 29)
- 3 wells were deepened and had B118WellUse adjusted to "Domestic" (3 of 29)
- 1 well had its B118WellUse adjusted to "Monitoring" (1 of 29)
- 1 well was removed from the analysis because it is no longer in use (1 of 29)
- 6 wells were left as is~~.~~ (6 of 29)

Therefore, after reviewing the 29 "Other" well completion reports, there are~~The count of XXX~~392 remaining wells used for this analysis ~~up to this point is~~ (4118 – 14 – 4 - 1) ~~= 399 wells~~.

Next, ~~98~~ 72 wells identified as Monitoring were removed from the analysis ~~(eight wells identified as Other that were additionally categorized as Test Well or Vapor Extraction, 62 wells identified as Monitoring, and 28 wells identified as Destroyed)~~, leaving a total of 32~~3~~0 WCRs to be evaluated to establish MTs.

~~Upon further review of the remaining 330 WCRs, 23 additional wells were removed from the analysis for the reasons below.~~

- ~~Well was drilled for sparging (14 wells identified as Industrial, Other or Unknown)~~
- ~~Issues arose during drilling, which resulted in not completing construction of the well (1 well identified as Irrigation and 1 well identified as Other)~~
- ~~Note on WCR confirmed well has been destroyed (1 well identified as Irrigation, 1 well identified as Domestic, and 3 wells identified as Unknown)~~
- ~~Well is a duplicate (1 Irrigation well)~~
- ~~Well is no longer in use, and household associated with well is abandoned (1 well identified as Other, see Attachment E which includes the WCR with an additional note about well status)~~

~~In addition, during review of the remaining 330 WCRs, 2 wells were reassigned to a different category for the reason below.~~

- ~~Well has since been deepened (2 Other reassigned to Domestic)~~

~~In total, 307 (428 less 98 less 23) wells were used to update the MTs for the representative monitoring wells.~~

The ~~307~~ 320 wells were organized into the following 4~~six~~ categories.

1. Domestic (~~155~~ 166 of 32007)
2. Irrigation (~~132~~ 144 of ~~307~~320)
3. Public Supply (4 of ~~307~~320)
4. Industrial~~,~~ or Other~~, or Unknown~~ (~~17~~ 6 of ~~307~~320)
5. ~~Monitoring (0 of 307)~~
6. ~~Destroyed (0 of 307)~~

Corrective Action A: Minimum Threshold Determination

As described in the GSP, the primary water supply for agricultural operations within the Tule Lake Subbasin is surface water from the Klamath Project. If the surface water supply is not sufficient to meet demand within the Tulelake Irrigation District (District) then the District will operate its groundwater wells to provide additional water supply. Lastly, private irrigation well owners within the District will operate their wells if the surface water supply and District well supply is not sufficient to meet their demand. Based on these operations, there were two methodologies established to determine the MT at each representative monitoring well, which are described below.

- Representative monitoring wells that are used for irrigation have MTs set to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer.
- The "Near" function in ArcGIS Pro software was used to associate each of the 3~~07~~ 20 WCRs with the closest representative monitoring well screened in the same aquifer,~~,~~ such that all 3~~07~~20 WCRs were associated with one representative monitoring well. All representative monitoring wells that are not an irrigation well have MTs set to either the shallowest or second shallowest well within its Near grouping. However, if there are not any wells within a representative monitoring well's Near grouping, then the MT is equal to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer, based on the depth of water below ground surface.

Table ~~1~~ 2 below shows the lowest static groundwater level measurement recorded at each of the representative monitoring wells identified as irrigation wells and the corresponding MT.

Table ~~2~~22221 MTs for Representative Monitoring Wells Identified as Irrigation Wells

Representative Monitoring Well	Lowest Static Well Measurement (ft bgs)	Date	Updated Minimum Threshold (ft bgs)
48N04E30F002M (TID Well 1)	71.70 ft	10/1/2022	79
48N04E13K001M (TID Well 5)	81.66 ft	10/1/2022	90
46N05E22D001M (TID Well 14)	48.39 ft	12/1/2022	54
48N05E26D001M (TID Well 8)	66.81 ft	8/1/2022	74

Table 32 below shows the updated minimum thresholds for each representative monitoring well that is not identified as an irrigation well.

Table 333332 MTs for Non-Irrigation Representative Monitoring Wells

Representative Monitoring Well	Original MT (ft bgs)	Updated MT (ft bgs)	Notes
46N05E01P001M	24	24	The two shallowest wells in WCR database have since been deepened. MT is set to shallowest domestic remaining well, which is a domestic well, with a depth of 24'.
48N04E22M001M	50	120	The shallowest wells were both was an irrigation wells with a depths of 28' and 31'; however, since private irrigation wells are not a main source of supply the MT was based on the shallowest non-irrigation well, which is a domestic well with a depth of 120'.
48N04E19C001M	29	3329	MT is set to shallowest domestic well, with a depth of 29'.The shallowest well was an irrigation well with a depth of 28'; however, since private irrigation wells are not a main source of supply the MT was based on the shallowest non-irrigation well, which is a domestic well with a depth of 33'
47N05E04M001M	15	33	MT is set to the shallowest domestic well (33'). WCR database has a double entry for a 31' deep irrigation well; however, since private irrigation wells are not a main source of supply the MT was based on the shallowest non-irrigation well.
47N05E01N001M	49	4236	There is a 15' domestic well drilled in 1996; however, based upon a review of a historical hydrograph for 47N05E01N001M this well likely went dry in 2011, which is prior to SGMA. Therefore, the MT is set to the next shallowest well which is a domestic well with a depth of 42'36'.
48N04E31M001M	48	29	MT is set to shallowest well which is a domestic well with a depth of 29'.
41S12E19Q001W	50	39	The shallowest well is a 14' deep domestic well; however, based on a conversation with the well owner the well is no longer in use, and the household associated with well is abandoned (see Attachment E). MT is set to the next deepest domestic well which has a depth of 39'. There is a 33' deep are 3 irrigation wells with depths of 31', 31' and 36', respectively; however, since private irrigation wells are not a main source of supply the MT was based on the shallowest non-irrigation well.
46N05E21J001M	32	32	MT is set to 32', which is the depth of 46N05E21J001M as it is the shallowest well in its group.
48N05E35F001M	32	29	MT is set to shallowest domestic well, with a depth of 29'.MT is set to 29' to cover a domestic well that was initially grouped
TL-T1 Q3B	35	35	There are no wellsThere is one irrigation well near TL-T1 Q3B with a depth of 1170', as noted above the MT is set to lowest measurement recorded plus a 10% buffer.
TL-T3 GP	16	16	There are no 5 irrigation wells near TL-T3 GP, all with completion depths at or greater than the depth of TL-T3 GP, as noted above the MT is set to lowest measurement recorded plus a 10% buffer.

Table ~~3~~4 below summarizes the original MTs identified in the GSP and the updated MTs based on the analysis described above. Hydrographs for each representative monitoring well, including the updated MTs, are provided in Attachment B.

Table ~~444443~~ Original and Updated MTs for all Representative Monitoring Wells

Representative Monitoring Well	Original MT (ft bgs)	Change (ft)	Updated MT (ft bgs)
46N05E01P001M	24	+0	24
48N04E22M001M	50	-70	120
48N04E19C001M	29	~~+~~10	~~28~~29
48N04E30F002M (TID Well 1)	80	+1	79
~~47N05E04M001M~~	~~15~~	~~-18~~	~~33~~
47N05E01N001M	49	+7	~~42~~36
~~48N04E31M001M~~	~~48~~	~~+19~~	~~29~~
41S12E19Q001W	50	~~+0~~+21	~~50~~39
48N04E13K001M (TID Well 5)	212	+122	90
46N05E21J001M	32	+0	32
46N05E22D001M (TID Well 14)	99	+45	54
48N05E35F001M	32	+3	29
48N05E26D001M (TID Well 8)	304	+230	74
TL-T1 Q3B	35	+0	35
TL-T3 GP	16	+0	16

Corrective Action B: Potential Dewatered Wells

Corrective Action B within DWR's letter requested the GSAs to determine the number of wells potentially dewatered if an undesirable result were to occur. For this analysis, it was assumed that the water levels dropped uniformly across all wells within its Near grouping. Four thresholds were examined for each representative monitoring well.

1. Total number of potential dewatered wells if MT is reached
2. Total number of potential dewatered wells if MT is exceeded by up to one (1) foot
3. Total number of potential dewatered wells if MT is exceeded by up to five (5) feet
4. Total number of potential dewatered wells if MT is exceeded by up to ten (10) feet

Table ~~5~~4 provides the results of the exercise described above, including the number of associated wells with each representative monitoring well. Maps showing each representative monitoring well and the associated potentially dewatered wells are provided in Attachment C. In addition Attachment C includes a tabular summary of all wells by grouping, potentially dewatered wells, and relevant characteristics for each well such as well use type and depth, as available.

Table 555554 Number of Potential Dewatered Wells if an MT is Reached or Exceeded

Representative Monitoring Well	No. Assoc. Wells	MT (ft bgs)	MT is Reached	Exceed by 1'	Exceed by 5'	Exceed by 10'
46N05E01P001M	101	24	1	1	1	1
48N04E22M001M	16	120	34*	43	6	6
48N04E19C001M	40	298	1	1	2	2
48N04E30F002M (TID Well 1)	3	79	0	0	0	0
47N05E04M001M		33	2*	2	3	5
47N05E01N001M	**42**	4236	2*	2	4	76
48N04E31M001M		29	1	1	1	1
41S12E19Q001W	9	39	34*	34	34	34
48N04E13K001M (TID Well 5)	15	90	0	0	0	0
46N05E21J001M	22	32	1	1	1	1
46N05E22D001M (TID Well 14)	6	54	0	0	0	0
48N05E35F001M	35	29	1	1	32	32
48N05E26D001M (TID Well 8)	25	74	0	0	0	0
TL-T1 Q3B	1	35	0	0	0	0
TL-T3 GP	5	16	0	0	0	0

**Refer to notes in Table 23 regarding wells used to determine MTs*

If undesirable results were to occur, they would likely be experienced by domestic wells users first as they tend to be shallower than irrigation wells, public water supply wells, industrial wells, and other/unknown wells. If groundwater levels were to decline below MTs then these domestic wells would potentially be dewatered, resulting in the need for deepening or replacement. As shown in the analysis above, the MTs are protective of domestic and water supply groundwater wells within the Tule Lake Subbasin. As described in Table 32, there are 54 irrigation wells and 2 domestic wells that are not protected by the MTs, as reflected in Table 54. However, the wells are no longer in use, not a primary water supply source, and/or may have gone dry during drought periods prior to SGMA, which led to those wells being excluded from the analysis.

In many cases if an MT is reached at any given representative monitoring well, then a single well could potentially be dewatered. As identified in Section 5.2.1.3 of the GSP the GSAs developed an undesirable result definition that includes both a number of measurements and a period of time. In regard to the number of measurements, as an exceedance at a single representative monitoring well could be a localized issue, the GSAs developed an undesirable result definition that MTs at four representative monitoring wells (i.e., 4 out of 15 13 or approximately 2631%) to exceed their MTs. As noted in Section 5.2.1.3 and Section 6.1.7 of the GSP, the GSAs plan to conduct additional monitoring at these wells, and in the event of an MT exceedance at a single representative monitoring well, the GSAs will meet to discuss if additional monitoring or action is necessary to hopefully prevent an issue from spreading. In an effort to prevent undesirable results from occurring, the GSAs developed the combination of the undesirable result definition and the plan for additional monitoring. In regard to the period of time to be considered, the undesirable result definition states that MTs need to be exceeded for three two consecutive spring fall measurements. to account for one to two year extreme hydrologic conditions that could result in outlier measurements.

Corrective Action B: Level of Impacts to Potential GDEs

Corrective Action B of DWR's letter also requested the GSAs to identify the level of impacts to potential Groundwater Dependent Ecosystems (GDEs) if undesirable results were to occur. As identified in Appendix H of the GSP, a total of 5.1 acres of potential GDEs have been identified within the Tule Lake Subbasin which covers a total area of 110,521 acres. This 5.1 acres is generally in five locations described below and shown on the maps in Attachment C.

1. Two potential areas of Greasewood totaling 1.5 acres located in the southwestern area of the Subbasin.
2. Two potential areas of Wet Meadows totaling 2.4 acres located in the eastern area of the Subbasin.
3. One potential area of Wet Meadows totaling 1.2 acres located in the southeastern area of the Subbasin.

As noted in Section 6.1.4 of the GSP, the GSAs have identified the potential GDEs as a data gap and plan to conduct a field inspection of these areas to better understand the vegetation present and confirm potential rooting depths. In addition, as noted in Section 6.1.3 of the GSP, the GSAs have identified the lack of monitoring wells as a data gap as additional monitoring could provide the GSAs a better understanding of water levels near the potential GDEs and confirm if the vegetation is able to access groundwater. Therefore, the GSAs through GSP implementation will attempt to gain a better understanding of these areas via field inspections and additional monitoring.

As noted in the GSP, the Tule Lake Subbasin is currently being sustainably managed. Projects and management actions like those noted above will promote better understanding of the Subbasin and allow for continued sustainability. If undesirable results were to occur, then up to 5.1 acres of potential GDEs may be impacted.

Attachments

Attachment A: January 18, 2024 letter from Department of Water Resources

Attachment B: Representative~~on~~ monitoring well hydrographs

Attachment C: Map~~s~~ showing potentially dewatered wells

Attachment D: Maps showing potential GDE locations

Attachment E: Updated Well Completion Report

Source
Department of Water Resources Well Completion Report Map Application. https://gis.water.ca.gov/app/wcr/ data accessed 9/23/2026



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Location of Potential Dewatered Wells if Minimum Threshold is Met

Appendix N

MBK ENGINEERS
Water Resources ◆ Flood Control ◆ Water Rights

TECHNICAL MEMORANDUM

DATE: September 3, 2026

PREPARED BY: Natalie Mendoza

REVIEWED BY: Kyle Knutson, P.E.

SUBJECT: Summary of Groundwater Contamination Sites in the Tule Lake Subbasin

Purpose

The Sustainability Groundwater Management Act (SGMA) regulations require that Groundwater Sustainability Plans (GSPs) identify locations of groundwater quality issues that may affect the supply and beneficial use of groundwater, including a description and map of the location of known groundwater contamination sites and plumes (CCR. Tit. 23, § 354.16 (d)). Locations of potential groundwater contamination sites within the Tule Lake Subbasin were identified by reviewing information available on the State Water Resource Control Board's (SWRCB's) GeoTracker website[1].

GeoTracker

GeoTracker is the SWRCB's data management system for contamination sites that impact, or have the potential to impact, water quality in California, with emphasis on groundwater. GeoTracker contains records for sites that require cleanup, such as Leaking Underground Storage Tank (LUST) Sites, Department of Defense Sites, and Cleanup Program Sites. GeoTracker also contains various unregulated projects as well as permitted facilities such as: Irrigated Lands, Oil and Gas production, operating Permitted Underground Storage Tanks (USTs), and Land Disposal Sites.

Evaluation of GeoTracker for Tulelake Subbasin

MBK Engineers (MBK) conducted a review of the GeoTracker website and identified thirteen sites within the Tule Lake Subbasin. Nine of these sites are identified on GeoTracker as "Closed" (GeoTracker Global ID: T0604900001, T0609300104, T0609300031, T10000000075, T0604900002, T0609300006, T0609391314, T0609300055, and T10000003883). Closure letters or other formal closure decision documents have been issued for these sites, indicating that no further actions are required. Therefore, these "Closed" sites will not be affected by groundwater management activities in the Subbasin. The remaining four sites within the Tule Lake Subbasin are summarized below.

Open Sites

The four open sites identified on the GeoTracker website within the Tule Lake Subbasin include three Cleanup Program Sites and one LUST Site. Cleanup Program Sites are "non-federally owned" sites that are regulated under SWRCB's Site Cleanup Program and/or similar programs conducted by each of the nine Regional Water Quality Control Boards (RWQCB). LUST Cleanup Sites include all UST sites that have

[1] https://geotracker.waterboards.ca.gov/

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had an unauthorized release of a hazardous substance and are being (or have been) cleaned up. The following summarizes the information available for each of the four open sites.

Cleanup Program Sites

The Basin Fertilizer Stronghold Plant Cleanup Program Site (Global ID: T10000013909) is classified as "Open – Site Assessment" as of January 9, 2020, with no cleanup actions reported and no contaminants or media of concern identified. The "Open – Site Assessment" status indicates that site characterization, investigation, risk evaluation, and/or development of the site conceptual model are currently in progress. The GSAs will continue to monitor GeoTracker for updates on this site.

The California, University, Ag Station Cleanup Program Site (Global ID: T0609393281) is classified as "Open – Inactive" as of February 7, 2011, with no cleanup actions reported and diesel identified as a potential contaminant of concern. The "Open – Inactive" status indicates that no regulatory oversight activities are being conducted by the Lead Agency. The GSAs will continue to monitor GeoTracker for updates on this site.

The Staub Oil Co. / Chevron Cleanup Program Site (Global ID: T0609300041) is classified as "Open – Assessment and Interim Remedial Action" as of January 2, 2017, with no cleanup actions reported, gasoline identified as the potential contaminant of concern, and a drinking water aquifer identified as a potential media of concern. The "Open – Assessment and Interim Remedial Action" status indicates that an "interim" remedial action is occurring at the site and additional activities, such as site characterization, investigation, risk evaluation, and/or development of the site conceptual model are currently in progress. The GSAs will continue to monitor GeoTracker for updates on this site.

LUST Cleanup Site

The Siskiyou County Public Works (D6) LUST Cleanup Site (Global ID: T0609300117) is classified as "Open – Remediation" as of June 25, 2014, with no cleanup actions reported, diesel identified as a potential contaminant of concern, and a drinking water aquifer identified as a potential media of concern. The "Open – Remediation" status indicates that an approved remedy or remedies has/have been selected for the impacted media at the site and the responsible party is implementing one or more remedy under an approved cleanup plan for the site. The GSAs will continue to monitor GeoTracker for updates on this site.

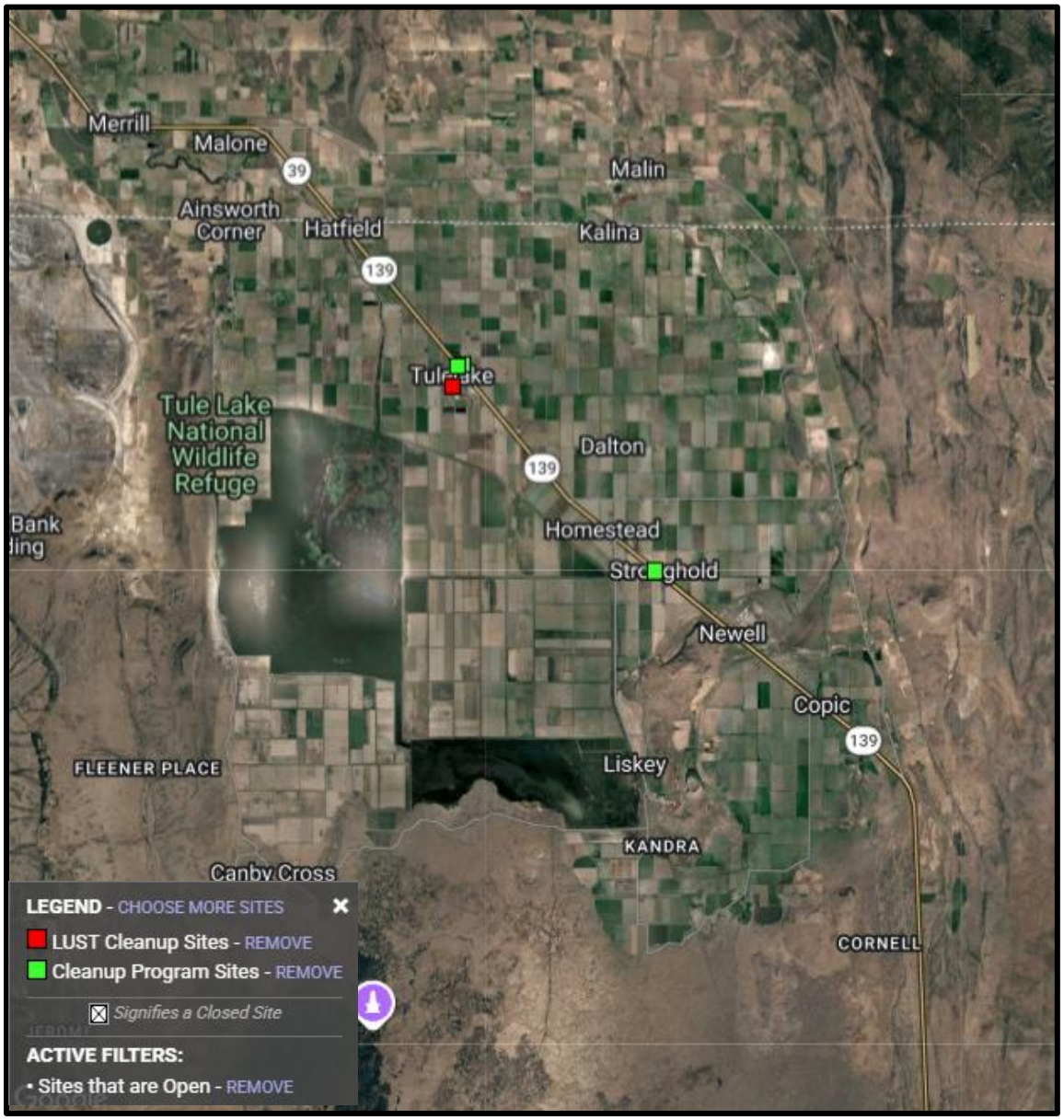

Figure 1 . GeoTracker - Open Sites, Tule Lake Subbasin

Table 1. GeoTracker – Open Sites, Tule Lake Subbasin

Site Name	Global ID	Site Type	Status	Address	City	Latitude	Longitude
Basin Fertilizer Stronghold Plant	T10000013909	Cleanup Program Site	Open - Site Assessment	45869 Highway 139	Tulelake	41.901990	-121.402220
California, University, Ag Station	T0609393281	Cleanup Program Site	Open - Inactive	Highway 139 / Havlina	Tulelake	41.958926	-121.473652
Staub Oil Co. / Chevron	T0609300041	Cleanup Program Site	Open - Assessment & Interim Remedial Action	Highway 139 @ Main St	Tulelake	41.958150	-121.475138
Siskiyou County Public Works (D6)	T0609300117	LUST Cleanup Site	Open - Remediation	647 Main Street	Tulelake	41.952629	-121.477160

Appendix O

MBK ENGINEERS
Water Resources ◆ Flood Control ◆ Water Rights

DRAFT TECHNICAL MEMORANDUM

DATE: September 30, 2026

PREPARED BY: Annali Flores

REVIEWED BY: Kyle Knutson, P.E.

SUBJECT: Preliminary Analysis of Interconnected Surface Waters in the Tule Lake Subbasin

Purpose

In a letter dated February 27, 2025, the Department of Water Resources (DWR) notified the Tule Lake Subbasin Groundwater Sustainability Agencies (GSAs) that the Groundwater Sustainability Plan (GSP) had been approved. The letter identified several recommended corrective actions, including actions related to the depletion of interconnected surface waters (ISW). DWR acknowledged that its ISW guidance was not yet complete, and this remains the case at the time of this memorandum. The GSAs will continue to review new guidance as it becomes available and incorporate relevant information into the GSP, as appropriate. To begin addressing these corrective actions, preliminary analyses using simulated data from the model developed in support of the GSP (GSP Model) and other available data are summarized below.

Preliminary Analysis

A preliminary analysis was conducted using data from the GSP Model, flow over the Anderson Rose Dam into the Lost River Improved Channel (LRIC) data, and groundwater level data from a groundwater well located near the LRIC. The purpose of this preliminary analysis was to attempt to identify when and where ISW reaches are located within the Subbasin, including an attempt to quantify the volume, location, and timing of depletions of ISW.

GSP Model Data

Review of projected water budget data from the GSP Model can assist with identifying potential indicators of volume, timing and location of ISW. This review includes a comparison of conditions at the Tule Lake Sumps and the LRIC, and total groundwater pumping for the projected water budget baseline conditions and the projected water budget with climate change incorporated. If the comparison shows an increase in pumping which coincides with a large discharge of water from a surface water feature, this may indicate potential depletions of ISW. Figure 1 below provides a summary of this comparison.

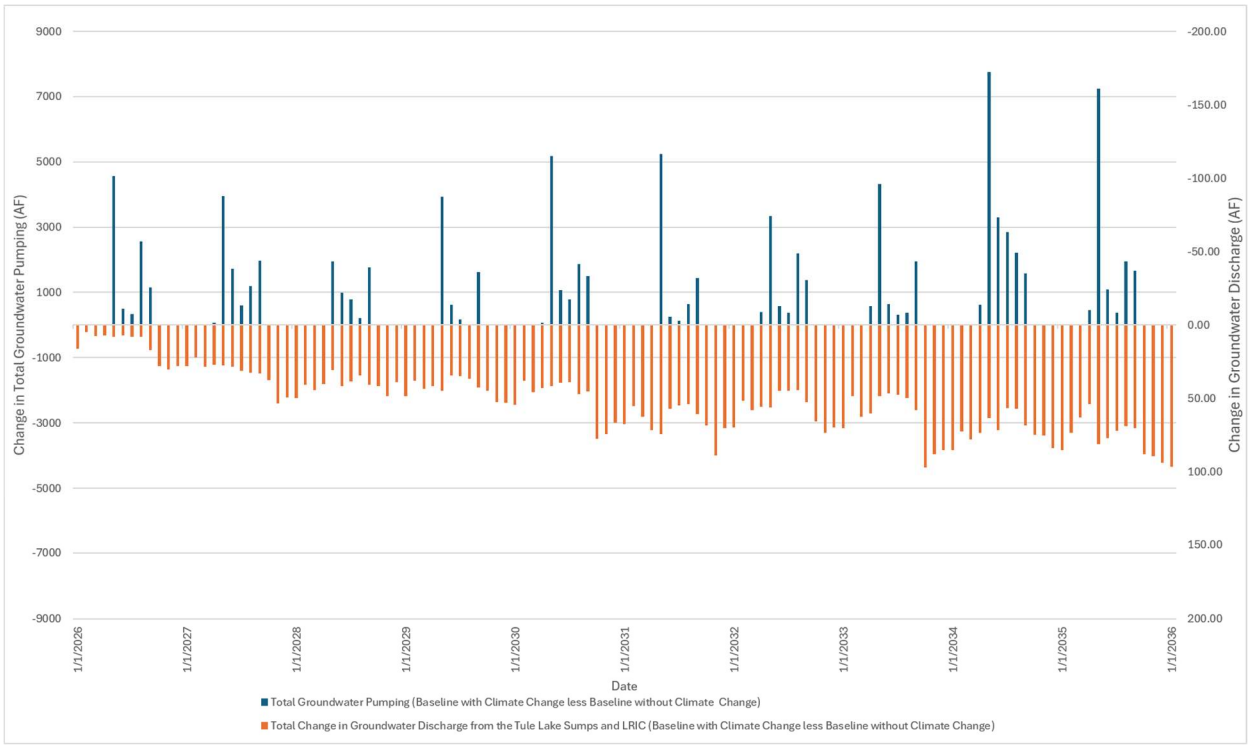

Figure 1. Change in Total Groundwater Pumping vs. Changes in Groundwater Discharge from the Tule Lake Sumps and Lost River Improved Channel for WY 2026 – 2036.

The comparison shown in Figure 1 may indicate a correlation between the timing of increased groundwater pumping and volume of depletions of surface water from the Tule Lake Sumps and the LRIC to groundwater. Within this ten-year period, seasonal patterns appear to exist, with changes in simulated surface water discharge following the end of the irrigation season during which groundwater pumping occurs.

Additionally, a comparison by each surface water feature was conducted to begin to identify potential locations of ISW.

Figure 2 below is the comparison of the change in groundwater discharge from the Tule Lake Sumps versus the change in total groundwater pumping. The change in discharge from the Tule Lake Sumps has a downward slope from about 2026 to 2036, then appears to be more consistent from about 2051 to 2071. Changes in total groundwater pumping do not appear to follow a similar pattern. Therefore, a correlation of ISW between changes in total groundwater pumping and total discharge from the Tule Lake Sumps does not appear to be present.

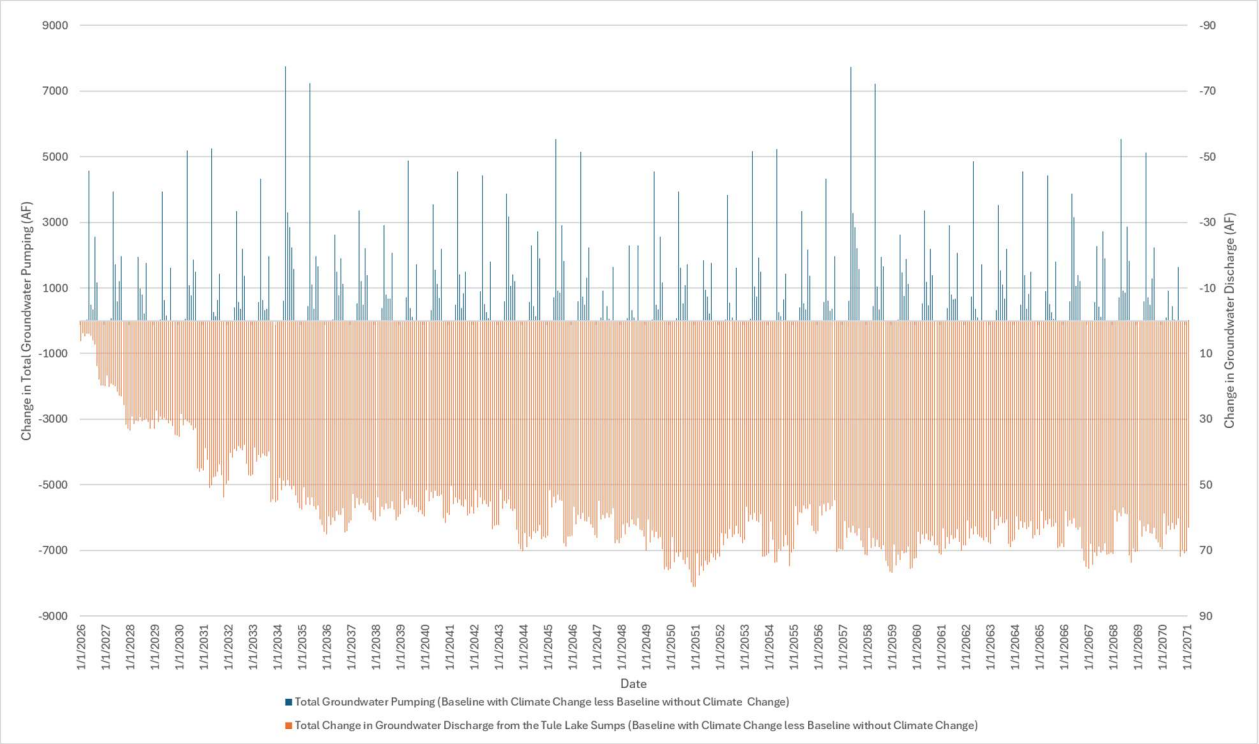

Figure 2. Change in Total Groundwater Pumping vs. Change in Groundwater Discharge from the Tule Lake Sumps for WY 2026 -2071.

As shown in Figure 3 below, a similar comparison for the LRIC was conducted. The annual cycle seems to follow a similar pattern observed in Figure 1, with increased discharge from the LRIC occurring near the end of the irrigation season; however, a pattern over the entire projected timeline does not appear to be present.

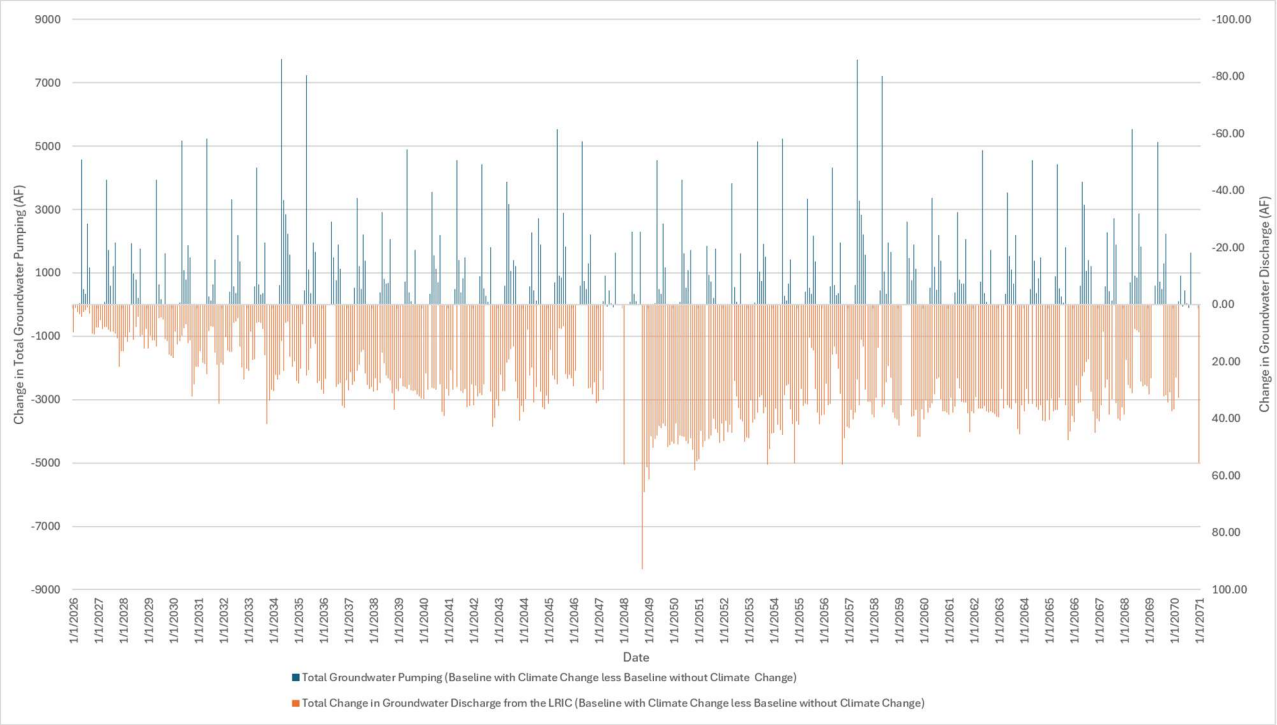

Figure 3. Change in Total Groundwater Pumping vs. Change in Groundwater Discharge from the LRIC for WY 2026 - 2071.

Flow Over the Anderson Rose Dam into the LRIC vs. Groundwater Level Data from 48N04E22M001M (Amy King)

Spill over the Anderson Rose Dam into the LRIC data was provided by Tulelake Irrigation District. Groundwater level data for 48N04E22M001M (also known as the Amy King well) was obtained from DWR's water data library[1]. A comparison of this data was conducted to observe if there was a potential hydraulic connection between surface water and groundwater at the location of the groundwater well. If groundwater levels in the well respond to LRIC flows, this could potentially indicate hydraulic connectivity from the LRIC to the groundwater system. Data for flow over Anderson Rose Dam was limited to the period of January 2019 through July 2026. Groundwater level data for 48N04E22M001M (Amy King) is available since 2001, but for the purposes of this comparison only data from January 2019 to January 2025 is provided. Figure 4 includes a comparison of groundwater level data (depth to groundwater) and flow over the Anderson Rose Dam into the LRIC.

[1] https://wdl.water.ca.gov/waterdatalibrary/

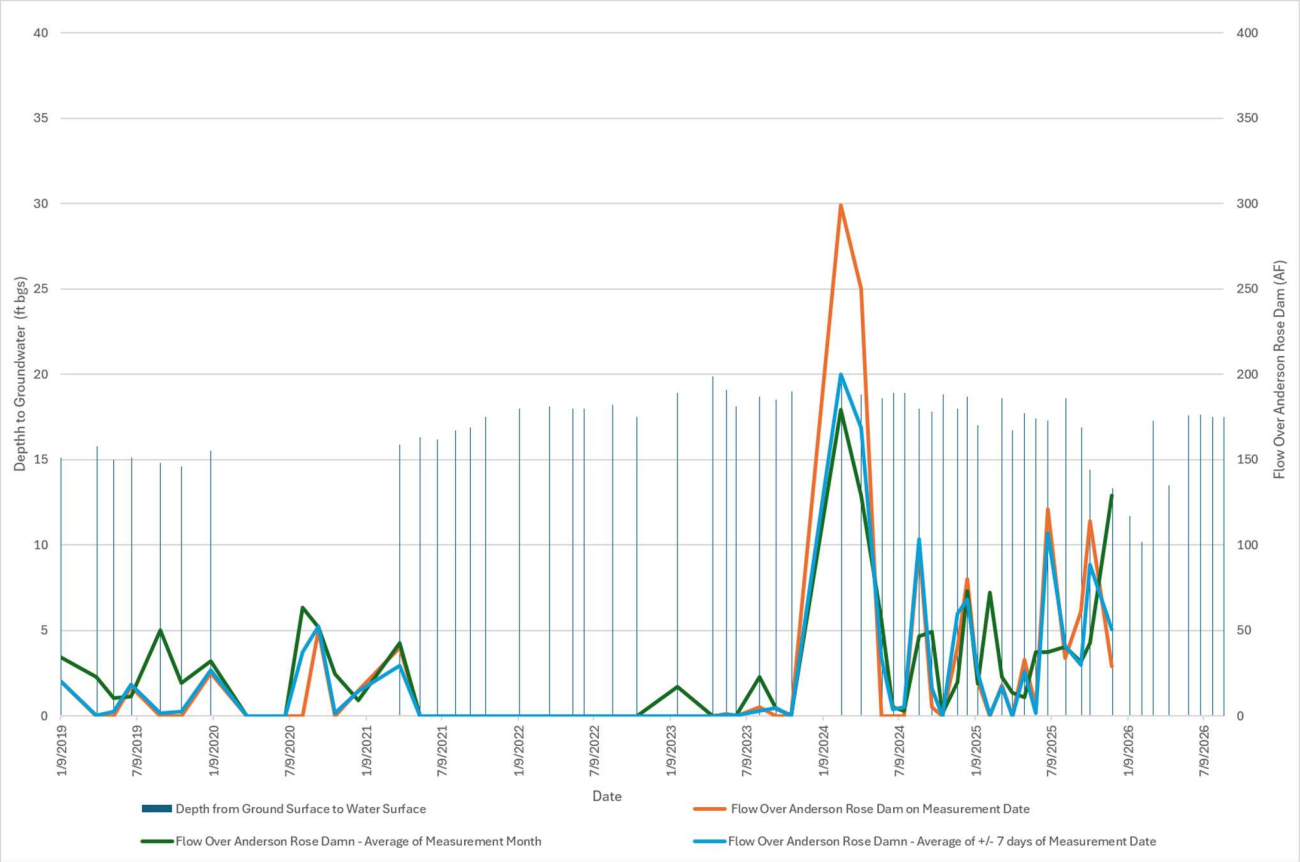

Figure 4. Flow Over the Anderson Rose Dam into the LRIC vs. Depth to Groundwater at 48N04E22M001M (Amy King).

The comparison shown in Figure 4 does not appear to show a correlation between LRIC flows and depth to groundwater at 48N04E22M001M (Amy King).

Summary

The GSP Model is a limited representation of a large and complex physical system. While it may have limitations it can be used to provide insight and qualitative projections of future conditions in the groundwater system it represents. When reviewing these data, seasonal patterns in simulated total groundwater pumping and groundwater discharge from the Tule Lake Sumps and LRIC appear to happen concurrently. However, the analyses do not establish a clear correlation between total groundwater pumping and depletions of ISW. After reviewing the data by each surface water feature, less correlation seems to be present, indicating that the overall patterns may be due to seasonal fluctuations or other model limitations.

Available monitoring data collected from the well nearest the LRIC is insufficient in frequency to determine whether a hydraulic connection exists between groundwater and surface water at that location. More frequent groundwater level data and LRIC water level stage may be helpful in future analyses. In addition, the GSAs will review DWR guidance, once available, to continue to attempt to gain a better understanding of ISW in the Tule Lake Subbasin.