Final Draft
Yolo Subbasin Groundwater Agency
2022 Groundwater Sustainability Plan
Yolo County, CA

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Yolo Subbasin Groundwater Agency – 34274 State Highway 16, Woodland CA 95695

FINAL DRAFT

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Yolo County, CA

Submitted to:
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January 2022

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Preface

In September 2014, the Sustainable Groundwater Management Act (SGMA) was signed into law to provide for the local control of groundwater while requiring proof of sustainable management of the groundwater resource. In June 2017, the Yolo Subbasin Groundwater Agency (YSGA) was formed to serve as the Groundwater Sustainability Agency for the Yolo Subbasin and to develop, adopt, and implement a Groundwater Sustainability Plan (GSP). The primary purpose of the Yolo Subbasin GSP is to comply with SGMA. The Yolo Subbasin GSP documents monitoring conditions, establishes management criteria to avoid undesirable results, and identifies potential actions that will maintain and achieve sustainable groundwater management by 2042.

Since 2017, the YSGA has been engaged in efforts to develop the Yolo Subbasin GSP; however, sincere public outreach and planning activities started in September 2019, with a focused review of empirical data and technical analyses to define sustainable management criteria starting in early 2020. Public outreach and engagement were a critical component of developing the Yolo Subbasin GSP; unfortunately, plan development coincided with the COVID-19 pandemic and in-person workshops and meeting opportunities were limited. YSGA Directors and staff hosted virtual workshops for stakeholders and participated in numerous public meetings to discuss the formation of the YSGA and GSP development and implementation. YSGA staff plan to resume in-person engagement opportunities, in compliance with County guidelines, as soon as possible. Public outreach and engagement efforts will continue throughout GSP implementation to achieve a responsive, adaptive management process.

In addition to the COVID-19 pandemic, another challenge was introducing a plan for sustainable groundwater resources during a historic drought year when the Subbasin was impacted by declining groundwater levels. For Northern California, the previous water year (Water Year 2020-21: October 1, 2020 – September 30, 2021) was the third driest year on record, and it is likely that Water Year 2021-22 will be a third consecutive dry year. In April 2021, Governor Newsom issued a drought emergency in certain counties impacted by the dry conditions, and in October 2021, the Governor extended the drought emergency statewide. Additionally, in response to the ongoing drought conditions and associated water supply shortages in the Sacramento – San Joaquin Delta watershed, the State Water Board adopted emergency regulation on August 3, 2021 authorizing the curtailment of the majority of surface water diversions in the Yolo Subbasin, and thereby increasing the reliance on groundwater.

Water resource managers have historically practiced conjunctive use management in the Yolo Subbasin – relying on surface water supplies in wet years and groundwater supplies in dry years. Groundwater resources are considered reserves for dry years; however, responsive short-term and long-term management is necessary to mitigate impacts and ensure overdraft does not occur. Because the development of this plan overlapped with a significant drought period, public feedback identified the lack of 2021 hydrologic conditions and short-term drought mitigation management actions within the plan. The first 5-year update to the Yolo Subbasin GSP will include 2021 groundwater elevation data and updated surface water supply scenarios based on Water Year 2021-

22. Annual reports submitted to the Department of Water Resources will include groundwater elevation and quality data from 2019 to 2021.

In response to public feedback, the YSGA formed an ad hoc Drought Contingency Planning Committee in October 2021. The Committee will advise the Board of Directors on 1) local planning strategies; 2) appropriate management actions for drought conditions; and 3) coordination with Yolo County Supervisors for management of groundwater resources during drought. Additionally, the Committee intends to identify available resources to mitigate drought impacts, implement sustainability projects, and investigate whether demand management strategies are necessary. As of December 2021, the Committee has had two meetings and is currently focusing on developing a joint Yolo County/YSGA Groundwater Communications Plan to provide clarity on the authority and purpose of the YSGA and Yolo County in groundwater resources management. Additionally, the Committee is working closely with County staff to improve the well permitting data collection process to better understand the true spatial impacts of the 2021 drought on hydrogeologic conditions, and declining groundwater levels.

Water resource managers in Yolo County have been monitoring groundwater elevations since the 1950's, although, the most robust data collection began in the 1970's; for this reason, the Yolo Subbasin GSP is based on physical groundwater data for 1971-2018. In addition to the collection of observed data, the Yolo Subbasin GSP includes a water budget to quantify all inflows and outflows for the Subbasin at a spatial and temporal resolution that balances data and resource availability with the overall goals of the water budget. Surface water and groundwater budgets were created for the historical, current, and future scenarios. In the Yolo Subbasin, groundwater storage changes are positive in wet years and negative in dry years, with no significant declining trend over the past 50 years.

The Yolo Subbasin GSP includes future projections based on various climate change model simulations to estimate the potential impacts of climate changes to groundwater resources. An important element of the future projections are land use changes. Recently, in the Yolo Subbasin, there has been an increase in total irrigated acres and total perennial acres. This type of land use change can result in an increase and 'hardening' of irrigation demand. Unfortunately, due to budget and time constraints, the future model simulations for the Yolo Subbasin GSP did not include land use change forecasts but held the 2016 land use patterns constant into the future. It is important that we invest in future scenario simulations to consider the impact to the overall water budget given the continued land use changes, increases in agricultural development, and new demand on groundwater. We intend to conduct this analysis during the implementation of the GSP and to incorporate the results in the first 5-year update to the Yolo Subbasin GSP.

YSGA staff have started to monitor and track the fringe areas (primarily along the western edge of the Subbasin where the hilly rangeland begins) where an increase in new agricultural production and groundwater demand has been observed. YSGA staff are working to expand our network in "Areas of Special Concern" – the YSGA is currently focusing on and prioritizing the fringe areas surrounding the town of Winters and Hungry Hollow area. Additionally, the YSGA is currently investigating the potential for implementing a demand management program that would incentivize voluntary water conservation. Historical conjunctive management of the Subbasin has been sustainable; however, given the current uncertainty of a prolonged drought period and increasing water demand, it is important to consider whether temporary or long-term demand management strategies are necessary. Demand management strategies such as an allocation system, a financial incentive program, and/or a groundwater market program may be evaluated to reduce consumptive use of water within a specific area (such as an Area of Special Concern) or at the basin-wide scale. As part of considering whether demand management strategies are an appropriate management action for the Yolo Subbasin, the YSGA will conduct a cost-benefit analysis to better understand both the long-term and short-term impacts to the County economy and to all beneficial users of groundwater.

This GSP includes a list of existing and ongoing projects and management actions that can contribute to sustainability in the Yolo Subbasin. Enhancing the Yolo Subbasin groundwater monitoring network is important to effectively track and mitigate the potential impacts of increased pumping during dry years and to ensure long-term sustainability throughout the entire Yolo Subbasin. New monitoring wells are planned in the fringe areas of the Subbasin (on the westside of the County along the Coast Range, along the Dunnigan Hills, and around the Plainfield Ridge) to provide the YSGA with baseline data to observe and monitor the impacts of expanding development and increased groundwater demand. Additionally, the immediate focus of the YSGA will be on implementing groundwater recharge projects to ensure the groundwater table can recover from the 2021 drought. Pilot projects that can showcase the benefits of regenerative agriculture, such as cover cropping and rebuilding soil organic matter to reduce runoff and increase infiltration of precipitation to groundwater, will be encouraged for immediate implementation. Additionally, the YSGA intends to promote strategies for water conservation and to optimize infiltration and retention of rainfall during storm events. The annual reporting process will provide an opportunity to evaluate and incorporate additional projects that are not included in the first version of the GSP.

YSGA's implementation of the GSP will begin in 2022 after adoption and official submission of the plan to the Department of Water Resources. The YSGA intends to form Advisory Committees for each Management Area to construct a framework for on-the-ground implementation of the plan. These Advisory Committees will provide a forum for collaboration of YSGA members and stakeholders to facilitate an adaptive response to local issues and to develop the roadmap for successful plan implementation. The Advisory Committees will provide a timely response to minimum threshold exceedances or other identified concerns and prioritize local implementation of projects and management actions. Advisory Committees will be comprised of an equal representation of stakeholders, including agricultural, urban, and environmental representatives. These local committees will provide an opportunity for information sharing, innovation, and the collaborative development of adaptive management practices. Updates from the Management Area Advisory Committees, progress of project implementation, and other YSGA activities will be posted regularly on the YSGA website and will be published in an annual newsletter.

This is just the beginning of ensuring sustainable management of groundwater resources in the Yolo Subbasin. The GSP is considered a living document that will be adaptively managed as we continue to use the best available science and tools to complete ground surveys and access credible and sufficient data for making effective decisions. The YSGA and the stakeholders in the Subbasin are committed to an open, transparent, and all-inclusive process to resolve important local issues related to groundwater. This is an exciting opportunity to work together in preserving this valuable community resource and ensuring the well-being of Yolo County.

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Abbreviations and Acronyms

AB	Assembly Bill
ACE	CDFW's Areas of Conservation Emphasis
AEM	Airborne electromagnetic
AFY	acre-feet per year
bfw	base of freshwater
bgs	below ground surface
BMP	Best Management Practice
CASGEM	California Statewide Groundwater Elevation Monitoring
CCR	California Code of Regulations
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
Coalition	Sacramento Valley Water Quality Coalition
COCs	constituents of concern
County	Yolo County
CSD	Community Services District
CVRWQCB	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley-Salinity Alternatives for Long-Term Sustainability
CWC	California Water Code
DAC	Disadvantaged Community
DDW	Division of Drinking Water
DEM	Digital Elevation Model
DPR	Department of Pesticide Regulations
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
EC	Electrical Conductivity
ESA	European Space Agency
Ft	feet
GAMA	Groundwater Ambient Monitoring and Assessment Program
GAR	Groundwater Quality Assessment Report
GDE	Groundwater Dependent Ecosystem

gpm	gallons per minute
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
HSG	NRCS Hydrologic Soils Group
HUC 12s	USGS' 12-digit Hydrologic Unit Code polygons
iGDE	Indicators of Groundwater Dependent Ecosystem
IGSM	Integrated Groundwater Surface-Water Model
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic-Aperture Radar
IRWM	Integrated Regional Water Management
IWFM	Integrated Water Flow Model
JPA	Joint Powers Agreement
LUST	Leaking Underground Storage Tank
MA	management areas
MAF	million acre-feet
MCL	maximum contaminant level
MODFLOW	USGS modular finite-difference flow model
MOU	memoranda of understandings
msl	mean sea level
mybp	million years before present
NCWA	Northern California Water Association
NCCAG	Natural Communities Commonly Associated with Groundwater
NDMI	Normalized Difference Moisture Index
NDVI	Normalized Difference Vegetation Index
NRCS	Natural Resources Conservation Service
NTNC	Non-Transient Non-Community water systems
NWIS	USGS National Water Information System
Plan	Groundwater Sustainability Plan
ppb	parts-per-billion
ppm	parts per million
RD	Reclamation District
Ridge	Plainfield Ridge

RMC	RMC Water and Environment 2016, formerly Water Resources Information Management Engineering, Inc
RMW	representative monitoring wells
RP	Reference Point
SAGBI	Soil Agricultural Groundwater Banking Index
SCWA	Solano County Water Agency
SDWIS	State Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SMC	sustainable management criteria
SNMP	Salt and Nitrate Management Plan
SSURGO	Soil Survey Geographic Database
State Water Board	State Water Resources Control Board
Subbasin	Yolo Subbasin
SWN	State Well Number
TAC	Technical Advisory Committee
TAF	thousand acre-feet
TDS	total dissolved solids
TNC	Transient Non-Community water systems
UC Davis	University of California, Davis
ug/L	micrograms per liter
UNAVCO	University NAVSTAR Consortium
USGS	U.S. Geological Survey.
UST	underground storage tank
UWMP	Urban Water Management Plan
WCR	Well Completion Report
WDR	Waste Discharge Requirements
WEAP	Water Evaluation and Planning
WPCF	Water Pollution Control Facility
WRA	Water Resources Association
WRID	Water Resources Information Database
WRIME	Water Resources and Information Management Engineering, Inc.
WY	water year
YCEH	Yolo County's Department of Community Services Environmental Health Division

YCFC&WCD	Yolo County Flood Control and Water Conservation District
YCIGSM	Yolo County Integrated Groundwater and Surface Water Model
YDWN	Yocha Dehe Wintun Nation
YSGA	Yolo Subbasin Groundwater Agency

Executive Summary

ES 1.0 Introduction

On September 16, 2014, Governor Jerry Brown signed into law a three-bill legislative package, composed of AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act (SGMA). This legislation provides for the local control of groundwater while requiring the sustainable management of the groundwater resource. One of the first requirements under SGMA was to establish a local governance body, a Groundwater Sustainability Agency (GSA), with the local authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP or Plan). Further, under SGMA law, groundwater basins throughout California were classified as "high", "medium" or "low" priority by California Department of Water Resources (DWR). The Yolo Subbasin is classified as a "high" priority basin, which requires the Subbasin to prepare, adopt, and submit a GSP by January 31, 2022.

GSPs must document conditions and establish management criteria to avoid undesirable results and identify potential actions that will maintain and/or achieve sustainable groundwater management by 2042, or 20 years from the date of the adoption of the GSP. Through a Joint Powers Agreement (JPA), the Yolo Subbasin Groundwater Agency (YSGA) is the recognized GSA for the entire Yolo Subbasin (**Figure ES-1**) and responsible for developing and implementing a GSP.

The YSGA JPA was officially executed on June 19, 2017 by 19 member agencies and five affiliated parties via memoranda of understandings (MOU). Since the YSGA was formed, three additional member agencies have signed onto the JPA; three other member agencies consolidated into one; and one affiliated party has entered into an MOU with the JPA, which has resulted in 20 member agencies and six affiliated parties for a total of 26 YSGA members (**Figure ES-2**). The YSGA covers approximately 540,700 acres, spanning nearly 845 square miles. **Table ES-1** lists each member agency involved in the development of this GSP.

ES 2.0 Plan Area Description

The Yolo Subbasin (Subbasin) is located in the southwestern side of the Sacramento Valley Groundwater Basin and is about 27 miles wide from west to east and up to 45 miles long from north to south (**Figure ES-1**). The current Subbasin boundaries are the result of the consolidation of portions of the Capay Valley, Colusa, and Solano subbasins *via* two applications for jurisdictional modifications of the Subbasin's boundary. Land use designations within the YSGA jurisdictional boundary are predominately agriculture and native vegetation, accounting for approximately 60 and 31 percent, respectively. Approximately 6 percent of the Subbasin contains managed wetlands, which provide migratory bird habitat and other ecosystem services. Source of water for agricultural lands is a combination of surface water and groundwater. Urban and incorporated land use areas are scattered throughout the Subbasin and account for approximately 5 percent of the Subbasin.

Table ES-1. Yolo Subbasin Groundwater Agency Members.

Member Agencies	
City of Davis	Reclamation District 307
City of Woodland	Reclamation District 537
City of West Sacramento	Reclamation District 730
City of Winters	Reclamation District 765
County of Yolo	Reclamation District 787
Dunnigan Water District	Reclamation District 999
Esparto Community Service District	Reclamation District 1600
Madison Community Service District	Reclamation District 2035
Reclamation District 108	Yocha Dehe Wintun Nation
Reclamation District 150	Yolo County Flood Control & Water Conservation District
Affiliated Parties	
California American Water Company, Dunnigan	University of California, Davis
Colusa Drain Mutual Water Company	Environmental Representative
Private Pumper Representative – Yolo County Farm Bureau appointed	Rumsey Water Users Association

Figure ES-3 provides an overview of the disadvantaged communities within the Subbasin designated by DWR. Three census-designated places within the Yolo Subbasin are identified as disadvantaged communities. These include the town of Dunnigan (disadvantaged), Knights Landing (severely disadvantaged), and the main campus of University of California, Davis (severely disadvantaged). Dunnigan is an unincorporated town with a population of 1,278. Domestic water to the community is provided by California American Water and by domestic wells. The town of Knights Landing is served by Knights Landing Community Services District (CSD). Knights Landing CSD relies entirely on groundwater to serve its 869 residents. The area within the University of California, Davis (UC Davis) campus is populated by 7,379 residents. The campus uses a mix of groundwater and surface water for its water supply. California American Water and UC Davis are member agencies of the YSGA with voting seats on the Board, and at the time of formation, the Knights Landing CSD was not interested in participating as a YSGA member.

Yocha Dehe Wintun Nation (YDWN) owns and/or manages approximately 5,000 acres within the Capay Valley MA, including trust land held by the federal government and fee land owned by the Tribe. While YDWN federal trust lands are shown in **Figure ES-2**, the entirety of Capay Valley is within the Tribe's ancestral territory. Their water demand is supplied from a combination of surface water from Cache Creek and groundwater pumping.

Section 2.0 – Basin Setting, provides an extensive overview of the physical features and water resources conditions of the Yolo Subbasin. Included in Section 2.0 of the GSP is the following information.

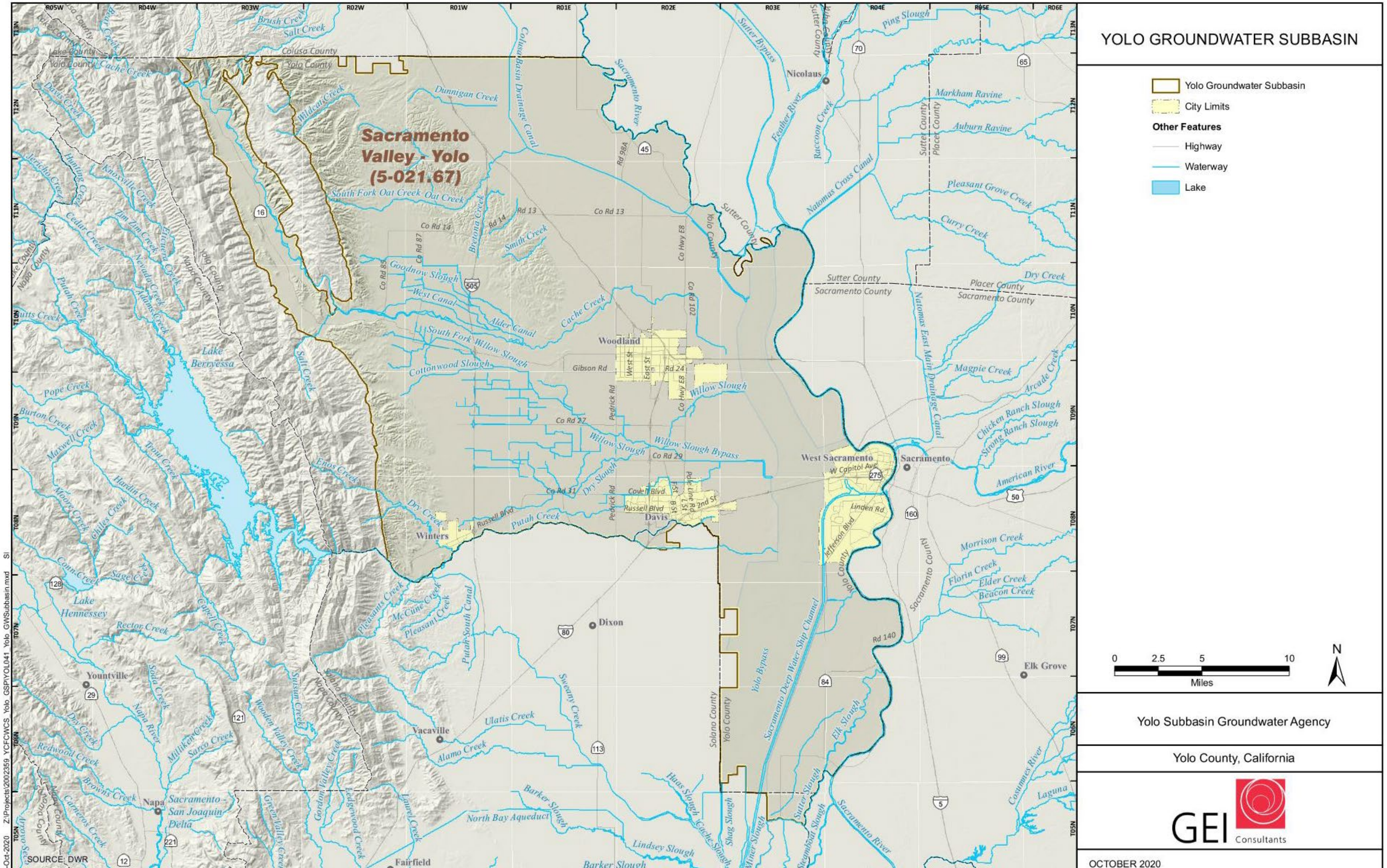

Figure ES-1.Yolo Subbasin.

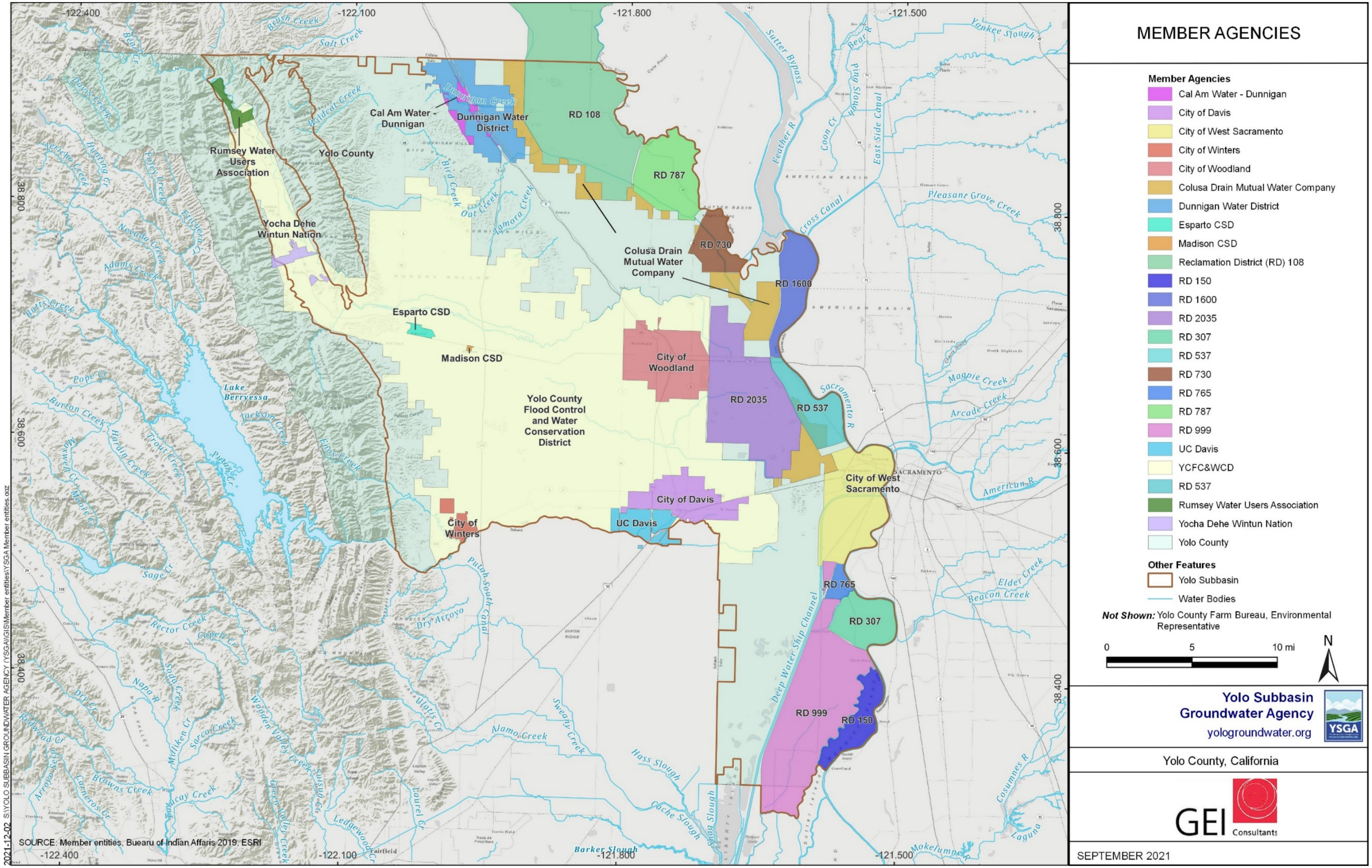

Figure ES-2.Yolo Subbasin Groundwater Agency Member Agencies.

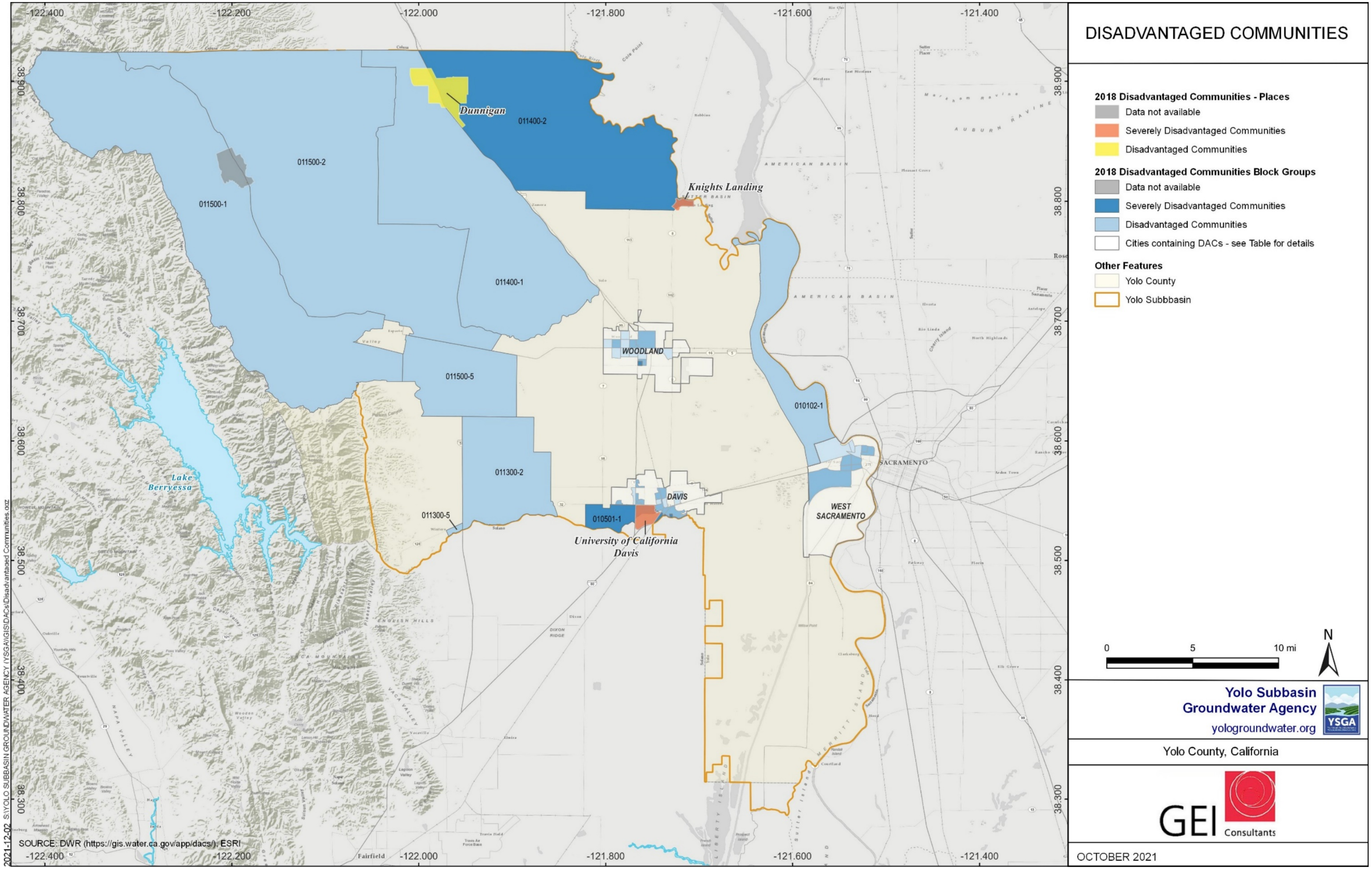

Figure ES-3. **Disadvantaged Communities.**

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Section 2.1 – Hydrological Conceptual Model contains detailed descriptions of the physical features of the groundwater basin, identifying principal aquifers, sources and areas of recharge, along with a description of water bodies and sources of local and imported surface waters.

Section 2.2 – Groundwater Conditions provides a description of conditions related to the six sustainability indicators: groundwater levels, groundwater storage, seawater intrusion, groundwater quality, land subsidence; and interconnected surface waters. This section also includes a description of groundwater dependent ecosystems.

Section 2.3 – Water Budget Information provides an overview of the Subbasin's water budget as evaluated through an extensive groundwater modeling exercise that considered current and future conditions with DWR-provided climate change conditions.

Section 2.4 – Management Areas describes the six management areas (MAs) that have been established in the Subbasin for management of the SGMA sustainability indicators. Each management area is unique in either its level of groundwater use, land uses, overlying jurisdictions, or access to surface waters. In some cases, these differences require a unique approach to groundwater management. In the Clarksburg management area, for example, there is very little groundwater use and an abundance of available surface water supplies, for the mostly rural landscape. In contrast, the Central and North Yolo management areas consist of a well-developed agricultural and municipal landscape with a heavy reliance on groundwater. These, and the remaining management areas, require different approaches to groundwater management that are driven by local stakeholders and at the same time integrated with the Subbasin as a whole.

As described in **Section 2.0 – Basin Setting** of the GSP, the ***Yolo Subbasin is a relatively stable basin, with groundwater levels maintaining a relatively consistent long-term average elevation or depth to groundwater.*** While groundwater levels decline during dry conditions due to reduced recharge from precipitation, local runoff, and seepage, and continued reliance on groundwater for agricultural and municipal demands, groundwater levels substantially recover during wet years.

ES 3.0 Sustainable Management Criteria

Under SGMA, the sustainable management criteria (SMC) define conditions for sustainable groundwater management that will be used to guide sustainability in the Yolo Subbasin. SMC includes characterization of the sustainability goal for the Subbasin and the establishment of undesirable results, minimum thresholds, measurable objectives and interim milestones for applicable Subbasin sustainability indicators. The SMC concepts are outlined below and provide a basis of understanding for the development of sustainable groundwater management in the Subbasin.

- **Sustainability Goal:** The sustainability goal guides sustainable groundwater management across all MAs in the Subbasin by providing qualitative descriptions of the objectives and desired conditions.
- **Undesirable Results:** Undesirable results are established for each applicable sustainability indicator and constitute as significant and unreasonable groundwater conditions in the Subbasin.
- **Minimum Thresholds:** Minimum thresholds are the quantitative values that represent groundwater conditions at a representative monitoring site that, when exceeded, in combination with exceeded minimum thresholds at other representative monitoring sites, may cause an undesirable result in the subbasin. Minimum thresholds are set for each applicable sustainability indicator at each representative monitoring site using the same metrics as the measurable objectives. This section defines the minimum thresholds at each representative monitoring site for applicable sustainability indicators considering interests of beneficial uses and users of groundwater in the Subbasin.
- **Measurable Objectives:** Measurable objectives are quantitative goals that reflect the Subbasins' desired groundwater conditions and allows the MAs within the Yolo Subbasin to be managed sustainably through the 20-year Implementation Period. In the Subbasin, the quantitative goals expressed as the measurable objectives are currently met and are intended to continue to be met. Measurable objectives are set for each applicable sustainability indicator. Measurable objectives are set such that there is a reasonable margin of operational flexibility that will anticipate recoverable fluctuations due to droughts, climate change, conjunctive use operations, or other groundwater management activities.
- **Interim Milestones:** Interim milestones are target values representing measurable groundwater conditions, in increments of 5 years, set to ensure that the Subbasin moves towards its sustainability goal over the 20-year Implementation Period. As the Subbasin is already meeting its sustainability goal, the interim milestones are set at the measurable objective for the applicable sustainability indicators.

  In the Yolo Subbasin, interim milestones are set equal to measurable objectives for all sustainability indicators for which minimum thresholds and measurable objectives have been set. As described in this plan, the YSGA is establishing SMCs to be equal to recent historical conditions. Therefore, provided a normal range of hydrology, the groundwater basin is expected to maintain its historical regime and from the outset of the plan is expected to operate within a reasonable range of established measurable objectives.
- **Undesirable Results Watch Area:** An undesirable result watch area is a MA which has triggered the exceedance criteria for an undesirable result for a given sustainability indicator, but where the number of MAs exceeding the criteria has not been reached. An undesirable result watch area triggers responses from the YSGA and its member agencies to address the local exceedance of minimum threshold values to avoid triggering the criteria for a basin-wide undesirable result.

ES 3.1 Sustainability Goal

As required by SGMA, a sustainability goal is to be defined for the basin (CWC §10727(a)). This is further clarified as a basin-wide goal in DWR's GSP emergency regulations. The sustainability goals for the Yolo Subbasin are as follows:

- *Achieve sustainable groundwater management in the Yolo Subbasin by maintaining or enhancing groundwater quantity and quality through the implementation of projects and management actions to support beneficial uses and users.*
- *Maintain surface water flows and quality to support conjunctive use programs in the Subbasin that promote increased groundwater levels and improved water quality.*
- *Operate within the established sustainable management criteria and maintain sustainable groundwater use through continued implementation of a monitoring and reporting program.*
- *Maintain sustainable operations to maintain sustainability over the implementation and planning horizon.*

ES 3.2 Chronic Lowering of Groundwater Levels

The basin-wide definition of "undesirable results" for the chronic lowering of groundwater levels is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth or elevation of ground water, affect the reasonable beneficial use of, and access to, groundwater by overlying users.*
>
> *An undesirable result occurs when the minimum threshold criteria is exceeded in **51 percent or more** of representative monitoring wells in **two (2) MAs**.*

The 51 percent value was established to allow for interim projects and management actions to take place within the Subbasin to mitigate negative groundwater trends. This value was selected and agreed to by the YSGA member entities and the YSGA Board.

Minimum thresholds for the chronic lowering of groundwater levels were established through a collaborative process with local stakeholders and interested parties. ***While groundwater levels decline during dry conditions due to reduced groundwater recharge from lower amounts of precipitation and local runoff, groundwater levels substantially recover during wet years.*** Based on historic, current, and projected groundwater conditions in the Subbasin, the YSGA developed several methodologies for establishing the minimum threshold value for each representative monitoring well, based on management area boundaries. The resulting minimum thresholds for each management area is described below and shown in **Table ES-2**.

Capay Valley, Dunnigan Hills, Central Yolo, and South Yolo:

> *A well violates the minimum threshold when the groundwater elevation exceeds the historic (pre-2016) minimum elevation in the period of record of each Representative Well in two consecutive fall measurements.*

North Yolo:

> *A well violates the minimum threshold when the groundwater elevation exceeds the historic minimum elevation in the period of record (pre-2016) of each Representative Well* **plus** *20 percent of the depth between the historic maximum and historic minimum elevation for the period of record (pre-2016) of the Representative Well in two consecutive fall measurements.*

Clarksburg:

No minimum threshold has been established for the Clarksburg MA due to the lack of groundwater usage in the MA. The YSGA will annually monitor groundwater conditions in the Clarksburg MA to determine if groundwater conditions or usage changes to the degree that minimum thresholds are required to ensure sustainable management of this portion of the Subbasin.

To establish the measurable objectives for the Yolo Subbasin, the YSGA utilized the representative wells identified for minimum thresholds, shown in **Table ES-2** and **Figure ES-4**, to determine the measurable objectives for chronic lowering of groundwater levels. Based on historic, current, and projected groundwater conditions in the Subbasin, the following criteria were used to establishing measurable objectives at all MAs, with the exception of the Clarksburg MA:

> *Measurable objective is equal to the average fall (Sep.-Dec.) groundwater elevation for the water year period of 2000 to 2011 at each Representative Well. Performance of the measurable objective will be measured as the five (5) year running average of the minimum fall (Sep.-Dec.) groundwater elevation.*

Table ES-2. Yolo Subbasin Representative Wells and Minimum Threshold and Measurable Objective Values.

Management Area	YSGA Representative Well Number	State Well Number	Measurable Objective (ft)		Minimum Threshold (ft)	
			Depth to Water	*Groundwater elevation*	*Depth to Water*	*Groundwater elevation*
Capay Valley	276	10N02W16R001M	14.4	215.0	21.9	207.7
	277	10N02W18F001M	20.4	315.6	31.8	304.2
	280	10N03W02R002M	18.7	319.5	29.9	308.2
	285	11N03W09Q001M	20.4	383.7	48.3	355.8
	287	11N03W23L001M	15.2	296.0	23.6	287.6
	288	11N03W23N001M	32.9	287.3	49.1	271.0
	289	11N03W33F001M	19.8	351.2	29.6	341.2
	293	12N03W20D001M	19.8	382.8	26.2	376.4
	415	11N03W35D003M	28.6	280.7	36.3	273.0
	416	10N03W24B002M	65.4	324.8	109.1	281.1
Central Yolo	114	08N02E15A002M	71.5	-25.1	107.7	-61.3
	132	08N03E07N500M	58.3	-22.0	114.3	-78.0
	151	09N03E33B002M	16.2	4.7	56.1	-35.3
	170	08N02E18M002M	48.1	20.4	67.0	1.5
	220	08N01E07R001M	25.3	82.3	91.0	16.5

Management Area	YSGA Representative Well Number	State Well Number	Measurable Objective (ft)		Minimum Threshold (ft)	
			Depth to Water	*Groundwater elevation*	*Depth to Water*	*Groundwater elevation*
	222	08N01W09C001M	57.3	110.9	127.9	40.3
	224	08N01W13G003M	37.7	80.0	69.9	47.8
	229	08N01W20R005M	79.8	72.8	116.2	36.4
	230	09N01E03C003M	81.7	19.3	157.4	-56.4
	231	09N01E07D001M	13.4	111.1	56.2	68.3
	233	09N01E20E001M	10.0	104.8	47.7	67.1
	234	09N01E24D001M	17.2	52.2	61.7	7.6
	235	09N01E31D001M	13.4	104.6	49.8	68.3
	239	09N01W08Q001M	13.8	185.1	46.7	152.2
	240	09N01W21E001M	11.9	163.4	30.5	144.7
	246	09N02E07L001M	46.1	24.7	116.2	-45.4
	248	09N02E32M001M	31.9	29.1	68.0	-7.0
	250	09N03E19R002M	17.6	6.7	38.3	-14.1
	254	10N01E23Q002M	65.0	26.8	134.8	-43.0
	256	10N01E29K001M	34.9	77.8	54.4	58.4
	261	10N01W08B001M	41.3	139.5	107.6	73.3
	265	10N01W21J001M	33.8	127.5	70.4	90.9
	268	10N01W32E001M	18.9	169.9	44.3	144.5
	269	10N01W35Q001M	20.8	120.5	48.4	93.0
	275	10N02W14A001M	69.9	137.8	116.5	91.1
	279	10N02W26P001M	112.6	241.7	141.7	212.7
	406	10N02E29A001M	21.5	35.7	47.4	9.9
	400	09N02E22H002M	16.1	22.9	63.8	-24.8
	401	10N02E36E001M	8.1	22.1	21.2	9.0
	403	09N01E26N001M	8.4	71.7	48.0	32.2
	404	09N01W23D001M	10.5	135.8	63.4	82.9
	419	08N01W22G500M	59.6	71.9	125	6.5
North Yolo	127	11N01E02D001M	41.5	-13.3	116.5	-88.3
	128	11N01E16P001M	88.6	-33.1	185.3	-129.8
	129	12N01E03R002M	23.2	9.1	76.6	-44.3
	131	12N01E26A002M	30.1	-4.2	72.0	-46.1
	153	10N03E33B011M	21.0	3.8	98.0	-73.3
	178	12N01W14M001M	37.0	10.5	78.4	-30.9
	180	12N01W36K002M	48.2	-7.7	90.2	-49.7
	251	10N01E02Q002M	45.2	32.1	109.8	-32.6
	405	10N02E06B001M	34.7	26.0	146.4	-85.7
	411	12N01W05B001M	94.4	49.5	169.2	-25.3

Management Area	YSGA Representative Well Number	State Well Number	Measurable Objective (ft)		Minimum Threshold (ft)	
			Depth to Water	*Groundwater elevation*	*Depth to Water*	*Groundwater elevation*
	410	10N02E09N001M	48.5	12.9	125.0	-63.7
	420	10N02E03R002M	30.6	12.2	81.9	-39.2
	421	11N02E20K004M	24.7	28.8	85.1	-31.6
South Yolo	122	08N03E32L001M	30.5	-1.9	100.3	-71.8
	160	06N03E07M001M	9.0	9.9	29.7	-10.8
	422	08N03E31N001M	40.6	-7.0	82.8	-49.3
	423	07N03E04Q001M	24.0	0.5	51.6	-27.1
Dunnigan Hills	253	10N01E18C001M	51.4	143.1	61.6	132.8
	260	10N01W02Q001M	66.5	128.3	121.2	73.6
	402	10N01E15D001M	76.9	17.5	164.0	-69.6

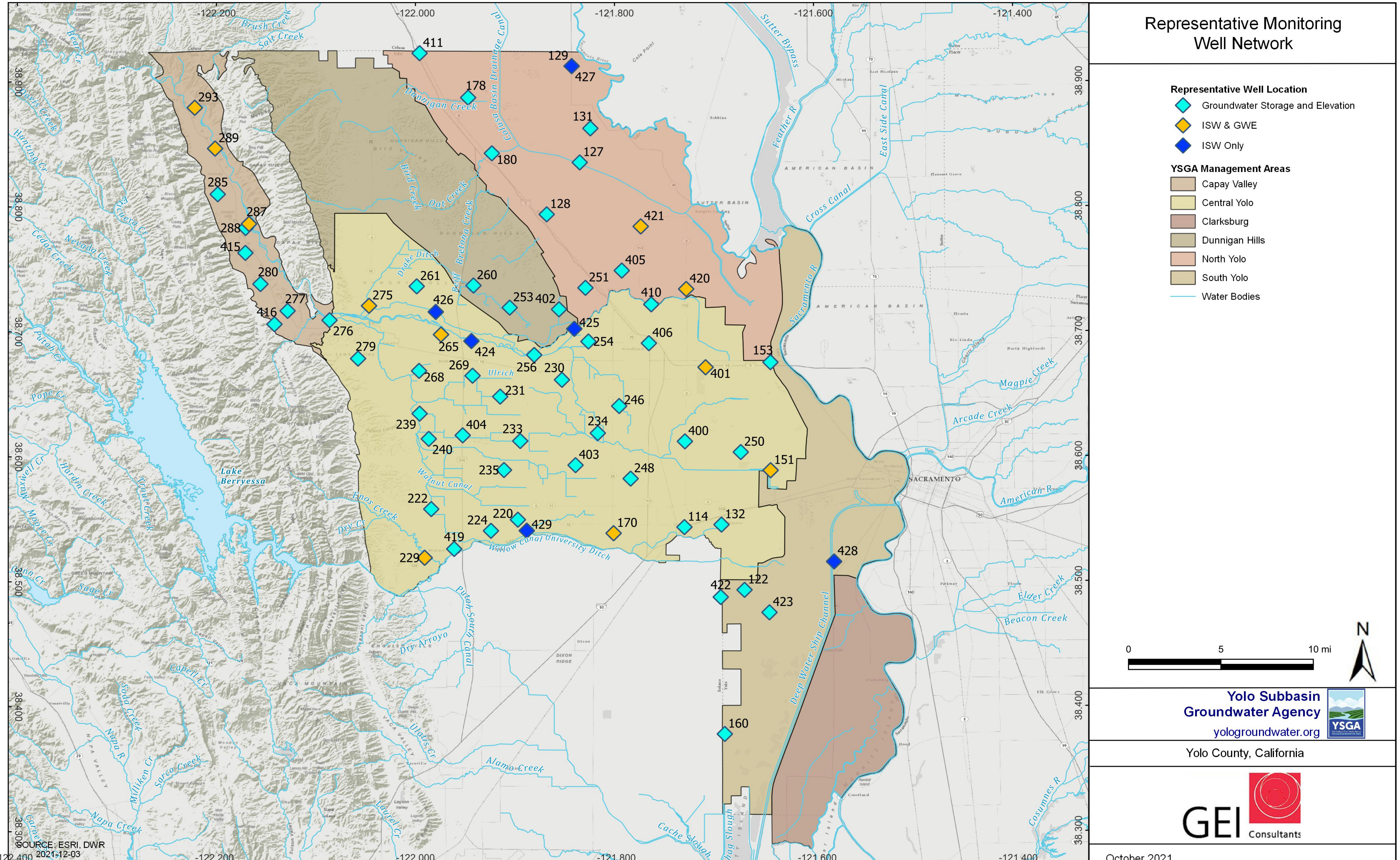

Figure ES-4.Yolo Subbasin Representative Wells.

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Due to the lack of significant groundwater use in the Clarksburg MA no measurable objective has been established in the MA.

Interim milestones for the Chronic Lowering of Groundwater Levels are set equal to measurable objectives.

ES 3.3 Reduction in Groundwater Storage

The basin-wide definition of "undesirable results" for the reduction of groundwater storage is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by the amount of groundwater storage in the Yolo Subbasin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users. In the Subbasin groundwater elevations serve as a proxy for groundwater storage.*

A groundwater storage undesirable result occurs under the same definition as the chronic lowering of groundwater levels. As with the chronic lowering of groundwater levels, no sustainable management criteria are established for the Clarksburg management area, due to the lack of significant groundwater use in the management area.

The minimum threshold values for reduction of groundwater storage have been established for each management area and are based on and identical to the minimum threshold values established for chronic lowering of groundwater elevations.

The measurable objective values for reduction of groundwater storage have been established for each management area and are based on and identical to the measurable objective values established for chronic lowering of groundwater elevations.

Interim milestones for the reduction of groundwater storage are set equal to measurable objectives.

ES 3.4 Degraded Water Quality

The YSGA is only establishing sustainable management criteria for total dissolved solids and has elected to not established specific sustainable management criteria for other constituents of concern identified within the Subbasin. For all constituents of constituents of concern, except total dissolved solids, the Subbasin will rely on current and future water quality standards established for drinking water and agricultural water uses by state and County regulatory agencies. The YSGA will annually review water quality monitoring data, in collaboration with regulating agencies, to determine if water quality is being negatively affected by groundwater management activities. In the future, where significant negative impacts to water quality associated with groundwater management activities are identified, the YSGA will coordinate with stakeholders and regulatory agencies to establish appropriate sustainable management criteria that can be used to define the occurrence of basin-wide undesirable results for specific water quality constituents.

The YSGA has identified a list of water quality constituents of concern, including those constituents whose presence, distribution, or concentration can be influenced by groundwater management activities. The list of water quality constituents of concern for the Subbasin includes:

- Total Dissolved Solids
- Nitrate
- Arsenic
- Boron
- Hexavalent Chromium (VI)

The basin-wide definition of "undesirable results" for degraded water quality is as follows:

> *The point at which water quality is degraded to the extent of causing significant and unreasonable impacts from groundwater management actions in the Yolo Subbasin, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *An undesirable result occurs when the minimum threshold criteria is exceeded in* ***50 percent or more*** *of representative monitoring wells monitored for total dissolved solids.*

The YSGA has established a minimum threshold for total dissolved solids as follows:

> *A representative monitoring well violates the minimum threshold when the total dissolved solids concentration exceeds 1,000 ppm over a three (3) year rolling average.*

The YSGA has established a measurable objective for total dissolved solids as follows:

> *A representative monitoring well violates the measurable objective when the total dissolved solids concentration exceeds 750 ppm over a three (3) year rolling average.*

ES 3.5 Land Subsidence

The basin-wide definition of "undesirable results" for land subsidence is as follows:

> *The point at which the rate and extent of subsidence in the Subbasin causes significant and unreasonable impacts to surface land uses or critical infrastructure.*
>
> *An undesirable result occurs when the minimum threshold value is exceeded over 25 percent of the management or sub-management areas in three (3) or more management or sub-management areas in the same reporting year.*

Within the Yolo Subbasin, a management or sub-management area will be considered an undesirable result watch area when that management exceeds its minimum threshold value, identified below. If three or more undesirable result watch areas exist, as defined above, the Subbasin would be considered to be experiencing an undesirable result relative to land subsidence.

The YSGA reviewed the level of subsidence in the Subbasin based on a number of studies. Land deformation occurs as both surface subsidence and surface uplifting and the Subbasin experiences both processes. In the east portion of the Central Yolo management area and nearly the entire

North Yolo management area steady levels of subsidence have been documented. In the western portion of the Central Yolo management area a slight amount of uplift has been observed.

Subsidence in the Subbasin has occurred at a steady rate according to available studies and occurs even in years when groundwater levels are stable or increasing. The rate of subsidence does not substantially increase during years when groundwater levels are declining. The cause of subsidence can be attributed to other tectonic activities, and not solely groundwater extractions. To fully understand the exact causes of subsidence additional data is needed to identify where in the substrata subsidence occurs.

The YSGA recognizes that, while the exact causes of subsidence in the Subbasin are not fully understood, subsidence can cause significant impacts to surface infrastructure and is often caused by increasing groundwater extractions.

The minimum threshold values for land subsidence have been established for each management or sub-MA as shown in **Table ES-3**.

Table ES-3. Minimum Thresholds for Land Subsidence.

Management / Sub-Management Area	Running Average	Max Subsidence Rate	Max Percent of Area
Capay Valley	TBD	TBD	TBD
Dunnigan Hills	5-year	1.8 cm/year	25%
North Yolo	5-year	3.0 cm/year	25%
East Central Yolo	5-year	2.5 cm/year	25%
West Central Yolo	5-year	1.8 cm/year	25%
South Yolo	5-year	0.0 cm/year	25%
Clarksburg	5-year	0.0 cm/year	25%

The measurable objectives values for land subsidence have been established for each management and sub-MA as shown in **Table ES-4**.

Table ES-4. Measurable Objective Thresholds for Land Subsidence.

Management / Sub-Management Area	Running Average	Max Subsidence Rate	Max Percent of Area
Capay Valley	TBD	TBD	TBD
Dunnigan Hills	3-year	1.8 cm/year	25%
North Yolo	3-year	3.0 cm/year	25%
East Central Yolo	3-year	2.5 cm/year	25%
West Central Yolo	3-year	1.8 cm/year	25%
South Yolo	3-year	0.0 cm/year	25%
Clarksburg	3-year	0.0 cm/year	25%

ES 3.6 Seawater Intrusion

Seawater intrusion has been determined not to be a concern in the Yolo Subbasin with no potential for seawater intrusion to occur under water quality management objectives in the Sacramento-San Joaquin Delta or changes in water management activities in the Subbasin. Accordingly, no definitions of undesirable results, minimum thresholds, or measurable objectives have been developed.

ES 3.7 Depletion of Interconnected Surface Water

Development of SMC for the depletion of interconnected surface waters was constrained by limited groundwater data and the lack of previous studies of stream-aquifer interaction. Additional investigations of stream-aquifer interactions and additional groundwater monitoring data in the Yolo Subbasin may necessitate a future change in the SMC for this sustainability indicator.

The YSGA intends to use groundwater levels at shallow near-stream representative monitoring wells as a proxy for the rate and volume of depletion of interconnected surface waters caused by groundwater use.

The basin-wide definition of "undesirable results" for interconnected surface water is as follows:

> *The point at which significant and unreasonable impacts to the surface waters affect the reasonable and beneficial use of those surface waters by overlying users, including associated ecosystems.*
>
> *An undesirable result occurs when the Minimum Threshold is exceeded in over 50 percent of the interconnected surface water representative monitoring wells in two (2) or more interconnected surface water management areas in the same reporting year.*

Based on historic, current, and projected conditions in the Subbasin, the YSGA developed several methodologies for establishing the minimum threshold value for each representative well. The primary sustainability criteria for establishing minimum thresholds for interconnected surface waters is to maintain interconnection of the local groundwater system to the critical surface water body at levels consistent with recent conditions (1971-2018). In this manner the YSGA is establishing SMCs that protect the existing level and frequency of interconnection, which in turn supports existing habitat and ecosystem conditions associated with critical surface water bodies, while preventing further degradation. The habitat associated with interconnected surface water bodies is supported by both surface flows (much of which is managed) and periodic connection to groundwater. ***The goal of the YSGA is to maintain conditions experienced in the past and to cause no degradation of habitat relative to the Subbasin's current baseline. Historically this condition included periods when groundwater elevations were below the level needed to support connection to surface water bodies. However, groundwater elevations recover during wet periods to reestablish connections between groundwater and surface water bodies. This regime of fluctuating and periodic recovery of groundwater levels maintains the current level of habitat in interconnected surface water bodies needed to support GDEs.***

Lower Cache Creek

The Minimum Threshold for depletion of interconnected surface water is the recurrence of the spring (March-May) average measurement for 1975 to present in at least one spring in every seven (7) years.

Lower Cache Creek is an intermittent water body with a known connection to groundwater that supports sensitive ecosystems, recreation, and surface water uses. The creek experiences connection to, and disconnection from, groundwater that varies in space and time. The intention of the established minimum threshold is to ensure that no depletion occurs in excess of what has been experienced since 1975, and to ensure that groundwater levels rise at regular intervals to maintain the stream's periodic connection to groundwater.

Upper Cache Creek, Putah Creek, and Lower Sacramento River:

Minimum Threshold value is equal to the minimum elevation for the period of record at the RMW, exceeded in 2 consecutive years.

Upper Cache Creek, Putah Creek, and the Sacramento River are perennial waterways that support a variety of beneficial uses. The effect of groundwater extraction on streamflow is difficult to determine due to flow management practices. However, hydrographs of monitoring wells adjacent to perennial water bodies display much less inter-annual variation than those of Lower Cache Creek. Generally, water levels are more stable, reflecting both the availability of surface water in the area and the replenishment of groundwater levels by the water body. Because groundwater levels at these wells generally rebound every spring, it is not appropriate to set a multi-year threshold. The minimum threshold is a single value aimed at limiting the rate of depletion from the water body. No undesirable results have been documented within the historical period of evaluation. Therefore, the minimum threshold is set to the historic minimum elevation for the period of evaluation at the representative monitoring well.

Upper Sacramento River:

Exceedance of the historic minimum elevation in the period of record of each RMW plus 20 percent of the depth between the historic maximum and historic minimum elevation for the period of record of the RMW in 2 consecutive years.

The minimum thresholds for the North Yolo management area are set lower than historical conditions recognizing that water districts, such as RD 108, in this area may experience reductions in surface water deliveries from the Sacramento River as potential Voluntary Agreements with the State Water Board are implemented. The Voluntary Agreements are expected to reduce surface water deliveries to Sacramento River Settlement Contractors during certain year types, requiring that water users increase their reliance on local groundwater during the same year types.

The minimum threshold is lower in this reach to provide operational flexibility to the beneficial users of groundwater in the region. However, the YSGA intends to manage the North Yolo management area towards the measurable objective, which seeks to maintain historical groundwater levels. In the long-term, groundwater levels will stay at their historically sustainable levels, and no undesirable results are predicted to occur.

The values for minimum thresholds at each of the representative wells is provided in **Table ES-5.**

Table ES-5. Interconnected Surface Water Minimum Thresholds.

YSGA Representative Well Number	Interconnected Surface Water Management Zone	Minimum Thresholds Value Depth to Water (Ft)	Minimum Thresholds Value Groundwater Elevation (Ft msl)	Minimum Thresholds Evaluation
265	Lower Cache	29.7	131.6	1 in 7 years
275	Lower Cache	64.4	143.2	1 in 7 years
424	Lower Cache	28.6	116.7	1 in 7 years
425	Lower Cache	29.4	55.1	1 in 7 years
426	Lower Cache	36.1	132.6	1 in 7 years
151	Lower Sacramento	56.1	-35.3	Single exceedance
401	Lower Sacramento	21.2	9.0	Single exceedance
428	Lower Sacramento	19.3	-1.3	Single exceedance
170	Putah Creek	67.0	1.5	Single exceedance
229	Putah Creek	116.2	36.4	Single exceedance
429	Putah Creek	47.7	56.1	Single Exceedance
287	Upper Cache	23.6	287.6	Single Exceedance
289	Upper Cache	29.6	341.2	Single exceedance
293	Upper Cache	26.2	376.4	Single exceedance
420	Upper Sacramento	81.9	-39.2	Single exceedance
427	Upper Sacramento	73.7	-35.4	Single exceedance
421	Upper Sacramento	85.1	-31.6	Single exceedance

To establish the measurable objectives for the Yolo Subbasin, the YSGA utilized the representative wells identified for minimum thresholds, shown in **Table ES-6**, to determine the measurable objectives for chronic lowering of groundwater levels. Based on historic, current, and projected groundwater conditions in the Subbasin, the used the following criteria for establishing measurable objectives at representative monitoring wells:

Measurable Objective is equal to the average spring (March-May) groundwater elevation for water years 2000-2011 at the RMW. Performance of the Measurable Objective will be measured as the five (5) year running average of the maximum spring (March-May) groundwater elevation.

This measurable objective ensures that groundwater levels continue to rebound in spring, maintaining connection to and preventing undesirable depletion of interconnected surface waters.

The measurable objective for depletion of interconnected surface waters has been established for each RMW in the interconnected surface water management zone, as described above. The

Measurable Objectives will be measured at specific RMWs representative of the surrounding area and capture groundwater conditions in the area that influence surface waters

Table ES-6. Interconnected Surface Water Measurable Objectives.

YSGA Representative Well Number	Interconnected Surface Water Management Zone	Measurable Objectives Value Depth to Water (Ft)	Measurable Objectives Value Groundwater Elevation (Ft msl)
265	Lower Cache	28.6	132.7
275	Lower Cache	62.2	145.4
424	Lower Cache	29.5	115.8
425	Lower Cache	23.3	61.2
426	Lower Cache	30.6	138.0
151	Lower Sacramento	5.1	15.7
401	Lower Sacramento	3.3	26.8
428	Lower Sacramento	9.3	8.7
170	Putah Creek	38.8	29.7
229	Putah Creek	61.0	91.6
429	Putah Creek	27.8	76.0
287	Upper Cache	12.5	298.7
289	Upper Cache	16.5	354.3
293	Upper Cache	17.4	385.2
420	Upper Sacramento	18.9	23.9
427	Upper Sacramento	9.0	29.3
421	Upper Sacramento	20.0	33.5

ES 4.0 Monitoring Networks

The monitoring network and protocols adopted by the YSGA are designed to collect data of sufficient quality, frequency, and distribution to characterize groundwater conditions and water budget components in the Yolo Subbasin, and to evaluate changing conditions due to local hydrology, water management actions, and water supply projects. The YSGA has established this SGMA representative monitoring network with those wells or sites that will be used to report the Subbasin's performance for each of the sustainability indicators (this includes the representative wells (RMW) along with additional monitoring sites). Within the Subbasin many hundreds of additional wells are also monitored for purposes other than SGMA reporting.

Since 2004, the Yolo Subbasin has maintained an established groundwater-level and water quality monitoring database known as the Water Resources Information Database (WRID) that includes more than 190,000 records from thousands of agricultural, domestic, municipal and dedicated monitoring wells that have been monitored for groundwater levels, water quality and subsidence. In addition, members of the YSGA and more than 40 other agencies also maintain and monitor wells throughout the Subbasin. Not all monitoring wells are included in the SGMA monitoring network. They are, nevertheless, important for monitoring conditions in the Subbasin and will continue to be monitored. All current and historic monitoring data on the WRID is available online for scientists and engineers.

The representative monitoring network identified for the Subbasin is designed to meet the following objectives of this GSP:

- Monitor impacts of groundwater pumping on beneficial uses and users of groundwater
- Monitor progress toward measurable objectives and minimum thresholds
- Collect data to quantify annual changes in water budget components of the Subbasin
- Monitor changes in groundwater conditions relative implementation of projects and management actions

The representative monitoring network design relative to these four objectives are discussed in **Section 4 – Monitoring Networks**. The representative monitoring network will monitor the following pertinent sustainability indicators:

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Degraded groundwater quality
- Land subsidence
- Depletion of interconnected surface waters

ES-5.0 Projects and Management Actions

The GSP describes projects and management actions proposed by the YSGA and its member agencies to meet the sustainability goal for the Yolo Subbasin. The projects and management actions presented in the GSP represent the best available engineering and analysis completed to-date. This list will be updated throughout the planning and implementation period (2022 to 2042) to reflect additional analyses and new and emerging opportunities.

As described in the Subbasin water budget in **Section 2.3 – Water Budget Information**, the Subbasin has an estimated Sustainable Yield of 346 TAF annually. Annual groundwater pumping under future scenarios supports urban and agricultural demands and is as follows:

- Future baseline 320 TAF

- Future 2030 337 TAF
- Future 2070 358 TAF
- Future 2070 DEW 400 TAF
- Future 2070 WMW 325 TAF

Throughout the course of the implementation period (2022 to 2042), the YSGA and its member agencies will implement a variety of management actions to protect groundwater sustainability. These management actions will include capital investment projects to develop additional water supplies to off-set groundwater pumping, a data collection and analysis program to better understand and manage the Subbasin, and improved outreach activities.

Many of the management actions will require additional planning, engineering, and environmental/regulatory analysis before they can be implemented. The possibility exists that some projects will not be feasible to implement. If the identified management actions cannot be implemented, the YSGA will consider additional management actions as needed to protect groundwater sustainability.

There are existing and on-going projects and management actions that contribute to sustainability in the Yolo Subbasin. Proposed future, existing, and ongoing projects and management actions are described in the GSP, including a brief description of the relevant sustainability indicator, status, expected benefits, and ongoing costs. These projects and management actions are proposed by the YSGA for development over the 20-year implementation period. A full table of projects and management actions identified by the YSGA is provided in **Appendix J** of this GSP

1.0 Introduction

The Yolo Subbasin (Subbasin) is located in the southwestern side of the Sacramento Valley Groundwater Basin and is about 27 miles wide from west to east and up to 45 miles long from north to south (**Figure 1-1**). The current Subbasin boundaries are the result of the consolidation of portions of the Capay Valley, Colusa, and Solano subbasins *via* two applications for jurisdictional modifications of the Subbasin's boundary. The western portion of the Subbasin is bound by the west uplifted, mountainous coast range consisting of marine sedimentary rocks.

The southern Sacramento Valley, including the Subbasin, has been a tectonically subsiding sedimentary basin with accumulating nonmarine, continental deposits since middle Tertiary time (Miocene, 24 million years before present [mybp]). Within these nonmarine sedimentary deposits, fresh groundwater extends to an elevation of -3,000 feet. Cache Creek enters the Subbasin in the northwest portion and flows south and east through the central part of the Subbasin towards the Cache Creek Settling Basin. Cache Creek is considered an intermittent stream and there is no hydraulic continuity to the Sacramento River during the summer months. In the winter months, Cache Creek flows over the Cache Creek Settling Basin weir, flowing into the Yolo Bypass, and ultimately into the Sacramento River, which is the eastern boundary of the Subbasin. Putah Creek forms the southern boundary from the southwestern corner of the Subbasin to the city of Davis at which point, the boundary follows the Yolo County (County) line to the south.

1.1 Sustainable Groundwater Management Act

On September 16, 2014, Governor Jerry Brown signed into law a three-bill legislative package, composed of AB 1739 (Dickinson), SB 1168 (Pavley), and SB 1319 (Pavley) collectively known as the Sustainable Groundwater Management Act (SGMA). This legislation provides for the local control of groundwater while requiring the sustainable management of the groundwater resource. One of the first requirements under SGMA was to establish a local governance body, a Groundwater Sustainability Agency (GSA), with the local authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP or Plan). Further, under SGMA law, groundwater basins throughout California were classified as "high", "medium" or "low" priority by California Department of Water Resources (DWR). The Yolo Subbasin is classified as a "high" priority basin, which requires the Subbasin to prepare, adopt, and submit a GSP by January 31, 2022.

GSPs must document monitoring conditions and establish management criteria to avoid undesirable results and identify potential actions that will maintain and/or achieve sustainable groundwater management by 2042, or 20 years from the date of the adoption of the GSP. Through a Joint Powers Agreement (JPA), the Yolo Subbasin Groundwater Agency (YSGA) is the recognized GSA for the entire Subbasin and responsible for developing and implementing a GSP.

Under SGMA, the sustainable management of groundwater is defined as the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (California Water Code (CWC) Section 10721 (v)). Undesirable results include the significant and unreasonable lowering of groundwater levels; loss of groundwater storage and supply; degradation of water quality; land subsidence; depletion of interconnected surface waters and seawater intrusion to levels that impact the beneficial use and users of local groundwater resources. Under SGMA, it is the responsibility of the overlying GSA to determine the levels at which beneficial uses and users are impacted.

1.2 Purpose of Groundwater Sustainability Plan

The purpose of this GSP is to comply with SGMA and serve as an implementation guide for groundwater management within the Subbasin (and management areas [MAs]) covered by the YSGA. This plan provides information on current groundwater conditions; establishes a groundwater Sustainability Goal; identifies and describes Undesirable Results for the Sustainability Indicators set forth in SGMA as they pertain to the Subbasin; identifies and describes Minimum Thresholds and Measurable Objectives for each Sustainability Indicator; and demonstrates how sustainability will be achieved within the 20-year implementation period through implementation of the developed projects and management actions.

The GSA for the Subbasin is made up of 20 member agencies and six affiliated parties under the YSGA JPA, explained in detail in **Section 1.4 – Agency Information**, and a diverse set of stakeholders. This GSP represents a coordinated effort of all YSGA members to comply with the requirement of developing and utilizing consistent data and methodologies throughout the Subbasin. The member agencies and affiliated parties of the Subbasin have worked collaboratively with beneficial users and stakeholders in the region to develop this GSP. The YSGA will implement this GSP accordingly in compliance with SGMA to achieve sustainability in the Subbasin.

1.3 Sustainability Goal

As required by SGMA, a sustainability goal is to be defined for the basin (CWC §10727(a)). This is further clarified as a basin-wide basis in DWR's GSP emergency regulations. The sustainability goals for the Yolo Subbasin are as follows:

- *Achieve sustainable groundwater management in the Yolo Subbasin by maintaining or enhancing groundwater quantity and quality through the implementation of projects and management actions to support beneficial uses and users.*
- *Maintain surface water flows and quality to support conjunctive use programs in the Subbasin that promote increased groundwater levels and improved water quality.*
- *Operate within the established sustainable management criteria and maintain sustainable groundwater use through continued implementation of a monitoring and reporting program.*
- *Maintain sustainable operations to maintain sustainability over the implementation and planning horizon.*

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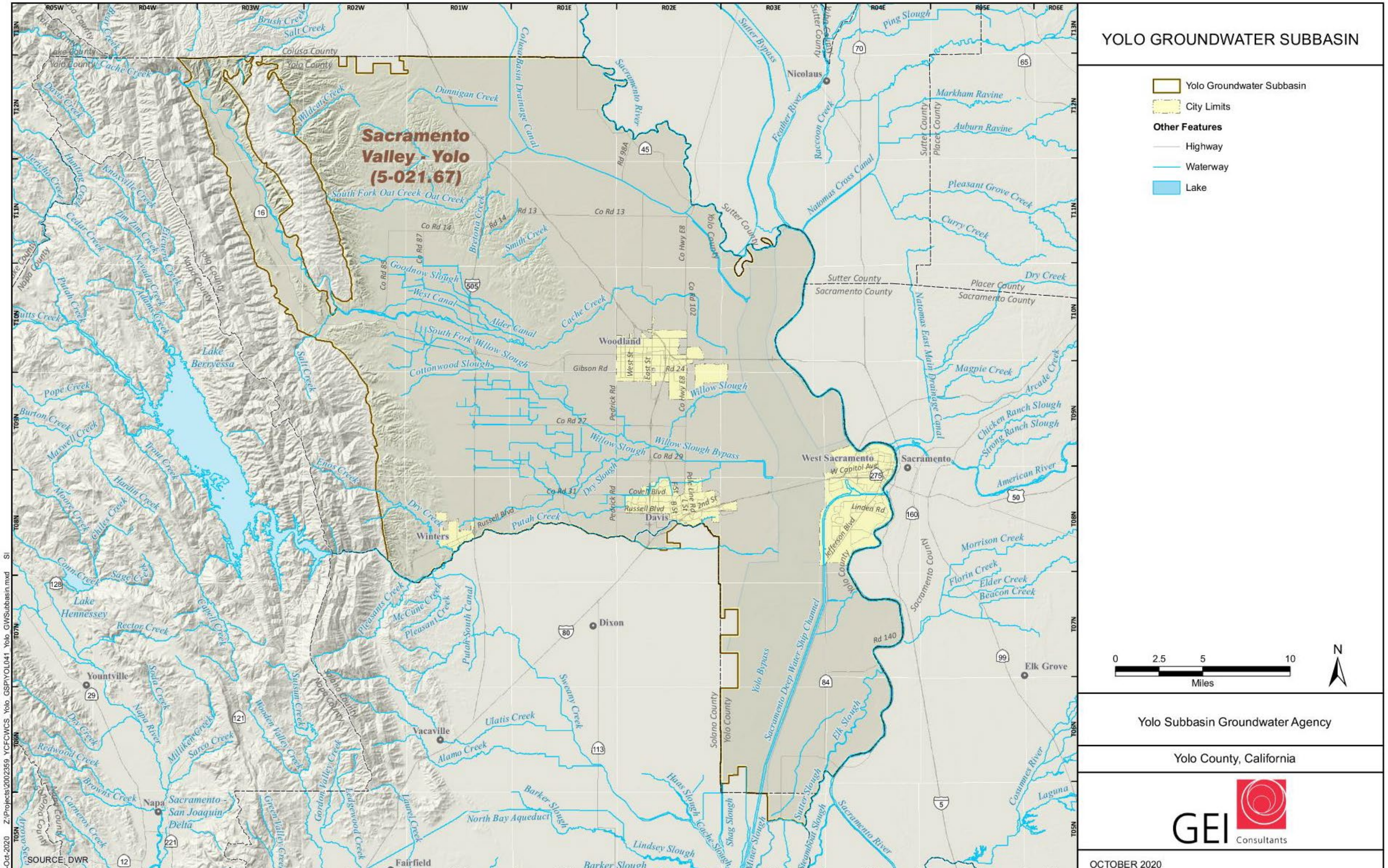

Figure 1-1. Yolo Subbasin.

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1.4 Agency Information

In complying with Section 354.6 of the GSP Regulations,[1] the following section provides agency information, legal authority, and estimated cost of plan implementation for the YSGA and its members in the Subbasin.

Agency's Name:	Yolo Subbasin Groundwater Agency
Agency's Address:	34274 State Highway 16, Woodland, CA 95695
Agency's Phone Number:	(530) 662-3211
Agency's Website:	https://www.yologroundwater.org/
Contact Person:	Kristin Sicke
Contact Person's Title:	Executive Officer
Contact Person's Email:	ksicke@yolosga.org

1.4.1 GSA Formation

The Water Resources Association of Yolo County (WRA) was established in 1993 to serve as a collaborative, consensus-based regional forum to plan, coordinate, and facilitate solutions to water management issues in the County. In 2014, upon legislation of SGMA, water interests in the Subbasin *via* the WRA and Yolo County Farm Bureau formed a Yolo SGMA Working Group to develop an efficient and effective groundwater governance structure for complying with and implementing SGMA. The Yolo SGMA Working Group proposed forming a JPA to offer economies of scale to all participants, honor the regional community, recognize the value of county partnerships, and create shared accountability for the shared water resources.

The YSGA JPA was officially executed on June 19, 2017 by 19 member agencies and five affiliated parties *via* memoranda of understandings (MOU). The JPA is provided in **Appendix A – Yolo Subbasin Groundwater Agency Joint Powers Agreements.** Since the YSGA was formed, three additional member agencies have signed onto the JPA; three other member agencies consolidated into one; and one affiliated party has entered into an MOU with the JPA, which has resulted in 20 member agencies and six affiliated parties for a total of 26 YSGA members (**Figure 1-2**). The YSGA covers approximately 540,700 acres, spanning nearly 845 square miles. **Table 1-1** lists each member agency and affiliated party involved in the development of this GSP.

1.4.2 YSGA Management Structure

The YSGA was created following the enactment of SGMA with the intent of establishing a collaborative GSP for the coordinated management of the groundwater basin underlying the Subbasin. This collaborative process builds off existing relationships among the parties and the

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1 https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I74F39D13C76F497DB40E93C75FC716AA&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)

existing groundwater monitoring network that has been operating for more than 50 years. A governance structure has been developed to preserve the autonomy and authority of local agencies throughout the development and implementation of SGMA over the 20-year planning horizon. YSGA has assumed the responsibility of developing a comprehensive GSP for an area that includes agricultural lands as well as urban and industrial development.

Table 1-1. Yolo Subbasin Groundwater Agency Members.

Member Agencies	
City of Davis	Reclamation District 307
City of Woodland	Reclamation District 537
City of West Sacramento	Reclamation District 730
City of Winters	Reclamation District 765
County of Yolo	Reclamation District 787
Dunnigan Water District	Reclamation District 999
Esparto Community Services District	Reclamation District 1600
Madison Community Services District	Reclamation District 2035
Reclamation District 108	Yocha Dehe Wintun Nation
Reclamation District 150	Yolo County Flood Control & Water Conservation District
Affiliated Parties	
California American Water Company, Dunnigan	University of California, Davis
Colusa Drain Mutual Water Company	Environmental Representative
Private Pumper Representative – Yolo County Farm Bureau appointed	Rumsey Water Users Association

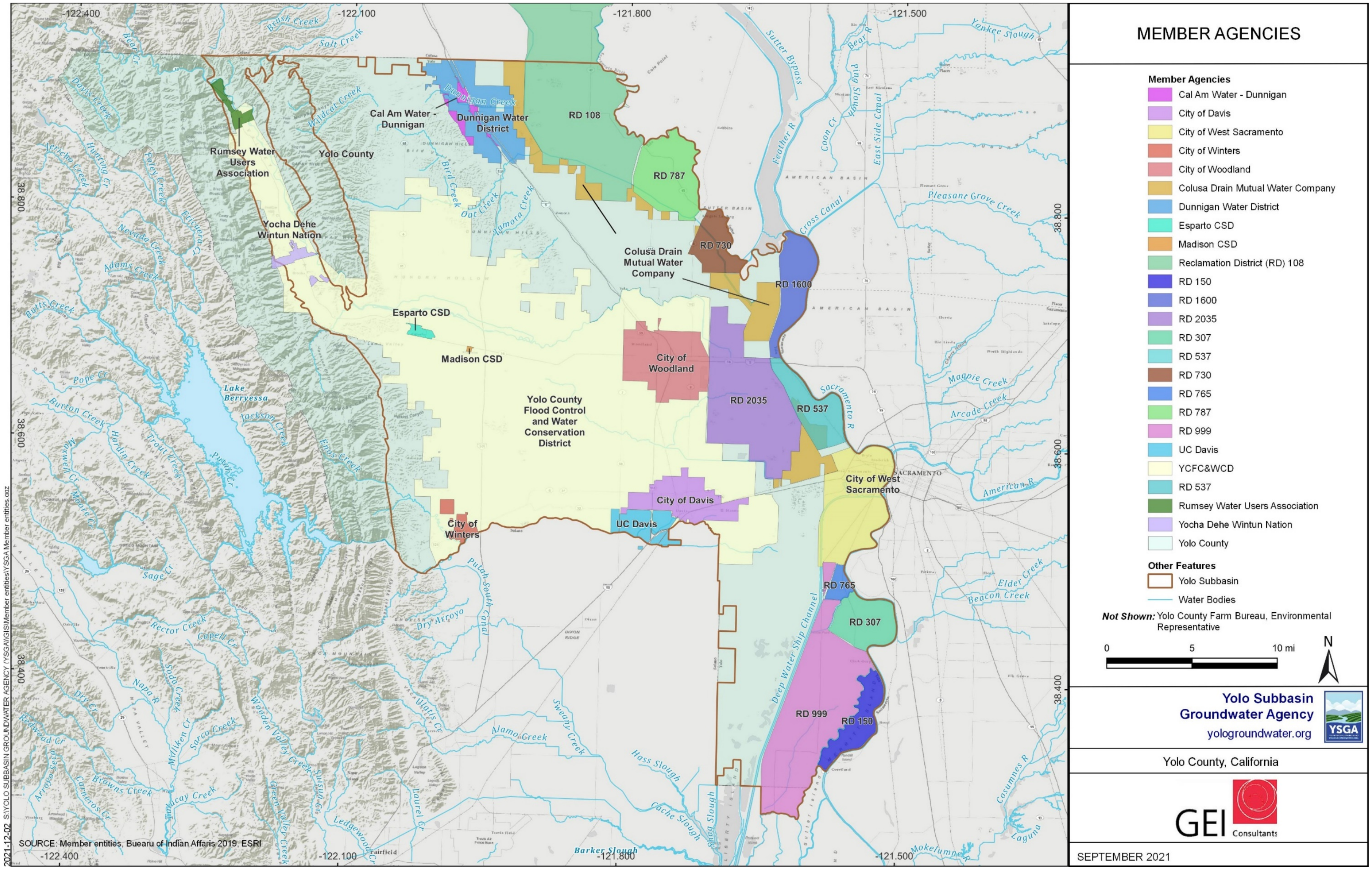

Figure 1-2. Yolo Subbasin Groundwater Agency Member Agencies.

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The business of the YSGA is conducted by the Board of Directors (Board) composed of one representative from each of the 20 member agencies and six affiliated parties, with one vote per board seat. Each member of the Board serves until replaced by the appointing Member or Affiliated Party. The Board elected a chairperson, vice chairperson, secretary, and treasurer. All the powers and authority of the YSGA are exercised by the Board, subject however, to the rights reserved by the Members and Affiliated Parties.

YSGA Board conduct most business by majority vote of those Directors' present. The following actions require a two-thirds vote by the Directors present:

a. Approval of the Agency's annual budget
b. Decisions related to the levying, imposition or collection of taxes, fees, charges, and other levies
c. Decisions related to the expenditure of funds by the Agency beyond expenditures approved in the Agency's annual budget
d. Adoption of rules, regulations, policies, bylaws and procedures related to the function of the Agency
e. Decisions related to the establishment or adjustment of the Members' or Affiliated Parties' obligations for payment of the Agency's operating and administrative costs as provided in the JPA (Article 5.1)
f. Approval of the GSP
g. Involuntary termination of a Member or Affiliated Party
h. Approval of the addition of a Member or Affiliated Party
i. Amendment and termination of the JPA Agreement
j. Modification of the Member and Affiliated Party fees

An Executive Committee, a Working Group, and a Technical Advisory Committee (TAC) were established to develop this GSP in compliance with SGMA. To facilitate implementation of the YSGA GSP, the Subbasin jurisdictional boundary area is divided into six separate management areas (MAs).

1.4.2.1 Executive Committee

The Executive Committee was established to administer the Agency in accordance with policies and procedures as established by the Board. The Executive Committee is comprised of

- Chair
- Vice Chair
- Executive Officer

- An Urban Representative
- An Agricultural Representative

The main purpose of the Executive Committee is to provide direction to the Executive Officer, address administrative issues in a timely manner, and help prepare and review Board agendas.

1.4.2.2 Executive Officer

The Executive Officer administers the activities of the YSGA and is the primary point of contact with the Board Chair. Among other duties, the Executive Officer works with the Board Chair and Vice Chair to establish the Board's meeting agendas, carry out the directives of the Board, and coordinate the activities of the Working Group and TAC.

1.4.2.3 Working Group

The process of creating the YSGA to oversee implementation of SGMA in the Subbasin relied heavily on input and feedback from stakeholders working collaboratively in what was called the "Working Group" that proved an effective forum for vetting issues and achieving consensus. This Working Group consisted of member agency staff, policymakers, and other interested stakeholders that wished to participate. At the June 2017 Board meeting, the Working Group was established as an official subcommittee of the Agency and was charged with developing recommendations and providing guidance to the Board on the development and implementation of the GSP and other matters related to the efficient management of the YSGA.

1.4.2.4 Technical Advisory Committee

The TAC was formed to advise the Working Group and Technical Team (technical staff and consultants involved in developing the GSP) in making sound technical decisions. The TAC was involved in evaluating the process for developing the sustainable management criteria, reviewing the representative well selection process, and advising future land use projections for developing future scenarios. The TAC also reviewed draft products and materials prepared as part of the development of the Yolo Subbasin GSP.

1.4.3 Legal Authority of the GSA

The YSGA was granted legal authority of a GSA by complying with CWC Section 10723.8 through adoption of a JPA pursuant to California Government Code 6500. The YSGA held the required public hearings regarding the establishment of a GSA as stated in CWC Section 10723(b) and passed a resolution to form the YSGA. The authority granted to YSGA is to develop, adopt, and implement a GSP for the Subbasin in compliance with SGMA, subject to the limitations set forth in the JPA. At the March 19, 2018, YSGA Board meeting, the Directors adopted Resolution 2018-01 formally initiating the development of the YSGA GSP and authorized the submission of the notice of intent to DWR. The required notification of intent to prepare a GSP was submitted to DWR on

March 26, 2018.[2] Under CWC Section 10723.2, the YSGA within its boundaries shall consider the interests of all beneficial uses and users of groundwater.

The YSGA was formed for the following purposes:

- To identify and address issues pertaining to sustainable groundwater management
- To coordinate groundwater management programs and activities
- To establish a framework for local groundwater management
- To develop, adopt, and implement a legally sufficient GSP for the Subbasin, subject to the limitations set forth in the JPA

The intent of the members under the JPA is to provide each member with the responsibility to implement SGMA and the GSP adopted by the YSGA within their respective MA, as delineated by this GSP. The members and affiliated parties worked collaboratively to develop this GSP for the Subbasin in compliance with SGMA.

1.4.4 GSP Implementation Costs & Funding

The YSGA, on behalf of its member agencies, will incur costs to implement the GSP and maintain the plan *via* annual reports and 5-year updates. The YSGA has developed these costs as shown in **Table 1-2**.

Table 1-2. Estimated Costs for GSP Implementation.

Item	Description	Estimated Cost
Annual Administration	Activities for ongoing coordination among member agencies	$150,000
Sustainability Management	Implementation of sustainability management practices	$60,000
Annual Monitoring	Basin-wide coordinated monitoring activities	$90,000
Annual Report	Data collection and consolidation from member agencies to facilitate annual reporting to DWR	$50,000
5-year GSP Update	Data collection, consolidation and report preparation for YSGA 5-year GSP update	$150,000

1.5 Description of Plan Area

YSGA's jurisdictional boundary accounts for the entire Yolo Subbasin, as defined in DWR Bulletin 118, in the southern portion of the Sacramento Valley Basin primarily within the County. The following section describes the area covered by the YSGA GSP.

[2] https://sgma.water.ca.gov/portal/gsp/init/preview/83

1.5.1 Summary of Jurisdictional Areas and Other Features

As shown in **Figures 1-1** and **1-2**, the YSGA jurisdictional area is approximately 844 square miles. The Subbasin is located in the southwestern side of the Sacramento Valley Groundwater Basin. Following two applications for jurisdictional modifications of the basin boundary, the Subbasin resulted in the consolidation of portions of the Capay Valley, Colusa, and Solano subbasins within the Yolo Subbasin. The Subbasin is bounded on the east by the Sacramento River and to the west by the coast range. The Sacramento River forms the eastern boundary of the Subbasin. Putah Creek forms the Southern boundary from the southwestern corner of the Subbasin to the city of Davis at which point, the boundary follows the County line to the south. Adjacent subbasins are shown in **Figure 2-**1.

There are several incorporated cities within the YSGA jurisdictional boundary as shown in **Figure 1-3** that are dependent on groundwater. Additionally, there are a number of domestic water users (what SGMA considers de minimis users) and multi-parcel water systems located within the YSGA jurisdictional area, which are also covered under this GSP.

Water agencies and private parties have been effective over the decades in obtaining and developing water supplies to meet the needs of the Yolo Subbasin. Over 20 agencies have land and water management responsibilities in the Subbasin, which includes agricultural water purveyors, urban water purveyors, agencies with flood management responsibilities, and agencies with land use management responsibilities.

- **Agricultural Water Purveyors**
  - Colusa Drain Mutual Water Company
  - Dunnigan Water District
  - Rumsey Water Users Association
  - University of California, Davis (Field Teaching and Research System, and Utility Water System)
  - Yolo County Flood Control & Water Conservation District
  - Reclamation District 108
  - Reclamation District 787 (River Garden Farms Company)
  - Reclamation District 2035 (Conaway Conservancy Group)
  - Deseret Farms
- **Urban Water Purveyors**
  - City of Davis
  - University of California, Davis (Domestic System)
  - City of West Sacramento
  - City of Winters
  - City of Woodland
- **Flood Management Agencies**
  - Reclamation District 108

- Reclamation District 150
- Reclamation District 307
- Reclamation District 537
- Reclamation District 730
- Reclamation District 765
- Reclamation District 787 (River Garden Farms Company)
- Reclamation District 900 (dependent of City of West Sacramento)
- Reclamation District 999
- Reclamation District 2035 (Conaway Conservancy Group)

- **Land Use and Resource Agencies**
  - Yolo County
  - North Delta Water Agency
  - Yolo County Resource Conservation District (non-regulatory special district)
  - Yolo Habitat Conservancy (operate in accordance with Yolo Habitat Conservation Plan)

1.5.2 Plan Area Setting

Land use designations within the YSGA jurisdictional boundary are predominately agriculture and native vegetation, accounting for approximately 60 and 31 percent, respectively (**Figure 1-4**). Approximately 6 percent of the Subbasin contains managed wetlands, which provide migratory bird habitat and other ecosystem services. Source of water for agricultural lands is a combination of surface water and groundwater, as shown in **Figure 1-5**. Urban and incorporated land use areas are scattered throughout the Subbasin and account for approximately 5 percent of the Subbasin[3].

A theoretical well distribution, or well densities, for production, domestic, and municipal supply wells within the Subbasin are presented in **Figures 1-6** through **1-8**, respectively. Average domestic well depth in each section is shown in **Figure 1-9**. This dataset is based on well statistics provided by DWR from the Online System for Well Completion Reports (WCRs) and was derived by section (township section)[4]. This dataset is intended to be for qualitative purposes since the YSGA (or the County) does not have a master list of all wells installed in the Subbasin. Production wells include those described in WCRs as irrigation, municipal, public, or industrial wells. In summary, higher well densities can be seen in the central portion of the Subbasin while well densities tend to decrease in the surrounding areas. For additional information on population and economic sectors, *please see* the Yolo County General Plan[5].

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[3] https://data.cnra.ca.gov/dataset/crop-mapping-2016
[4] https://data.cnra.ca.gov/dataset/well-completion-reports
[5] https://www.yolocounty.org/government/general-government-departments/county-administrator/general-plan

1.5.2.1 Disadvantaged Communities

Figure 1-10 provides an overview of the disadvantaged communities within the Yolo Subbasin designated by DWR's Disadvantaged Communities (DAC) Mapping tool[6]. Three census-designated places within the Yolo Subbasin are identified as disadvantaged communities. These include the town of Dunnigan (disadvantaged), Knights Landing (severely disadvantaged), and the main campus of University of California, Davis (severely disadvantaged). Dunnigan is an unincorporated town with a population of 1,278. Domestic water to the community is provided by California American Water and by domestic wells. The town of Knights Landing is served by Knights Landing Community Services District (CSD). Knights Landing CSD relies entirely on groundwater to serve its 869 residents. The area within the University of California, Davis (UC Davis) campus is populated by 7,379 residents. The campus uses a mix of groundwater and surface water for its water supply. California American Water, Knights Landing CSD, and UC Davis are member agencies of the YSGA with voting seats on the Board.

In addition to the places identified, there are several census block groups identified as disadvantaged communities. The location, population, and drinking water supply of these areas is summarized in **Table 1-3**. Population numbers provided represent the population within the County of Yolo, the boundaries of which differ from that of the Subbasin in some areas.

Table 1-3. Disadvantaged Communities Block Groups.

Area	Tract-Block Group	DAC Population	Drinking Water Source
City of Woodland	11102-2, 11001-3, 10901-3, 10902-1, 11102-1, 10902-3, 10800-2, 11001-2, 11101-1, 10800-3, 10902-2, 11205-1	24,423	Municipal SW/GW Mix
City of Davis	10701-2, 10510-3, 10602-4, 10703-4, 10602-2, 10513-2, 10501-2, 10512-1, 10608-2, 10703-3, 10606-4, 10701-3, 10701-4, 10602-1	27,528	Municipal SW/GW Mix
City of West Sacramento	10102-2, 10203-3, 10203-2, 10204-2, 10204-1, 10102-4, 10101-2, 10101-3, 10203-4	17,542	Municipal SW
North Yolo	11400-2	1,617	Groundwater
Sacramento River between Fremont Weir and West Sacramento	10102-1	2,325	GW; SW within city of West Sacramento

[6] https://gis.water.ca.gov/app/dacs/

Area	Tract-Block Group	DAC Population	Drinking Water Source
Dunnigan Hills	11400-1	1,266	Groundwater
Capay Valley	11500-1	623	Groundwater
Central Yolo south of Hwy 16	11500-5	1,036	Groundwater
Eastern edge of Winters	11300-5	965	Groundwater
Capay Valley, Dunnigan Hills	11500-2	560	Groundwater
Central Yolo east of I-505	11300-2	1,035	Groundwater
West UC Davis	10501-1	5,535	UC Davis Mixed SW/GW

1.5.2.2 Tribal Lands

Yocha Dehe Wintun Nation (YDWN) owns and/or manages approximately 5,000 acres within the Capay Valley MA, including trust land held by the federal government and fee land owned by the Tribe. While YDWN federal trust lands are shown in **Figure 1-2**, the entirety of Capay Valley is within the Tribe's ancestral territory. Their water demand is supplied from a combination of surface water from Cache Creek and groundwater pumping.

The Tribe's groundwater is closely monitored and safeguarded by the Yocha Dehe Environmental Department. Wells are monitored monthly, and updates on groundwater status are sent out regularly to residents. YDWN regulates all work associated with groundwater wells on Tribal lands through the Tribal Water Well Ordinance, in addition to County and state requirements. The Tribe prioritizes water conservation and water quality,[7] and in support of a newly developed event center project, the Tribe completed a comprehensive hydrologic model for the Capay Valley (RMC Water and Environment 2016, formerly Water Resources Information Management Engineering, Inc. ([WRIME]).

The Tribe's Environmental Department holds an ongoing working relationship with YSGA staff, and YDWN holds a member seat on the YSGA Board.

1.5.3 Existing and Ongoing Water Resources Programs

Per Section 354.8(c) of the GSP Regulations, this section identifies and describes existing water resource programs in the YSGA jurisdictional Area. This section provides an overview of each program being implemented within the YSGA. **Table 1-4** provides a matrix showing which programs are being implemented for each member agency and affiliated members.

1.5.3.1 Management Plans

Prior to SGMA, the state of California developed programs for the management of groundwater supply and quality. These programs are managed at various levels of government. The following section provides an overview of these management programs and the elements addressed in each.

[7] https://www.yochadehe.org/tribal-government/environmental-department/water

1.5.3.1.1 Groundwater Management Plans

The Groundwater Management Act (Assembly Bill [AB] 3030) was passed by the state of California in 1992. Guidelines for agencies and districts under this legislation are intended to provide planned and coordinated monitoring, operation, and administration of groundwater basins with the goal of long-term sustainability.

SB 1938 was passed by the state of California in 2002, requiring any public agency seeking state funds for groundwater projects to prepare and implement a groundwater management plan as outlined in AB 3030. In 2009, SB X7-6 established a statewide program for monitoring groundwater levels, available through the CASGEM interface. AB 359, passed in 2011, required a map of recharge areas as part of the local groundwater management plan.

Several YSGA member entities have established groundwater management plans in accordance with the above laws, including the cities of Davis and Woodland, Dunnigan Water District, Reclamation Districts 108, 787, 2035, and Yolo County Flood Control and Water Conservation District (YCFC&WCD).

1.5.3.1.2 Integrated Regional Water Management Plans

The Integrated Regional Water Management Planning Act of 2002 (SB 1672) created the Integrated Regional Water Management (IRWM) Program in 2002. The IRWM Program is geared toward a collaborative effort to identify and implement water management solutions at a regional level that will increase self-reliance; reduce conflict between agencies and users; and manage water to concurrently achieve social, environmental, and economic objectives. By collaboratively developing and implementing projects, participants in the IRWM Program can provide these benefits to meet their water supply and quality goals. The WRA resolved in 2001 to examine existing local water supplies in terms of quantity, quality, and the environment to develop the county's first IRWM Plan. The IRWM Plan describes water supply projects, and outlines comprehensive programs that encompass flood management, project water quality, enhance aquatic and riparian habitat, and improve recreational opportunities.

Prior to receiving any IRWM funding through DWR's IRWM Grant Program, the WRA was required to participate in the Region Acceptance Process, which allowed DWR to evaluate whether the County planning boundary was sufficient for the state's IRWM planning program. DWR requested a larger watershed planning area be created; and as a result, the County territory was merged with portions of Lake, Napa, Solano, and Colusa counties to create the Westside Sacramento Integrated Regional Water Management region. The Westside Sacramento IRWM Plan contains four watersheds within the region: Cache and Putah Creek watersheds and portions of the Sacramento-Stone Corral and Lower Sacramento watersheds. The Westside IRWM Plan was developed in 2013 and updated in 2019 to comply with updated DWR Guidelines and the passing of AB 1249 and SB 985.

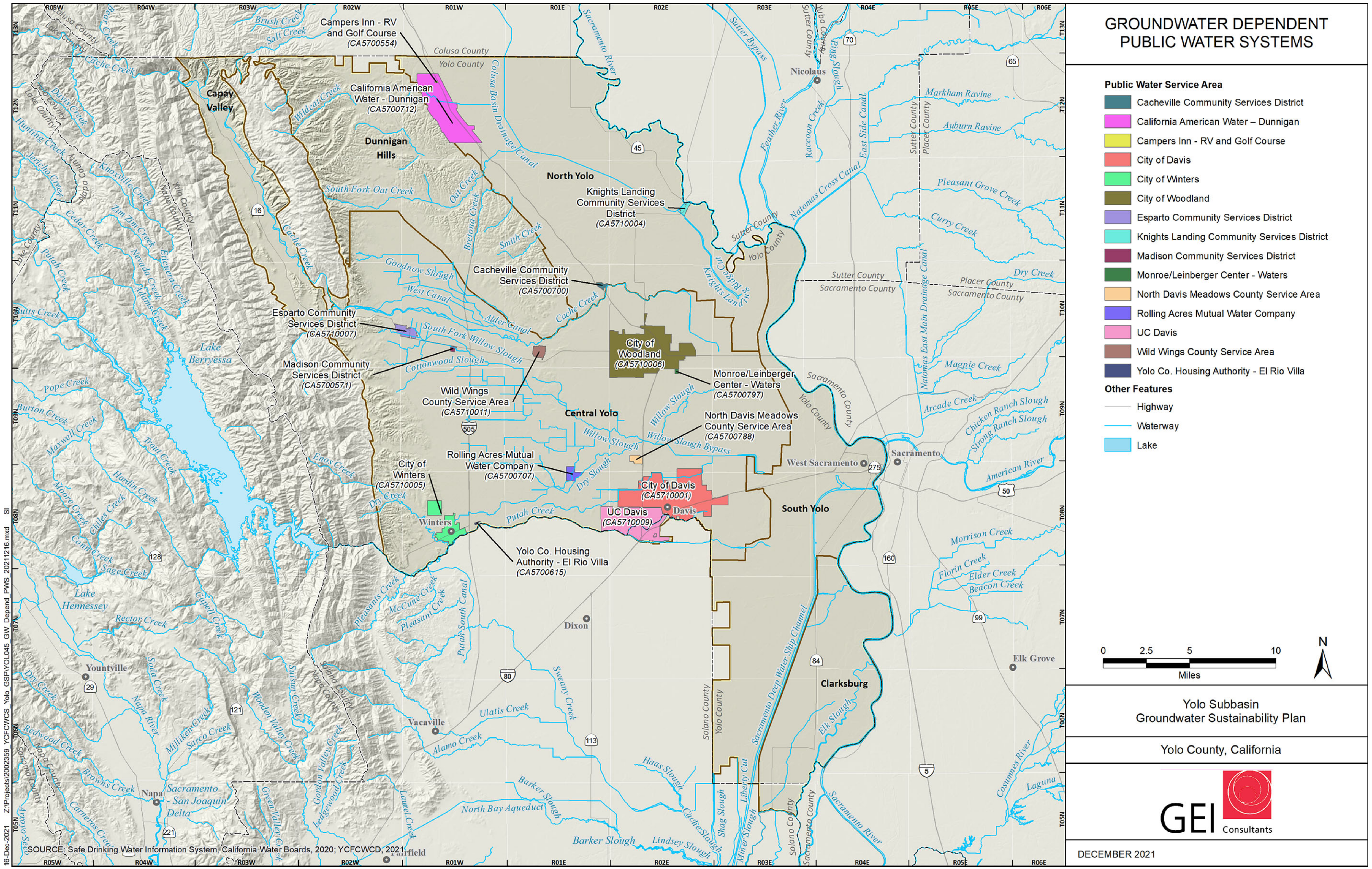

Figure 1-3. Groundwater Dependent Communities.[8]

[8] The city of West Sacramento is not shown on this map since it does not currently use groundwater as a source of supply; however, the City has diversified its water supply portfolio and considers groundwater an essential part of its usable water asset portfolio.

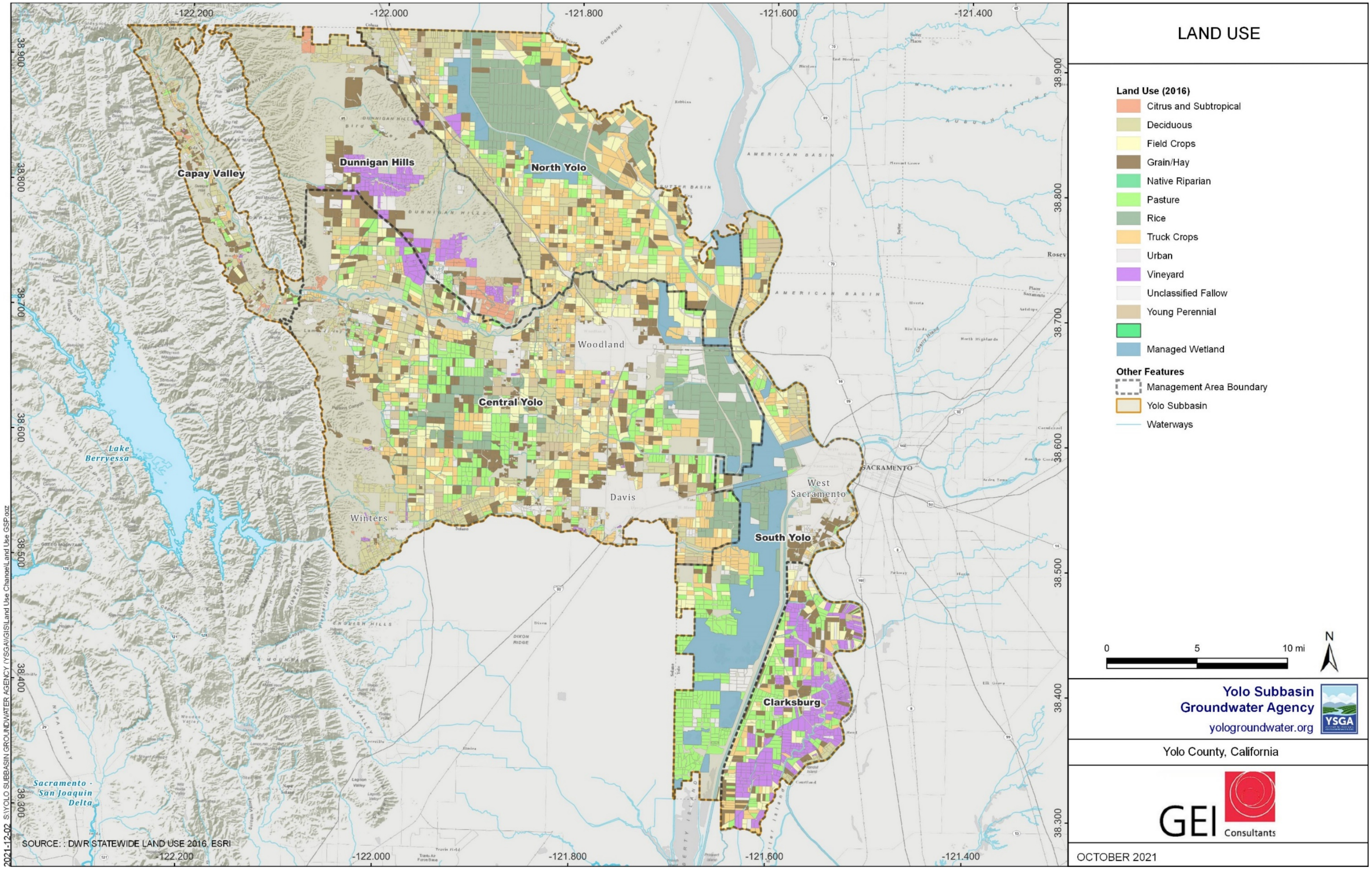

Figure 1-4. Yolo Subbasin Land Use.

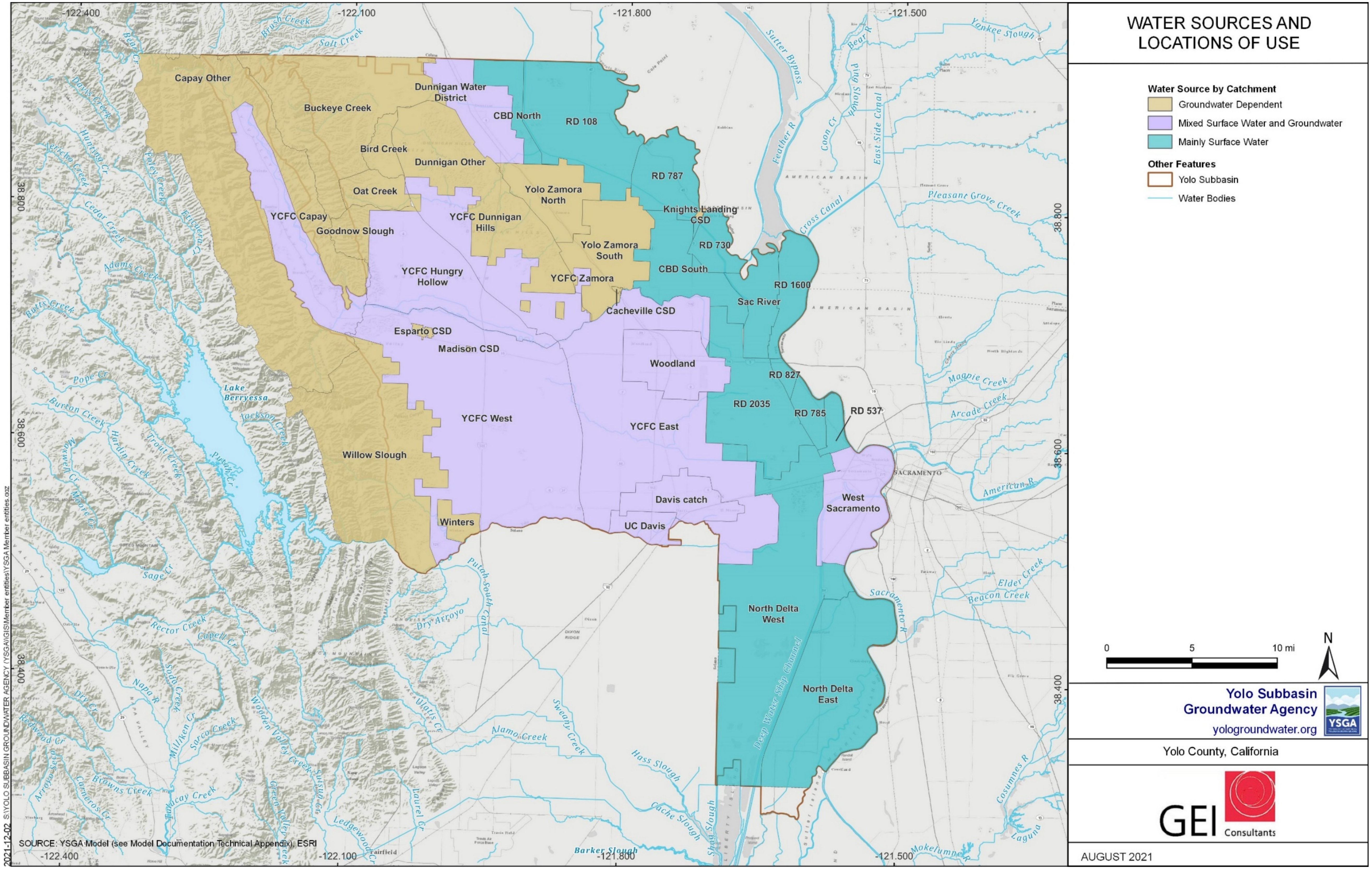

Figure 1-5. Water Sources and Locations of Use for the Yolo Subbasin.

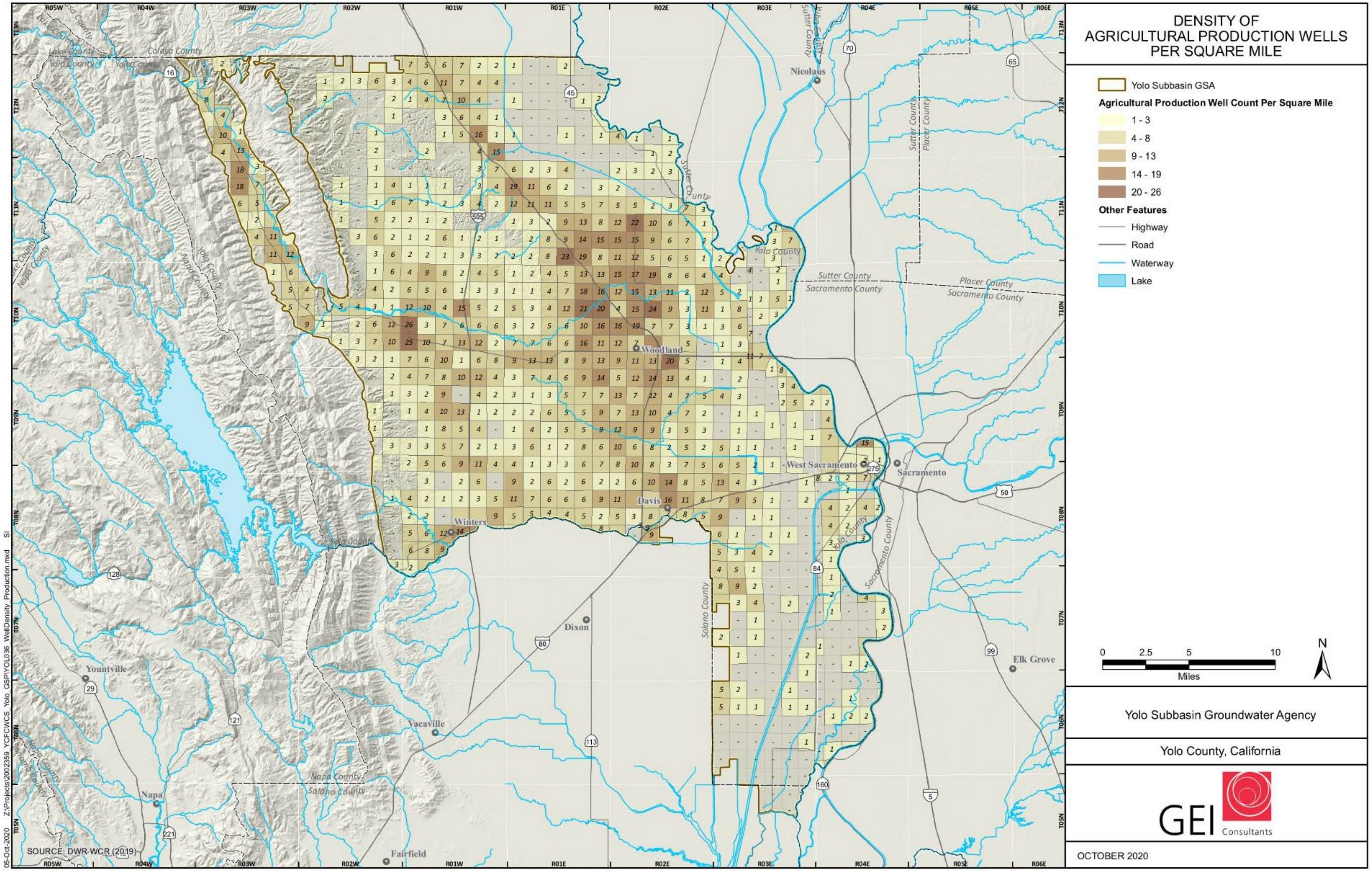

Figure 1-6. Well Density for Production Wells in the Yolo Subbasin.

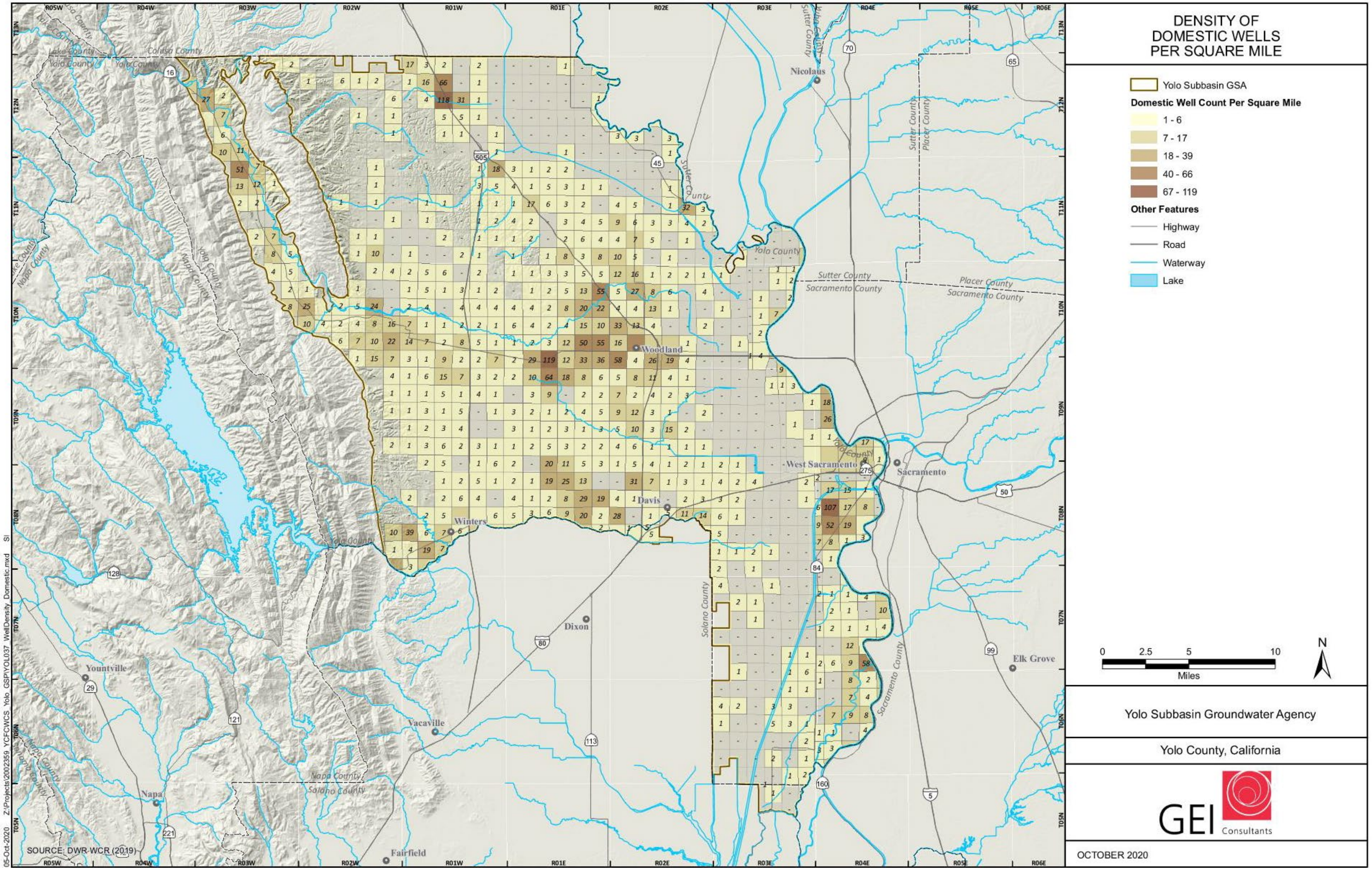

Figure 1-7. Well Density for Domestic Wells in the Yolo Subbasin.

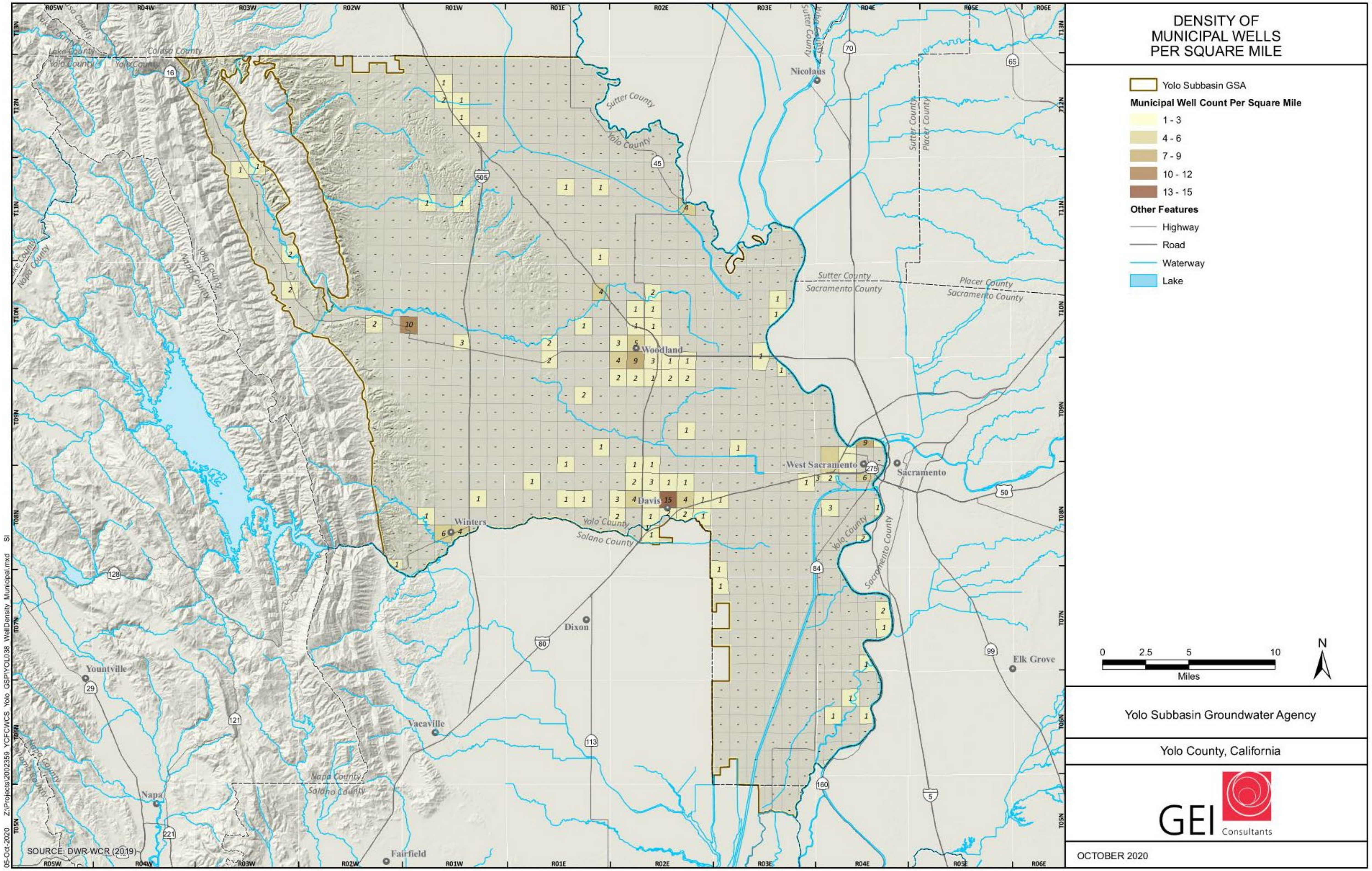

Figure 1-8. Well Density for Municipal Wells in the Yolo Subbasin.

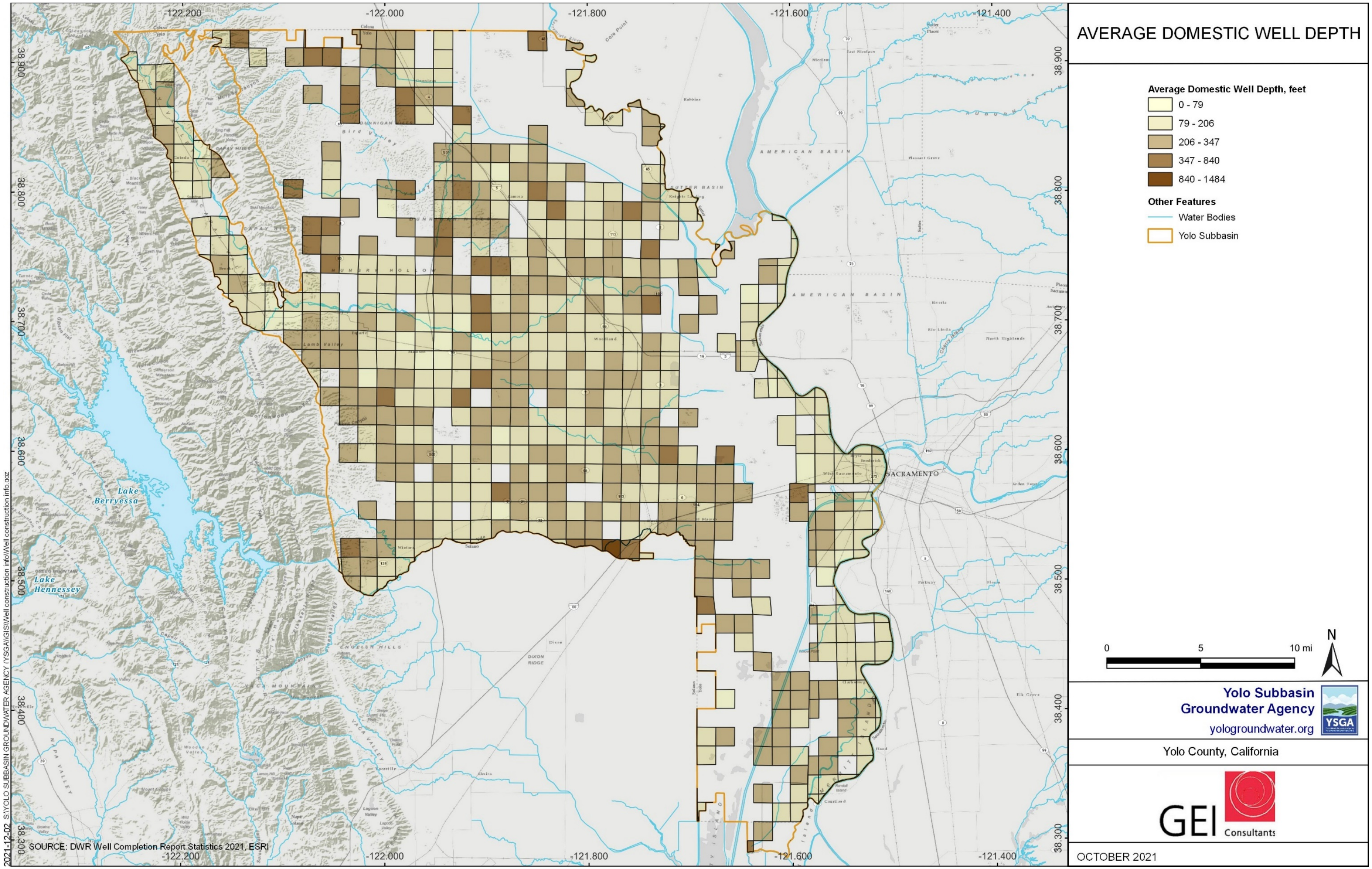

Figure 1-9. Average Domestic Well Depth in the Yolo Subbasin.

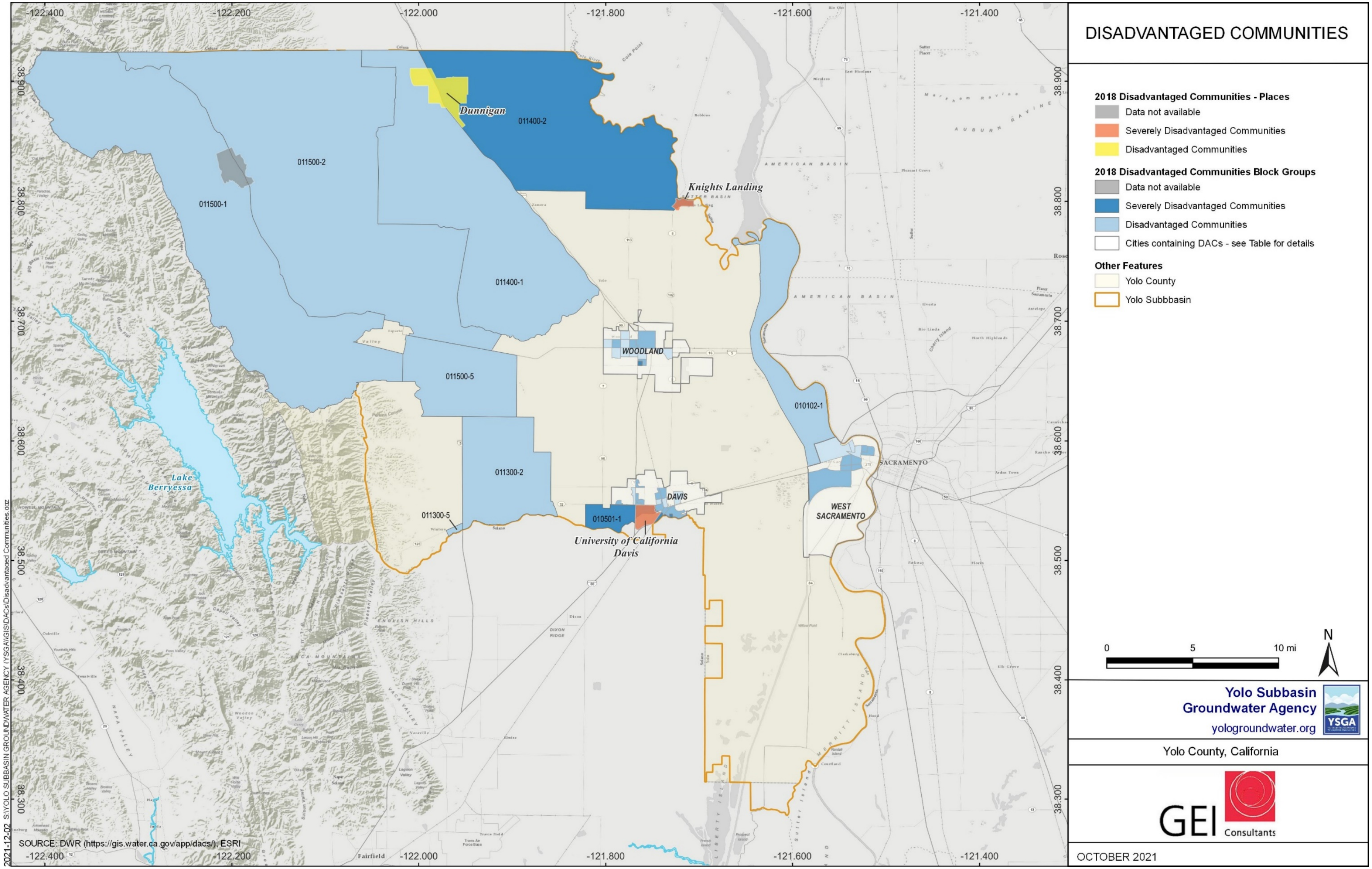

Figure 1-10. Disadvantaged Communities.

Table 1-4. Water Resources Programs Implemented by YSGA Members.

Yolo Subbasin Groundwater Agency	Other	Groundwater Management Plans			Water Management Programs							
	City/County General Plan	AB-3030 Plans	SB 1938 Plans	AB 359 Plans	IRWM Plan	Reclamation Water Management Plan	Irrigated Lands Regulatory Program	Yolo County Storm Water Resources Plan	Urban Water Management Plan	Title 22 Drinking Water Program	Agricultural Water Management Plan	Flood Management Plans
Members Agencies												
City of Davis	X	X			X			X	X	X		X
City of Woodland	X				X			X	X	X		X
City of West Sacramento	X				X	X		X	X	X		X
City of Winters	X				X			X		X		
County of Yolo*	X				X			X				X
Dunnigan Water District		X	X		X	X						
Esparto Community Services District										X		
Madison Community Services District								X		X		
Reclamation District 108		X	X			X					X	X
Reclamation District 150												X
Reclamation District 307												X
Reclamation District 537												X
Reclamation District 730												X
Reclamation District 765												X
Reclamation District 787		X	X	X								X

Yolo Subbasin Groundwater Agency	Other	Groundwater Management Plans			Water Management Programs							
	City/County General Plan	AB-3030 Plans	SB 1938 Plans	AB 359 Plans	IRWM Plan	Reclamation Water Management Plan	Irrigated Lands Regulatory Program	Yolo County Storm Water Resources Plan	Urban Water Management Plan	Title 22 Drinking Water Program	Agricultural Water Management Plan	Flood Management Plans
Members Agencies												
Reclamation District 999												X
Reclamation District 1600												X
Reclamation District 2035		X									X	X
Yocha Dehe Wintun Nation					X			X				
Yolo County Flood Control & Water Conservation District		X	X		X			X			X	X
Affiliated Members												
California American Water, Dunnigan									Upcoming process will include Sacramento District Urban Water Management Plan	X		
Colusa Drain Mutual Water Company										X		
University of California, Davis		X			X			X		X		
Yolo County Farm Bureau							X					
Rumsey Water Users Association												

	Other	Groundwater Management Plans			Water Management Programs							
Yolo Subbasin Groundwater Agency	City/County General Plan	AB-3030 Plans	SB 1938 Plans	AB 359 Plans	IRWM Plan	Reclamation Water Management Plan	Irrigated Lands Regulatory Program	Yolo County Storm Water Resources Plan	Urban Water Management Plan	Title 22 Drinking Water Program	Agricultural Water Management Plan	Flood Management Plans
Members Agencies												
*Yolo County also has a Habitat Conservation, or Creek Restoration, Plan known as the Cache Creek Resources Management Plan: https://www.yolocounty.org/general-government/general-government-departments/county-administrator/county-administrator-divisions/natural-resources/cache-creek-area-plan-ccap/cache-creek-resources-management-plan-ccrmp												

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1.5.3.1.3 Irrigated Lands Regulatory Program

The Sacramento River Watershed General Order (Order R5-2014-0030-R1) was passed by the Regional Water Quality Control Board (Regional Water Board) in 2006. This order requires that any irrigated land having the potential to discharge to surface water or groundwater must comply with the requirements set by the Regional Water Board. Compliance includes membership in a coalition or obtaining coverage through an individual order through the Regional Water Board. Several member agencies in the YSGA jurisdiction are members of the Sacramento Valley Water Quality Coalition (Coalition), which was formed in 2003.

1.5.3.1.4 Groundwater Export Ordinance

The County has a Groundwater Ordinance that came into effect from December 26, 1996 (Title 10, Chapter 7 of the County Code of Ordinances[9]). In the Ordinance, the County Board of Supervisors recognize the importance of groundwater to the County and the public benefit it provides. The Ordinance reviews regulation of the extraction and exportation of groundwater from the County; describes the permit process for exporting water outside of the County and drilling a new groundwater well; and explains the County's inspection process and civil penalty violations. The County's export permit process is currently very streamlined and processed in the County Administrator's Office.

1.5.3.1.5 Other County Groundwater Programs

The County offers a Groundwater Assistance Program during drought emergencies to assist the County property owners affected by a dry household well; the County provides water supplies to property owners while they wait for the drilling of a new well. During the 2021 drought, the YSGA coordinated closely with the Yolo County Office of Emergency Services to assist with depth to water measurements and ensure water deliveries to rural residences that are experiencing dry wells.

As discussed in the Ordinance, a permit is required to be submitted to the County prior to drilling a new well. The County's Division of Environmental Health staff respond to well drilling permit applications within 10 business days and the review process consists of complying with state and County well standards (*see* **Section 1.5.3.3**). The YSGA is currently coordinating closely with Division of Environmental Health to improve the data collection efforts as part of the well drilling permit application. The YSGA and County intend to use this data to make better land use and water resources decisions in the future.

The YSGA and County are currently developing a Communications Plan to provide the public with details on individual entity jurisdiction and responsibility related to groundwater, and technical and financial resources that are available.

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[9] https://codelibrary.amlegal.com/codes/yolocounty/latest/yolo/0-0-0-18677#JD_Title10Chapter7

1.5.3.1.6 Title 22 Drinking Water Program

The Division of Drinking Water (DDW) regulates public drinking water supplies, which include municipal and state small water systems. There are currently 83 public water systems that are identified through the Groundwater Ambient Monitoring and Assessment Program (GAMA) and State Drinking Water Information System (SDWIS). These systems are required to comply with the standards outlined in Title 22 of the California Code of Regulations (CCR).

1.5.3.1.7 Human Right to Water

Assembly Bill 685 was signed on September 25, 2012. AB 685 made California the first state in the nation to pass legislation recognizing the human right to water. In the Water Code, as Section 106.3, the state recognizes that, "…every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." The human right to water is extended to all Californians. The State Water Resources Control Board (State Water Board) has also recognized the human right to water as a core value.

1.5.3.2 Conjunctive Use Programs

Historically, in the County, there have been many studies and reports completed considering the feasibility of a conjunctive water use project. Many of the YSGA members have established and maintained conjunctive use programs for the sustainable management of water resources in the Subbasin. Conjunctive use refers to the coordinated use of surface water and groundwater to maximize efficient use of available resources. The primary considerations for successfully implementing a conjunctive use program include examining: 1) availability and storage, 2) access and distribution, 3) quality and treatment, 4) legal rights, 5) costs, and 6) reliability and local control (Jenkins 1992).

Since the formation of the YCFC&WCD, conjunctive water use has been a fundamental concept and program throughout the greater County region. Groundwater monitoring and reporting efforts have allowed for YCFC&WCD and other water resource entities to understand more about the success of groundwater recharge activities and efficient use of water supplies, or optimal conjunctive use.

A few notable conjunctive use programs exist within the Subbasin and are described below.

1.5.3.2.1 YCFC&WCD Conjunctive Use Programs

The YCFC&WCD delivers surface water from Clear Lake and Indian Valley Reservoirs to farmers in the County. The YCFC&WCD's Capay Diversion Dam allows for surface water to be distributed throughout the YCFC&WCD's 160-mile unlined canal system. Approximately, 25 percent of surface water diversions at Capay Dam are naturally recharged throughout the earthen canal system every irrigation season. On average, approximately 40,000 acre-feet of natural recharge to the aquifer occurs every year. During wet years, excess water traveling throughout the Subbasin *via* sloughs, irrigation canals, farmer drains, and Cache Creek is captured to recover lost groundwater in the aquifer by either pumping water back into the aquifer or providing additional area for the water to permeate down into the aquifer. Since development of this project, YCFC&WCD has focused efforts collecting data through their Foundational Actions: Flow Monitoring Network, Monitoring Program, and Groundwater Surface Modeling; these programs facilitate policy development and management practices. These efforts ensure reliable water supplies, which is essential to the economic viability of the region.

The YCFC&WCD has participated in the State Water Board's temporary permitting program for diverting excess storm flows to recharge the groundwater. On November 13, 2015, the Governor signed Executive Order B-36-15, which directed State Water Board staff to prioritize temporary water rights permits to accelerate approvals for projects that enhance the ability of local agencies to capture high precipitation events for local storage or recharge and later beneficial uses. For the past 5 years, the YCFC&WCD has applied for a temporary 180-day water permit to divert excess storm flows *via* the unlined canal system. The YCFC&WCD has successfully diverted storm flows in 3 of the 5 years for a total of 21,000 acre-feet groundwater replenished. The YCFC&WCD anticipates participating in the temporary permit program in the winter/spring of 2021 and in the near future, receiving a 5-year and long-term permit for groundwater recharge activities. Excess storm flows from Cache Creek are a huge asset in the conjunctive management options available to the YCFC&WCD and YSGA, and as long as permitting constraints are not an obstacle in the future, these excess storm flows will continue to provide a public benefit to the region. Additionally, percolation basins receiving storm runoff exist in the Yolo Subbasin, notably in the cities of Davis and Woodland.

In 2008, the YCFC&WCD implemented and managed this program to remove capacity constraints and provide delivery flexibility to farmers. This program is an incentive-based conjunctive use program where well water is pumped into canals to reduce effects of upstream capacity constraints. The intent of this program is to improve water delivery flexibility to minimize the waiting list period for farms during peak demand periods. By participating in this program, farmers who enroll wells will receive priority for water deliveries and a standard YCFC&WCD rate for all water delivered, including groundwater. Additionally, the YCFC&WCD now owns one agricultural production well that can also be used to assist with any capacity constraints within the YCFC&WCD customer base or service area.

1.5.3.2.2 Davis-Woodland Water Supply Project

The Woodland-Davis Clean Water Agency completed the Davis-Woodland Water Supply Project in July 2016. This project diverts up to 45,000 acre-feet of water per year from the Sacramento River to serve as drinking water for the cities of Woodland, Davis, and UC Davis. When water diversions are limited during summer or other dry periods, the city of Davis uses groundwater when demand for water cannot be met with surface water supplies alone. Additionally, the city of Woodland relies on aquifer storage recovery wells to meet peak demand. By conjunctively managing water from the Sacramento River and existing groundwater resources, these three entities can provide safe drinking water to community residents.

1.5.3.3 Well Permitting Process

The County's Department of Community Services Environmental Health Division (YCEH) has an established well permitting program that requires final approval prior to final implementation for water use. A permit must be acquired prior to the installation, modification, or abandonment of wells. Additionally, a permit is required for test holes, cathodic protection wells, geothermal heat exchange wells, and monitoring wells. Construction of wells are required to follow guidance of DWR well standards and all well contractors are required to submit a WCR to DWR.

Before implementation for water use, the well must meet the minimum construction standards per current California Well Standards and Yolo County Well Ordinance. These standards will include an adequate annular seal and setback requirements. In addition, water quality analysis will be required for domestic wells, state small water systems, Cal Code Water Systems, and public water systems prior to use. For abandoned wells, a permit must be acquired, and proper abandonment procedures must be followed. Additional well abandonment procedures are included in the following section.

The YSGA is currently working with the County to establish a well permit notification process to enhance information management as part of the groundwater management program.

1.5.3.4 Plan Elements from CWC Section 10727.4

Per Section 354.8(g) of the GSP Regulations, additional plan elements pertaining to CWC Section 10727.4 shall be included in order to comply with SGMA. This section provides a general overview of plan elements with reference to sections included throughout this GSP for further details. Plan elements from CWC Section 10727.4 include the following:

A. Control of Saline Water Intrusion
Seawater intrusion is not considered an issue in the Subbasin since the Subbasin is located approximately 50 miles from the coastal region. *See* **Section 2.2.3 – Seawater Intrusion for additional** details.

B. Wellhead Protection Areas
Permits are issued by YCEH for the construction, reconstruction, and destruction of water wells. This program includes overview of and guidance for wellhead protection.

YCEH regulates setback distances to maintain a zone of protection around water wells and preserve water quality. Activities such as animal enclosures, hazardous materials storage, septic tanks, and sewer lines must be located a minimum distance away from the wellhead. Setback distances vary from 50 to 150 feet based on the activity impact level and well type[10].

C. Recharge Areas
California Resource Lab at UC Davis developed a Soil Agricultural Groundwater Banking Index (SAGBI) for groundwater recharge on agricultural land (O'Geen et.al. 2015). As shown in

[10] https://www.yolocounty.org/home/showdocument?id=35584

Figure 1-11, approximately 20 percent of the subbasin has moderately good to excellent rating whereas approximately 63 percent of the area has poor to very poor rating.

D. Migration of Contaminated Groundwater

As further discussed in **Section 2.2.4 – Groundwater Quality**, groundwater quality in the Subbasin varies both spatially and with depth. As depth increases, groundwater quality generally increases.

E. Well Abandonment and Well Destruction Program

The YCEH has established and maintains a Water Well Abandonment Program in accordance with current California Well Standards and Yolo County Well Ordinance. An abandoned well is a well that is considered permanently inactive if it has not been in use for 1 year, unless intention of use is demonstrated by the owner. In order to abandon a well, a permit must be acquired through the County. The County's Well Abandonment Program provides guidance and requirements for destroying wells, which include the following elements:

- Preliminary work
- Filling and sealing conditions
- Placement of material
- Descriptions of sealing and fill materials
- Additional requirements for wells in urban areas
- Temporary cover

If intent of use is provided, the owner must maintain the inactive well in accordance with Section 115700 of the California Health and Safety Code. In addition to providing instruction for proper covering of the well, the well shall, "…not allow impairment of the quality of water within the well and groundwater encountered by the well" (Section 115700).

Unfortunately, there are various constraints involved in successfully implementing the well abandonment and well destruction program, such as financial, managerial, and technical complications. The YSGA intends to work with YCEH on the implementation of this program and will investigate state funding opportunities to assist with the financial component.

F. Replenishment of Groundwater Extractions

As previously mentioned, there are multiple conjunctive use programs ongoing in the Subbasin to efficiently manage groundwater replenishment. *See* **Section 1.5.4. – Existing Plans in Plan Area** for additional details. In addition to these efforts, the YSGA will work with the member agencies and affiliated members to implement additional projects to bring more water into the Subbasin to maintain sustainable groundwater.

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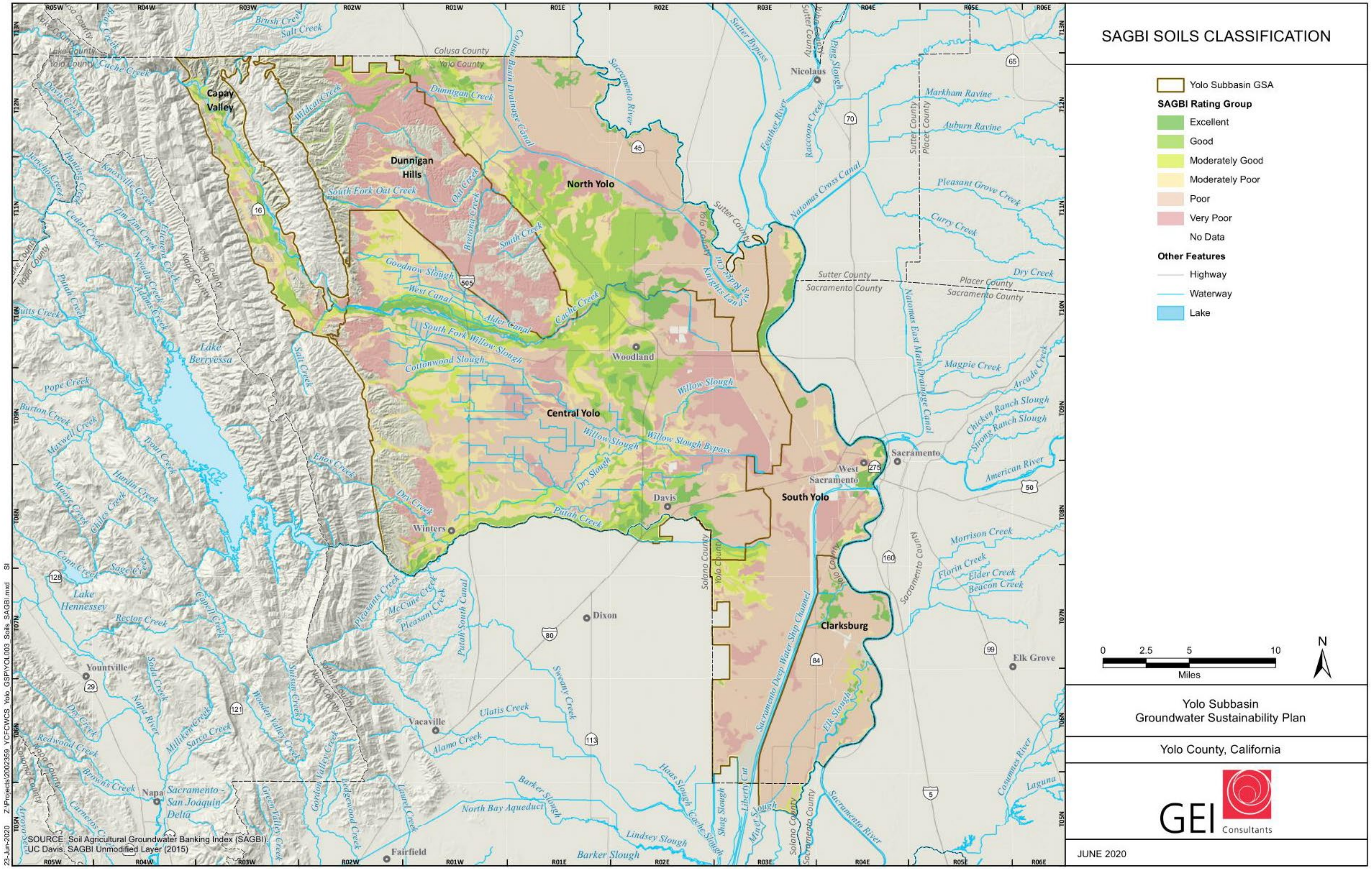

Figure 1-11. Soil Agricultural Groundwater Banking Index for Yolo Subbasin.

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G. Conjunctive Use or Underground Storage

As previously discussed in **Section 1.5.4** – Existing Plans in the Plan Area, there are many ongoing conjunctive use programs in the YSGA jurisdictional area. Efforts throughout implementation of SGMA will focus on expanding and capitalizing on those programs to ensure groundwater sustainability in the Subbasin.

H. Well Construction Policies

Policies on well construction are provided by the YCEH. All wells are to be constructed according to California Well Standards and County Ordinance. Before a well can be implemented for use, a final inspection is required.

Specific construction requirements are provided by the County which outline that a well must meet the required standards before final approval by the YCEH. As outlined in the YCEH "Water Well Requirements for Building Projects,[11]" construction requirements include the following:

- Adequate annual seal (i.e., sanitary seal) must be demonstrated
- Water quality analysis required (e.g., total coliform/E. coli and nitrate)
- Aboveground features must meet current standards

I. Efficient Water Management Practices

As previously discussed, conjunctive use and land use planning is an integral component for sustainably managing water resources in the Subbasin. Many land use planning activities such as those established under groundwater management plans, the County IRWM Plan, and conjunctive use programs have been developed and implemented to support efficient water management practices. This GSP has accounted for and will build off such activities and further implement such practices to support the sustainable management of groundwater in the Subbasin.

J. Relationships with State and Federal Regulatory Agencies

Many of the member agencies of the YSGA hold state and federal water contracts as well as work closely with DWR on projects and management practices. For example, the previously discussed County IRWM Plan has been developed and implemented with oversight from DWR to support water supply and quality goals in the region. Additionally, multiple members of the YSGA are Reclamation Districts formed by the State Lands Commission to provide drainage, levee maintenance, or irrigation services. These districts are formed to optimize water use practices in the region by reclaiming and repurposing land for water use efficiency purposes.

K. Land Use Planning and Coordination Efforts

As previously discussed, the Subbasin contains various land use plans, which were accounted for throughout the development of this GSP. As an entity, the YSGA intends to coordinate closely with

[11] https://www.yolocounty.org/home/showpublisheddocument/41443/636772081850800000

the cities, County, and the Yolo Habitat Conservancy to ensure land use decision-making is appropriately considering groundwater sustainability. The County and the cities are members of the YSGA JPA, which will facilitate close coordination on a frequent basis, and, as part of long-term planning strategies and project development, additional engineering analyses will be completed to better plan for land use decisions. For additional details, *see* **Section 1.5.4 – Existing Plans in Plan Area.**

During GSP development and throughout the 2021 drought, the YSGA provided groundwater conditions and GSP updates to the County Board of Supervisors and staff. Additionally, the YSGA is considering ways to integrate, streamline, and enhance groundwater data collection efforts as part of the County well permitting process and the YSGA's groundwater monitoring program. In October 2021, the YSGA Board appointed the ad hoc Drought Contingency Planning Committee to advise the Directors on improved coordination with County Board of Supervisors for management of groundwater resources during drought. The YSGA intends to proactively engage and work with the County to ensure groundwater sustainability in the County. Impacts on Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are present in the Yolo Subbasin. An identification and characterization of GDEs is included in **Section 2.2.7 – Groundwater Dependent Ecosystems**. GDEs were considered in the establishment of sustainable management criteria in the Yolo Subbasin. Sustainable management criteria and the rationale for selection are described in **Section 2.2.7**. Projects relating to GDEs are described in the **Section 5.0 – Proposed Actions, Description, and Timeline to Address Data Gaps**.

1.5.4 Existing Plans in Plan Area

Within the YSGA jurisdictional boundaries, there are multiple plans (e.g., the Yolo County General Plan) that provide goals, policies, and implementation measures that are complimentary to sustainable groundwater management set forth in this GSP relative to future land use development and conservation. Below is a list of existing general plans within the Subbasin. The agencies that have developed and adopted these general plans have retained their jurisdiction over land use and zoning as well as the elements included in their respective plans.

2030 Countywide General Plan – This plan was adopted in 2009 by the County Board of Supervisors. This document provides a comprehensive overview of long-term policies for the physical development of the unincorporated areas of the county. Plan goals are geared toward long-term sustainability that focuses on the development of successful agriculture; preserving open space and natural areas; accounting for community values and safety; and developing a sustainable economy[12].

City of Davis General Plan – This plan was adopted in May 2001 and has been amended through January 2007. Development of this plan was focused on preserving the economic and social

[12] Yolo County General Plan: https://www.yolocounty.org/government/general-government-departments/county-administrator/general-plan/adopted-general-plan

wellbeing of the community. A few goals of the plan include preserving quality of life; natural resource protection and restoration; and agriculture[13].

City of West Sacramento 2035 General Plan – This plan was adopted on November 1, 2016 by city of West Sacramento's City Council. Through 2035, this plan will steer the development of land use, transportation improvements, new parks and open spaces, and other public infrastructure. The city of West Sacramento adopted the 2021-2029 Housing Element Update on July 14, 2021[14].

City of Winters General Plan – This plan was originally adopted on May 19, 1992 and has been amended since to meet state and local needs. The City Council passed a resolution to extend the 1992 plan's planning horizon from 2010 to 2018; and staff is currently working on a plan update[15].

Implementation of this GSP will help to ensure the sustainable management of groundwater in the Subbasin. Existing policies will continue to be implemented and are expected to be compatible with strategies under this GSP to achieve groundwater sustainability. While existing general plans in the Subbasin are concurrently updated, it is assumed that future planning will account for this GSP and its intent to manage groundwater effectively to maintain the social and economic viability of the Subbasin.

The Subbasin accounts for a diverse set of land use planning that varies between each area, as member agencies implement policies to serve their communities. Since implementation of land use plans outside of the Subbasin could potentially affect the ability of the YSGA to achieve sustainable groundwater management, future activities of the YSGA will include increased coordination with neighboring land use planning to assess overlaps and impacts, if any.

1.5.5 Notice and Communication

Per Section 354.10 of the GSP Regulations, the following sections discuss the notice and communication processes conducted by YSGA with other agencies and interested parties. A list of public outreach meetings and workshops for the YSGA's beneficial water uses and users and other interested parties is provided, along with a brief overview of their respective purposes. All agencies/interested parties listed above, in **Section 1.5.1 – Summary of Jurisdictional Areas and Other Features**, were included in the notice and communication process. The YSGA also prepared a Communications and Engagement Plan that provided guidance to the communication and outreach effort to stakeholders in the Subbasin, which is provided in **Appendix B – Communication and Engagement Plan**.

[13] City of Davis General Plan: https://www.cityofdavis.org/city-hall/community-development-and-sustainability/planning-and-zoning/general-plan

[14] City of West Sacramento General Plan: https://www.cityofwestsacramento.org/government/departments/community-development/planning-division/general-plan-2035

[15] City of Winters General Plan: http://www.cityofwinters.org/city-of-winters-general-plan/

1.5.5.1 Beneficial Uses and Users in the Subbasin

As required by Section 354.10(a) of the GSP Regulations, beneficial use and users in the Subbasin have been identified. The beneficial uses of groundwater in the Plan Area, consistent with the uses defined in DWR Bulletin 118, are:

- Agricultural
- Municipal and Industrial
- Domestic
- Environmental

Users of groundwater have been identified as landowners, agricultural operations (including farms, dairies, and food processors), rural residents, managed and natural wetlands, groundwater dependent ecosystems, commercial and industrial users, incorporated cities and communities, unincorporated communities, and state facilities. These beneficial users of groundwater have been identified as stakeholders for public outreach activities in the Subbasin.

1.5.5.2 Communication

As previously mentioned, the YSGA was formed by a JPA for development and implementation of SGMA. The JPA is written to provide open and transparent communication to all beneficial users; thus, the YSGA's decision-making process consists of several public meeting opportunities, which include the following:

- YSGA Board – Meetings are held five times a year: January, March, June, September, and November. These meetings are meant to update the Board on YSGA activities. All meetings are open to the public and properly noticed in accordance with the Brown Act.
- YSGA Executive Committee –Meets at least twice per quarter. These meetings are a forum to provide directions to the Executive Officer of the YSGA, address administrative issues, and help prepare and review Board agendas. All meetings are open to the public and properly noticed in accordance with the Brown Act.
- YSGA Working Group –Meetings are held once every quarter. As mentioned previously, the Working Group was established to guide the development and implementation process of this GSP. Through collaboration and feedback from stakeholders, the Working Group was an effective forum for vetting GSP-related issues and achieving consensus. The Working Group worked to develop recommendations and provide guidance to the Board for this GSP as well as other matters related to the efficient management of the YSGA. All meetings were open to the public and properly noticed in accordance with the Brown Act.
- YSGA Technical Advisory Group –Meetings were held as needed throughout the development of this GSP. These meetings were used to review the representative well selection process, to evaluate the analysis or process for developing the sustainable

management criteria, and to advise future land use projections for developing future scenarios.

- YSGA Public Meetings – Meetings were held as needed throughout the development of this GSP. All meetings were open to the public and properly noticed in accordance with the Brown Act.

1.5.5.2.1 Public Engagement Opportunities

In addition to routinely scheduled YSGA meetings, further outreach and engagement opportunities were conducted, which included special workshops and outreach meetings. Details of all public engagement opportunities are included in the following section.

1.5.5.3 Informing Public and GSP Development Progress

During the formation of the YSGA, a Board was created consisting of Members and Affiliated Parties (as listed in **Section 1.4.1 – GSA Formation**). Throughout the development of this GSP, public meetings were held to coordinate and engage with the beneficial users within the Subbasin boundaries regarding the planning and implementation of SGMA. **Table 1-5** provides a list of public meetings held by the YSGA.

Table 1-5. Public Meetings and Workshops

Date	Meeting	Purpose
June 19, 2017	YSGA Board of Directors	General board administrative information and update on GSP development
July 25, 2017	Yolo Land Trust SGMA presentation	Public forum on overview of YSGA and update on YSGA activities including GSP development
September 11, 2017	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of management area (MA) workshops
September 18, 2017	YSGA Board of Directors	General board administrative information and update on GSP development
September 26, 2017	Woodland Chamber of Commerce Water Committee Meeting	Public forum on overview of YSGA and update on YSGA activities including GSP development
October 16, 2017	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
October 30, 2017	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
November 13, 2017	YSGA Board of Directors	General board administrative information and update on GSP development
December 14, 2017	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
January 18, 2018	Yolo County Farm Bureau Annual Meeting	Public forum on overview of YSGA and update on YSGA activities including GSP development
January 25, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
February 7, 2018	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
March 7, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development

Date	Meeting	Purpose
March 19, 2018	YSGA Board of Directors	General board administrative information and update on GSP development
April 26, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
May 3, 2018	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
May 29, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
June 18, 2018	YSGA Board of Directors	General board administrative information and update on GSP development
August 2, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
September 17, 2018	YSGA Board of Directors	General board administrative information and update on GSP development
October 23, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
December 11, 2018	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
January 14, 2019	YSGA Board of Directors	General board administrative information and update on GSP development
February 27, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
March 30, 2019	Winters Rotary Club Meeting	Public forum on overview of YSGA and update on YSGA activities including GSP development
April 3, 2019	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
April 3, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
April 22, 2019	YSGA Board of Directors	General board administrative information and update on GSP development
June 3, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
June 17, 2019	YSGA Board of Directors	General board administrative information and update on GSP development
July 16, 2019	Yolo County Board of Supervisors' Strategic Workshop	Public forum on overview of YSGA and update on YSGA activities including GSP development
July 22, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
August 26, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
September 5, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
September 16, 2019	YSGA Board of Directors	General board administrative information and update on GSP development
October 15, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
November 7, 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
December 10 2019	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development

Date	Meeting	Purpose
February 18, 2020	YSGA Executive Committee	Public forum on overview of YSGA and update on YSGA activities including GSP development
March 9, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
March 16, 2020	YSGA Board of Directors	General board administrative information and update on GSP development
April 13, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
May 6, 2020	YSGA Working Group	Update from DWR and overview of GSP Development including groundwater monitoring, water budgets, and sustainable management criteria development
May 18, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
June 15, 2020	YSGA Board of Directors	General board administrative information and update on GSP development
July 8, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
August 10, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
September 10, 2020	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
September 14, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
September 21, 2020	YSGA Board of Directors	General board administrative information and update on GSP development
October 6, 2020	Capay Valley Management Area (MA) Working Session	Public forum opportunity discussing the YSGA and GSP development
October 28, 2020	North Yolo MA Working Session	Public forum opportunity discussing the YSGA and GSP development
October 29, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
November 4, 2020	Clarksburg MA Working Session	Public forum opportunity discussing the YSGA and GSP development
November 13, 2020	South Yolo MA Working Session	Public forum opportunity discussing the YSGA and GSP development
December 4, 2020	Central Yolo MA Working Session	Public forum opportunity discussing the YSGA and GSP development
November 16, 2020	YSGA Board of Directors	General board administrative information and update on GSP development
December 16, 2020	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
December 18, 2020	GSP Update to Farmers	Public Update on GSP development presented to local farmers
January 11, 2021	YSGA Board of Directors	General board administrative information and update on GSP development
February 10, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
February 16, 2021	Capay Valley Community SGMA Workshop	Community workshop to discuss GSP development with Capay Valley constituents

Date	Meeting	Purpose
March 9, 2021	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
March 15, 2021	YSGA Board of Directors	General board administrative information and update on GSP development
March 28, 2021	Rumsey Water Users Association Annual Boaord Meeting	Public forum opportunity and update on YSGA activities including GSP development
April 13, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
April 19, 2021	YSGA Working Group	Update on GSP development including groundwater monitoring, sustainable management criteria, and scheduling of MA workshops
May 11, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
June 7, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
June 9, 2021	GSP Public Meeting – Projects in Capay Valley	Public forum discussing projects and management actions with Capay Valley residents
June 21, 2021	YSGA Board of Directors	General board administrative information and update on GSP development
July 26, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
July 27, 2021	Yolo Land Trust Board of Directors	Public forum discussing areas of special concern and GSP development
July 29, 2021	YSGA Working Group	Update on GSP development including Sustainable Management Criteria and Projects and Management Actions
August 10, 2021	Yolo County Farm Bureau Board of Directors Meeting	Public forum discussing YSGA activities including GSP development
August 16, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
August 25, 2021	YSGA GSP Public Workshop	Update to the general public on progress to date with groundwater sustainability plan implementation
September 1, 2021	YSGA GSP Public Workshop	Update to the general public on progress to date with groundwater sustainability plan implementation
September 2, 2021	YSGA Working Group	Update on GSP development including Sustainable Management Criteria and Projects and Management Actions
September 8, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
September 9, 2021	Yolo County Planning Commission	Public forum opportunity and update on YSGA activities including GSP development
September 20, 2021	YSGA Board of Directors	General board administrative information and update on GSP development
September 22, 2021	Yolo RCD Board of Directors	Public forum discussing YSGA activities including GSP development
October 7, 2021	GSP Public Meeting – Hungry Hollow Area	Public forum discussing GSP development and projects and management actions with Hungry Hollow Area residents
October 11, 2021	Special YSGA Board of Directors	Consideration of forming YSGA Ad Hoc Drought Contingency Planning Committee

Date	Meeting	Purpose
October 18, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
October 18, 2021	Winters Natural Resource Commission	Public forum opportunity and update on YSGA activities including GSP development
November 8, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
November 10, 2021	Lower Putah Creek Coordinating Committee	Public forum discussing GSP development and Putah Creek-related groundwater monitoring
November 15, 2021	YSGA Board of Directors	General board administrative information and update on GSP development
November 16, 2021	Yolo County Farm Bureau Ag Roundtable	Public forum discussing GSP development
December 15, 2021	YSGA Executive Committee	Public forum opportunity and update on YSGA activities including GSP development
January 10, 2022	YSGA Board of Directors	General board administrative information and adoption of GSP

All applicable meeting materials can be found on the meeting section of the governance portal on the YSGA's website, which is provided in **Section 1.4 – Agency Information**. This portal is used to communicate all information on YSGA's outreach and communication as well as the development and implementation of SGMA. This platform allows interested parties to register to receive updates on upcoming events, including board and working group meetings, to stay informed of YSGA activities and GSP implementation.

1.5.5.4 Public Comments Received

In addition to the comments received during the outreach process identified in **Table 1-5**, the YSGA provided for a formal comment period, between August 27, 2021, to October 27, 2021. The YSGA received comments through mail and email. The YSGA received a total of 280 comments addressing some aspect of this GSP. Those comments are included in **Appendix C – Public Comments Received and YSGA Responses**.

1.6 GSP Organization

The YSGA GSP provides SGMA coverage for all Subbasin lands covered in the MAs. This GSP has been developed in compliance with SGMA law and, as such, is organized as follows:

1. Introduction
2. Basin Setting
3. Sustainable Management Criteria
4. Monitoring Network
5. Projects and Management Actions
6. References
7. Appendices

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2.0 Basin Setting

The Basin setting section is made up of the hydrogeologic conceptual model; the current and historical groundwater conditions; the water budget for the Subbasin; and the description of the six Subbasin MAs. This section provides the local and regional details as context for defining reasonable sustainable management criteria and projects and management actions for the Yolo Subbasin.

2.1 Hydrogeologic Conceptual Model

2.1.1 Basin Regional Setting

The Subbasin is located in California, USA, in the southwestern side of the Sacramento Valley Groundwater Basin and is roughly 27 miles wide from west to east and up to 45 miles long from north to south (**Figure 2-1**). The western portion of the Subbasin is bounded on the west by the uplifted, mountainous coast range consisting of marine sedimentary rocks, while the eastern boundary is the Sacramento River. The middle of the basin is mostly alluvium, with relatively flat alluvial fans from the Cache Creek and Putah Creek drainages, with other areas of alluvium in the north from smaller coast range drainages. The Capay Hills are in the northwestern corner of the Subbasin and are an "inselberg" or island of marine rocks that are excluded from the Subbasin. Between the Coast Range and the Capay Hills is situated the Capay Valley, a complex mix of alluvium and hardrock aquifers with Cache Creek running through it.

2.1.2 Subbasin Extent and Boundaries

The Yolo Subbasin boundary was updated and subsequently approved by DWR in 2016 and 2018 through jurisdictional basin boundary modifications so that the Subbasin boundary more closely matched the political administrative boundaries of the County. The 2016 modification consisted of consolidation of the Capay Valley (5-21.68) and portions of the Colusa (5-21-52), Yolo (5-21.67), and Solano (5-21.66) subbasins that lie within the County. The 2018 modification consisted of extending the southeastern boundary to the Sacramento River to include several reclamation districts. The 2018 modifications also included boundary adjustments along the County line.

2.1.2.1 Lateral Subbasin Boundaries

The Yolo Subbasin is adjacent to five other subbasins within the Sacramento Valley Basin, as discussed below and shown in **Figure 2-1**. YSGA coordinated with neighboring subbasins to collaborate and share data regarding modeled groundwater flows across basin boundaries, sustainable management criteria, minimum thresholds, measurable objectives, interconnected surface water bodies, and groundwater dependent ecosystems. **Appendix D** contains letters from neighboring subbasins discussing inter-basin coordination efforts.

2.1.2.1.1 Adjacent Subbasins

Colusa Subbasin

The Colusa Subbasin is located north of Yolo Subbasin. These subbasins are separated by the boundary between Yolo and Colusa counties, except for a small area (2.3 square miles) of the Colusa County Water District that extends south of the Yolo-Colusa county line, west of Interstate 5 (I-5).

Sutter Subbasin

The Sutter Subbasin is located along the northeastern portion of the Yolo Subbasin. These subbasins are separated by the boundary between Yolo and Sutter counties, which is coincident with the Sacramento River. This boundary extends downriver until the confluence with the Feather River.

North American Subbasin

The North American Subbasin is located along the eastern, central portion of the Yolo Subbasin. These subbasins are separated by the Yolo and Sacramento County line, which is also coincident with the Sacramento River.

South American Subbasin

The South American Subbasin is located along the southeastern portion of the Yolo Subbasin. These subbasins area separated by the Yolo and Sacramento County line, which is mostly coincident with the Sacramento River but shifts to Sutter Slough for the last 2 miles.

Solano Subbasin

The Solano Subbasin is located along the southern/southwestern boundary of the Yolo Subbasin. These subbasins are mostly separated by the boundary between Yolo and Solano counties. The Yolo Subbasin extends into small areas of Solano County, including a 3.8-square-mile area bounded by Miner Slough at its southeastern corner and a 2-square-mile area of the UC Davis. (The Solano Subbasin extends into the County in three small areas (4.8 square miles, total) to the south of Davis and are related to the jurisdiction of two reclamation districts.)

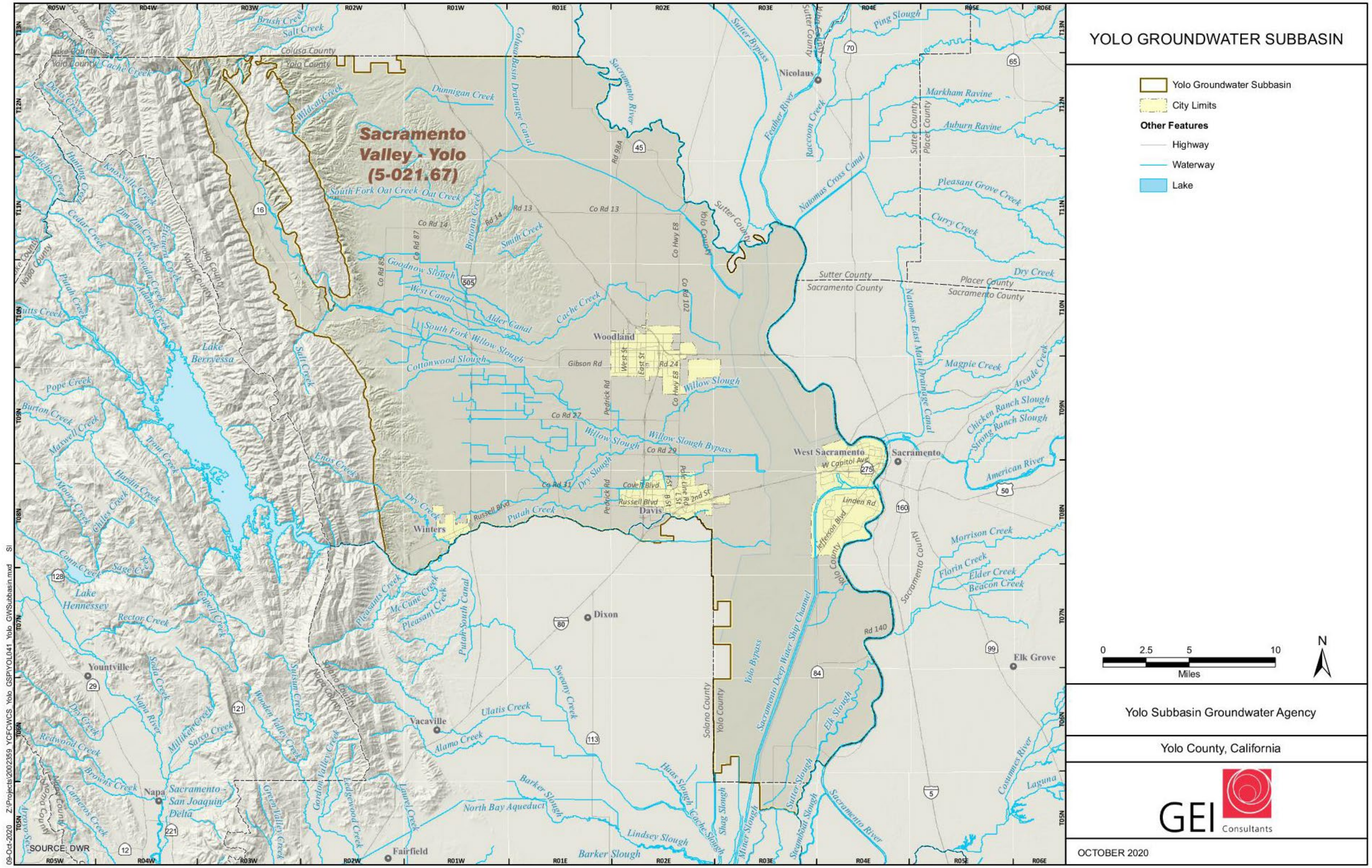

Figure 2-1. Yolo Subbasin Boundaries.

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2.1.2.1.2 Physical Subbasin Boundaries

The western boundary of the Yolo Subbasin abuts the Coast Range which is comprised of Upper Cretaceous marine sedimentary and metasedimentary rocks (Ku), including sandstone, shale, and conglomerate (Jennings 1977). The consolidated nature of these rock limits infiltration of precipitation, which produces runoff that flows eastward into the Yolo Subbasin. As such, higher groundwater levels are present along the western boundary of the Subbasin, which produces a general easterly direction of groundwater flow. The Capay Hills are a north-south trending ridge of marine rocks (Ku) near the northwestern corner that isolate Capay Valley from the main part of Yolo Subbasin. As such, Capay Valley is a small tributary groundwater body to the Yolo Subbasin.

2.1.2.2 Vertical Subbasin Boundaries – Bottom of the Subbasin

The bottom of the Yolo Subbasin has been defined by the base of fresh groundwater as shown by **Figure 2-2** (LSCE 2004). The base of fresh groundwater was defined as specific conductance measurements less than 3,000 micromhos per centimeter (µmhos/cm) (Olmsted and Davis 1961). The deepest area of fresh groundwater is located in the southernmost part of the Subbasin at an elevation of below -3,000 feet mean-sea-level (msl). The depths are somewhat less at more than -2,500 feet msl in a broad, north-trending area beneath the cities of Davis and Woodland that extend further north toward the community of Zamora. A narrow north-trending trough with a bottom elevation of -2,500 feet msl is present on the east side of the city of Winters and extends northward toward the town of Esparto. These north-trending features area consistent with the structural fabric of the Sacramento Valley. Bottom elevations increase quickly on the west side of the narrow trough to greater than -1,000 feet msl while bottom elevations increase more gradually elsewhere in the Subbasin. Bottom elevations vary between -1,500 and -2,000 feet msl along the eastern boundary of the Subbasin and between -1,000 and -2,000 along the northern boundary.

The base of fresh groundwater is several hundred feet above the base of the post-Eocene continental deposits, which are generally equivalent to the base of the Tehama Formation (Page 1974).

2.1.3 Principal Aquifers and Aquitards

An aquifer is a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant quantities of groundwater to wells and springs. An aquitard is a confining bed or formation composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. It does not readily yield water to wells or springs but stores groundwater. The hydrogeology of the Yolo Subbasin was described in *Groundwater Monitoring Program, Data Management System, and Update of Groundwater Conditions in the Yolo County Area* (YCFWCD, 2004), and the following sections are essentially quoting that text.

The report divided the aquifer system, consisting of alluvium and the upper Tehama Formation, into three zones: shallow, intermediate, and deep zones, which are described below. The three zones were delineated by LSCE through "rough correlation of geologic units and on water well completion depths" (LSCE 2004).

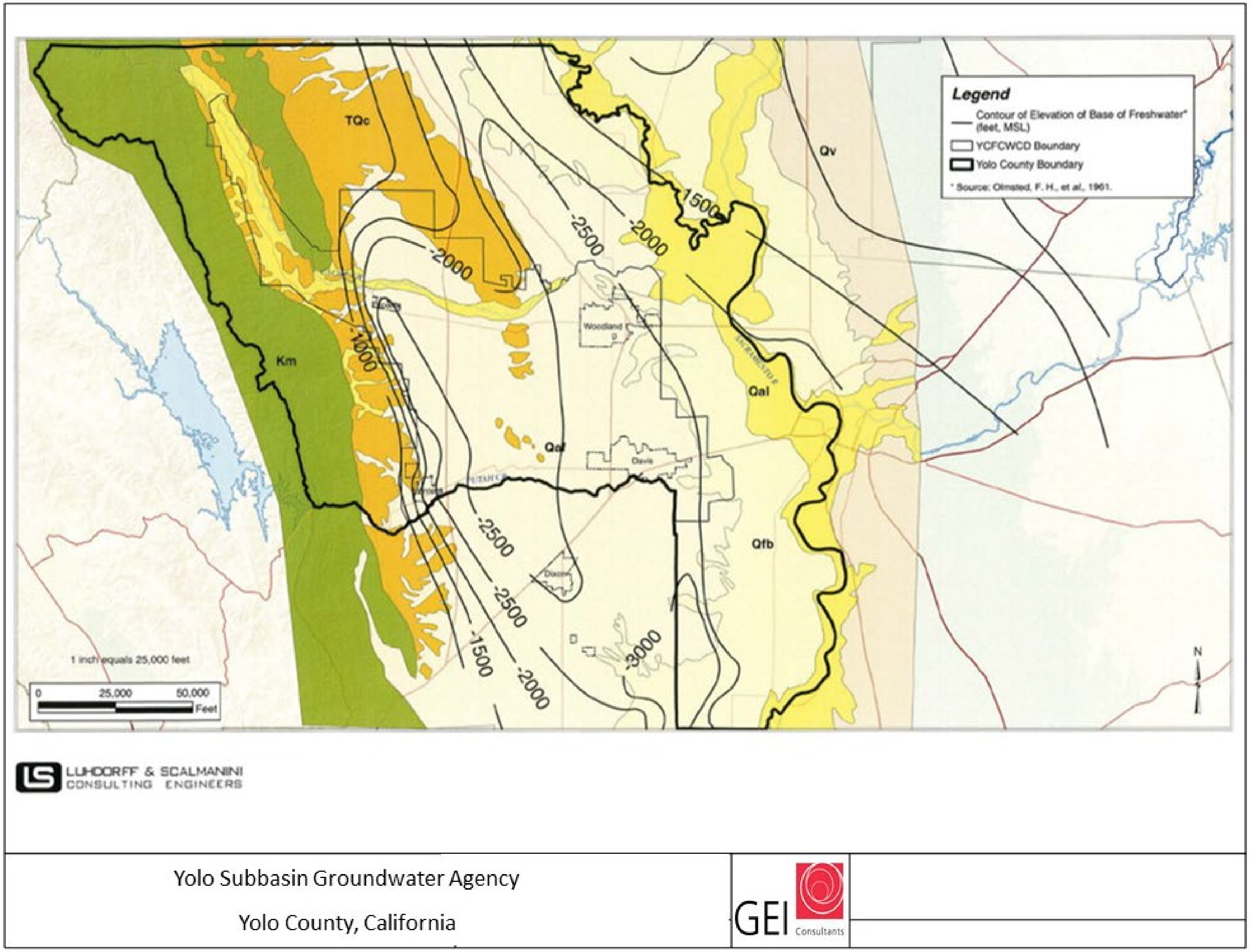

Figure 2-2. Elevation of the Base of Freshwater.

2.1.3.1 Shallow Zone

The shallow zone extends from the surface to a depth of about 220 feet below ground surface (bgs) and consists predominantly of alluvium as well as the upper portion of the Tehama Formation. The deposits consist of thick sand and gravel deposits within a mile or 2 of the major sediment sources of Cache and Putah creeks. The coarse beds appear to thin laterally from the present stream channels with thinner distributary channel, and sheet flood sand deposits occurring under the more distal alluvial plains.

Well yields can be relatively high where thick channel deposits are encountered with yields of several hundred to 1,500 gallons per minute (gpm). Specific capacities range up to 100 gpm per foot of drawdown or greater in this setting. More modest production (e.g., up to 500 gpm yields) likely results from wells constructed in thin sands that are more distant from stream channels and have lower specific capacities. Wells completed in even just a few thin sand beds produce sufficient quantities for domestic use. In the Capay Valley, more information about the aquifer conditions is needed. There are many wells in this area with total depths of less than 100 feet. For additional information, see Section 4.11.2 – Plan to Address Data Gaps.

2.1.3.2 Intermediate Zone

The intermediate zone extends from depths of about 220 to 600 feet bgs and occurs exclusively within the upper Tehama Formation. These deposits are believed to be largely alluvial plains with distributary channel and sheet flood sands interbedded in silts and clays. These deposits are believed to be slightly more consolidated than the shallow zone, although the coarser beds may remain loose.

Well yields appear to be high for eastern areas with ranges of 500 to 1,000 gpm where thick sands are encountered. Wells yields in the western alluvial plain area appear to be lower and range from about 100 to 500 gpm where thick sands are encountered. In this area, a higher percentage of test holes may not encounter sufficient sand to provide desired production well yields. Specific capacities for wells completed in the intermediate zone are comparatively lower than those for the shallow zone. Intermediate zone wells in the western alluvial plain likely have poor to low yields due to the lack of sand beds, in comparison to wells in the eastern alluvial plain. However, thick sand beds are less prevalent in the intermediate zone than the shallow zone.

2.1.3.3 Deep Zone

The deep zone extends from depths of about 600 to 1,500 feet bgs and encompasses the deeper upper Tehama Formation (Els, Elus, D sands, and F sands). These sands sequences are believed to be of central fluvial origin in eastern Yolo County.

Well yields appear to be high in the eastern area where thick or numerous sand beds or sand sequences are encountered. Well yields of 1,000 to 3,000 gpm are not uncommon. However, if sand sequences with low sand content are encountered, supply wells may not be feasible. Specific capacities for deep zone wells completed in thick sand sequences appear to be about 20 to

30 gpm/foot. The deeper (below -1,500 feet elevation) lower Tehama Formation is not utilized by water wells in the County.

2.1.3.4 Aquifer Properties

The aquifer properties summarized in the following section provide input parameters to the YSGA Model and form the basis of understanding of how water is stored in and flows throughout the Subbasin. A finite element numerical model was established for the Yolo Subbasin in 2006 by WRIME (now called RMC Water and Environment) using the Integrated Groundwater Surface-Water Model (IGSM). As detailed in **Table 2-1**, the aquifer system was represented by three layers which generally correspond to alluvium in the shallow zone (#1), upper Tehama Formation or intermediate and deep zones (#2) and the lower Tehama Formation or deepest zone (#3).

Table 2-1. Summary of Aquifer Parameters Data in the Yolo Subbasin IGSM (WRIME 2006).

Zone (Layer)	Location/General Area	Transmissivity feet^2/day	Hydraulic Conductivity feet/day	Storage Coefficient unitless
Shallow (1)	Yolo County	3,000 to 46,000		7.3E-02
	RD 108	26,000 to 52,000	13 to 67	8.0E-02 to 9.0E-02
	RD108, RD 787, RD730, Yolo-Zamora WD	26,000 to 65,000	64	6.0E-02 to 1.2E-01
	Yolo-Zamora WD	9,000 to 26,000	48	7.0E-02 to 9.0E-02
	Woodland	10,000 to 105,000		3.1E-02
	Cache Creek above Moore's Siphon	25,000 to 260,000		
	Knights Landing Ridge Drainage District	26,000 to 52,000	21	6.0E-02 to 1.1E-01
Intermediate & Deep (2)	Dunnigan WD	5,600 to 13,000		9.0E-04 to 2.3E-03
	Yolo County			6.5E-02 to 7.2E-02
	RD108, RD 787, RD730, Yolo-Zamora WD	26,000 to 65,000	19 to 119	6.0E-02 to 1.2E-01
	Yolo-Zamora WD	9,000 to 26,000	41 to 118	7.0E-02 to 9.0E-02
	Davis	4,000 to 18,000		
	Capay Valley	9,000 to 10,000		
	Cache Creek below Moore's Siphon	1,000 to 18,000	400	
	Knights Landing Ridge Drainage District	26,000 to 52,000	21 to 139	6.0E-02 to 1.1E-01
Yolo County IGSM				
1	Model-wide		8 to 38	5.0E-02 to 9.0E-02
2	Model-wide		4 to 20	5.0E-02
3	Model-wide		1 to 20	5.0E-02

Similarly, RMC Water and Environment (formerly WRIME) utilized IGSM for a 5-layer simulation of groundwater flow in the Capay Valley (RMC 2016), *see* **Table 2-2**. Layers 1 and 2 in Capay Valley represent the shallow zone, while layers 3 and 4 represent the intermediate and deep zone, and layer 5 is the deepest zone. The aquifer parameters for the Capay Valley used in the YSGA model come from **Table 2-2.**

Tables 2-1 and 2-2 summarize the available aquifer properties from these various agencies and/or the two models. As defined by Heath (1983), aquifer properties include:

- Hydraulic Conductivity (K): Volume of water that will move through material during a unit amount of time under a unit gradient through a unit area. Units are typically gallons per day per square foot or feet per day.
- Transmissivity (T): Capacity of material to transmit water and is equal to the product of hydraulic conductivity and thickness. Units are typically gallons per day per foot or square feet per day.
- Storage Coefficient (S): Volume of water that is released from or takes into storage per unit surface area per unit change in water level (head). No units.
- Specific Yield (SY): Amount of water that will drain from material under the influence of gravity. Unit is % volume.

Table 2-2. Summary of Aquifer Parameters in the Capay Valley IGSM (RMC 2016).

Yolo Subbasin Zone (Equivalent IGSM Layer)	Capay Valley Layer	Hydraulic Conductivity feet/day	Storage Coefficient unitless	Specific Yield
Shallow (1)	1	25 to 50	1E-02	15%
Shallow (1)	2	10	1E-02	10%
Intermediate & Deep (2)	3	1	8E-03	8%
Intermediate & Deep (2)	4	4	8E-03	8%
(3)	5	2	5E-03	5%

Figure 2-3 indicates that the aquifer system is comprised of mostly sand with some gravel in the intermediate and deep zone. The IGSM values were similar to agency values for the shallow zone but were somewhat less for the intermediate and deep zone, and the Capay Valley model values were less than the County model.

Finer-grained layers (silt and clay) undoubtedly exist with the Subbasin and the respective hydraulic properties would be notably less than the coarse-grained layers (gravel and sand). However, wells are not typically installed (screens) in the fine-grained layers so hydraulic properties have not been measured directly.

Groundwater within the Subbasin occurs under water table or unconfined conditions in the shallow zone and possibly semi-confined conditions with increasing depth.

2.1.4 Topography

The topography of the Yolo Subbasin is presented in **Figure 2-4** and is based on the U.S. Geological Survey (USGS) National Elevation Dataset[16]. Detailed topographic information can be obtained from 25, 7.5-minute maps, as listed below, plus a tangential portion of the Glascock Mountain map.

Glascock Mtn	Rumsey	Wildwood School	Dunnigan	Kirkville		
	Guinda	Bird Valley	Zamora	Eldorado Bend	Knights Landing	Verona
	Brooks	Esparto	Madison	Woodland	Grays Bend	Taylor Monument
		Monticello Dam	Winter	Merritt	Davis	West Sacramento
					Saxon	Clarksburg
					Liberty Island	Courtland

[16] Viewable at https://apps.nationalmap.gov/viewer/

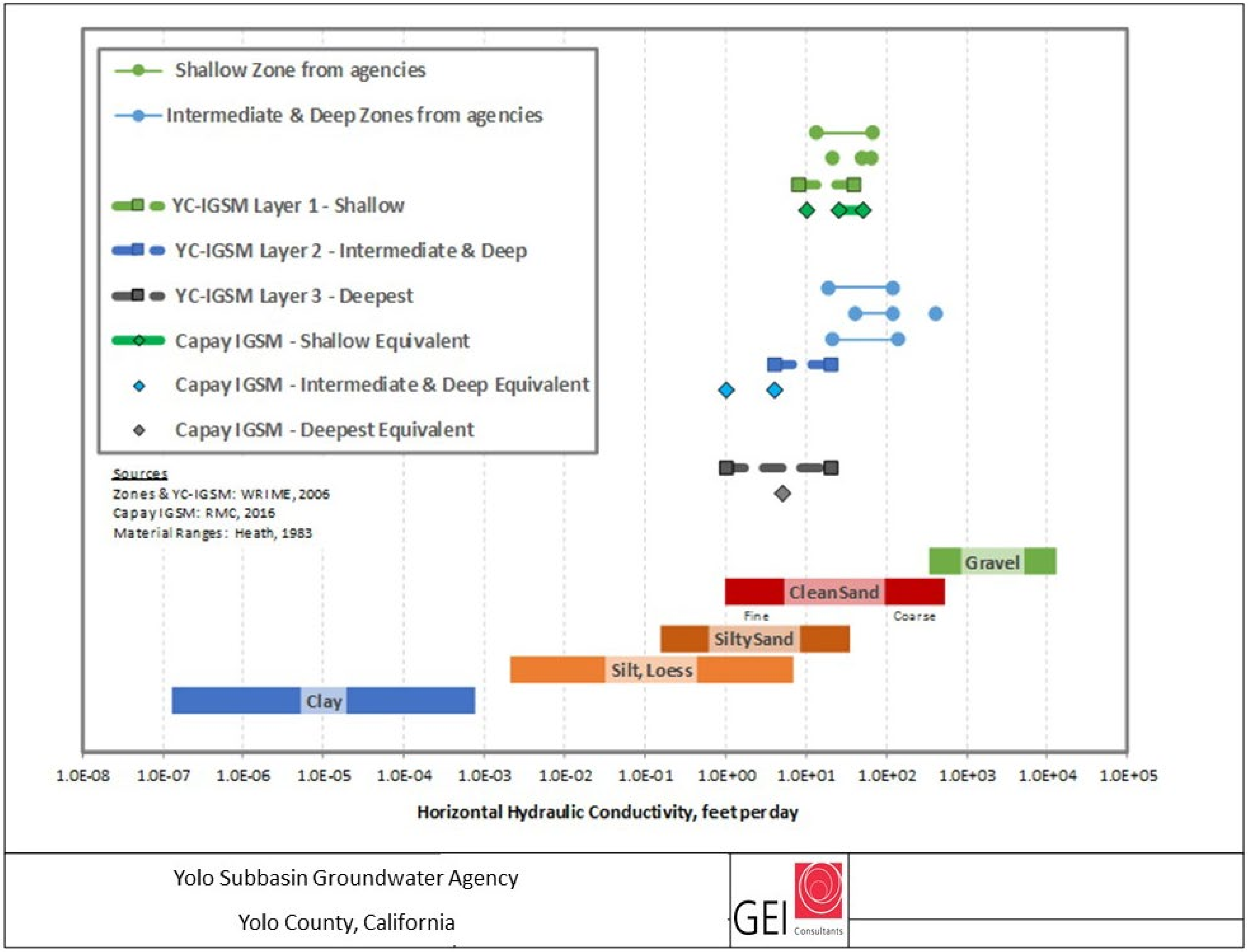

Figure 2-3. Hydraulic Conductivity Values for the Yolo Subbasin.

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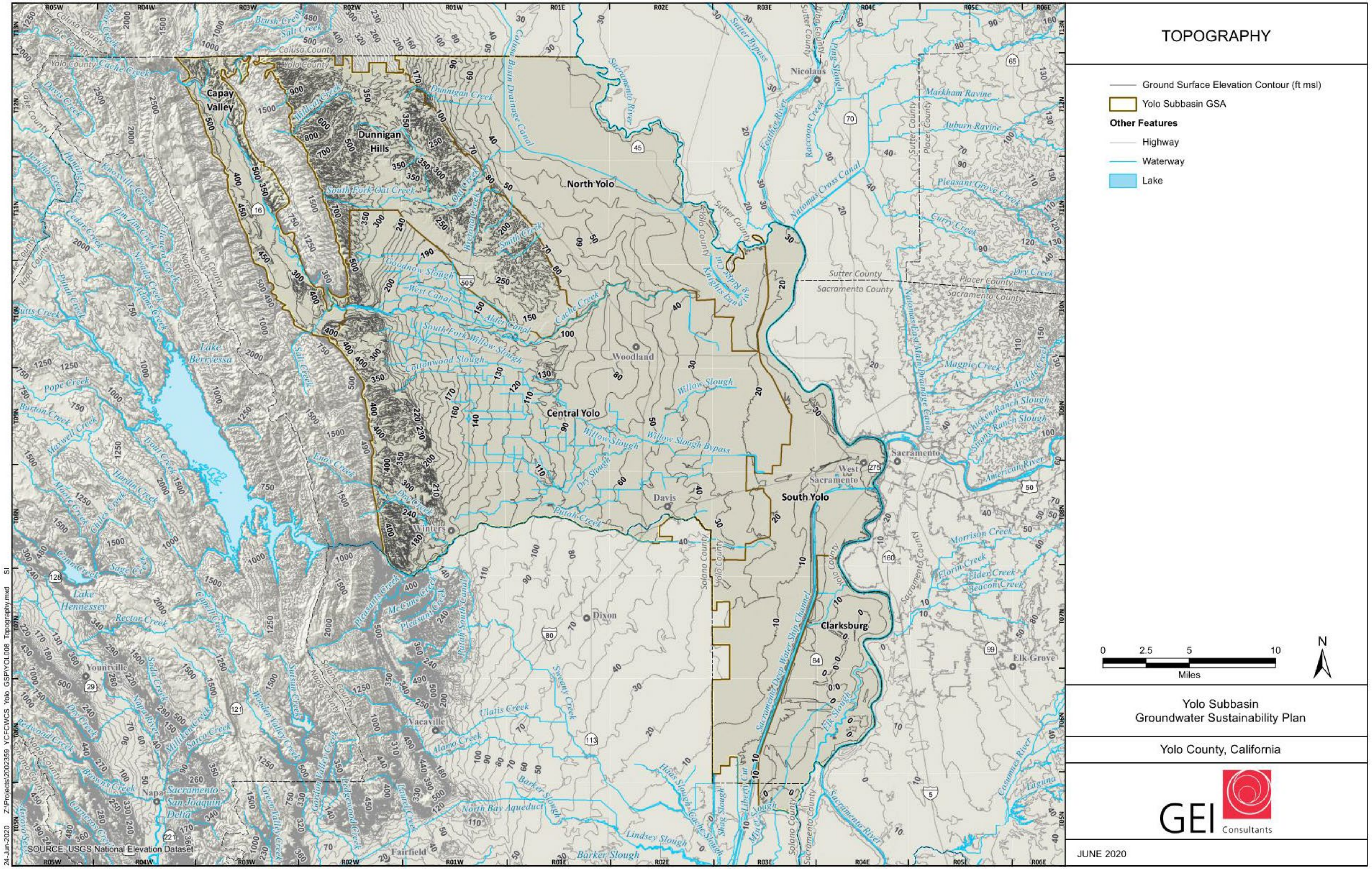

Figure 2-4. Yolo Subbasin Topography.

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Ground elevations vary from mean sea level in the Clarksburg and South Yolo MAs (MA) to as over 1,740 feet above mean seal level (amsl) in the Capay Valley MA (*see* **Section 2.4 – Management Areas** for description of MAs). The most rugged terrain occurs in the Dunnigan Hills MA and on the western side of the Central Yolo MA. The highest topographic relief occurs in the Capay Valley MA while the lowest relief occurs in the Clarksburg MA, as listed in **Table 2-3** below.

In general, the topography slopes in an overall easterly direction toward the center of the Sacramento Valley, except for Capay Valley MA where the topography slopes both east and west toward the center of the narrow valley, which drains to the south into the Central Yolo MA.

Table 2-3. Summary of Surface Elevations in the Yolo Subbasin.

Management Area	Maximum Contour	Minimum Contour	Relief (Difference)
Capay Valley	1,740	210	1,530
Dunnigan Hills	1,250	60	1,190
Central Yolo	880	20	860
North Yolo	220	20	200
South Yolo	40	0	40
Clarksburg	30	0	30

Figure 2-4 shows the numerous creeks, canals, and sloughs that convey surface water within the Subbasin as well as the Sacramento River, which defines the eastern limit of the Subbasin. The majority of the surface water bodies are located in the Central Yolo MA, most notably Cache Creek and Putah Creek. The headwaters of these creeks are located in the mountainous terrain to the west of Subbasin and are sustained by Clear Lake and Lake Berryessa, respectively. As noted in a previous section, Putah Creek forms the southern boundary from the southwestern corner of the Subbasin to the city of Davis. Other notable surface water features include the Colusa Basin Drainage Canal in the North Yolo MA and the Sacramento Deep Water Ship Canal in the Clarksburg and South Yolo MAs. The southern Sacramento Valley, including the Yolo Subbasin, has been a tectonically subsiding sedimentary basin with accumulating nonmarine, continental deposits since middle Tertiary time (Miocene, 24 mybp).

2.1.5 Geology

Geology determines the boundaries of an aquifer, and dictates many aquifer properties, such as storage, transmissivity, and hydraulic conductivity; an understanding of subsurface geology is thus vital for effective groundwater planning. For example, geologic structures such as the Plainfield Ridge can restrict the flow of groundwater through the Subbasin. Considerable effort has been made over many years by numerous investigators to evaluate the geology and groundwater resources of the Yolo Subbasin. Most of this work has focused on the Central Yolo MA. Luhdorff & Scalmanini and Wood Rodgers (2004) provided a comprehensive assessment of this information and is utilized by this GSP. The following regional geologic setting is adapted largely from Harwood and Helley (1987), Page (1986), Hackel (1966), DWR (1978), and the California Geological Survey (2010). **Figure 2-5** shows the regional geology of the area around the Yolo Subbasin and the following text provides a description of the groundwater-bearing formations. **Figure 2-6** provides a somewhat larger-scale map and shows the locations of cross sections from previous evaluations of the area.

2.1.5.1 Geologic Formations

- Alluvium (Q) - The uppermost nonmarine deposit is the Pleistocene-Holocene alluvium and is 100 to 200 feet thick. The alluvium appears to be a complexly stratified sequence of unconsolidated**,** interbedded sands and gravels with fine-grained silts and clay beds. Coarser-grained deposits of sand and gravel typically occur adjacent to major stream channels like Cache and Putah creeks. Thinner sand beds occur as alluvium plain and distributary channel deposits across the areas of the western Subbasin. Separation of the alluvium from the underlying deposits is difficult because of their similar appearance and lack of distinctive marker characteristics. According to Helley and Harwood (1985), the alluvium is considered correlative to the Pleistocene Red Bluff, and younger Holocene alluvium deposits.
- Red Bluff Formation (Qrb) - Overlies the Tehama Formation and consists of a thin, wide-spread pediment sand and gravel bed. The age of the Red Bluff is constrained by underlying and overlying aged-dated volcanic beds to between 1.09 and 0.45 mybp (Harwood and Helley, 1985).
- Tehama Formation (TQc) [Upper and Lower] –Is a non-marine deposit of poorly stratified silts and clay beds interbedded with thin to locally thick sand beds of alluvial plain to fluvial channel sediments. The deposition of the Tehama Formation occurred through the end of the Tertiary Period (Pliocene Epoch) and into the early Pleistocene (5.3 to 1.5 mybp). The formation has been divided into upper and lower units.
    - Upper Tehama Formation - The upper unit occurs from an approximate elevation of -1,500 feet below msl to depths of 100 to 200 feet bgs in the center of the basin. The deposits were previously subdivided into layers called (deep to shallow): E lower sands, E lower-upper sands, E upper sands, D sands, and F sands by LSCE (2004). These layers are shown in the cross sections AA' and BB', **Figure 2-7** and **Figure 2-8** respectively.
    - Lower Tehama Formation - The lower unit occurs from the base of freshwater (bfw) (about -3,000 feet msl) to the bottom of the upper unit (about -1,500 feet msl). The Lower Tehama Formation has not been utilized for water supply in the County as the formation occurs below the depths of the deepest production wells. Pre-Pliocene nonmarine deposits are present beneath the lower Tehama Formation, but this contact cannot be identified in the subsurface due to the similar nature of the sediments. The lower unit has been subdivided into fluvial sand sequences: A, B, and C sands. These layers are also shown in the cross sections AA' and BB' (**Figure 2-7** and **Figure 2-8**, respectively)

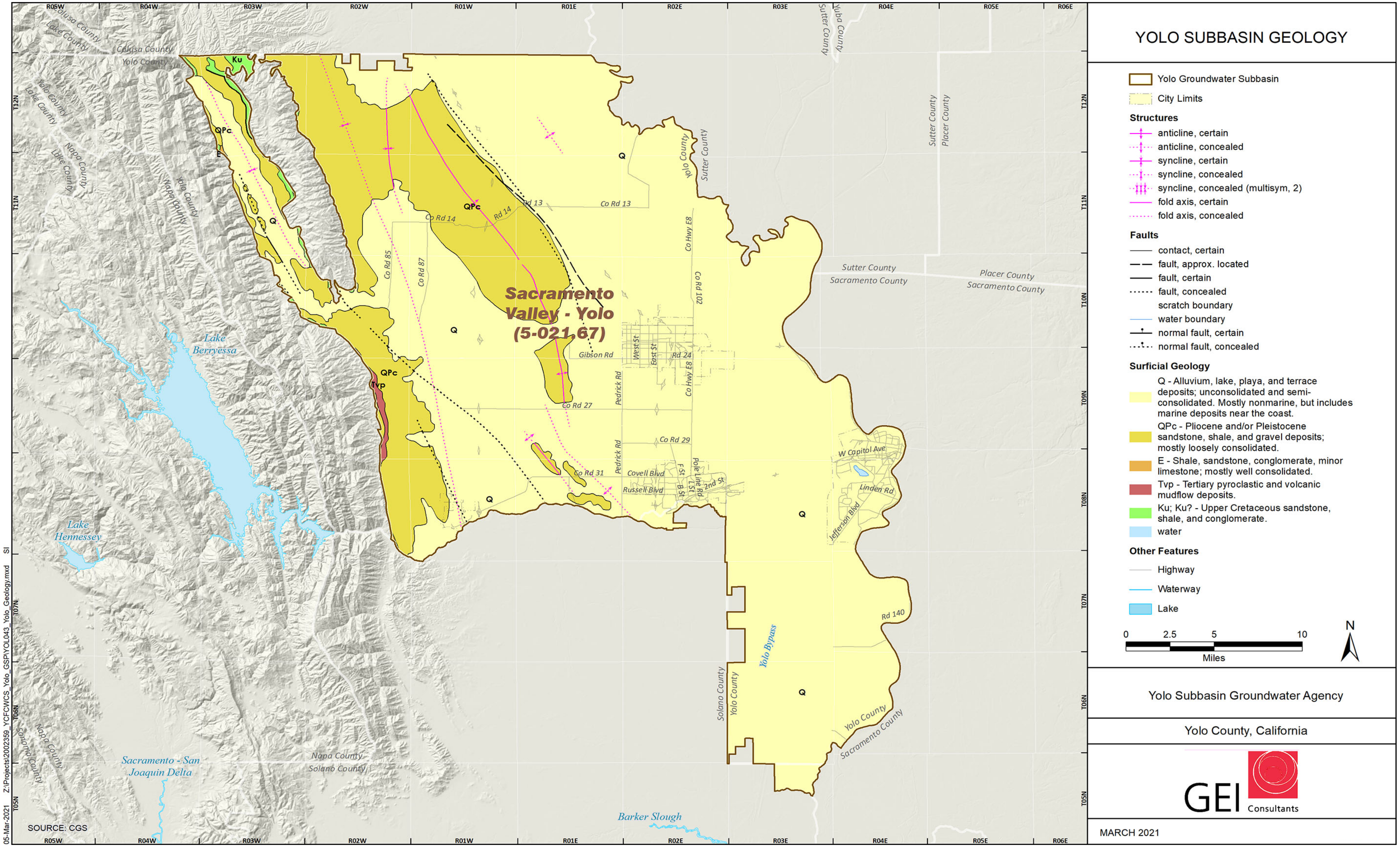
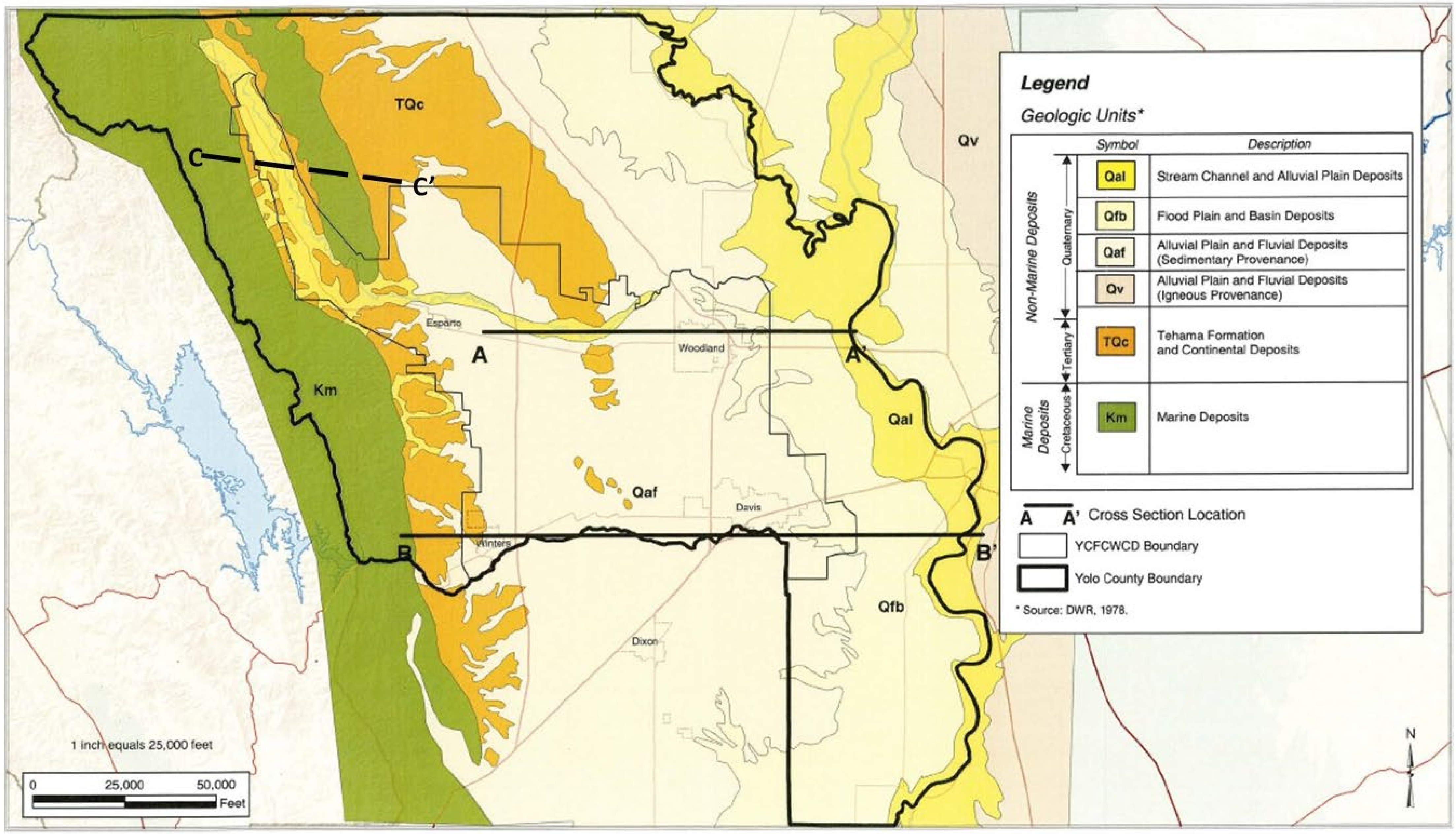


Figure 2-5. Geologic Map for the Yolo Subbasin.



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Modified from Luhdorff & Scalmanini

Yolo Subbasin Groundwater Agency

Yolo County, California

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Figure 2-6. Location Map for Geologic Cross Sections.

  - On the west half of the basin, beneath the A sand, a thick (400 feet) to thin, brackish to saline sandy bed (Z sand) has been identified which overlies the distinctly marine deposits and the Markley Gorge Fill. While this unit is below the bfw, it appears to mark the transition to nonmarine deposition in this portion of the valley.

- Marine Deposits (Km) - Mesozoic marine rocks are present in the mountains to the west of the Subbasin and in the ridges that separate the Capay Valley from the main Yolo Subbasin. These rocks occur at depth beneath the Subbasin and extend eastward to pinch out and overlap onto the granitic and metamorphic basement rocks beneath the eastern Sacramento Valley. The marine rocks consist of well-consolidated sandstone and shales that are over 15,000 feet thick. These Mesozoic (and older Tertiary) rocks beneath the Sacramento Valley contain saline water from their original marine deposition. **Figures 2-7** and **2-8** are east-west cross sections along the northern (A-A') and southern (BB') boundaries of the Central Yolo MA. The cross sections show that the aquifer system extends to a depth of over 2,000 feet throughout much of the area and is over 3,000 feet thick within the center of the basin. The aquifer has been divided into three zones, including a shallow alluvial zone, an intermediate, and a deep zone. These latter two zones are part of the upper Tehama Formation. These three zones are known in the vicinity of the cities of Davis and Woodland and are likely present in much of the Subbasin. A fourth zone could be assigned to the lower Tehama Formation, but this zone has not been developed to much extent for groundwater production.

Figure 2-9 is a nominal east-west cross section (C-C') across the center of Capay Valley and was drawn by Wanger and Saucedo (1984) to illustrate the hard rock structure of the Capay Hills. The cross section shows approximately 1,000 feet of the Tehama Formation (and a veneer of alluvial deposits) within the valley of a syncline in the underlying Cretaceous rocks. The presence of the three groundwater zones has not been defined within the Capay Valley.

The Capay Hills to the east were formed by an anticline with the eastern limb extending beneath the North Yolo MA into a series of synclines and anticlines, as shown in **Figure 2-9**. Normal and reverse faults are present in the folded structures and a normal fault is shown to cut the Tehama Formation.

Other studies such as Yolo County Integrated Groundwater and Surface Water Model (YCIGSM) developed in 2006 have reviewed driller's logs and created cross sections in many areas of the basin (WRIME 2006), shown in **Figure 2-10** for reference purposes and are not evaluated here.

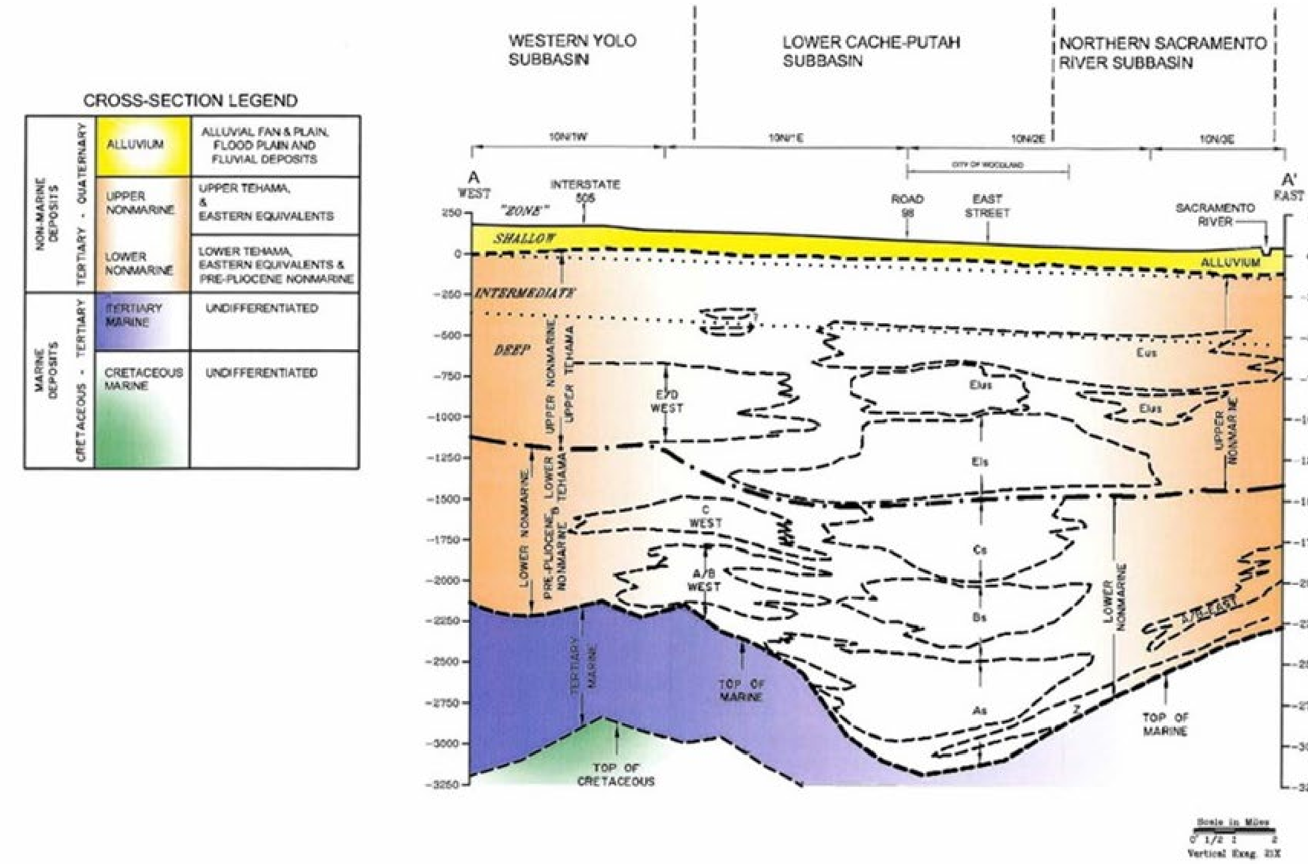

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Figure 2-7. Geologic Cross Section A-A'.

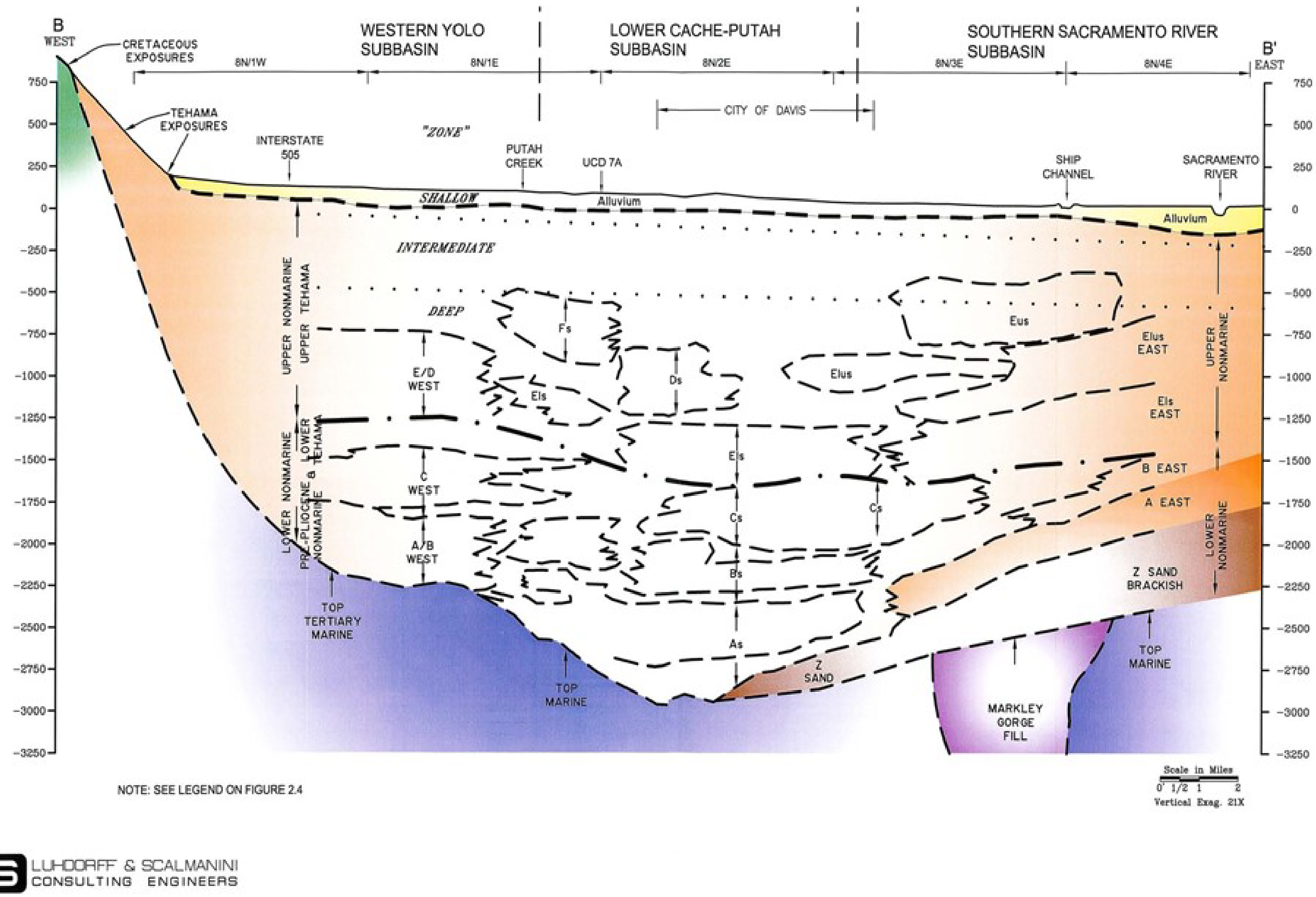

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Figure 2-8. Geologic Cross section B-B'.

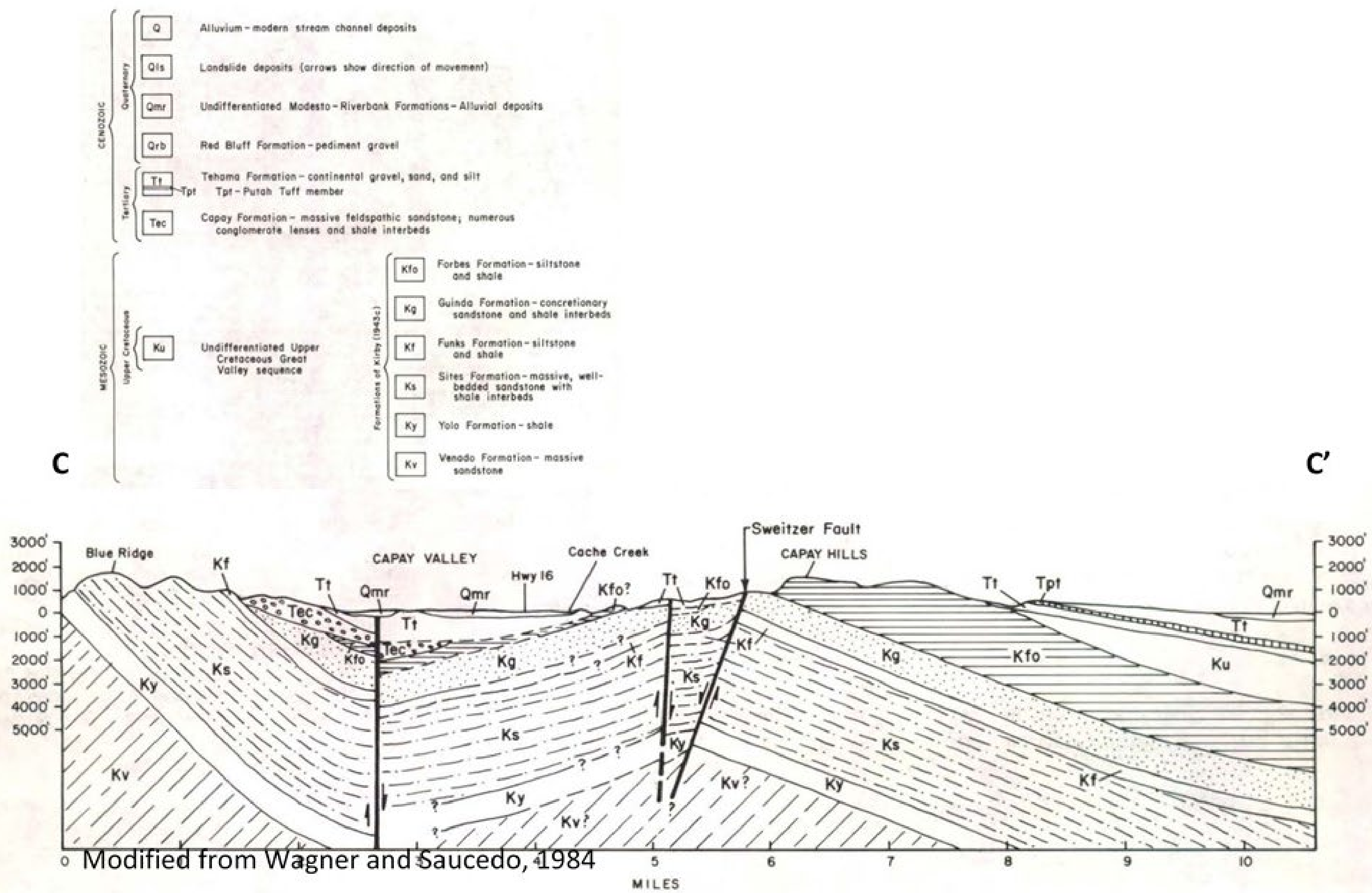

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Figure 2-9. Geologic Cross section C-C'.

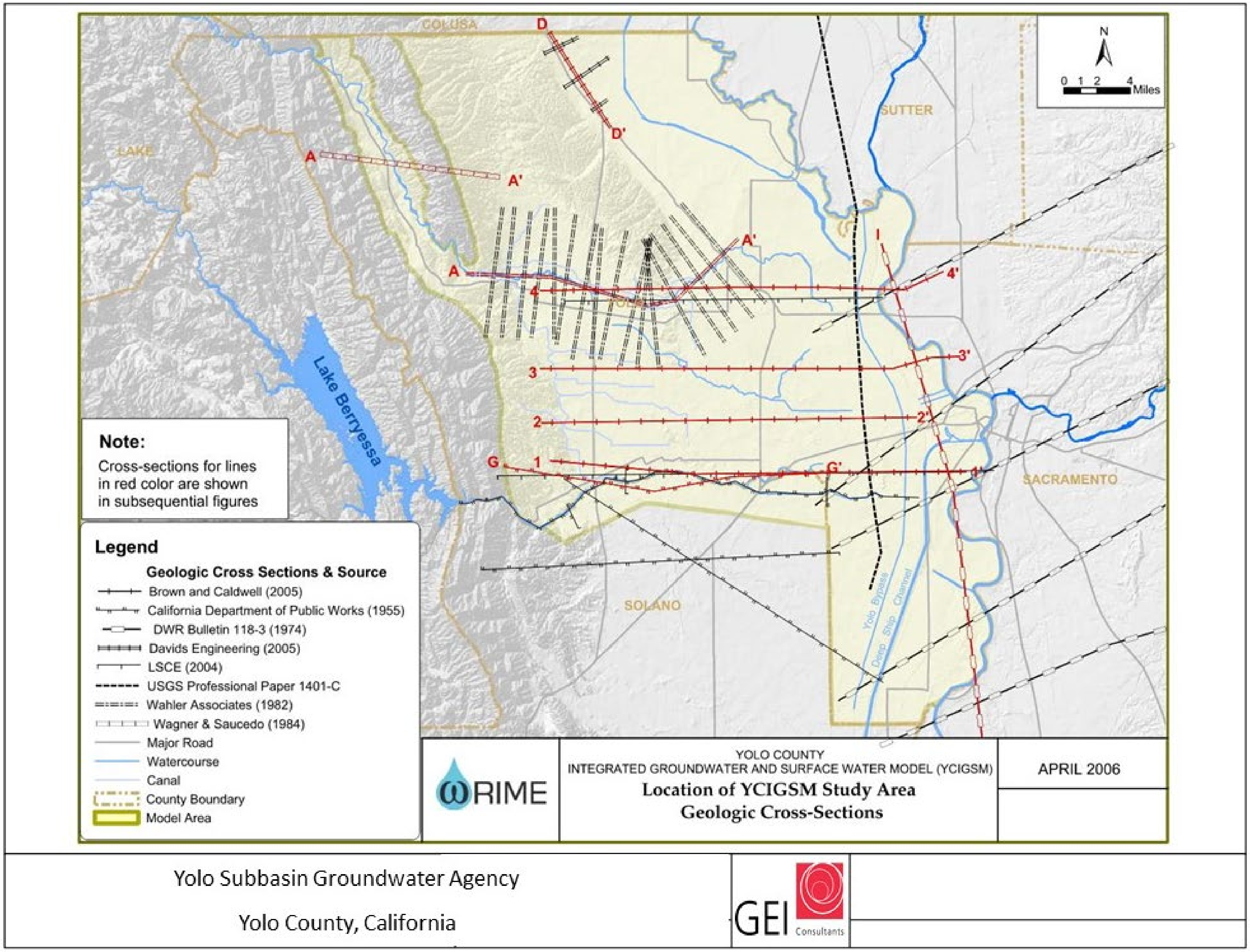

Figure 2-10. Geologic Cross Sections evaluated in Yolo County Integrated Groundwater and Surface Water Model.

2.1.5.2 Structural Restrictions to Groundwater Flow

The Yolo Subbasin portion of the Sacramento Valley Basin has structural deformations that may restrict the flow of groundwater, as previously described by the YCIGSM model report (WRIME 2006) and the Groundwater Monitoring Program (LSCE 2004). The main features are the Madison syncline and the Dunnigan Hills/Plainfield Ridge anticline that trend north-south (WRIME 2006).

The Plainfield Ridge (Ridge) consists of an upward bulging of the denser, less pervious Tehama geologic formation. The Ridge, which is barely visible at the surface of the ground, is oriented in a north-south direction and acts as a "cutoff wall," intercepting groundwater moving southeasterly and directs the groundwater flow more southerly, toward the deeply incised Lower Putah and Cache creeks stream channels, where it "daylights" and becomes part of the surface stream flow. The stream segment where these isolated pools historically occurred is commonly referred to as the "gaining reach" of Lower Putah and Cache creeks.

Exposures of the Red Bluff Formation around and on top of Tehama Formation on the Dunnigan Hills and Plainfield Ridge, has been used to define the Pleistocene to present structural Dunnigan Hills domain. The domain consists of the reverse Zamora fault on the northeast edge of the Hills which offsets Tehama, Red Bluff, and alluvium; the doubly plunging Dunnigan Hills anticline; and the southeast plunging Madison syncline. South of the Dunnigan Hills, subsurface expression of the syncline and anticline in the Tehama Formation is difficult to discern due to lack of correlative stratigraphic units and a lower density of well control information (LSCE 2004).

2.1.5.3 Soils

Information on soils within the Yolo Subbasin were obtained from the Soil Survey Geographic Database (SSURGO) of the Natural Resources Conservation Service (NRCS)[17]. The SSURGO data included two categories of information relevant to the GSP: taxonomic soil orders and hydrologic soil groups. Taxonomic data include general characteristics of a soil and the processes of formation while hydrologic data relate to the soil's ability to transmit water under saturated conditions and is an important consideration for hydrology and groundwater recharge. In addition, SAGBI was developed by the UC Davis and provides a rating of suitability of the soils for groundwater recharge. SAGBI is based on the hydrologic soil groups but includes considerations for topography, soil surface conditions, and chemical limitations. The following section describes the soils of Yolo Subbasin.

2.1.5.3.1 Taxonomic Soil Orders

Of the 12 established taxonomic soil orders, five are present within the Yolo Subbasin, as listed below, and their distributions are presented in **Figure 2-11** and in **Table 2-4**. Descriptions below were taken from the *Illustrated Guide to Soil Taxonomy* (NRCS 2015):

[17] https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

- Alfisols – Naturally fertile soils with high base saturation and a clay-enriched subsoil horizon. Alfisols develop from a wide range of parent materials and occur under broad environmental conditions, ranging from tropical to boreal. The movement of clay and other weathering products from the upper layers of the soil and their subsequent accumulation in the subsoil are important processes. The soil-forming processes are in relative balance. As a result, nutrient bases (such as calcium, magnesium, and potassium) are supplied to the soil through weathering and the leaching process is not sufficiently intense to remove them from the soil before plants can use and recycle them.

- Entisols – Young soils with little or no soil profile development. Entisols occur in settings where processes of erosion or deposition are happening at rates faster than those needed for the formation of soil horizons. Typical settings include steep, actively eroding slopes, flood plains that receive new deposits at frequent intervals, and shifting sand dunes. Entisols have not been in place long enough for soil-forming processes to create distinctive horizons.

- Inceptisols – Youthful soils with a weak, but noticeable, degree of profile development although the soil profile is no adequate for other soil orders. Inceptisols occur on relatively young geomorphic surfaces that are stable enough to allow some development of a soil profile. Typical settings include upland slopes, flood plains, and stream terraces, and are found in diverse settings but not in desert or very cold regions. Drainage for Inceptisols can vary from very poorly to excessive.

- Mollisols – Very dark-colored, naturally very fertile soils of grasslands. Mollisols develop from predominantly grasslands in temperate regions at midlatitudes and result from deep inputs of organic matter and nutrients from decaying roots, especially the short, mid, and tall grasses common to prairie and steppe areas. Mollisols have high contents of base nutrients throughout their profile due to mostly non-acid parent materials in environments (subhumid to semiarid) where the soil was not subject to intense leaching of nutrients.

- Vertisols – Very clayey soils that shrink and crack when dry and expand when wet. They are dominated by clay minerals (smectites) and tend to be very sticky and plastic when wet and very firm and hard when dry. Vertisols are commonly very dark in color and distinct soil horizons are often difficult to discern due to the deep mixing (churning) that results from the shrink-swell cycles. Vertisols form over a variety of parent materials, most of which are neutral or calcareous, over a wide range of climatic environments, but all Vertisols require seasonal drying.

- Alifols and Vertisols account for nearly half the soils in the Yolo Subbasin, followed by Inceptisols and Entisols, and then Mollisols as shown below. However, each MA exhibits a unique composition of soils

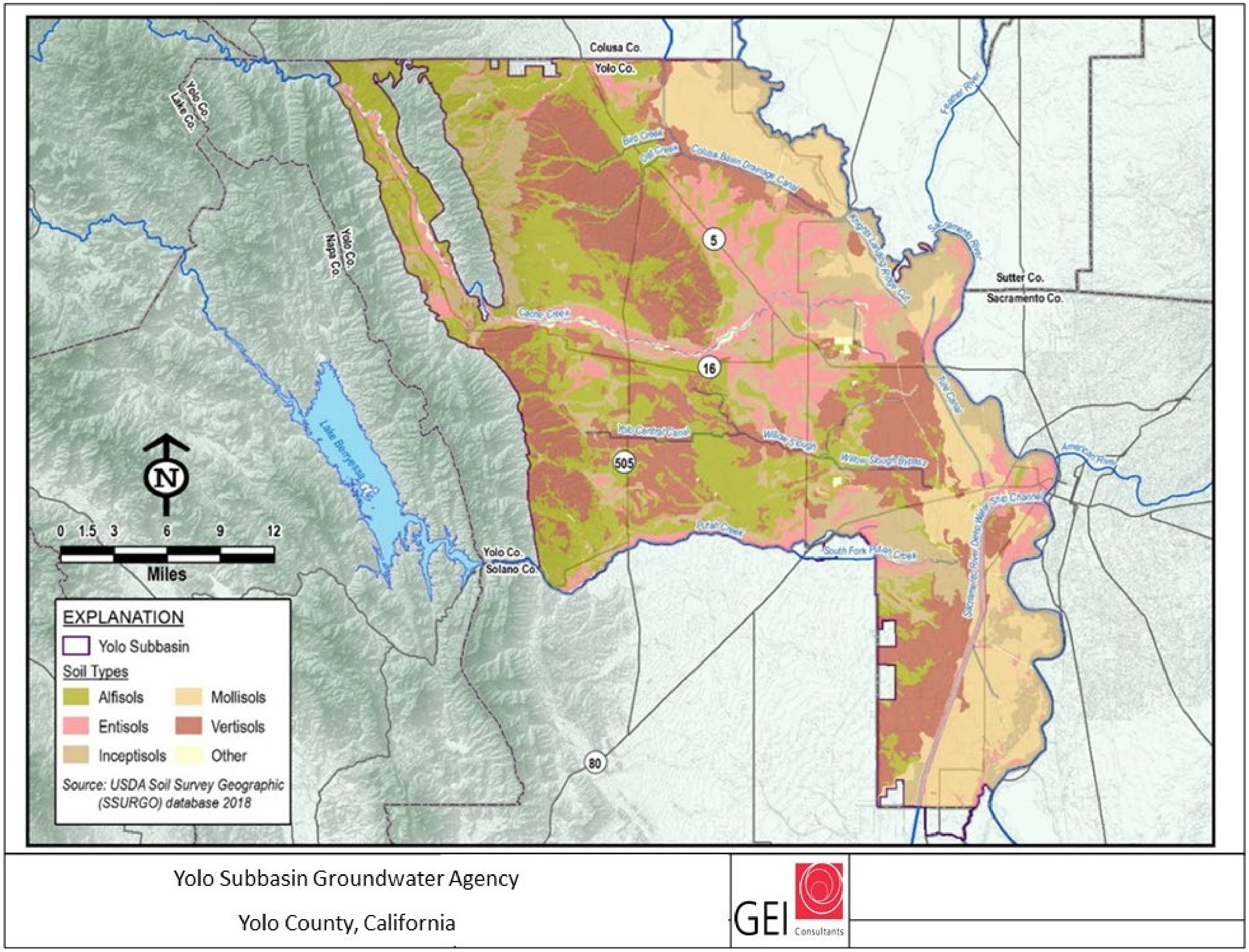

Figure 2-11. Soils in the Yolo Subbasin.

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Table 2-4. Distribution of Soils by Management Area in the Yolo Subbasin.

		Management Areas					
Soil Order	Yolo Subbasin	Capay Valley	Dunnigan Hills	North Yolo	Central Yolo	South Yolo	Clarksburg
Alfisols	25%	48%	32%	16%	33%	8%	0%
Entisols	14%	17%	3%	20%	14%	17%	6%
Inceptisols	20%	30%	16%	23%	18%	22%	22%
Mollisols	14%	0%	0%	27%	2%	21%	71%
Vertisols	27%	4%	49%	13%	33%	32%	1%

2.1.5.3.2 Hydrologic Soil Groups

The NRCS Hydrologic Soils Group (HSG) classifications provide an indication of soil infiltration potential and ability to transmit water under saturated conditions, based on hydraulic conductivities of shallow, surficial soils. **Table 2-5** shows the distribution of the hydrologic soil groups, where higher conductivities (greater infiltration) are labeled as Group A and lowest conductivities (lower infiltration) as Group D. As defined by the NRCS (2007), the four HSGs are:

- Hydrologic Soil Group A – "Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures." Group A soils have the highest conductivity values (greater than 5.67 inches per hour [in/hr]) and therefore a high infiltration rate[18], and the greatest recharge potential.
- Hydrologic Soil Group B – "Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission is unimpeded. Group B soils typically have between 10 and 20 percent clay and 50 to 90 percent sand and have loamy sand or sandy loam textures. Group B soils have a wide range of conductivity values (1.42 - 5.67 in/hr), a moderate infiltration rate, and a moderate potential for recharge.
- Hydrologic Soil Group C – "Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures." Group C soils have a relatively low range of conductivity values (0.14 - 1.42 in/hr), a slow infiltration rate[2], and limited potential for groundwater recharge due to their fine textures.
- Hydrologic Soil Group D – "Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have

[18] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey

greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential." Group D soils have conductivity values less than 0.14 in/hr, a very slow infiltration rate, and a very limited capacity to contribute to groundwater recharge.

Table 2-5. Distribution of Hydrologic Soils Groups in the Yolo Subbasin.

		Management Areas					
HSG (Infiltration)	**Yolo Subbasin**	**Capay Valley**	**Dunnigan Hills**	**North Yolo**	**Central Yolo**	**South Yolo**	**Clarksburg**
A (high)	3%	3%	1%	4%	4%	0%	1%
B (moderate)	14%	14%	3%	27%	15%	12%	7%
C (slow)	**49%**	**60%**	**60%**	**34%**	**57%**	**49%**	19%
C / D	14%	1%	0%	26%	5%	15%	**70%**
D (very slow)	20%	22%	35%	10%	19%	24%	3%
High to Moderate	17%	17%	4%	31%	19%	12%	8%
Slow to Very Slow	83%	83%	96%	69%	81%	88%	92%

A dual hydrologic group (C/D) is assigned to an area to characterize runoff potential under drained and undrained conditions, where the first letter represents drained conditions, and the second letter applies to undrained conditions. For the purposes of this GSP, these dual soils are considered to have a very slow infiltration rate.

Note that the NRCS develops these data using a variety of information, including remote sensing and some limited field data collection, and does not always capture variations that may occur on a small scale. Additionally, Group C and D soils may have slow infiltration rates due to shallow hardpan, and groundwater recharge could potentially be enhanced if this hardpan can be disrupted.

As shown in the following summary, most of the Yolo Subbasin (83%) has slow to very slow infiltration rates although each MA exhibits a unique proportion of classifications. The Dunnigan Hills MA has the largest proportion (96%) of soils with slow to very slow infiltration while the North Yolo MA has the smallest proportion (69%).

2.1.5.3.3 Soil Agricultural Groundwater Banking Index

The UC Davis has established the SAGBI, using data from the SSURGO database, and produces a rating of suitability of the soils for groundwater recharge. This index expands on the HSG to include topography, chemical limitations, and soil surface condition. This effort has resulted in a mapping tool that illustrates six SAGBI classes (excellent - very poor) and has been completed for much of the state, although over 25 percent of the Yolo Subbasin was not assigned a SAGBI value. SAGBI values are not available for over half of the areas within the Capay Valley MA and Dunnigan Hills

MA. Note that the SAGBI is a large-scale planning tool and does not preclude local site conditions that are good for groundwater recharge. The index is based on large-scale current soil conditions; local site conditions can be changed by human action.

Table 2-6 and **Figure 1-11** show the SAGBI distribution across the Yolo Subbasin. Overall, the Subbasin indices are mostly poor (moderately to very) as summarized below, while the MAs exhibit unique proportion of indices. Three MAs have very large proportions (+90%) of poor SAGBI values, including Dunnigan Hills, Clarksburg, and South Yolo, although the conditions in Dunnigan Hills MA are considerably different than the conditions in Clarksburg and South Yolo MAs. The Capay Valley MA appears to have the smallest proportion (54%) of poor SAGBI values, but this condition might be due to the incomplete spatial coverage of the SAGBI dataset in this MA, largely lacking in the steep terrain and hilly rangelands. In contrast, the NRCS dataset in **Table 2-5** has full coverage of the Capay Valley MA and illustrates a fairly high runoff potential in the area.

Table 2-6. SAGBI Distribution in the Yolo Subbasin.

		Management Areas					
SAGBI	**Yolo Subbasin**	**Capay Valley**	**Dunnigan Hills**	**North Yolo**	**Central Yolo**	**South Yolo**	**Clarksburg**
Excellent	4%	4%	2%	5%	4%	5%	6%
Good	11%	25%	3%	19%	12%	1%	3%
Mod Good	6%	17%	3%	5%	8%	4%	1%
Mod Poor	15%	27%	10%	11%	21%	10%	1%
Poor	44%	5%	3%	51%	37%	66%	87%
Very Poor	20%	22%	79%	10%	17%	15%	2%
Excellent to Mod Good	21%	46%	8%	29%	24%	9%	9%
Mod Poor to Very Poor	79%	54%	92%	71%	76%	91%	91%

2.1.6 Natural Recharge, Direct Recharge Areas, and Potential Recharge Areas

According to LSCE (2004), recharge to the shallow zone occurs from infiltration along Cache and Putah creeks and the associated YCFC&WCD distribution system of unlined canals and laterals. Aquifer sand bodies are probably weakly connected to sand bodies surrounding the major streams. Recharge from the Sacramento River may occur along the northeastern boundary of the Subbasin (but the river could be a discharge area along the southeaster boundary). Additional recharge likely occurs by deep percolation of precipitation and irrigation waters. The shallow zone is probably unconfined, although local confinement in thin sands may occur where overlain by a thick flood clay sequence.

Recharge to the intermediate zone occurs generally through precipitation recharge at outcrop areas and by interconnection and leakage from the overlying shallow zone, including possibly from the Sacramento River, Cache Creek, and Putah Creek *via* the shallow alluvium. The Coast Range may transmit a limited amount of recharge to the intermediate aquifer along the interface between the fractured rock and the sedimentary basin. The intermediate zone may be unconfined in the upper portions of the zone, although local confinement occurs due to thick overlying clay, but probably becomes progressively confined with depth due to the additive effects of the variable fine/coarse stratigraphy.

Recharge to the deep zone beneath the eastern alluvial plain is believed to be from leakage from overlying aquifers, probably sourced from Sacramento River and Cache Creek to the north. The western alluvial plain deep zone is probably recharged from the overlying units and Tehama Formation outcrops to the west, especially those units associated with Cache and Putah creeks. The deep zone is an increasingly confined system due to the presence of extensive overlying clay units and its overall depth.

2.1.7 Natural Discharge Areas

Natural discharge areas are limited within the Yolo Subbasin and the primary area is probably located along the Sacramento River in the southeastern portion of the Subbasin in the vicinity of the Delta. Several springs are present along the central east side of Capay Valley and at the mountain front west of the city of Winters, and single springs are located at other locations along the mountain front and beyond the southeastern base of Dunnigan Hills. **Figure 2-12** shows the location of these springs based on the National Hydrography Dataset[19].

2.1.8 Surface Water Bodies

Surface water supplies in Yolo Subbasin include numerous creeks emanating from the Coast Range and foothills. These creeks flow eastward toward the Sacramento River, which is the eastern boundary of the Subbasin. Significant surface water courses include Cache Creek, Putah Creek, the Sacramento River, and the Colusa Basin Drainage Canal. **Figure 2-12** shows the location of these surface water bodies.

Precipitation and runoff strongly influence local hydrology. According to Scott and Scalmanini (1975) precipitation occurs in cyclonic storm fronts where most of the rainfall occurs during 6 to 12-hour periods. Topographic characteristics result in high percentages of runoff from the mountains and foothills and the potential for flooding.

The YCFC&WCD water supply system consists of Clear Lake and Indian Valley Reservoir, which are located west of the Subbasin in the Coast Range, and Cache Creek which conveys surface water to the Subbasin, plus groundwater within the Subbasin. The YCFC&WCD manages a small

[19] Available at https://apps.nationalmap.gov/viewer/

hydroelectric plant, two reservoirs, more than 150 miles of canals and laterals, and three dams including the world's longest inflatable rubber dam.

2.1.9 Water Rights

A water right is a legal entitlement authorizing surface water to be diverted from a specified source and put to beneficial use. Based on the State Water Board water rights database, there are approximately 243 water right holders in the Yolo Subbasin[20]. **Figure 2-14** shows the active points of diversion in the Subbasin. For additional information on water rights within the Yolo Subbasin, *please review* **Appendix E – Yolo SGA Model Documentation**.

2.1.10 Data Gaps in the Hydrogeologic Conceptual Model

Due to the Yolo Subbasin being redefined in 2016 and 2018 by combining portions of four different subbasins, additional research needs to be conducted to assess the connectivity of these different regions and the continuity of the three aquifer zones as described in this HCM.

The delineation of the different aquifer zones and their corresponding aquifer characteristics is a data gap of this HCM. More research is required to study the lithology in the uppermost 1,500 feet of the upper nonmarine deposits and to assess if any regional aquitards are present and create district separation between the different zones for groundwater management purposes.

The hydrogeology of the Dunnigan Hills area is not well defined due to the limited number of wells in the area and availability of data.

Data gaps exist relating to the bfw in the Yolo Subbasin. Reviewing upcoming and recent studies may yield beneficial information about the bfw.

2.1.11 Source and Point of Delivery for Imported Surface Water

Importation of surface water occurs to a limited extent in the northeastern corner of the Yolo Subbasin *via* flows from the Colusa Basin Drain and from the Tehama-Colusa Canal. The Colusa Basin Drain enters the Yolo Subbasin from the north, east of I-5, and arches eastward to Knights Landing where it terminates with the Sacramento River. Similarly, the Tehama-Colusa Canal enters the Subbasin from the north, west of I-5 and skirts the base of the Dunnigan Hills to its abrupt termination 3 miles south of Dunnigan, near the intersection of I-5 and I-505. **Figure 2-13** shows the location of these conveyance structures.

[20] Accessible via the Electronic Water Rights Information Management System: https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/

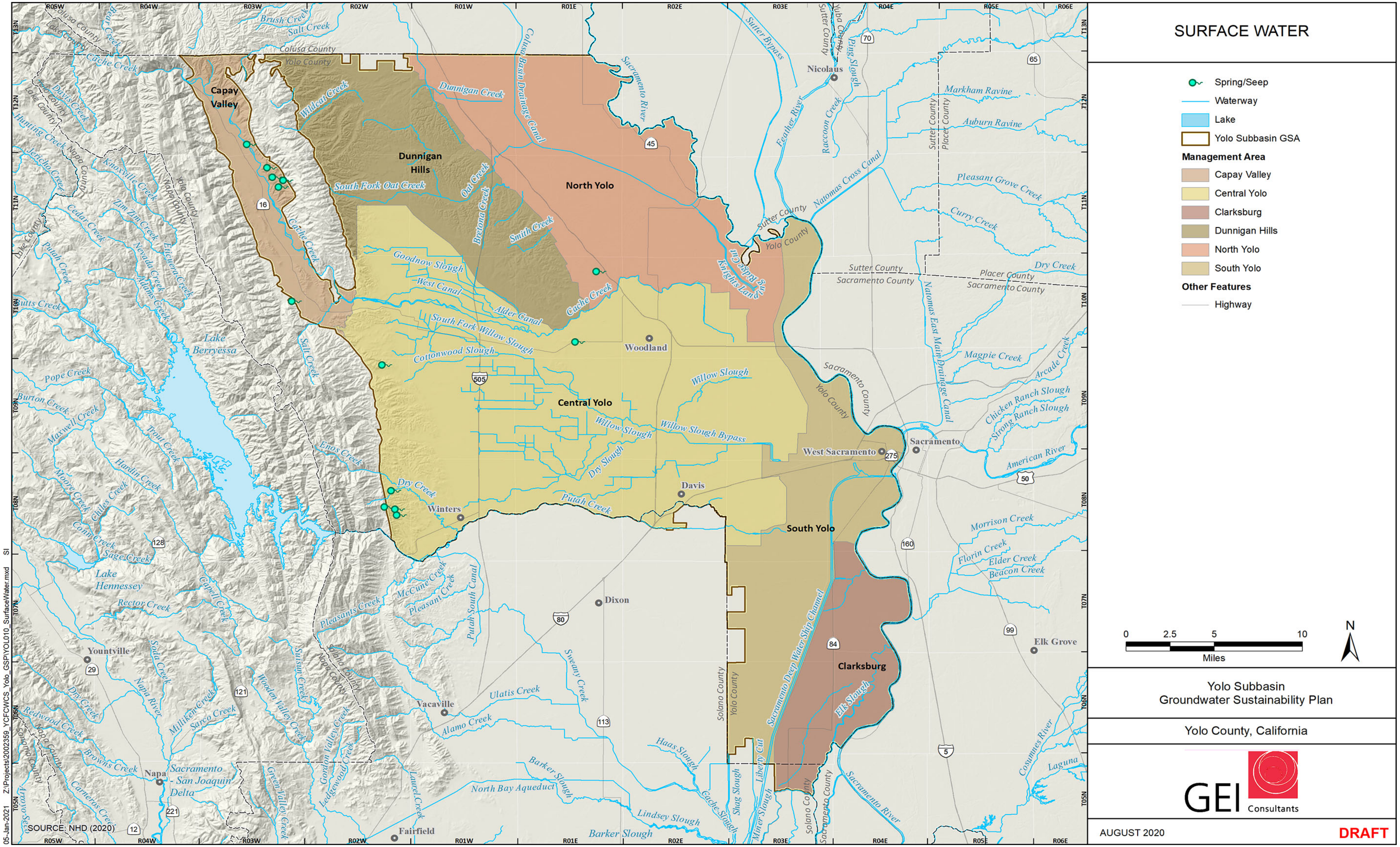

Figure 2-12. Surface Water Features and Springs in the Yolo Subbasin.

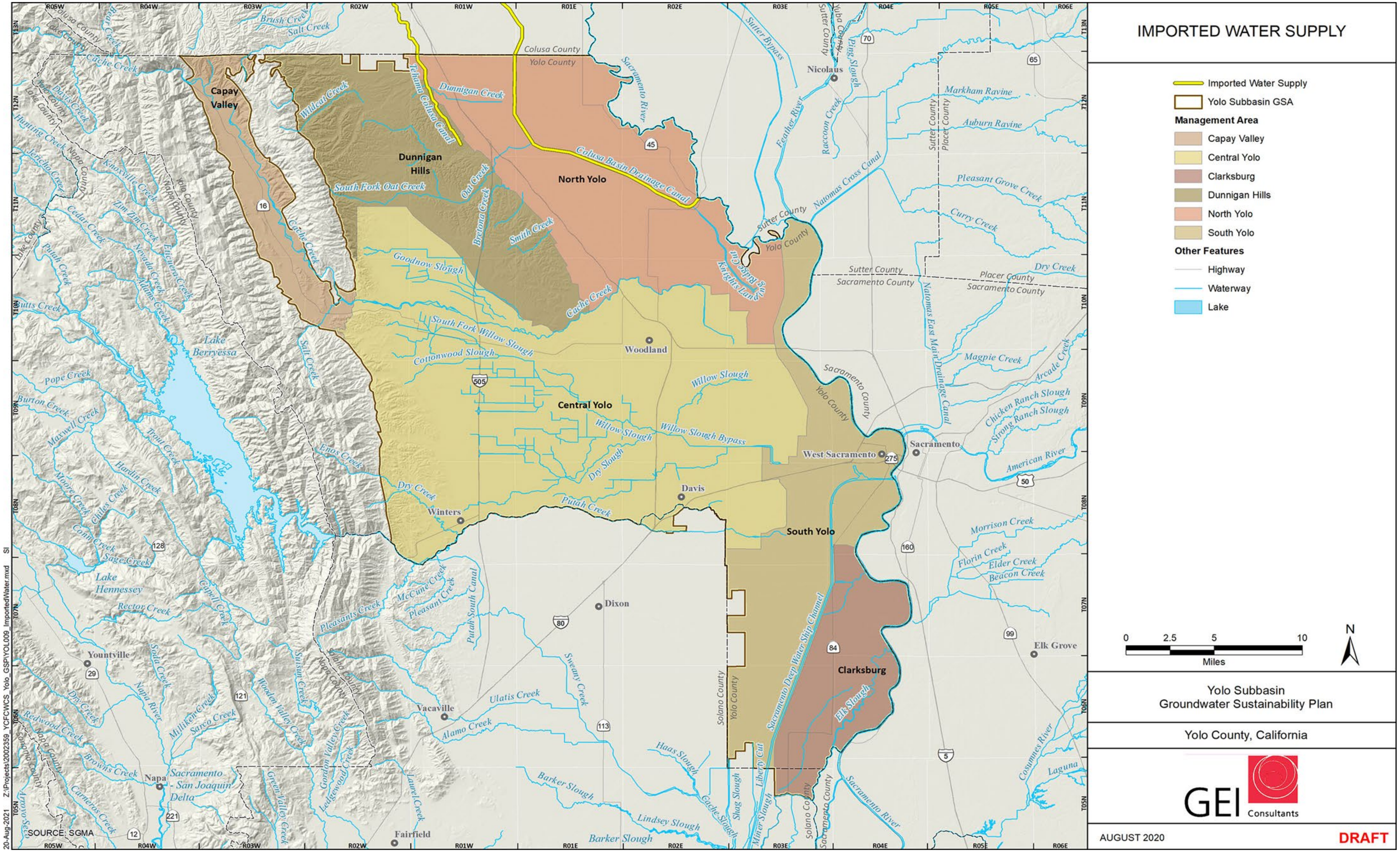

Figure 2-13. Location of Facilities for Importation of Surface Water into the Yolo Subbasin.

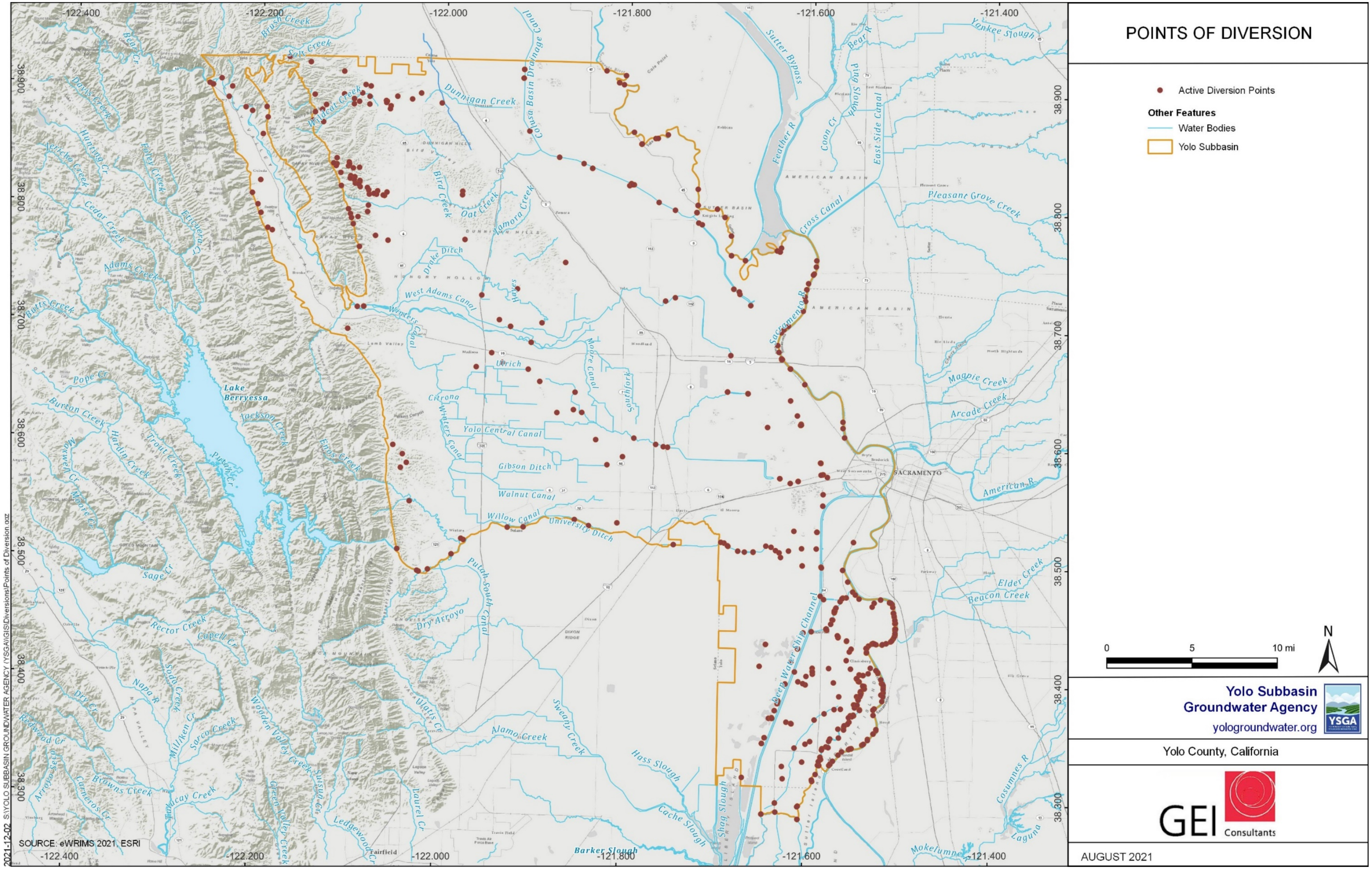

Figure 2-14. Yolo Subbasin Points of Diversion.

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Diversions from the Sacramento River water are not considered importation where the Sacramento River flows along the eastern boundary of the Subbasin. Similarly, diversions from Cache Creek and Putah Creek are not considered importation of water because these creeks flow through the Subbasin and along the southwestern boundary, respectively, even though the headwaters are located in the mountains on the west side of the Subbasin. These surface water bodies are part of the natural hydrology of the Yolo Subbasin and should not be considered foreign to the Subbasin. While the use of reservoirs in the mountains changes the natural flow of the creeks and facilitates the management of this resource, the locations of the reservoirs in the mountains do not justify any designation as imported water.

2.1.12 Previous Studies

Groundwater resources in the County have been investigated by numerous studies over the last century; the most significant or relevant reports are identified below.

- An early reconnaissance report of the Sacramento Valley groundwater resources was presented by Bryan (1923).
- The California Division of Water Resources (1955) encompassed most of the groundwater areas of the County, curiously titled "The Putah Creek Cone Investigation." This report presented shallow cross-sections along and across Putah Creek and preliminary deep cross-sections from a concurrent USGS investigation.
- The USGS published their detailed study of southern Yolo County and parts of Solano County with the finalized deep cross-sections as Thomasson Jr., Olmsted, and LeRoux (1960). A regional study of the entire Sacramento Valley soon followed (Olmsted and Davis 1961).
- Scott and Scalmanini (1975) presented a study of the County groundwater resources. A DWR report (1978) covered the evaluation of the groundwater resources of the Sacramento Valley.
- The USGS published a series of reports on the entire Central Valley in their regional-aquifer system investigations (Bertoldi et al. 1991).
- Hull (1984) and Bertoldi et al. (1991) covered the geochemistry of groundwater in the Sacramento Valley.
- Page (1986) summarized the geology of the entire Central Valley with an extensive list of references.
- The most widely available geologic maps covering the County area is from California Division of Mines and Geology (Wagner et al. 1981, 1982).
- The most detailed surficial geologic mapping of groundwater basins was summarized in Helley and Harwood (1985) from previous mapping by themselves and others.
- Detailed soil mapping of the County by the U.S. Soil Conservation Service was published in 1972.

- A report by the state of California (1987) as a proposal for siting the Super Conductor Super Collider provides a 360-degree cross-section extending to about 200 feet deep at about a 10-mile radius centered on the city of Davis.
- Hubbard (1989) presented an evaluation of the youngest alluvial deposits across the County area with an interpretive map of the top of the underlying Tehama Formation.
- Graham (1997) presented a hydrological and geological study of the alluvial aquifer in the Davis area.
- West Yost and Associates (1991, 1992) presented the results of a groundwater investigation of eastern Yolo County.
- LSCE (2003) presented a conceptualization of the deep freshwater stratigraphy around Davis.
- DWR (1997) Lower Colusa Basin Conjunctive Use Study.

Additional references on the County containing shallow hydrogeologic information are a result of aggregate resources evaluations along Cache Creek. Some of these reports include Wahler et al. (1982); Woodward-Clyde Consultants (1976); and Dames and Moore (1990). Numerous additional references for individual aggregate resource sites exist.

2.2 Groundwater Conditions

The sections that follow summarize current and historical groundwater conditions in the Subbasin. SGMA Regulations §354.16 define current conditions as those existing after January 1, 2015, and therefore implicitly define historical conditions as those existing prior to January 1, 2015. The provided summaries emphasize information required by the GSP Regulations. Current and historical groundwater conditions summarized herein are presented at a scale and level of detail appropriate for meeting the GSP sustainability requirements under SGMA.

This section is organized to align with the six indicators of groundwater sustainability, including:

- Chronic lowering of groundwater elevations (Section 2.2.1)
- Changes in groundwater storage (Section 2.2.2)
- Seawater intrusion (Section 2.2.3)
- Groundwater quality (Section 2.2.4)
- Subsidence (Section 2.2.5)
- Depletion of interconnected surface waters (Section 2.2.6)
- Groundwater dependent ecosystems (Section 2.2.7)

The freshwater aquifer system in the Yolo Subbasin includes the shallow alluvium and upper Tehama Formation, which together have been divided into the shallow, intermediate and deep zones. All three zones occur within the non-marine deposits. The shallow zone consists of groundwater encountered from the water table to approximately 220 feet bgs and is considered unconfined. The intermediate zone occurs from the base of the shallow zone to a depth of approximately 600 feet bgs and is considered unconfined, and the deep zone extends from approximately 600 feet bgs to approximately 1,500 feet bgs.

2.2.1 Groundwater Levels

Groundwater levels have been measured at numerous wells in the Subbasin for the last 90 years, starting in the early 1930s. Currently, more than 40 different entities monitor groundwater levels in the County (YCFC&WCD 2006) from approximately 500 wells. A timeline of the County groundwater monitoring is presented in **Table 2-7.** The largest monitoring networks in the County are from the USGS, DWR, the U.S. Bureau of Reclamation, and YCFC&WCD, with 50 to 150 wells in each program. Smaller water districts, UC Davis, YDWN, and each of the cities in the County also have substantial monitoring networks with between 10 and 50 wells.

Some monitoring data is submitted to state-sponsored programs, and available from DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) program[21], DWR's SGMA Data Viewer[22], DWR's Water Data Library[23], and the California Natural Resources Agency Open Data Portal[24], among others. However, many programs do not report data to the state and data are only available from the locally managed Yolo County Water Resources Information Database (WRID)[25]. An overview of the WRID is presented in the Yolo County Groundwater Monitoring Program proposal (WRA 2009). Groundwater level data that is only found in the WRID program come from the cities, Aggregate Mine networks along Cache Creek, the YDWN in the Capay Valley, UC Davis, and the YCFC&WCD's 20 well real-time telemetry network. The YSGA has developed a publicly accessible data viewer containing data for all currently monitored wells in the WRID, available at www.sgma.yologroundwater.org.

DWR's Enterprise Water Management database is the 'master' database for all of DWR's groundwater monitoring programs and is accessible through the open data portal. It shows 632 wells with monitoring data (from any time period) in the County. The WRID, on the other hand, has data for more than 3,000 wells, of which data from 855 wells are labeled as being from DWR. As part of the GSP implementation, the YSGA will investigate these differences. It is likely that some of the differences are due to the different boundaries of the County *versus* the YSGA. Additionally, the WRID's geographic coverage has a 1-mile buffer extending outside of the County, to account for nearby wells.

[21] https://www.casgem.water.ca.gov/
[22] https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer
[23] https://wdl.water.ca.gov/
[24] https://data.cnra.ca.gov/
[25] https://wrid.facilitiesmap.com/

Table 2-7. Timeline of Groundwater Monitoring Activities in Yolo County.

Year	Activity
1951	Spring/Fall groundwater level measurements started by DWR (100+ wells)
1957	Solano Project Groundwater Monitoring started, many in the County (99 wells)
1967	YCFC&WCD takes over DWR Spring/Fall monitoring, District Formation Act stipulates Annual GW Report if there is a GW Charge
2002	Subsidence program starts (surveys in 2002, 2005, 2009, 2016, 2017, 2018)
2004	YCFC&WCD grant funded project evaluates groundwater data from 41 agencies in the County
2004	WRID created and the total number of wells was expanded (grant funded)
2007	WRA funds development of web access to the WRID
2008	Nine agencies in the County have adopted Groundwater Management Plans over the past few years (SB1938 or AB3030 compliant)
2009	WRA member agencies starts regularly funding upkeep of the WRID (as a Foundational Action in the Yolo IRWM Plan)
2009	YCFC&WCD starts network of real-time groundwater monitoring (20 wells as of 2021)
2011	WRA becomes the CASGEM monitoring entity
2013	WRA funds a major update of the WRID
2014	More than 100 active accounts in the WRID
2018	Groundwater Sustainability Plan grant to be used to upgrade well data network (survey surface elevations, add new wells, etc)

2.2.1.1 Elevation and Flow Direction

Figure 2-15 and **Figure 2-16** display 2018 groundwater elevation contours in the spring and fall, respectively. These contours represent below-normal water conditions, following an extraordinary wet year (2017), following a historic 5-year drought (2012-2016).

Groundwater in the Yolo Subbasin generally moves from west to east because groundwater levels occur at a higher elevation along the western mountain front, where recharge occurs, to lower elevations on the valley floor. In spring, this eastward gradient is the predominant hydrologic feature across much of the Subbasin (**Figure 2-15**) due to recent recharge during the previous winter wet season and minimal pumping. Localized gradients are more prominent in the fall, the result of pumping occurring over the summer months (**Figure 2-16**). As discussed in **Section 2.2.1.3 – Vertical Groundwater Gradients,** vertical gradients exist between the shallow, deep, and intermediate zones, driving groundwater flow downward in the Subbasin. Vertical groundwater flow occurs relatively slowly due to the intermingling of fine-grained sediments with coarser sands and gravels being common across the Subbasin (WRIME 2006).

Groundwater elevations are highest in the western portion of the Subbasin between the cities of Winters, Capay, and Guinda. These areas border the foothills of the Northern Coast Ranges, and therefore benefit from increased rainfall and higher surface elevations. Groundwater elevations are generally 60 to 100 feet lower in the eastern portion of the Subbasin near the cities of Davis, Woodland, and West Sacramento. Here conditions reflect the relatively low gradients seen across the Central Valley floor. Cones of depression exist near Davis and Woodland due to groundwater extraction for municipal supply and in rural areas, particularly the Zamora area, due to extraction for agricultural irrigation. These cones of depression are more prominent during the fall, a result of minimal precipitation during the dry season and increased extraction during the growing (dry) season. Seasonal variation in recharge and groundwater extraction results in a difference in groundwater elevations of around 20 to 40 feet between spring and fall (**Figure 2-15** and **Figure 2-16**). Groundwater elevations in spring reflect recharge received during the rainy season, while groundwater elevations in fall reflect the antecedent dry season and the cumulative effects of groundwater extraction throughout the growing season.

Figure 2-17 and **Figure 2-18** are respective contour maps for groundwater conditions during Spring and Fall 2015. Groundwater flows from uplands along the mountain front on the west side of the valley toward the center of the valley on the east. Groundwater levels were nearly 20 feet lower during Fall 2015 beneath the city of Davis, 10 feet lower beneath the city of Woodland, and 35 feet lower beneath the community of Zamora. The seasonal decline was less along the mountain front with up to 10 feet of decline in the vicinity of Capay-Esparto-Madison and beneath the city of Winters. The 2015 contours represent the gravest, critically dry conditions in the fourth year of the 5-year drought.

A comparison of 2015 and 2018 conditions shows that groundwater levels rose 10 to 20 feet across much of the Subbasin during the Spring seasons with a few isolated areas with a 30-foot rise. For Davis and Zamora, the rise was approximately 15 feet, 20 feet for Woodland, and 30 feet for Yolo. For mountain-front communities (Winters, Capay, Esparto, and Madison), groundwater levels rose 10 feet. For the Fall seasons, the change in groundwater levels is more complicated due to the residual effects of variable pumping during the irrigation season. In general, groundwater levels were higher in much of the Subbasin in 2018, compared to 2015.

A comparison of Spring 2006 (wet year at the end of a mostly wet 10-year period) to Spring 2016 (below-normal year at the end of a mostly dry 10-year period) shows on overall decline throughout the Subbasin as might be expected from the mostly dry conditions (**Figure 2-19**). The decline was 10 feet in the vicinity of Esparto and Madison, over 30 feet in the broad area west of Davis and Woodland and the Winters area, over 30 feet northwest of Zamora, and over 40 feet near the northern boundary of the Subbasin west of I-5.

2.2.1.2 Subbasin-Wide Groundwater Elevations

Groundwater is an important resource in Yolo Subbasin, supporting multiple beneficial uses including urban and domestic supplies, agriculture, and groundwater dependent ecosystems. Historically, groundwater pumping and associated depth to water measurements have occurred in the shallow and intermediate zones, resulting in a groundwater elevation dataset from approximately 1955 to the present. Data are more robust from the late 1970s onward, due to an increasing focus on groundwater management. Development of deep zone groundwater has occurred more recently and available groundwater elevation data from this zone are available after approximately 1980. **Figure 2-20** shows average depth to groundwater in selected long-term groundwater monitoring wells in the Yolo Subbasin for 1975 through Spring 2020. The YCFC&WCD's monitoring wells, along with other Yolo Subbasin monitoring wells, are updated in the WRID twice a year with the spring and fall water level measurements. Wells are measured for depth to water from the reference point (usually the top of the well casing), in feet. Throughout this GSP, an increase in depth-to-water therefore represents a declining water level, while a decreasing depth-to-water represents a recovering water level and increasing groundwater elevation. All of the data utilized to create **Figure 2-20** are within the WRID, and publicly viewable through the YSGA's groundwater data map[26]. Most of these measurements are also stored within the SGMA Data Viewer and the Water Data Library.

Figure 2-20 shows that:

- Depths to groundwater fluctuate seasonally due to recharge by precipitation (higher levels) during the late fall, winter, and early spring (wet months) and become deeper during the late spring, summer, and early fall (dry months) due to the paucity of recharge and the use of groundwater during the irrigation season.
- Depths to groundwater also fluctuate due to variations between water year (WY) type which have been classified as wet, above normal, below normal, dry, and critical.
- Depths to groundwater increased significantly during 1976 and 1977, which was the severest 2-year drought period for the 114-year period of WY records, resulting in limited groundwater recharge and greater reliance on groundwater extraction to meet local demands. The preceding 10-year period, ending in 1975, was an overall wet period which produced relatively shallow depths.
- Depths to groundwater recovered between 1978 and 1984. Conjunctive use, specifically the completion of the Indian Valley Project in 1975, likely contributed to this recovery along with 3 consecutive wet years, including the wettest year (1983) in the 114-year period of records. During this period, the average groundwater depth rose to one of the highest levels during this 45-year period.
- Depths to groundwater fluctuated notably due to a dry 1985 and a wet 1986, and this rapid response was also evident between a critical 1992, above normal 1993, and a critical 1994. These fluctuations are indicative of a robust groundwater system.
- Depths to groundwater increased between 1987 and 1992 due to a significant 6-year drought period of mostly critical WYs.
- Depths to groundwater generally decreased from 1993 to 1999 during a mostly wet period, including 5 consecutive wet years. Groundwater depths rose again to one of the highest levels in 1998, which is the fourth wettest WY on record (1995 is the seventh wettest WY).

[26] sgma.yologroundwater.org

- Depths to groundwater were relatively stable between 2000 and 2006, fluctuating as might be expected from a mixture of WYs (overall above-normal conditions).
- Depths to groundwater increased again between 2007 and 2011, including a notable dip in 2009, due to an overall dry period of WYs. Groundwater depths recovered briefly thereafter through 2011 due to overall above-normal conditions.
- Depths to groundwater increased after 2011 during most of the historic 5-year drought period, including a significant drop between 2014 and 2015, which are the sixth and fourth lowest WYs respectively. This decline occurred during the transition from the pre-SGMA Historical Period (prior to January 1, 2015) and the SGMA GSP development or Current Period.
- Depths to groundwater decreased after the drought due to an overall wet period, including the second wettest WY (2017) on record. New water management actions likely contributed to the decrease in depths to groundwater, including the Woodland-Davis Clean Water Project which reduced groundwater pumping with the development of potable water from the Sacramento River sources.

The Yolo Subbasin appears to have a robust groundwater system that has recovered quickly after various periods of dry and critical WYs, including single and multi-years. Overall, the last 21 years of the 45-year hydrograph could be considered a below normal period. Future years are expected to be variable and possibly more extreme which will require vigilant attention to hydrologic conditions and a flexible management plan for surface water and groundwater. The YSGA Model considers five climate change scenarios projecting future groundwater levels, presented in **Section 2.3 – Water Budget Information**.

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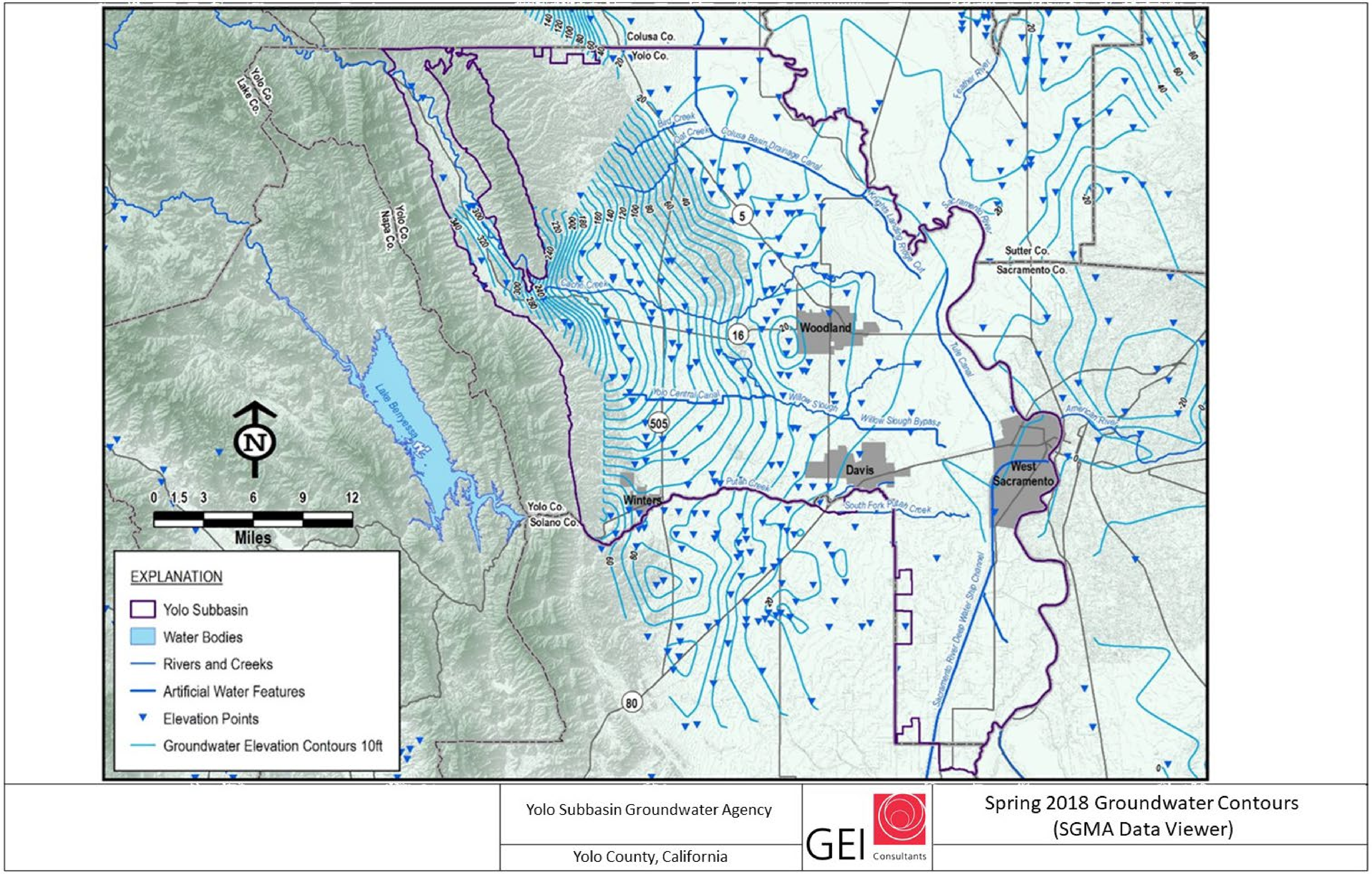

Figure 2-15. Spring 2018 Groundwater Contours. (Source: SGMA Data Viewer, https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels)

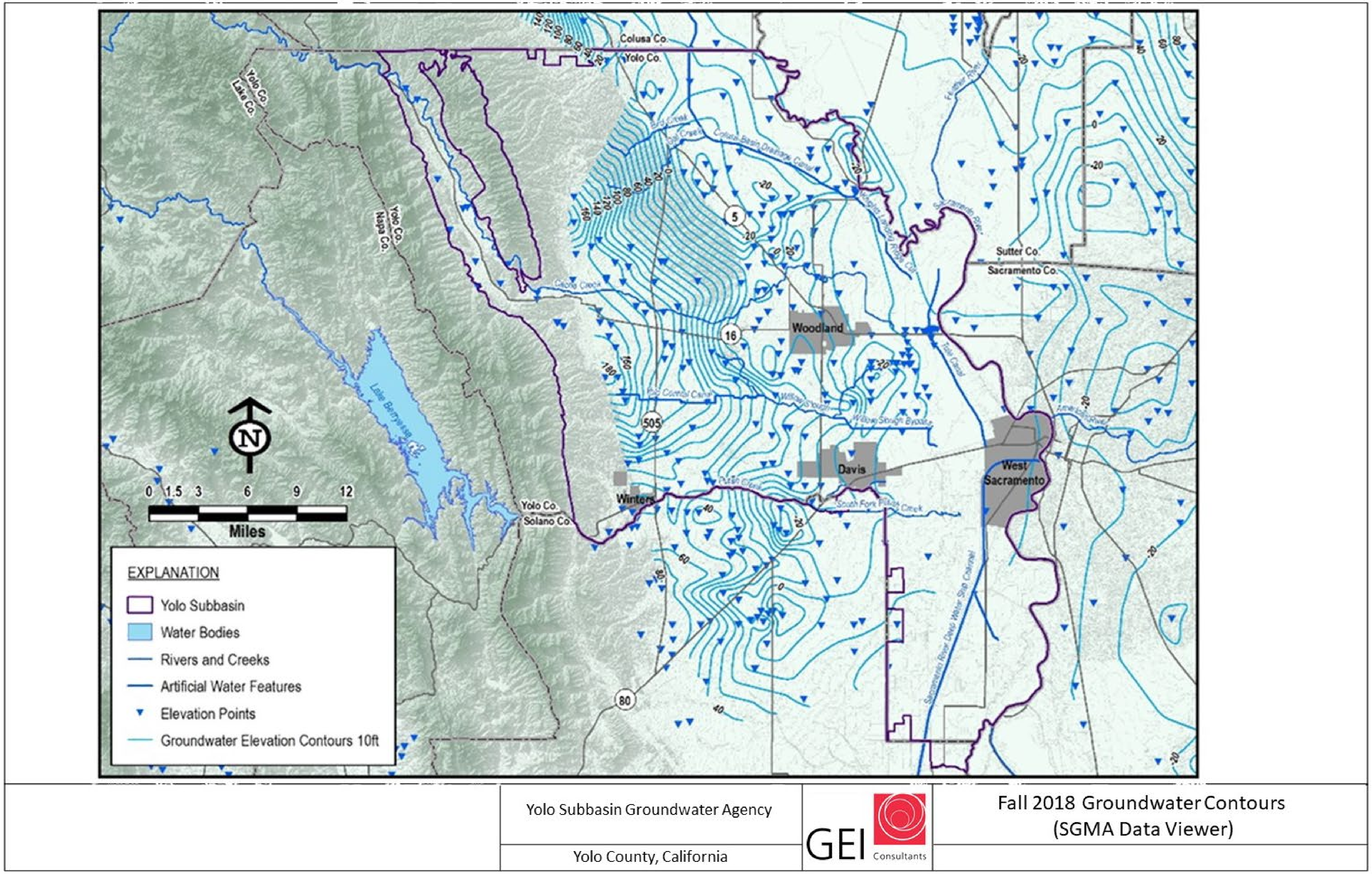

Figure 2-16. Fall 2018 Groundwater Contours (Source: SGMA Data Viewer, https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels).

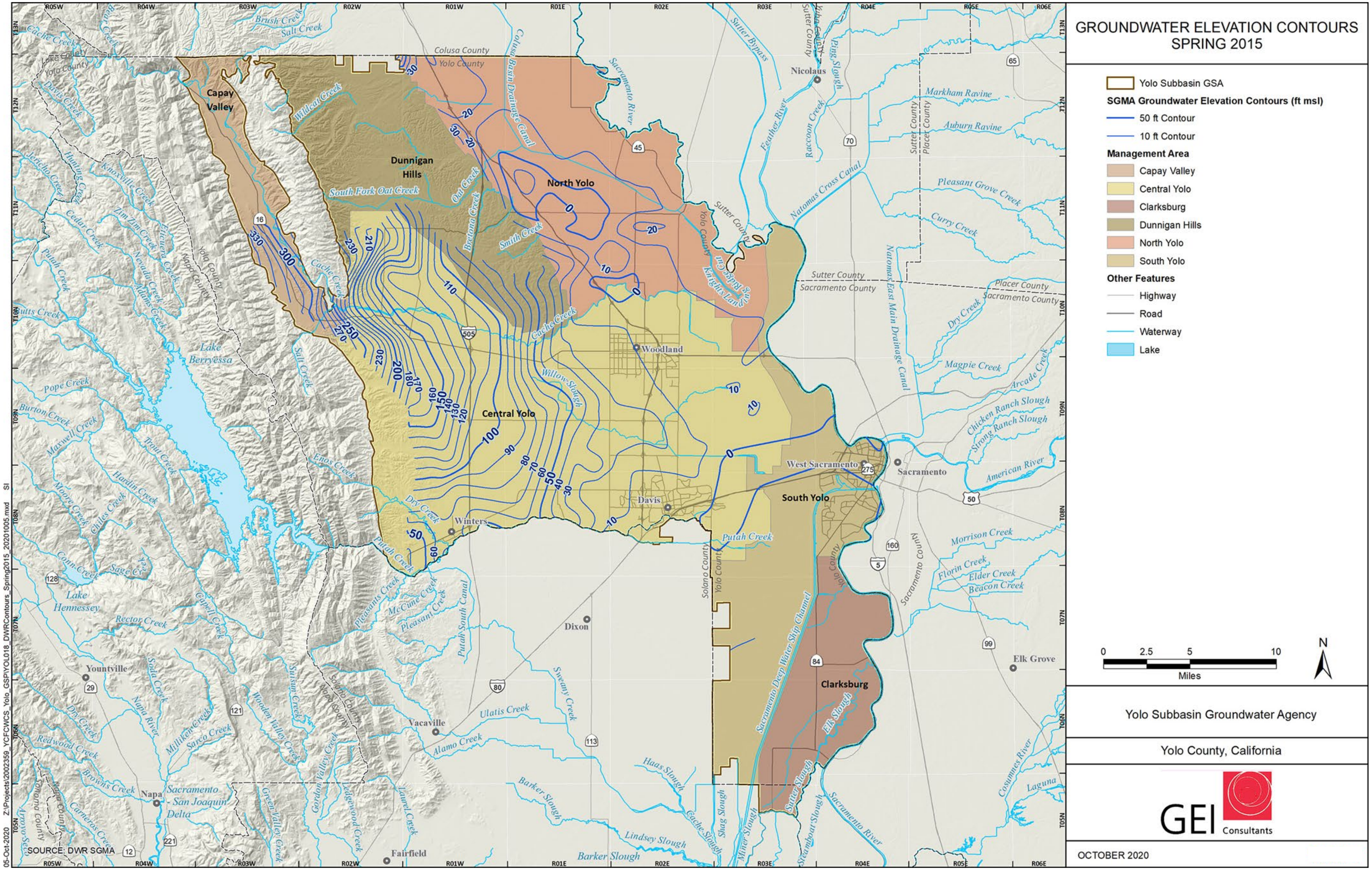

Figure 2-17. Spring 2015 Groundwater Contours (Source: SGMA Data Viewer, https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels).

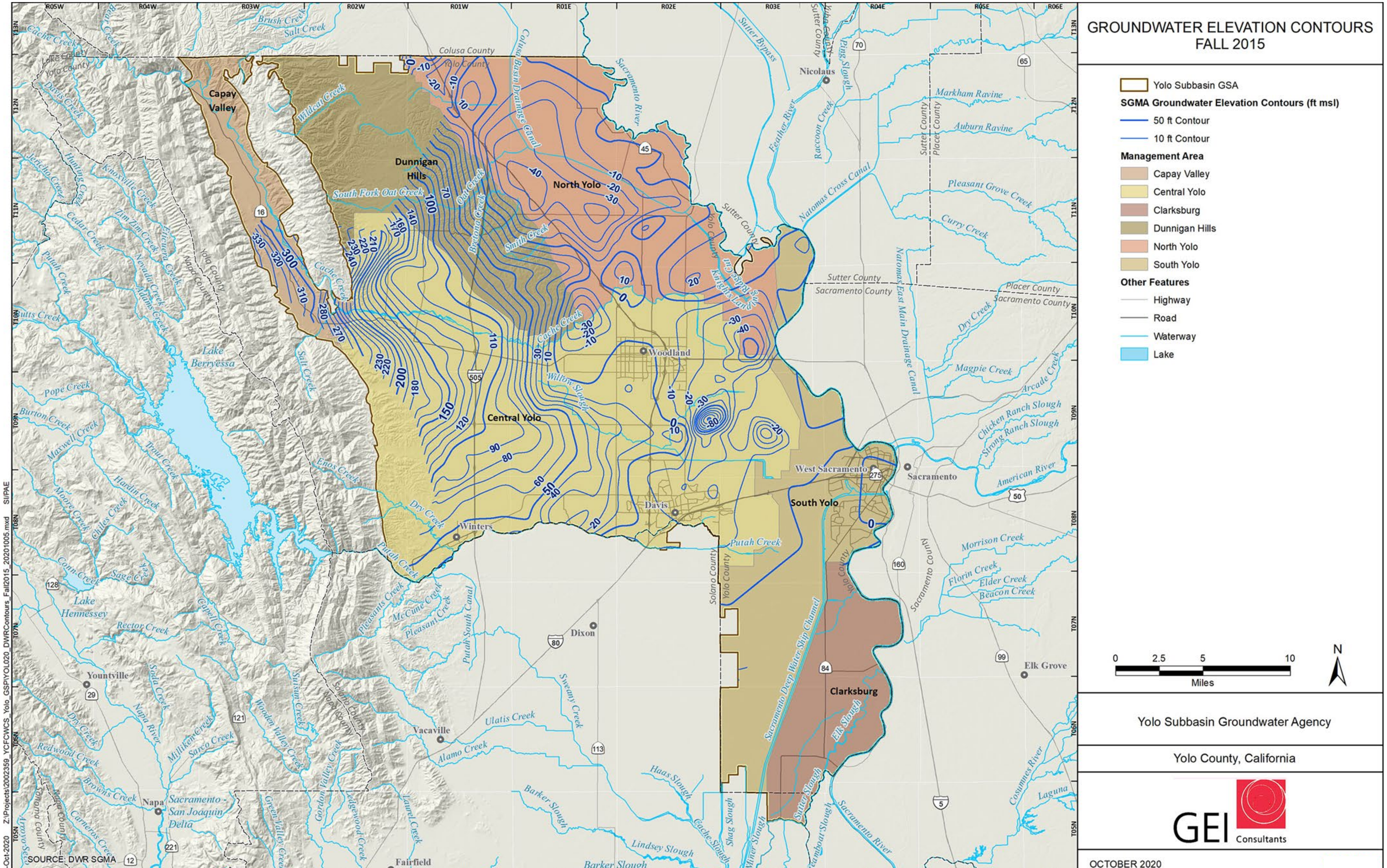

Figure 2-18. Fall 2015 Groundwater Contours (Source: SGMA Data Viewer, https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels).

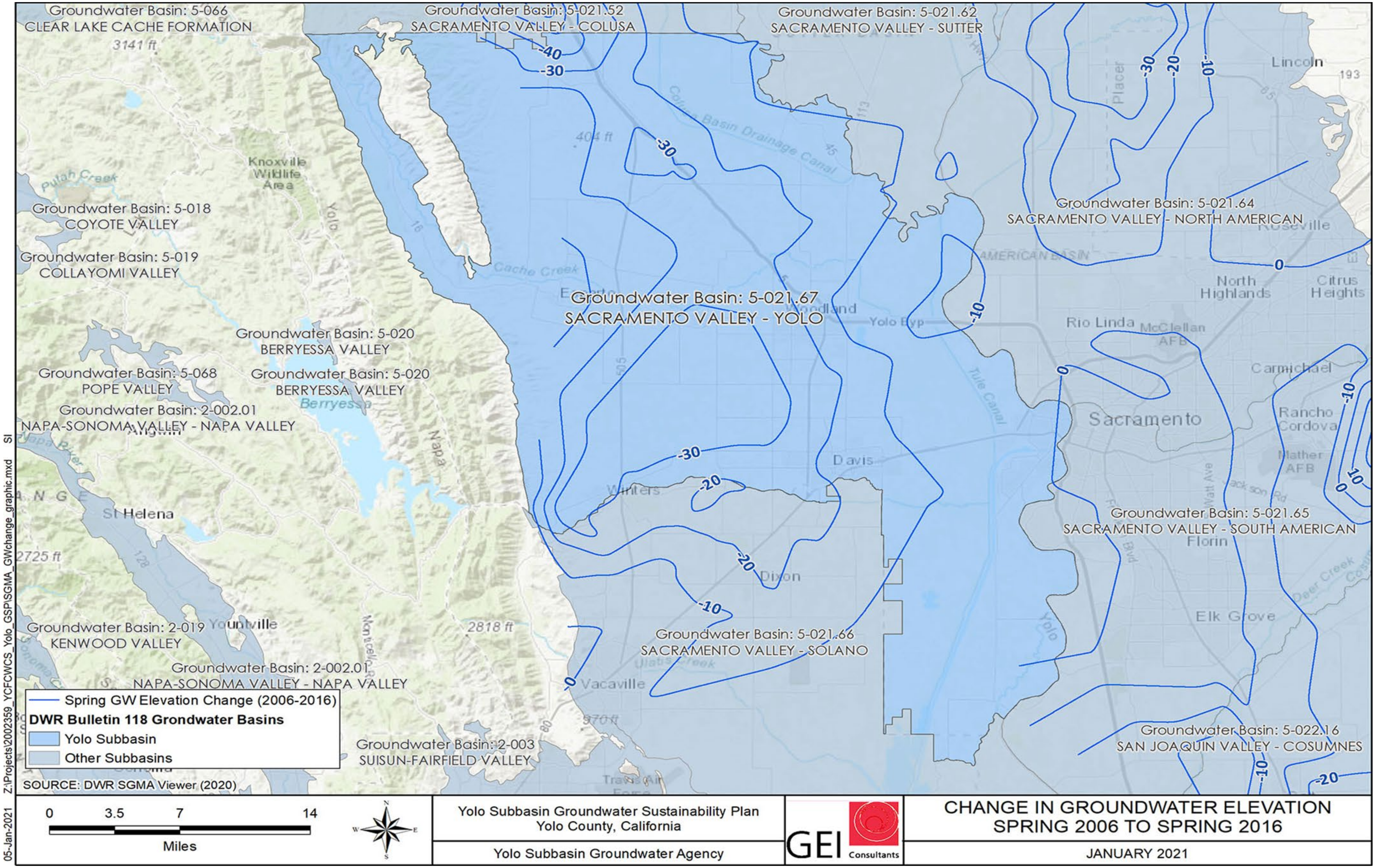

Figure 2-19. Change in Groundwater Elevations from Spring 2006 to Spring 2016. (Source: SGMA Data Viewer, https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels).

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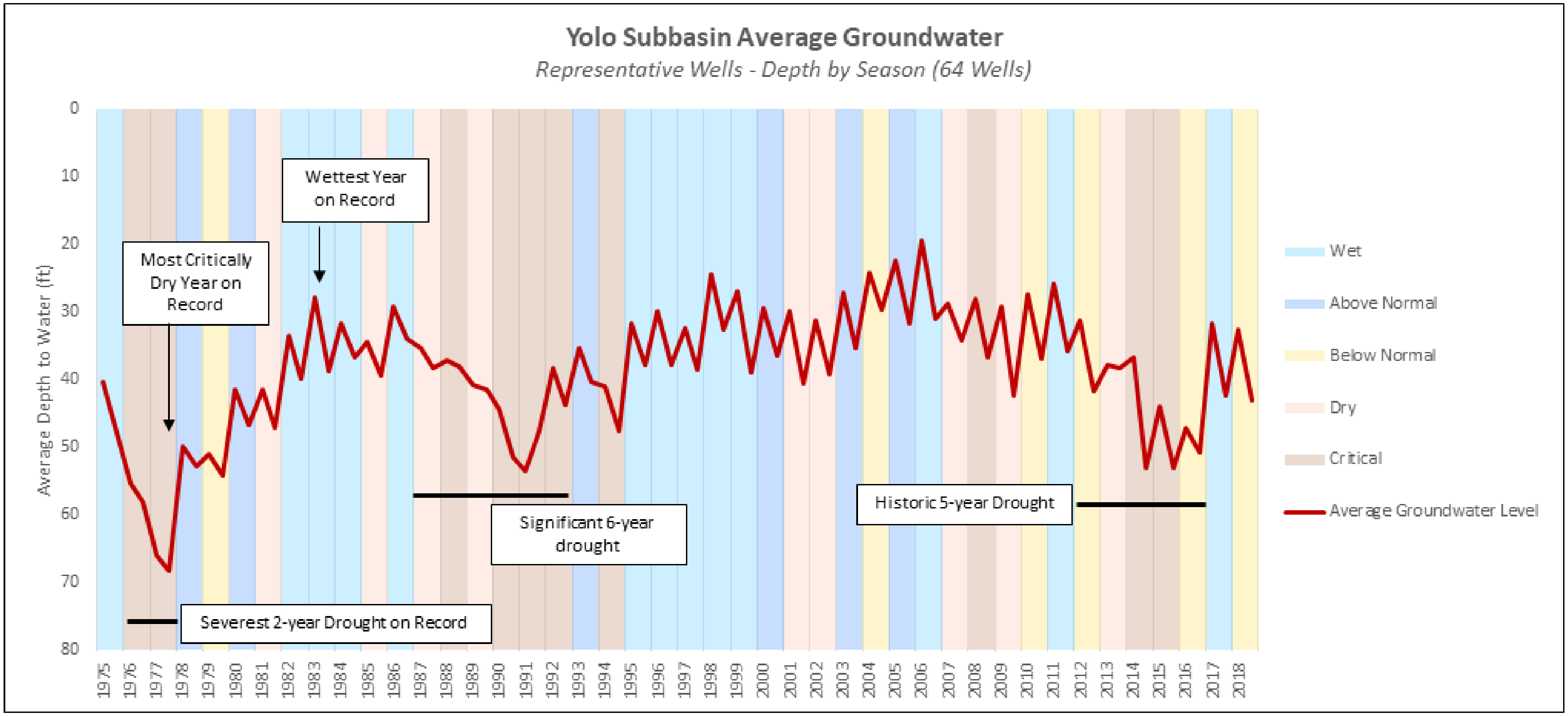

Figure 2-20. Historical Average Depth to Groundwater in the Yolo Subbasin.

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2.2.1.3 Vertical Groundwater Gradients

Natural groundwater flow is typically downward in recharge areas, such as the upland areas on the west side of the Subbasin, and upward in discharge areas, like areas found along the Sacramento River. Groundwater pumping can alter these natural gradients seasonally and over time as groundwater is withdrawn from the Subbasin. Upward movement of groundwater can occur from the deep aquifer to the intermediate aquifer, and intermediate to shallow. **Figure 2-21** and **Figure 2-22** are hydrographs for two multi-depth well configurations with four well completions at each location. The hydrographs illustrate 14 years of data, WY 2005 through 2019.

These wells were installed in association with an extensimeter for subsidence monitoring. Nested wells 11N01E-24Q-04 / -05 / -06 / -07 were installed in single boring and are located in the North Yolo MA to the southeast of Zamora. Well cluster 09N03E-08C-01 / -02 / -03/ -04 is a configuration of four separate wells, which are located in the Central Yolo MA, east of Woodland (Conaway). Construction details and groundwater gradients are summarized below.

The nested North Yolo MA wells provide groundwater data for the shallow (1), intermediate (2), and the deep (1) zones. **Table 2-8** summarizes vertical gradient observations for these wells. The seasonal fluctuations in groundwater levels are substantial, especially in the shallow and intermediate zones. Groundwater levels start out relatively high and in unison during the WY 2005 but were generally on the decline thereafter, with increasing divergence after WY 2008. The shallow and intermediate zones rise somewhat in response to wet WY 2010, while declining to lows at the end of the historic 5-year drought, in WY 2016. Groundwater levels increased after the wet WY 2017 held relatively steady due wet WY 2019. The vertical gradient is downward from the shallow zone to the upper intermediate zone, somewhat upward between the lower and upper intermediate zones, and upward from the deep zone to the intermediate zone.

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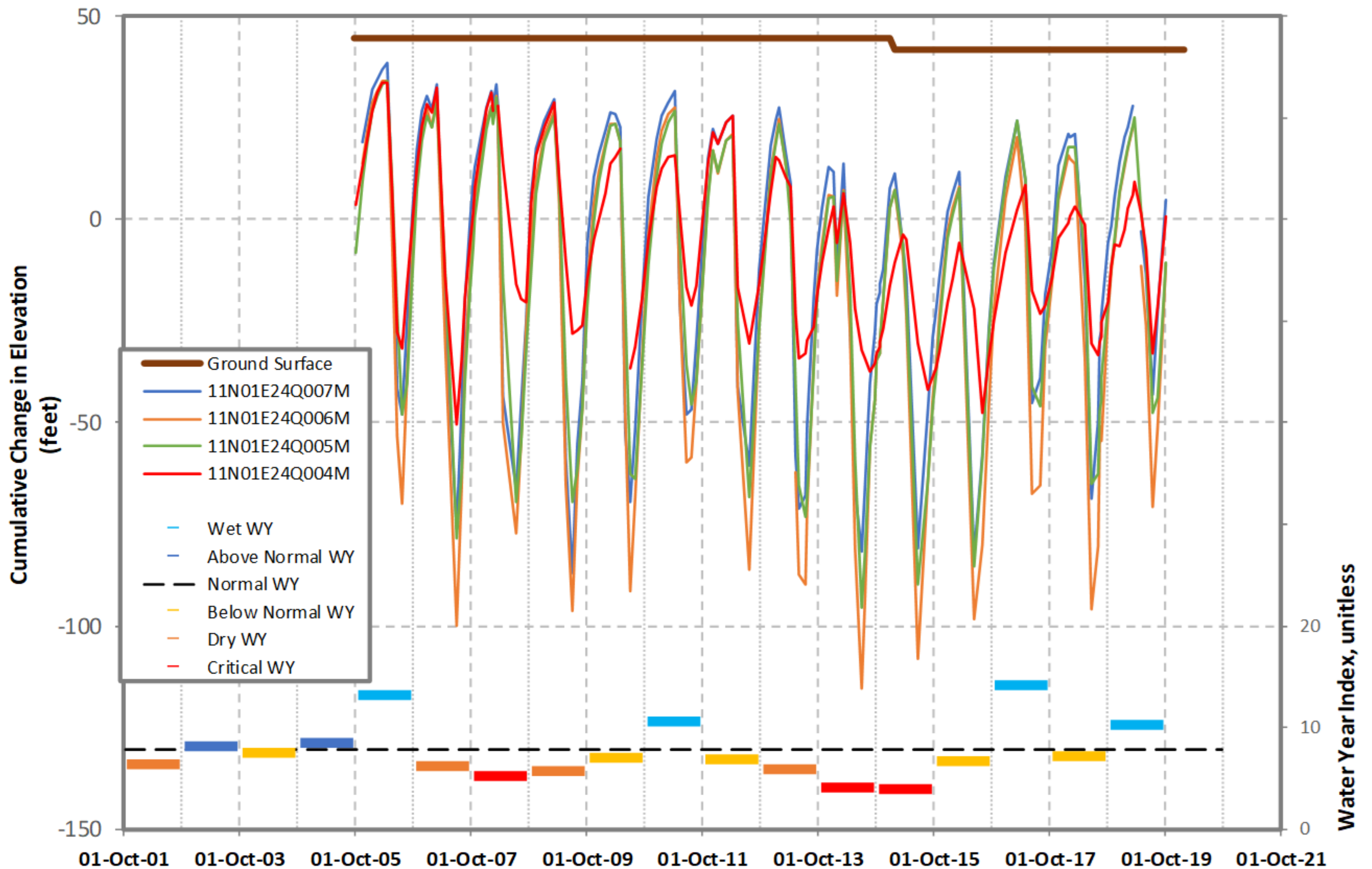
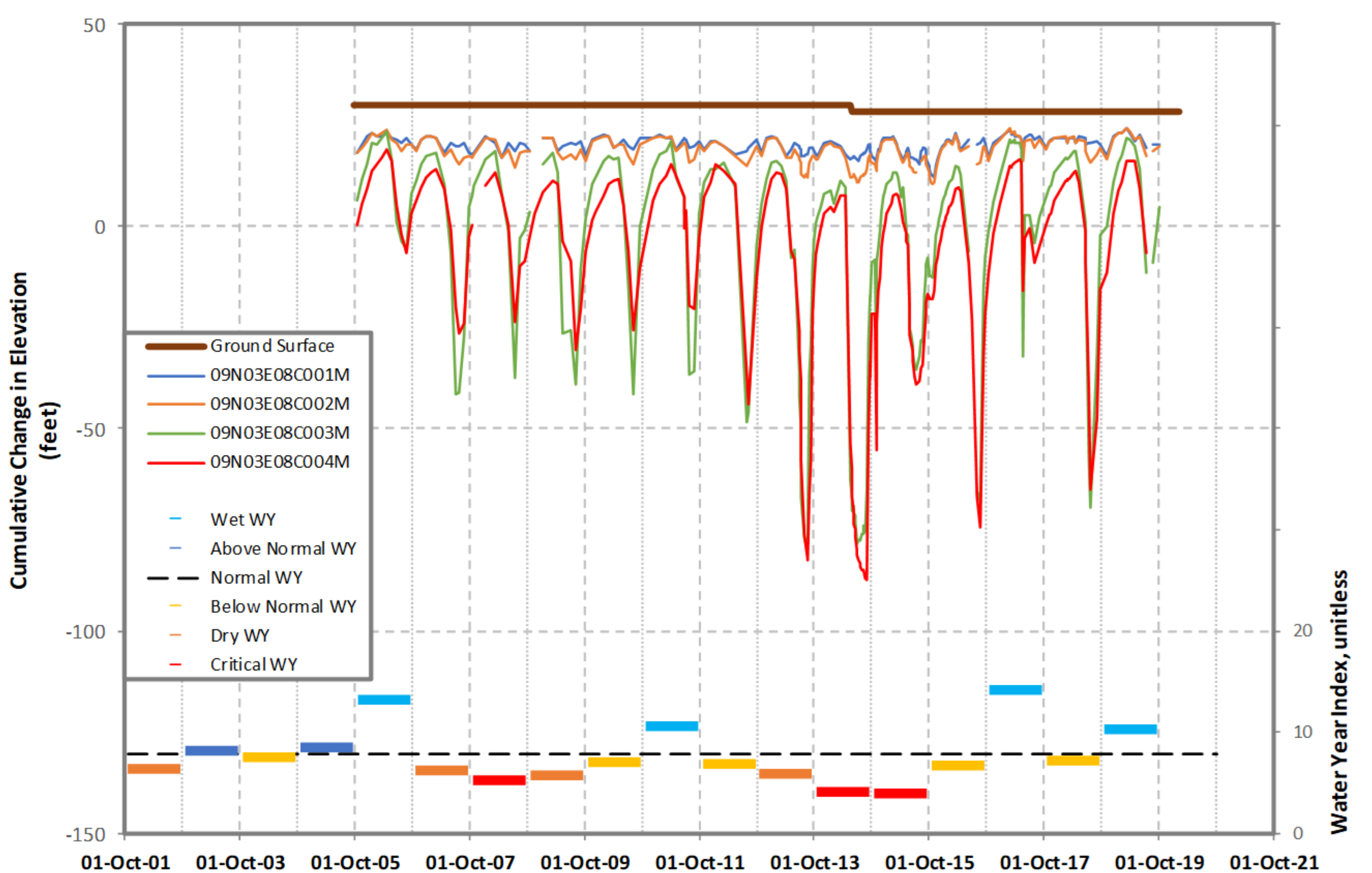


Yolo Subbasin Groundwater Sustainability Plan	GEI Consultants	**Hydrograph of Nested Wells 11N01E-24Q-04/05/06/07** **(Zamora)**	
Yolo Subbasin Groundwater Agency		Sep-20	

Figure 2-21. Hydrograph of Zamora Nested Well 11N01E-24Q-04 / 05 / 06 / 07.



Yolo Subbasin Groundwater Sustainability Plan	GEI Consultants	Hydrograph of Nested Wells 09N03E-08C-01/02/03/04
Yolo Subbasin Groundwater Agency		Sep-20

Figure 2-22. Hydrograph of Conaway Nested Well 09N03E-08C-01 / 02 / 03 / 04.

Table 2-8. Vertical Gradient Summary for the North Yolo MA Wells.

Aquifer Zone	Well Depths	Mean WL (msl)	Mean Gradient	
Shallow well	180-200’	-9.4’	Downward	0.058
Intermediate well	382-387’	-19.9’		
Intermediate well	583-588’	-14.4	Upward	-0.025
Deep well	784-789’	-6.9’	Upward	-0.040

The nested Central Yolo MA well provides groundwater data for the shallow (2) and the intermediate (2) zones. **Table 2-9** summarizes vertical gradient observations for these wells. Seasonal fluctuations occur in all four wells, but the fluctuations are considerably less in the shallow zone. Fluctuations in the intermediate zone are substantially greater due the groundwater pumping during the irrigation season, with the upper intermediate zone exceeding the lower intermediate zone until the 5-year drought period, when the relationship reverses. During the wet, non-pumping period, the shallow zone groundwater levels are quite similar and somewhat higher than the levels in the intermediate zone to produce a vertical downward gradient between the Shallow and Intermediate Zones. During the irrigation season, the lower Shallow Zone levels are deeper than the upper Shallow Zone due to groundwater pumping and the downward vertical gradient increases. For the two intervals in the Intermediate Zone, the vertical gradient was downward during the non-pumping period but was reversed during the pumping season (upward gradient) in the early period of record. During the drought, groundwater levels in the lower Intermediate Zone decreased to better match the levels in the upper Intermediate Zone to minimize the vertical gradient within the Intermediate Zone. However, the downward vertical gradient between the Shallow and Intermediate Zone increased substantially.

Table 2-9. Vertical Gradient Summary for the Central Yolo MA Wells

Aquifer Zone	Well Depths	Mean WL (msl)	Mean Gradient	
Shallow well	80-100’	19.8’	Downward	0.031
Shallow well	140-150’	18.3’	Downward	0.206
Intermediate well	260-280’	-8.6	Downward	0.016
Intermediate well	535-545’	-12.7’		

2.2.2 Change in Groundwater Storage

2.2.2.1 Change in Storage Calculations

Change in storage over time across the Yolo Subbasin can be estimated from hydrologic modeling results. Previous modeling reports have estimated change in groundwater storage, presented as an average over the model calibration period. For example, the previously developed Yolo County Integrated Groundwater Simulation Model provided simulation results for inflows, outflows, and changes in storage for each year from 1971 to 2000 (WRIME 2006). Over this 30-year period, groundwater storage increased slightly by roughly 7,200 acre-feet. However, the Subbasin experienced a wide range of variation in climate and groundwater use during the time period.

The more recent YSGA Model, which is used for the development of this GSP and encompasses the new Subbasin boundary, provides annual cumulative change in groundwater storage estimates between 1975 and 2018, as shown on **Figure 2-23**. Values above the x-axis (positive values) indicate an increase in groundwater storage, and values below the x-axis (negative values) indicate a decrease in groundwater storage (or loss of groundwater in storage). The change in groundwater storage in the Yolo Subbasin is generally positive and a substantial loss of storage cannot be seen over this period. The total storage of the Subbasin has been estimated at 13 million acre-feet (MAF) (*see* **Section 2.3.6 – Groundwater Storage**); therefore, the difference between the initial 1975 value and current 2018 storage represents a loss of less than 1.5 percent. The 2012 to 2016 drought showed a large decline in storage of nearly 400,000 acre-feet, similar to the drought of the late 1970's, which caused the maximum storage loss of about 3 percent of total storage. Change in storage increased to a positive value during 2017 due to a wet year, but then started decreasing again due to a below normal 2018. This illustration shows that the Subbasin responds quickly to variable recharge and pumping conditions. It is important to note that **Figure 2-23** represents a large-scale modeled estimate of groundwater storage. Information on groundwater storage within each MA, and an evaluation of water budget estimates, are presented in **Appendix F – Yolo Subbasin Water Budget Documentation**.

2.2.3 Seawater Intrusion

Seawater intrusion, as observed in California's coastal aquifers, will not likely occur within the Yolo Subbasin because the ocean is over 50 miles away, farther if measured along the waterways. The southern portion of the Yolo Subbasin is located within the Sacramento-San Joaquin River Delta and has been subject to salinity intrusions[27] during the early part of the last century but not since 1944 and 1990 (DWR 1995) and probably not thereafter due to the state management of flows through the Delta to prohibit salinity intrusion. The maximum annual salinity intrusion occurred in 1931 and flowed upstream midway between Courtland and Hood during the period 1921 to 1990. A maximum salinity intrusion reached the southern boundary of the Yolo Subbasin at Miner Slough in 1934 and was within a mile of the slough during 1939. Undoubtedly, salinity intrusion occurred during 19th-century drought periods and throughout early history. As such, elevated levels of sodium and chloride are likely to occur along the southern and southeastern boundaries of the Subbasin, and at depth due to the deposition of sediments in a marine environment during the Miocene epoch. There is the potential for changes in surface water conditions within the Sacramento-San Joaquin River Delta. Sea level rise, Delta water conveyance modifications, and changing land use have the potential to allow surface water with higher salinity values to move farther into the Delta than they have in the recent historic period. This has the potential to affect the South Yolo and Clarksburg MAs. These actions or projects are related to surface water management and are not directly considered in this plan; however, the quality of groundwater, specifically the increase or intrusion of salinity in the South Yolo and Clarksburg MAs will be considered when potential changes are

[27] Maximum salinity is defined as 1000 ppm of chloride measured 1 ½ hours after high tide.

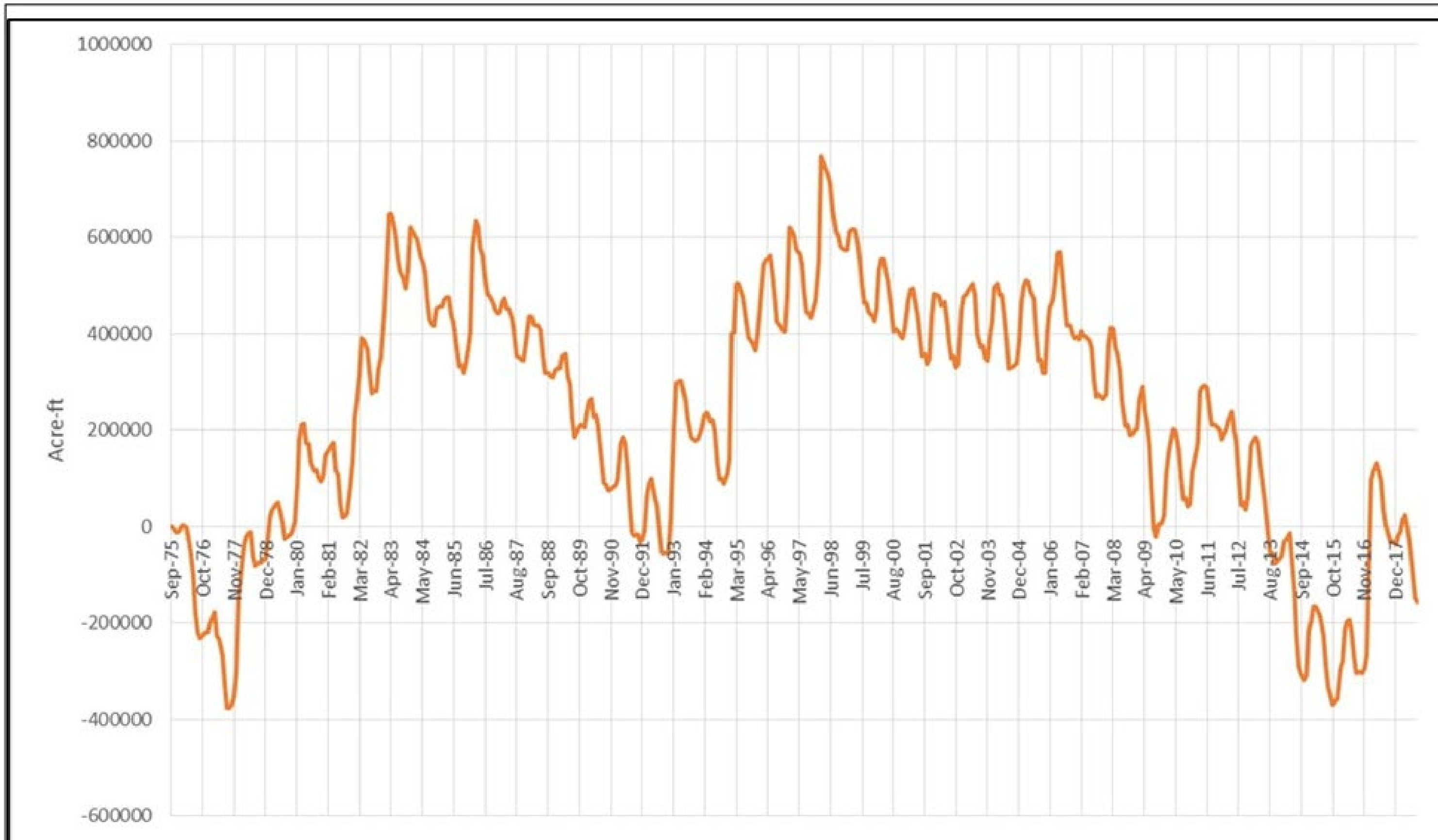
proposed in the Delta within the Degraded Water Quality Sustainable Management Criteria. Additionally, the water resource managers within the Yolo and Clarksburg MAs will proactively engage with the YSGA and ensure relevant information is updated in future plan updates.

2.2.4 Groundwater Quality

The purpose of this groundwater quality section is to review groundwater quality issues that may affect the supply and beneficial uses of groundwater as stated under CCR §354.16. This section includes a discussion of water quality standards used and information relevant to capturing groundwater quality conditions in Yolo Subbasin. A summary of groundwater quality findings for community water systems is included in **Section 2.2.4.5 – Water Quality Evaluation of Public Community Water Systems.**

2.2.4.1 Existing Water Quality Monitoring Programs

Groundwater quality monitoring and reporting is conducted through numerous public agencies. The following sections provide a summary of databases, programs and agencies that actively collect groundwater data, information on where the data is stored, and how it was used in the Basin Setting. **Table 2-10** summarizes the databases described in the following sections.



Source: SEI

Yolo Subbasin Groundwater Agency Yolo County, California	Cumulative Change in Groundwater Storage

Figure 2-23. Cumulative Groundwater Storage Change.

Table 2-10. Summary of Data Sources for Groundwater Quality Data.

Lead Agency	Database	Data Summary
State Water Board	GeoTracker[1]	Data from Irrigated Lands Regulatory Program, cleanup sites, oil & gas production, underground storage tanks, and land disposal sites. Includes programs run by State Water Board and other agencies.
State Water Board	GAMA Groundwater Information System[2]	Accumulation of groundwater quality data from state & regional boards, DWR, Department of Pesticide Regulations, USGS, Lawrence Livermore National Laboratory, and local entities.
DTSC	EnviroStor[3]	Data from hazardous waste facilities and contaminated sites.
State Water Board – DDW	SDWIS[4]	Compliance monitoring and results for all public water systems.
USGS	USGS California Water Science Center[5]	Various water data including surface water, groundwater, and atmospheric sites, often available in real-time.
USGS	NWIS[6]	Groundwater database recording groundwater levels, well depth, aquifer parameters, and more.
State and Regional Water Quality Control Boards	California Integrated Water Quality System[7]	Tracks places of interest; manages permits and inspections. Includes Waste Discharge Requirements (WDRs) and WDRs waiver records.
YSGA	WRID[8]	Incorporates local data from databases above, as well as from YCEH and local studies.

[1] https://geotracker.waterboards.ca.gov/
[2] https://gamagroundwater.waterboards.ca.gov/
[3] https://www.envirostor.dtsc.ca.gov/
[4] https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting
[5] https://www.usgs.gov/centers/ca-water
[6] https://waterdata.usgs.gov/nwis
[7] https://www.waterboards.ca.gov/water_issues/programs/ciwqs/
[8] https://wrid.facilitiesmap.com/

2.2.4.1.1 Irrigated Lands Regulatory Program

The Irrigated Lands Regulatory Program (ILRP) is a statewide program initiated in 2003 with focus on protecting surface waters; groundwater regulations were added in 2012. ILRP regulates all commercial irrigated lands within the Yolo Subbasin. ILRP was implemented to protect receiving water bodies from impairment associated with agricultural runoff, tile drain flows, and storm water runoff from irrigated fields. Elements of this program that overlap with SGMA requirements are the monitoring programs focused on identifying groundwater impairment associated with irrigated agriculture. As of March 12, 2014, a new set of water quality regulations were imposed on Sacramento River Watershed irrigated agriculture and managed wetland landowners and operators.

The Coalition was formed in 2003 as a logical extension of the Northern California Water Association (NCWA) mission to partner with over 200 agricultural representatives, natural resource professionals, wetlands managers and local governments throughout the region. The Coalition is composed of more than 8,600 farmers and wetlands managers encompassing more than 1.3 million irrigated acres. They are supported by local farm bureaus, resource conservation districts, County

Agricultural Commissioners, and crop specialists with the University of California Cooperative Extension. The Coalition is comprised of 13 sub-watershed groups. In the County, the Yolo County Farm Bureau formed as a sub-watershed group.

To date, the program has focused on sampling surface waters. Since groundwater regulations were implemented in 2012, planning related to groundwater quality has been underway, with data collection that began in Fall 2018. NCWA and the Coalition's *Comprehensive Groundwater Quality Management Plan* (ch2m 2016a) identified areas where groundwater is vulnerable to degradation that is contributed by irrigated agriculture, which were classified as high vulnerabilities. This addressed the requirements of the Waste Discharge Requirements General Order for Growers within the Sacramento River Watershed that are Members of the Third-Party Group (Sacramento River WDR) (R5-2014-0030-R1). The *Sacramento Valley Water Quality Coalition Groundwater Quality Trend Monitoring Workplan,* (LSCE 2017 and 2018) outlines the Coalition's compliance strategies, which includes, continuing to educate their members on management practices that are protective of water quality; reporting on management practices that are actively used; and a robust sampling program to trend nitrate levels in groundwater.

The focus of ILRP's groundwater regulation is to measure nitrate and demonstrate that current management practices are protecting groundwater from further degradation. The State Water Board's objective is to eventually restore nitrate as nitrogen (N) concentrations to levels below the drinking water standard of 10 parts per million (ppm) as N. Data collected and reported as a part of ILRP are provided to the State Water Board and will be available in the State Water Board GeoTracker (GeoTracker)[28] database for download and use.

The Fall 2018 sampling event was successfully completed for 21 Groundwater Trend Monitoring wells (LSCE 2019). Annual monitoring will include static water level; temperature; pH; electrical conductivity; dissolved oxygen; oxidation-reduction potential; turbidity; and nitrate as N. Once every 5 years, a limited group of general minerals will be collected.

2.2.4.1.2 Central Valley-Salinity Alternatives for Long-Term Sustainability

Central Valley-Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is a collaborative stakeholder driven and managed program to develop sustainable salinity and nitrate management planning for the Central Valley. The program objective is intended to facilitate the salt and nitrate implementation strategies recommended in the Salt and Nitrate Management Plan (SNMP) developed in 2017. They are designed to address both legacy and ongoing salt and nitrate accumulation issues in surface and groundwater. The overarching management goals, and priorities of the control are: 1) ensure safe drinking water supply; 2) achieve balanced salt and nitrate loading; and 3) implement long-term, managed restoration of impaired water bodies. The program is phased with the primary focus of early actions on nitrate impacts to groundwater drinking water supplies and established specific implementation activities. The Yolo Subbasin is a Priority 2 basin for nitrate management. Consequently, the nitrate control program schedule is set to begin in 2022.

[28] https://geotracker.waterboards.ca.gov/

CV-SALTS will enact a nitrate control program as part of the SNMP which requires forming an MA as a regulatory option to comply with the requirements of the nitrate program. The MAs will consist of a defined MA to manage nitrates, ensure safe drinking water, and meet applicable water quality objectives. Local management plans will be created to implement the long-term goals of the nitrate control program. As programs are implemented, there will be versions of MAs to meet the objectives of their individual programs. While ILRP allows for compliance of their regulatory program through coalitions that cover a broad, non-contiguous area based on similar land use, SGMA and CV-SALTS will both require contiguous areas regardless of land use. In January 2022, domestic wells on lands enrolled in the ILRP will require testing. CV-SALTS has historically been a point source program.

Both the ILRP and CV-SALTS programs involve permittees and local stakeholders working towards water management objectives set forth by the state. In this regard, collaborative efforts should be made to maximize the resources of each program and provide a more integrated approach to developing local solutions for groundwater management.

2.2.4.1.3 Groundwater Ambient Monitoring and Assessment Program

The GAMA Program was created by the State Water Board in 2000. It was later expanded by the Groundwater Quality Monitoring Act of 2001 (AB 599). AB 599 required the State Water Board to integrate existing monitoring programs and design new program elements as necessary, to monitor and assess groundwater quality. The GAMA Program is based on collaboration among agencies including the State and Regional Water Boards, DWR, Department of Pesticide Regulations (DPR), USGS and USGS National Water Information System (NWIS), and Lawrence Livermore National Laboratory. In addition to these state and federal agencies, local water agencies and well owners also participate in this program.

The main goals of GAMA are to:

1) Improve statewide comprehensive groundwater monitoring
2) Increase the availability to the general public of groundwater quality and contamination information. Data is publicly available *via* the GAMA Groundwater Information System[29]

2.2.4.1.4 GeoTracker and EnviroStor Databases

The State Water Board oversees the GeoTracker database. This database systems allows the State and Regional Water Boards to house data related to sites that impact or have the potential to impact groundwater. Records available on GeoTracker include cleanup sites for Leaking Underground Storage Tank (LUST) Sites, Department of Defense Sites, and Cleanup Program Sites. Other records for various unregulated projects and permitted facilities include Irrigated Lands, Oil and Gas production, operating Permitted Underground Storage Tanks (USTs), and Land Disposal Sites. **Figure 2-24** shows all historic and current cleanup sites in the County as of 2019.

[29] https://gamagroundwater.waterboards.ca.gov/

GeoTracker is a public and secure portal that can retrieve records and view data sets from multiple State Water Board programs and other agencies through Google maps GIS interface. This database is not only useful for the public, but also to help other regulatory agencies to monitor the progress of cases. It also provides a web application tool for secure reporting of lab data, field measurement data, documents, and reports.

The California Department of Toxic Substances Control (DTSC) oversees the EnviroStor database[30]. This data management system tracks cleanup, permitting, enforcement, and investigation efforts at hazardous waste facilities and sites with known contamination or sites where further investigation is warranted by the DTSC. This database only provides reports, inspection activities and enforcement actions completed on or after 2009. Like the GeoTracker database, this is not only useful for the public, but other regulatory agencies that may use it to monitor progress of ongoing cases. The primary difference between the two databases is that EnviroStor only houses records of cases for which the DTSC is the lead regulatory agency, whereas the GeoTracker database houses records of cases from many regulatory programs, including the DTSC, Department of Defense, U.S. Environmental Protection Agency (EPA) Cleanup sites, and many others. For the Basin Setting, both databases were searched to identify and report on any contaminated sites that may have had impacts to groundwater water quality. **Figure 2-24** shows all historic and current cleanup site in the County as of 2019 and **Figure 2-25** shows all open case cleanup sites in the County as of 2019.

2.2.4.1.5 State of California Drinking Water Information System

All public drinking water systems (a system that has 15 or more service connections or regularly serves 25 individuals daily at least 60 days out of the year) are regulated by the State Water Board – DDW to demonstrate compliance with state and federal drinking water standards through a rigorous monitoring and reporting program. Required monitoring for each well within each water system is uploaded to the DDW's database and subsequently available for the public through SDWIS[31]. In addition to providing compliance monitoring data for each regulated water system, other information such as monitoring frequency, basic facility descriptions, lead and copper sampling, disinfection by products, violations and enforcement actions, and consumer confidence reports are also available.

All drinking water systems are required to collect samples, known as Title 22 constituents on a given frequency depending on the constituent and regional groundwater vulnerability. The following is a summary of the minimum sampling frequency for a public water supply well:

- General minerals, metals, and organics (Synthetic Organic Chemicals and Volatile Organic Compounds) sampling is required every 3 years. If any organics are detected, sampling frequency must be increased to quarterly.
- Nitrate is required annually. If nitrate is ≥5 ppm, then sampling is required quarterly.

[30] https://www.envirostor.dtsc.ca.gov/

[31] https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting

- If arsenic is ≥5 parts-per-billion (ppb), sampling should be increased to quarterly but is not always done.
- If perchlorate is detectable, sampling shall be increased to quarterly for at least 1 year to determine further monitoring requirement.
- Radiologicals (gross alpha and uranium) are sampled once every 3 years (when initial monitoring is ≥ ½ the maximum contaminant level [MCL]), 6 years (when initial monitoring is ≤ ½ the MCL) or 9 years (when initial monitoring is non-detect) depending on historical results.

Public water systems provide the most abundant source of data since the testing requirements are fairly frequent intervals, and data collection began in 1974. All sample results are easily available from the SDWIS database. When using this data to characterize groundwater quality for the Basin Setting, only raw water quality data is considered. It is important to understand that this characterization is not intended to represent water supplied by purveyors because they may provide wellhead treatment to remove or reduce contamination.

2.2.4.1.6 United States Geological Survey

The USGS California Water Science Center provides California water data through data collection, processing, analysis, reporting, and archiving. Data includes surface water, groundwater, spring sites, and atmospheric sites, with data often available in real-time *via* satellite telemetry. The NWIS groundwater database consists of records of wells, springs, test holes, tunnels, drains, and excavations. Available information includes groundwater level data, well depth, aquifer parameters, and more.

2.2.4.1.7 Department of Pesticide Regulation

The DPR Ground Water Protection Program evaluates and samples for pesticides to determine if they may contaminate ground water, identifies areas sensitive to pesticide contamination and develops mitigation measures to prevent that movement. DPR obtains ground water sampling data from other public agencies, such as SDWIS, USGS, and GAMA, and through its own sampling program. Sampling locations and constituents are determined by pesticides used in a region, and from review of pesticide detections reported by other agencies. Because of their sample selection methodology, DPR typically only collects one sample per well, they do not confirm positive detections with repeat sampling. Rather, their focus is on validating contamination through their research and sampling program. These data are reported annually along with the actions taken by DPR and the State Water Board to protect ground water from contamination by agricultural pesticides.

2.2.4.1.8 California Integrated Water Quality System

California Integrated Water Quality System is a database used by the State and Regional Water Boards for tracking information about places of environmental interest, manage permits and other orders, track inspections, and manage violations and enforcement activities. Programs within this database that is used for SGMA water quality evaluation are the WDRs through Non-Subchapter 15 and Confined Animal Sites. Non-Subchapter 15 program are discharges of wastewater to land or non-federal waters which are exempt from Title 27 regulations and National Pollutant Discharge Elimination System regulations. This program regulates both point and non-point source discharges to land or to groundwater that could affect the quality of the groundwater. WDRs and WDR waivers are important since they are in place to protect groundwater quality and compliance with Basin Plans. Some regulated discharges that have the potential to affect groundwater quality include agricultural runoff, domestic septic systems, injection wells, wastewater recycled for reuse or discharge to land, dairy operations, and timber harvesting.

2.2.4.1.9 Water Resources Association of Yolo County Water Resources Information Database

YCFC&WCD has developed a robust groundwater monitoring program and data management system and was a key player in building out the WRA's WRID. Through AB 303 Project, DWR awarded AB 303 grant funds to implement a formal Yolo County region-wide comprehensive groundwater quality monitoring program in 2002. The YCFC&WCD was established as the lead agency for implementing an ongoing groundwater monitoring program for the County area and to promote coordinated and effective water resources management and dissemination of information on water resources management of groundwater conditions. As a result of AB 303, the County-wide WRID was created. Data obtained for this monitoring program includes the south to southwest portions of the Sacramento Valley Groundwater Basin that underlie the Cache and Putah creeks Alluvial Plain and all of the County.

The YSGA's WRID includes data from various regulatory agencies such as DDW, DPR, DWR, and YCEH. Information obtained from the regulatory agencies include well construction, well location, groundwater levels, and groundwater and surface water quality data. The WRID also contains groundwater quality data from potentially contaminated sites and groundwater level and quality data from domestic and private wells.

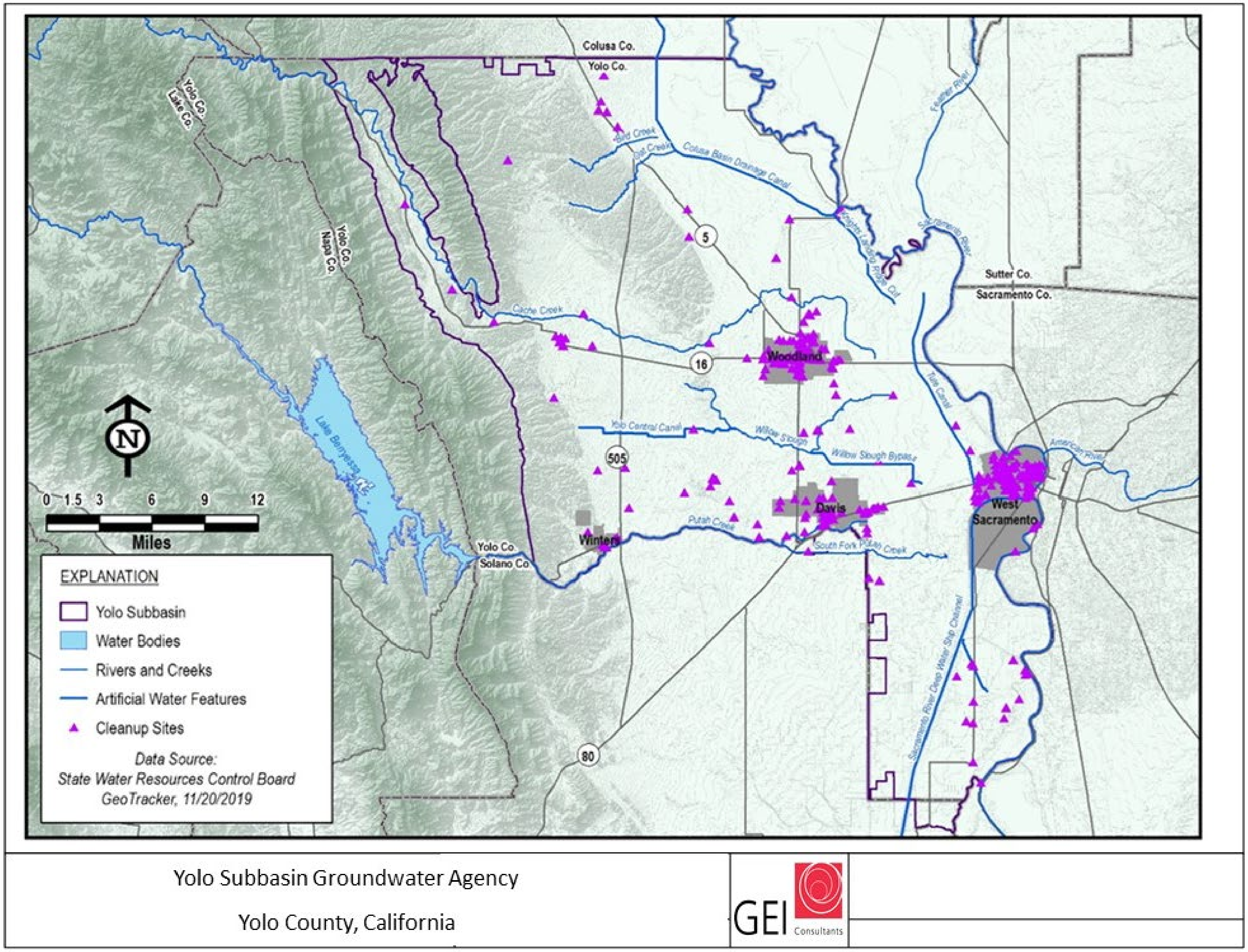


Figure 2-24. All Historic and Current Cleanup Sites.

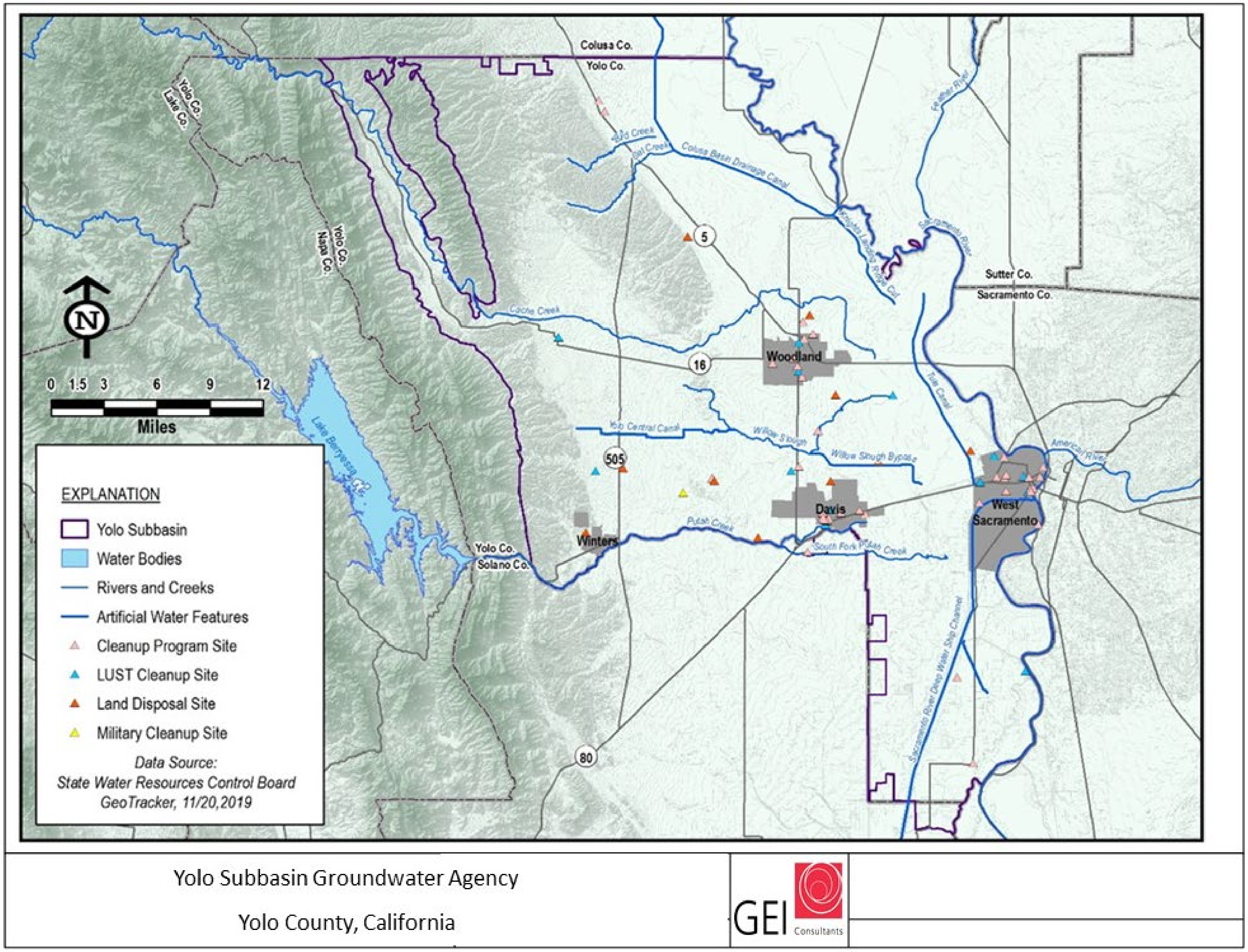


Figure 2-25. **Open-Case Cleanup Sites.**

2.2.4.2 Water Quality Standards

Federal and state Drinking Water Standards are predominantly referenced when discussing water quality standards. However, land use in the Yolo Subbasin is roughly 60 percent for agricultural purposes and drinking water salinity limits are not protective enough for agriculture. For this reason, the State Water Board's *Agricultural Water Quality Goals*[32] is also referenced for evaluation of groundwater quality in this area. The most applicable standard will be used as a reference point when discussing each constituent.

Water quality constituents that have the potential to impact the groundwater quality of the Yolo Subbasin are arsenic, hexavalent chromium, nitrate, chloride, sodium, boron, selenium, conductivity, and total dissolved solids (TDS). The list of these constituents along with their corresponding standards are listed in **Table 2-11.** In the Subbasin, arsenic, hexavalent chromium, boron, and selenium are predominately naturally occurring. Constituents related to salinity – chloride, conductivity, sodium, and TDS - also naturally occurring but concentrated by surface activities. Nitrate is predominately anthropogenic.

Table 2-11. List of Constituents and Standards.

Constituent	Units*	Drinking Water Standard	Agricultural Water Quality Goal
Arsenic	ppb	10	100
Boron	ppb	n/a**	700
Chloride	ppm	250	106
Hexavalent Chromium	ppb	n/a	100
Nitrate	ppm	10	n/a
Selenium	ppb	50	20
Sodium	ppm	n/a	69
Total Dissolved Solids	ppm	500	450

*ppb = parts per billion; ppm = parts per million
**There is no MCL established for boron; 1,000 ppb represents the State Water Board notification level

To adequately assess groundwater quality in the Subbasin, two assessments have been conducted. Basin wide conditions are first discussed followed by an evaluation of groundwater quality in community water systems.

2.2.4.3 Water Quality Evaluation – Basinwide Conditions

The following sections discuss several potential constituents of concern within the Subbasin including salinity, nitrate, boron, arsenic, total and hexavalent chromium, manganese, and selenium. All available water quality data was evaluated to identify constituents of concern. While commonly found in the Subbasin, not all constituents identified in **Table 2-11** are of concerning concentrations. Sections herein review each constituent in terms of groundwater zones including

[32] https://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/

shallow, intermediate, and deep to capture the basin wide conditions. Based on the 'Nitrate Fingerprinting and Groundwater Age Determination Study' in December 2012, Nitrate was identified as a concern and will be discussed to align with other regulatory programs in the Subbasin such as ILRP and CV-SALTS (YCFC&WCD 2012b).

2.2.4.3.1 Salinity – Basinwide Conditions

Currently, the Basin has some areas with elevated salinity as indicated by either Electrical Conductivity (EC) or TDS. For the purpose of this assessment, EC and TDS may be collectively referred to as salinity. Salinity in deeper groundwater zones is generally lower than in the shallow and intermediate zone. **Figure 2-26** shows the maximum recorded EC in groundwater quality monitoring wells from 2000 to 2004, collected as part of the AB 303 Groundwater Management Assistance Act Program. In the shallow groundwater zone, average EC ranges from around 480 μmhos/cm near Buckeye and Zamora, to over 1,450 μmhos/cm in the Lower Cache-Putah and Southern Sacramento River areas (YCFC&WCD 2004). High EC in the shallow zone is also observed in southern portions of the Capay Valley. Intermediate groundwater EC values are similar to the shallow zone, in the vicinity of Davis and Woodland. The deep groundwater zone, though limited to the Davis and Lower Cache-Putah areas, display lower EC values than the intermediate and shallow groundwater zones.

TDS data were obtained from 603 wells and were described in the Groundwater Quality Assessment Report (GAR) (NCWA 2016) and are presented in **Figure 2-27**. The GAR provides available data as of 2014. The GAR distributions generally agree with results mentioned above, as TDS is elevated in the agricultural areas surrounding Woodland, Davis, and the Capay Valley. However, these data show additional pockets of elevated TDS, including areas near Clarksburg and Knight's Landing.

Recent data (2000-2016) have been collected for the Central Valley Salinity Alternatives for Long-Term Sustainability database (NCWA 2019) and display similar concentration trends to the AB 303 and GAR data discussed above. In the shallow groundwater zone, TDS is high (>1,000 ppm) across a large portion of the eastern Subbasin, overlying West Sacramento, Davis, and Woodland. TDS values are also elevated in the Capay Valley. TDS is generally lower in the deeper groundwater zone, though patches of elevated TDS are present near Madison and north of Woodland, and concentrations in Capay Valley are uniformly above 500 ppm.

Salinity tends to decrease with depth in Yolo Subbasin. For example, EC measurements taken from 2000 to 2004 in the Lower Cache-Putah area decrease from 1,470 to 1,040 to 600 micromhos/cm for the shallow, intermediate, and deep groundwater zones respectively (**Figure 2-26**). Notable decreases in salinity with depth were also present in the Capay Valley and Southern Sacramento River areas (**Figure 2-28**). Intermediate zone EC is slightly higher than shallow zone EC near Davis, though this condition is likely a byproduct of data availability (YCFC&WCD 2004).

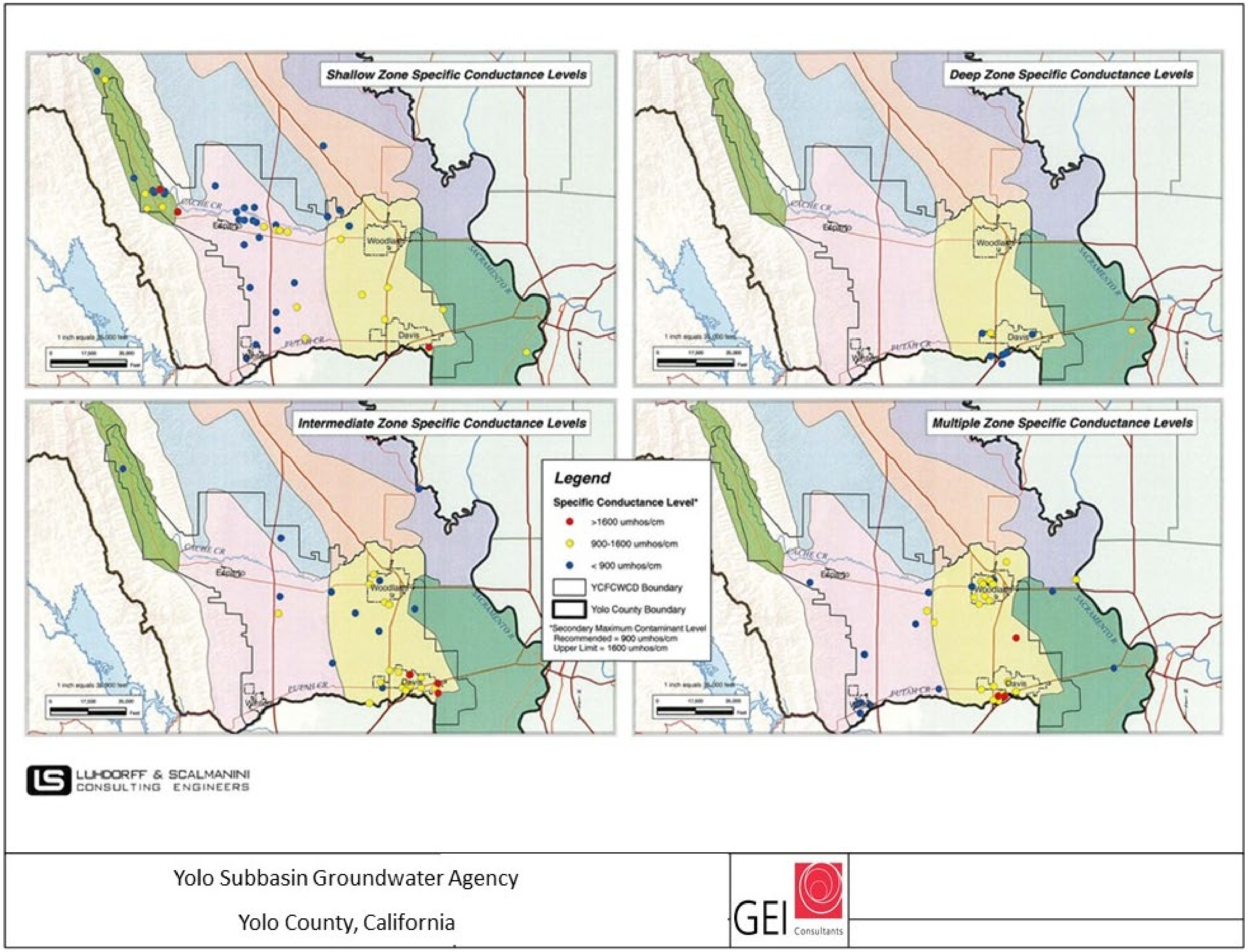


Figure 2-26. Maximum Observed Specific Conductance by Groundwater Zone, 2000-2004.

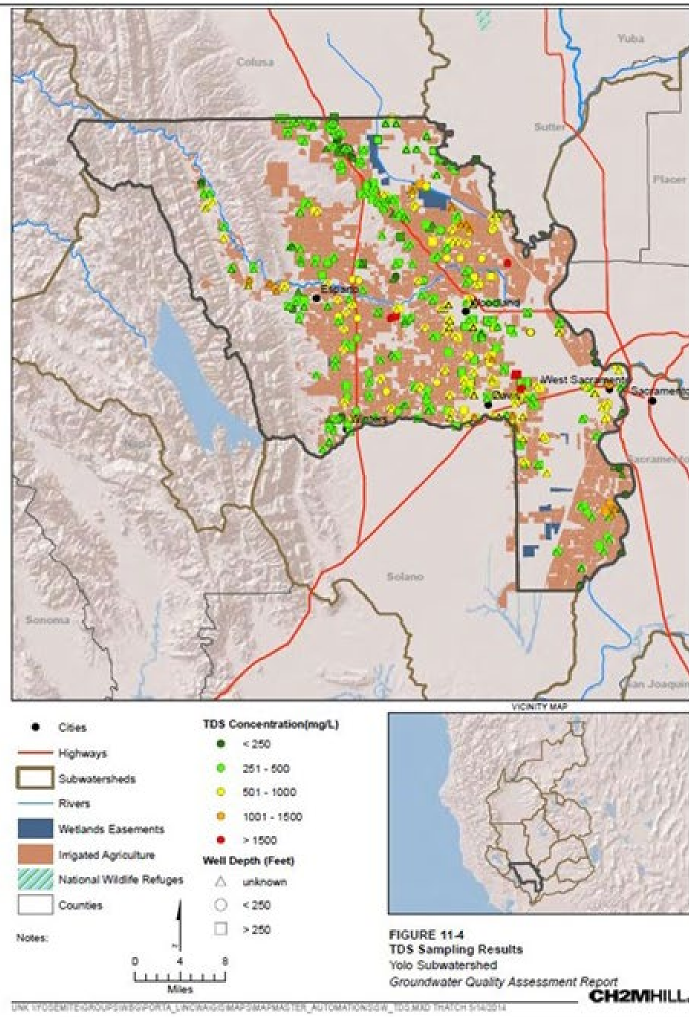


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Figure 2-27. TDS Concentrations, 2014.

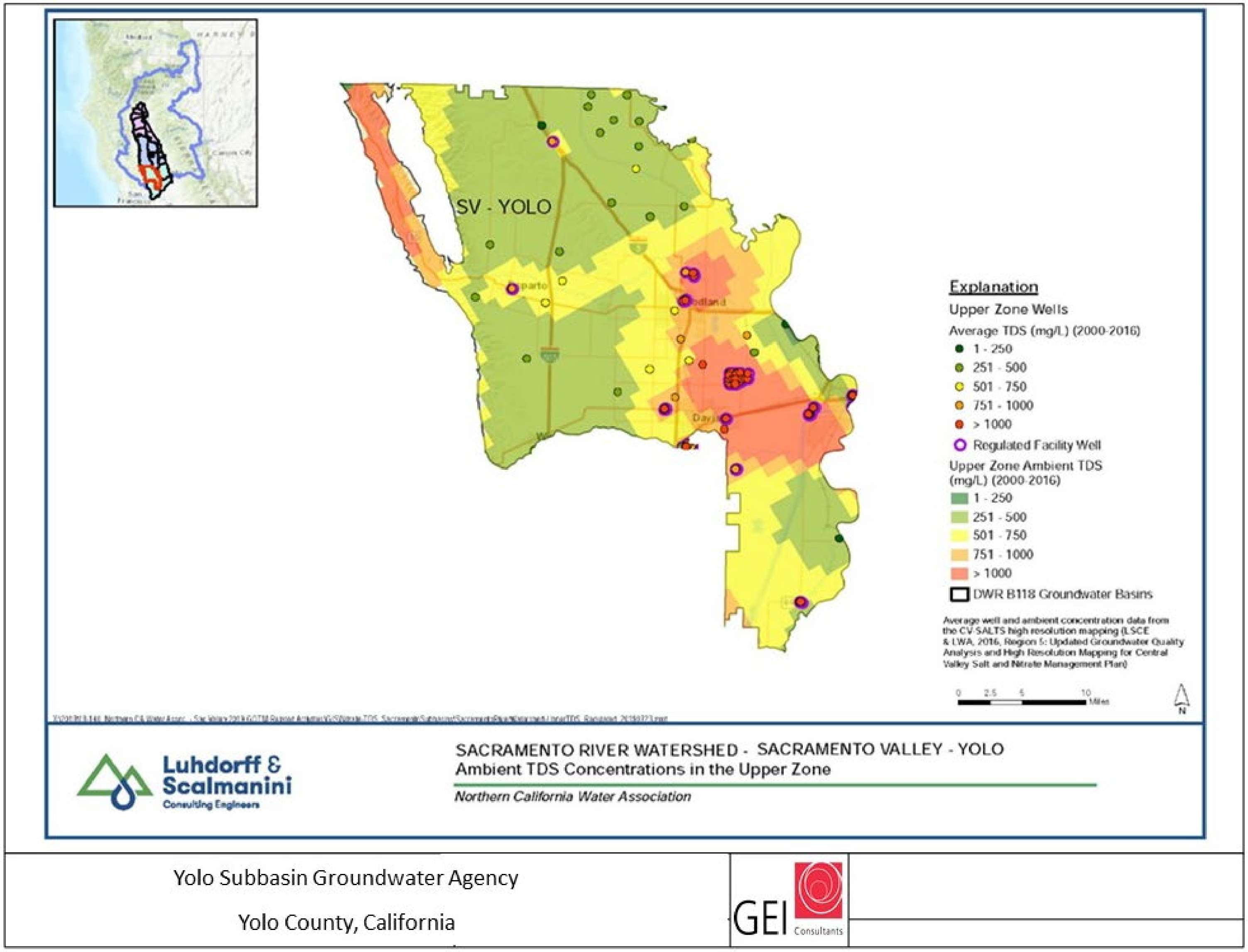

Figure 2-28. TDS Concentrations, 2016.

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Salinity in the shallow and intermediate zones of the Yolo Subbasin is generally increasing. An early groundwater quality investigation (Scott and Scalmanini 1975) found that TDS in the shallow zone near Davis increased from 500 ppm in 1931 to 684 ppm in 1970. Current levels in that area exceed 1,000 ppm (**Figure 2-27**). Similarly, shallow zone TDS near Woodland was around 480 ppm in 1950 to 1959, around 455 ppm in 1970, which was around half the current concentrations.

Salinity in Yolo Subbasin can be attributed to a variety of land use factors including evapo-concentration of applied irrigation water (YCFC&WCD 2004 and CVRWQCB 2008). Elevated salinity in the south of the Subbasin may also be attributable to the prehistoric/historic influence of the nearby Sacramento-San Joaquin Delta, which allowed brackish water to encroach into Subbasin prior to implementation of water quality programs that began during the 1950s. Extreme climatic conditions have the potential to introduce brackish waters into the Subbasin again and possibly saline waters, depending on future sea level rise and mitigation. However, in order to identify potential seawater intrusion under these conditions, further chemical analysis would need to occur, especially analysis of chloride concentrations and sodium/chloride ratios. Such analysis would become necessary if a substantial increase in Delta salinity is observed.

2.2.4.3.2 Nitrate – Basinwide Conditions

While figures may reference nitrate as nitrate (NO_3,) moving forward nitrate will be discussed as nitrate as N to reflect the current standard adopted by the State Water Board in 2016. Accordingly, nitrate as NO_3, results have been converted to nitrate as N in this section. **Figure 2-29** shows the maximum observed nitrate concentrations in groundwater quality monitoring wells, collected from 2000 to 2004 as part of the AB 303 Groundwater Management Assistance Act Program. Nitrate averages in the shallow groundwater zone range from about 3.6 ppm near Buckeye and Zamora to 14.5 ppm in the Southern Sacramento River area (YCFC&WCD 2004). Nitrate poses a significant threat to human health and therefore is subject to a primary drinking water standard. The MCL is 10 ppm as N.

Notably, wells along Cache Creek also show elevated nitrate concentrations, which may reflect the shallow completion depths of these wells. Elevated shallow zone nitrate concentrations (≈10 ppm) in the Lower Cache-Putah area are very near or exceed the primary MCL, indicating a significant water quality concern for shallow zone wells.

Figure 2-30 presents the nitrate concentrations for 384 wells as a part of the GAR (NCWA 2016). The GAR provides available data as of 2014. The nitrate distributions are consistent with the results of the previous studies discussed above – nitrate concentrations are elevated in the agricultural areas surrounding Woodland and Davis.

Recent nitrate concentrations (2000-2016) have been collected for the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) database (NCWA 2019) and display similar concentration trends to the AB 303 and GAR data discussed above. In the unsaturated zone, nitrate concentrations are high (>10 ppm) across a broad swath of the central Subbasin (**Figure 2-31**). A particularly large strip of nitrate concentration exists between West Sacramento and Davis, with other pockets of high nitrate present near Woodland, Knight's Landing, and Madison water systems.

Nitrate contamination in the lower groundwater zone is less extensive than in the upper zone, however pockets of high concentrations are present north of Woodland and near Madison (**Figure 2-32**).

As mentioned previously, nitrate concentration typically decreases with depth in Yolo Subbasin. Notable differences between zones are especially present in the Western Yolo, Southern Sacramento River, and Lower Cache-Putah areas. For example, average nitrate concentrations in the Lower Cache-Putah area decline with depth from 10 to 4 to 0.7 ppm in the shallow, intermediate, and deep zones, respectively. **Figure 2-29** through **Figure 2-32** further illustrate differences in nitrate concentrations at depth.

Historical groundwater quality investigations in the County have shown increasing shallow and intermediate zone nitrate concentrations in much of the central-eastern portion of the Subbasin, particularly near Davis and Woodland (Scott and Scalmanini 1975). For example, shallow zone nitrate concentrations near Davis increased from 1 ppm in 1931 to 2.5 ppm in 1970. Similarly, shallow zone nitrate concentrations near Woodland increased from 0.6 ppm in the 1950s to 1 ppm in 1970. More current data suggest nitrate accumulation in the shallow and intermediate groundwater zones is ongoing in some areas and may be extending into the deep zone (YCFC&WCD 2004; NCWA 2016, 2019).

Nitrate in Yolo Subbasin is mostly of agricultural origin. A recent fingerprinting study (YCFC&WCD 2012a) identified 24 wells with nitrate, and 83 percent of the nitrate originated from artificial fertilizer. For the remaining 17 percent of wells, the nitrate was an organic source, either septic which is commonly rural or manure. Previous studies have obtained similar results, indicating that the elevated nitrate in Yolo Subbasin is mostly a byproduct of agricultural discharges in the Subbasin (LW&A 2010; YCFC&WCD 2006).

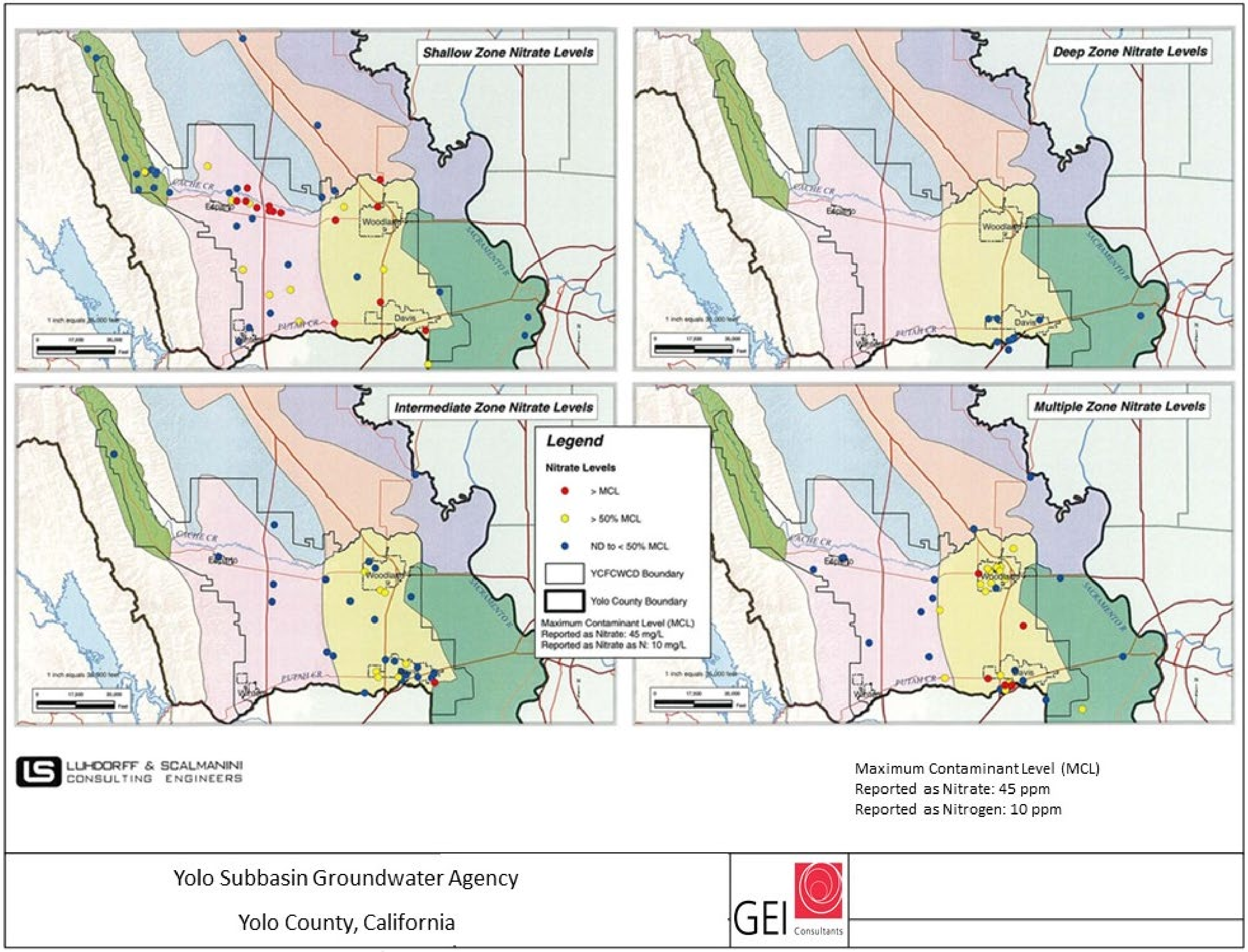

Figure 2-29. Maximum Observed Nitrate Concentrations by Groundwater Zone, 2000-2004.

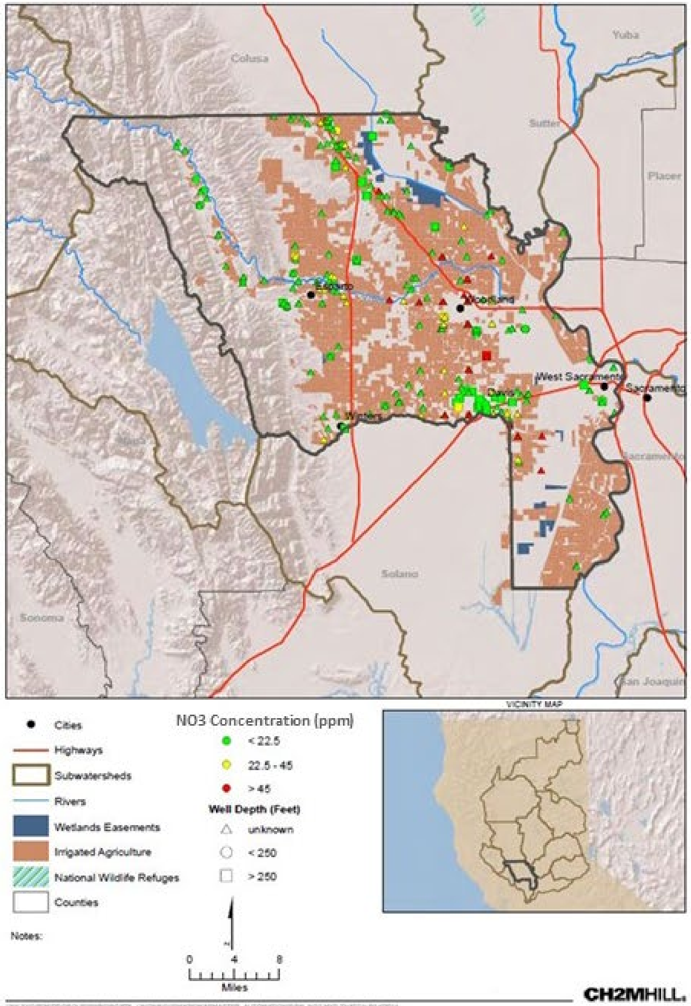

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Figure 2-30. Nitrate Concentrations, 2014.

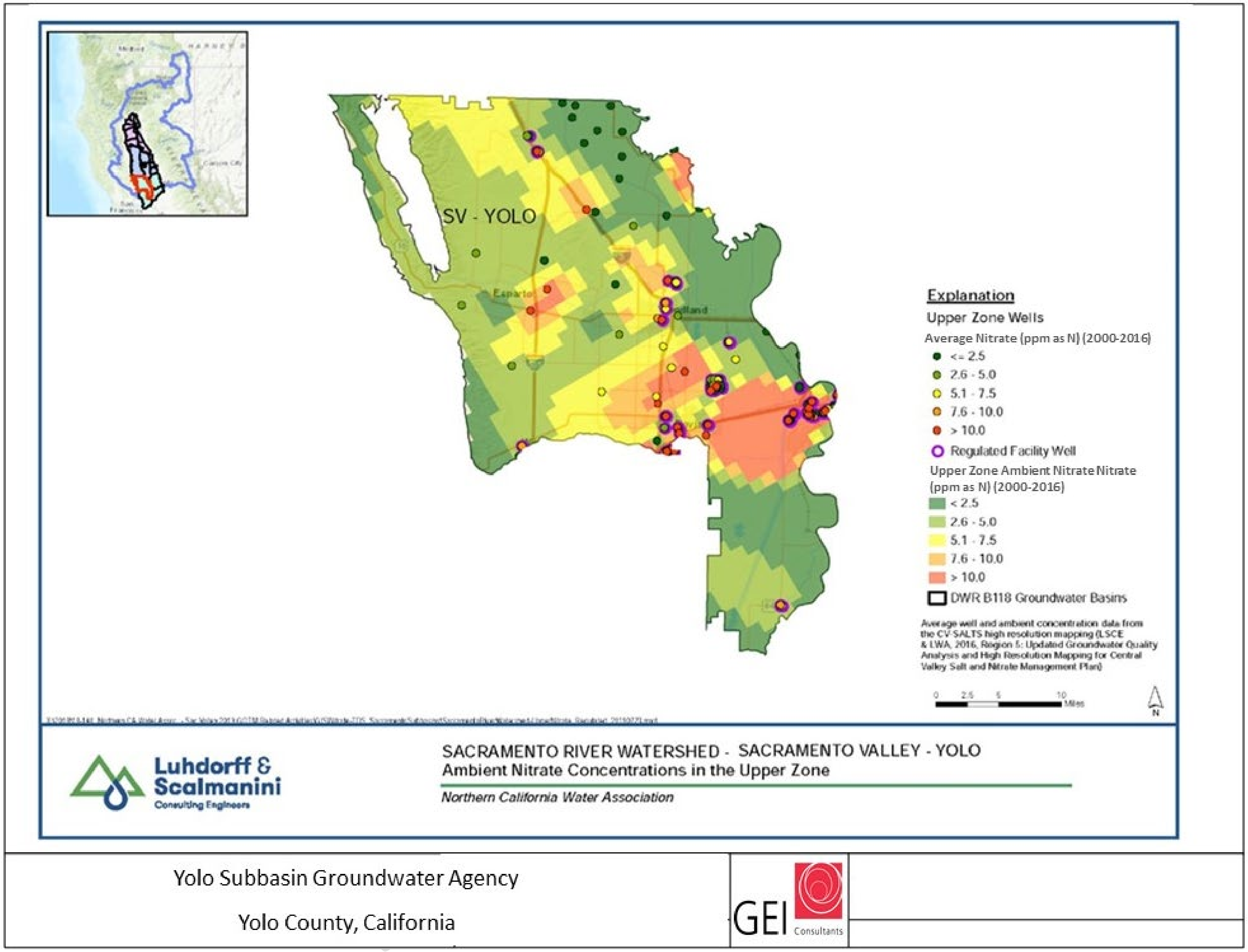

Figure 2-31. Upper Groundwater Zone Nitrate Concentration in Yolo Subbasin, 2000-2016.

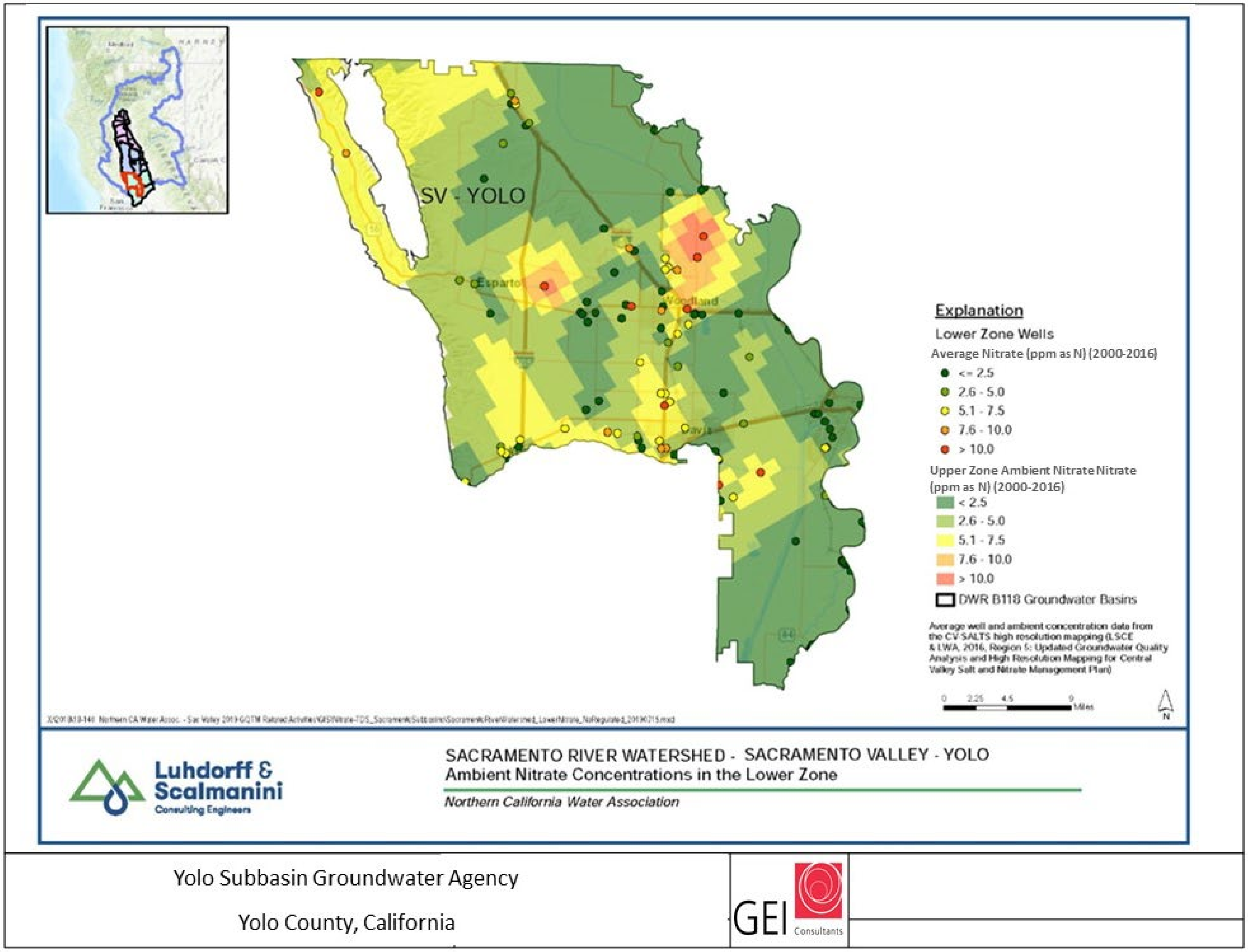

Figure 2-32. Lower Zone Nitrate Concentration in Yolo Subbasin, 2000-2016.

2.2.4.3.3 Boron – Basinwide Conditions

Figure 2-33 and **Figure 2-34** display maximum observed boron measurements in groundwater quality monitoring wells for 1951 to 2004. This compilation was part of the AB 303 Groundwater Management Assistance Act Program. Average boron concentrations for the shallow groundwater zone ranged from about 660 micrograms per liter (ug/L) in the Western Yolo area to 2,300 ug/L in the Capay Valley area. The Capay Valley has been identified as particularly high in boron, and hosts a disparate range of boron concentrations, ranging from 392 to 9,490 ug/L. The second highest average shallow boron concentration (1,600 ug/L) was present in the Lower Cache-Putah area (YCFC&WCD 2004).

In general, boron concentrations decrease with depth in Yolo Subbasin. For example, average concentrations in the Lower Cache Creek-Putah area decrease from 1,600 to 1,100 to 730 ug/L for the shallow, intermediate, and deep groundwater zones respectively. Boron concentrations also decline notably with depth in the Capay Valley and Southern Sacramento River areas.

In general, boron concentrations in Yolo Subbasin have been historically stable. While some wells across the Subbasin have been identified as increasing in boron concentration, these fluctuations are small relative to the historical range and are not spatially correlated (YCFC&WCD 2004). Previous studies of the boron distribution in Yolo Subbasin correlate well with more current data, suggesting large changes in boron concentration have not occurred historically (Scott and Scalmanini 1975; Evenson 1985)

While boron is an essential plant nutrient, concentrations greater than 4 ppm are generally toxic to non-tolerant plants. Further, concentrations between 0.5 and 4 ppm can be harmful to sensitive plant species (Ayers and Westcot 1985). Boron in groundwater systems often occurs naturally, a result of interaction between water and borate/borosilicate minerals in rocks and soils. In some instances, boron may be present in groundwater as a result of wastewater discharges, typically associated with domestic washing products (WHO 1998). The distribution of boron in Yolo Subbasin suggest a naturally occurring source, associated with the hydrogeologic setting of the Subbasin (YCFC&WCD 2004).

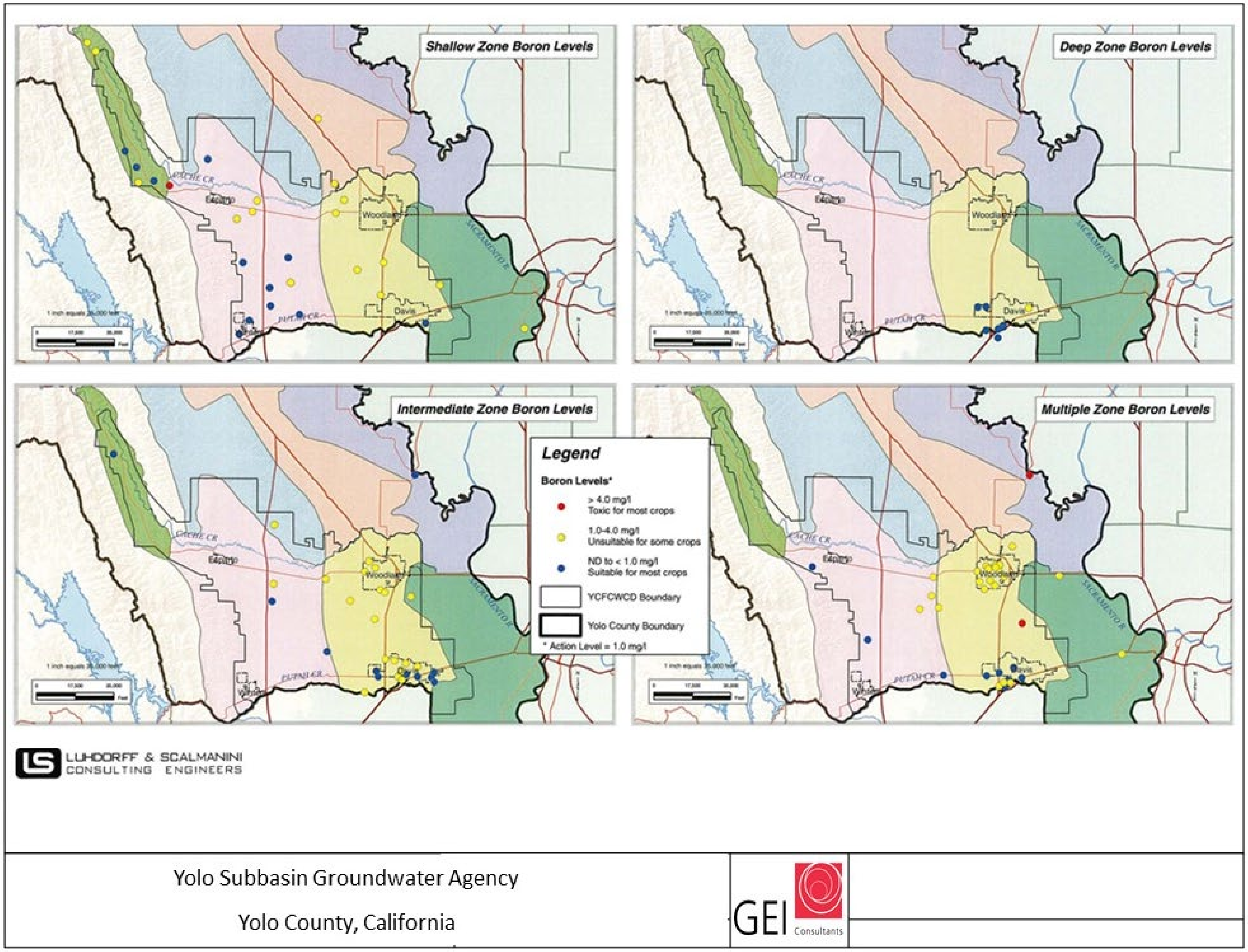

Figure 2-33. Maximum Observed Boron Concentrations by Zone, 1951-2004.

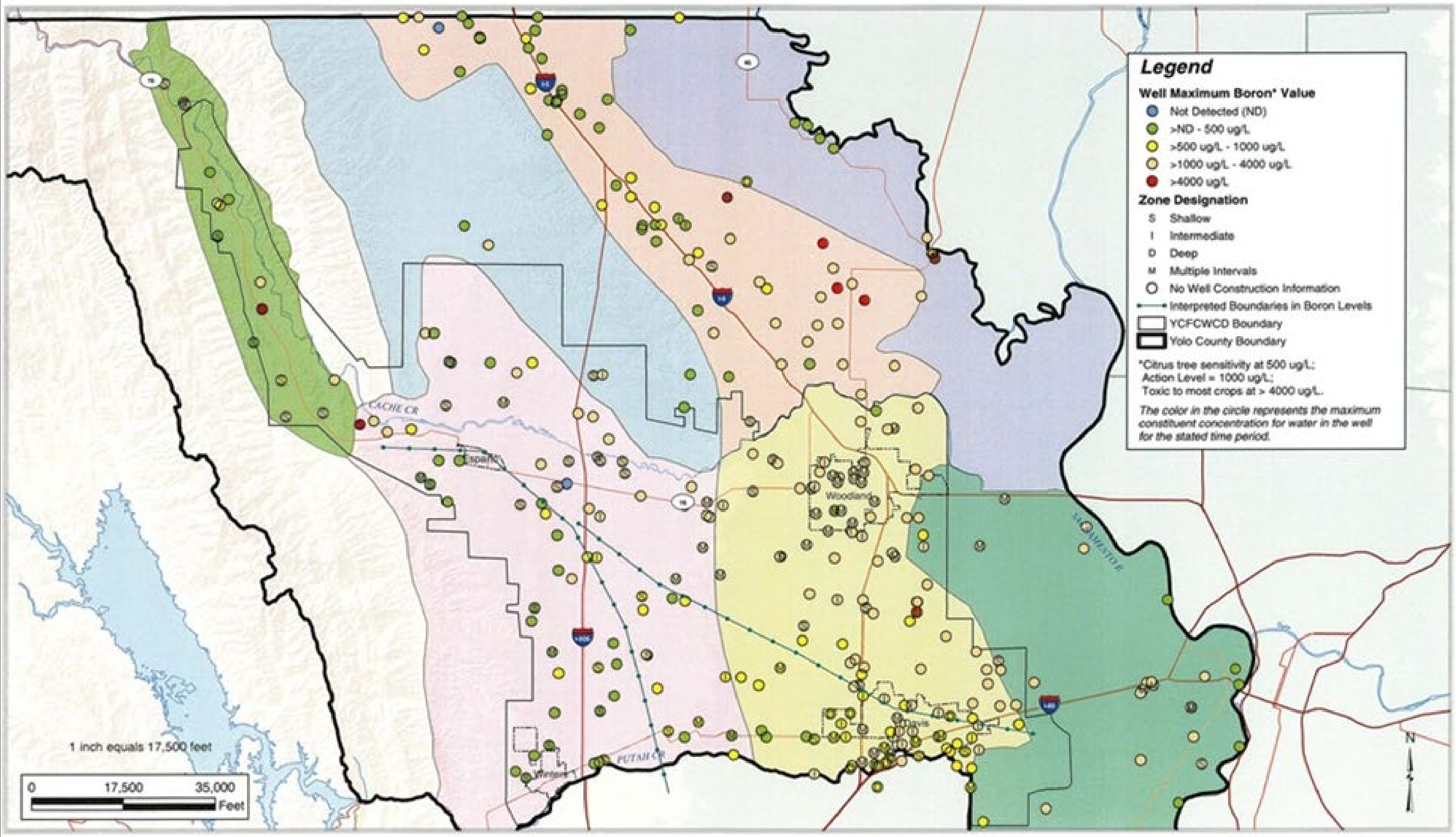

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Figure 2-34. Maximum Observed Boron Concentrations, 1951-2004.

2.2.4.3.4 *Arsenic – Basinwide Conditions*

Figure 2-35 shows arsenic data compiled for samples collected from 1951 to 2004 as part of the AB 303 Project. Although the data are limited due to high detection limits and sampling quantity, results are useful in the identification of potential arsenic trends in the Subbasin. The limitations were discussed in the full report (YCFC&WCD 2004). Maximum arsenic detection values from 1951 to 2004 are displayed on **Figure 2-35**. Arsenic was not typically detected in the shallow groundwater zone, while concentrations range up to 6.4 ug/L in the intermediate zone. Arsenic detections in the deep groundwater zone are slightly higher, ranging up to 10 ug/L.

The distribution of arsenic across the Subbasin illustrates some possible patterns of distribution. However, the high detection limit(s) of the older analyses may have actually omitted an area(s) of naturally occurring arsenic at very low concentrations. In general, concentrations increase from the west to the east of the Subbasin, possibly correlated with increased thickness of the Tehama formation. Historical arsenic results in the Capay Valley and Western Yolo area show mostly non-detects and low concentrations up to 2.5 ug/L. Arsenic trends relatively higher in the area between Woodland south to Davis, exhibiting a greater prevalence of values between 2.5 and 5 ug/L. Near Davis, arsenic concentrations can range from 5 to 10 ug/L.

Arsenic is a trace element naturally present in the basin-fill aquifers in the Western U.S that can negatively impact human health when consumed in drinking water (Smith et al. 2002; Henke 2009; Anning et al. 2012). The source of arsenic has not been documented thoroughly for the Yolo Subbasin.

2.2.4.3.5 *Chromium / Hexavalent Chromium – Basinwide Conditions*

Total chromium (chromium III and chromium VI) data were compiled for samples collected from 1951 to 2004 as part of the AB 303 Project and are displayed on **Figure 2-36**. While the following discussion focuses on total chromium, it should be noted that hexavalent chromium, when detected, generally occurred at lower concentrations than chromium (YCFC&WCD 2004).

Historical total chromium data in the Capay Valley and Western Yolo areas were generally non-detects or up to 10 ug/L. Chromium levels were relatively high in the area between Woodland and Davis, which exhibited a greater prevalence of values between 10 and 50 ug/L. Total chromium was particularly elevated near the City of Davis, where results ranged between 25 and 50 ug/L. It is possible that chromium concentrations decrease with depth, as maximum detected chromium decreases from 71 to 31 ug/L between the intermediate and deep groundwater zones respectively. Existing data are not sufficient to pinpoint trends in chromium concentration over time.

Chromium (III) in Yolo Subbasin probably occurs naturally due to its presence in the serpentine geology of the Coast Range (Chung, Buran, and Zasoski 2001). Chromium, especially hexavalent chromium, is commonly present in geologic environments associated with convergent plate boundaries (Oze et al. 2007) which were present in the geologic history of the Subbasin. Chromium can also be anthropogenic in origin, typically a byproduct of the engineering metal industry (Johnson et al. 2006).

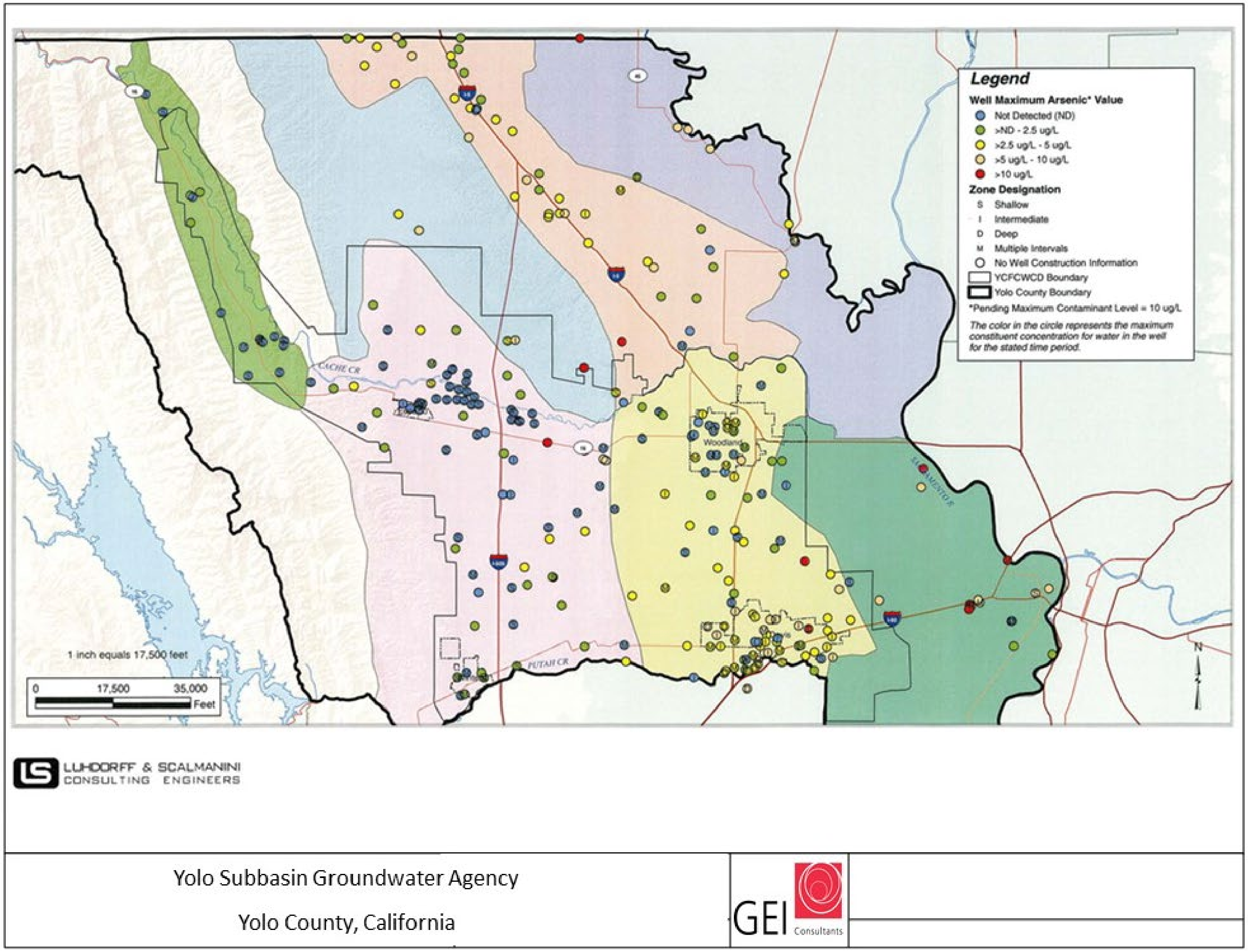

Figure 2-35. Maximum Observed Arsenic Concentrations, 1951-2004.

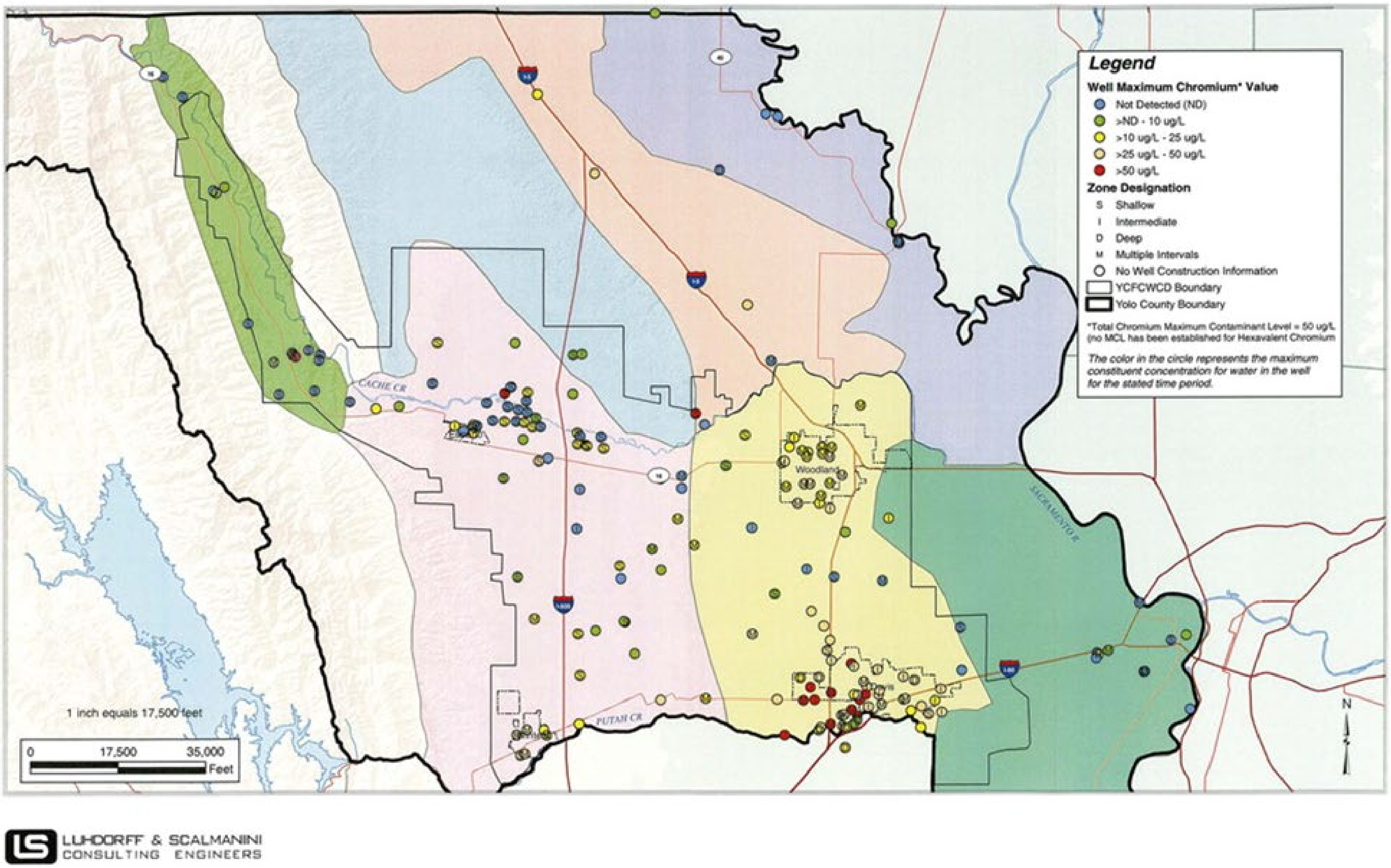

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Figure 2-36. Maximum Observed Chromium Concentrations, 1951-2004

2.2.4.3.6 Manganese – Basinwide Conditions

Maximum manganese detections were compiled for samples collected from 1951 to 2004 as part of the AB 303 Project and are displayed on **Figure 2-37**. The distribution of high manganese is quite scattered, with few obvious patterns present in the data (YCFC&WCD 2004). Pockets of high concentration (>0.05 ppm) exist between West Sacramento and Davis and in the vicinity of Davis. The Western Yolo area displays elevated concentrations along Cache Creek and east of I-505 between Madison and Winters.

Near the City of Davis, manganese concentration appears to increase with depth, and is especially high to the north and east of the Davis area. (YCFC&WCD 2004). Historical data are not sufficient to establish significant increasing or decreasing trends.

Though manganese is a required nutrient in the human diet, concentrations greater than 0.05 ppm (secondary MCL) can create aesthetic problems for drinking water, including metallic taste, staining of plumbing fixtures and laundry, and accumulation of manganese oxides in pipes.

Concentrations above 0.3 ppm may pose a significant risk for human health (Agency for Toxic Substances and Disease Registry 2000; EPA 2004). The State Water Board established a notification level of 0.5 ppm, which requires purveyors to notify local government of the condition and recommends consumer notification.

Manganese occurs naturally in much of the world's groundwater and surface water. However, elevated manganese concentrations can also originate from anthropogenic sources including automobile exhaust and manufacturing (WHO 2011). Historically, manganese has been a constituent of concern in community water supplies in the eastern Subbasin including Broderick, Bryte, and West Sacramento (YCFC&WCD 2004).

2.2.4.3.7 Selenium – Basinwide Conditions

Maximum detected selenium data were compiled for samples collected from 1969 to 2004 as part of the AB 303 Project and are displayed on **Figure 2-38**. Relatively high detection limits were common for the older analyses so non-detects may have omitted an area(s) of low concentration selenium (YCFC&WCD 2006). Nevertheless, some general selenium trends can be gleaned from the data. Elevated concentrations of selenium were historically present in the lower Cache-Putah area, particularly near Davis and generally range from 10-50 ug/L. Conversely, selenium is quite low in the Capay Valley and Western Yolo areas, where concentrations range up to 10 ug/L.

While selenium is an essential nutrient, concentrations greater than 50 ug/L can be harmful to human health. Selenium is naturally occurring in many areas, though it may also be generated by industrial and manufacturing processes such as copper refining (ATSDR 2003).

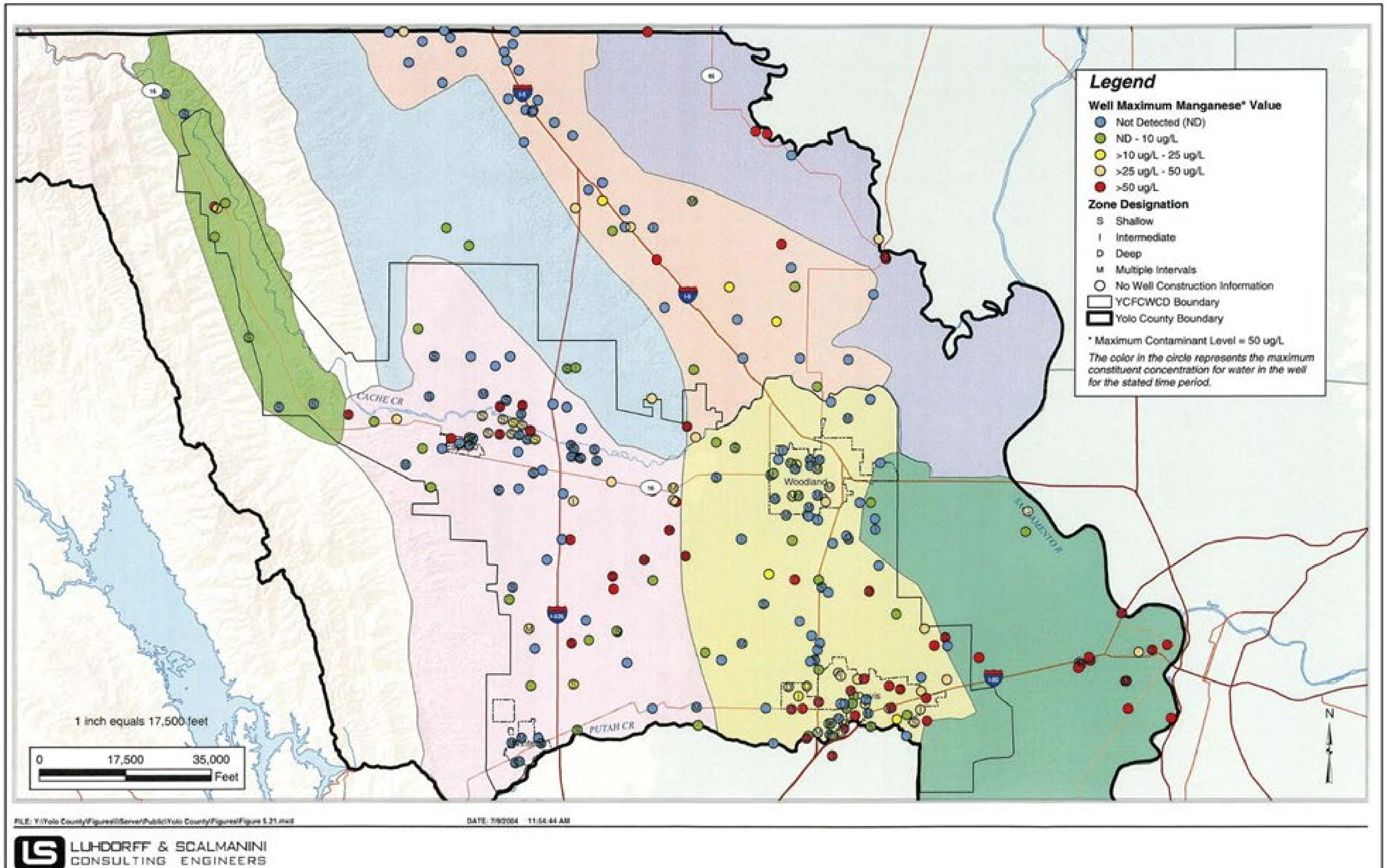

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Figure 2-37. Maximum Observed Manganese Concentrations, 1951-2004.

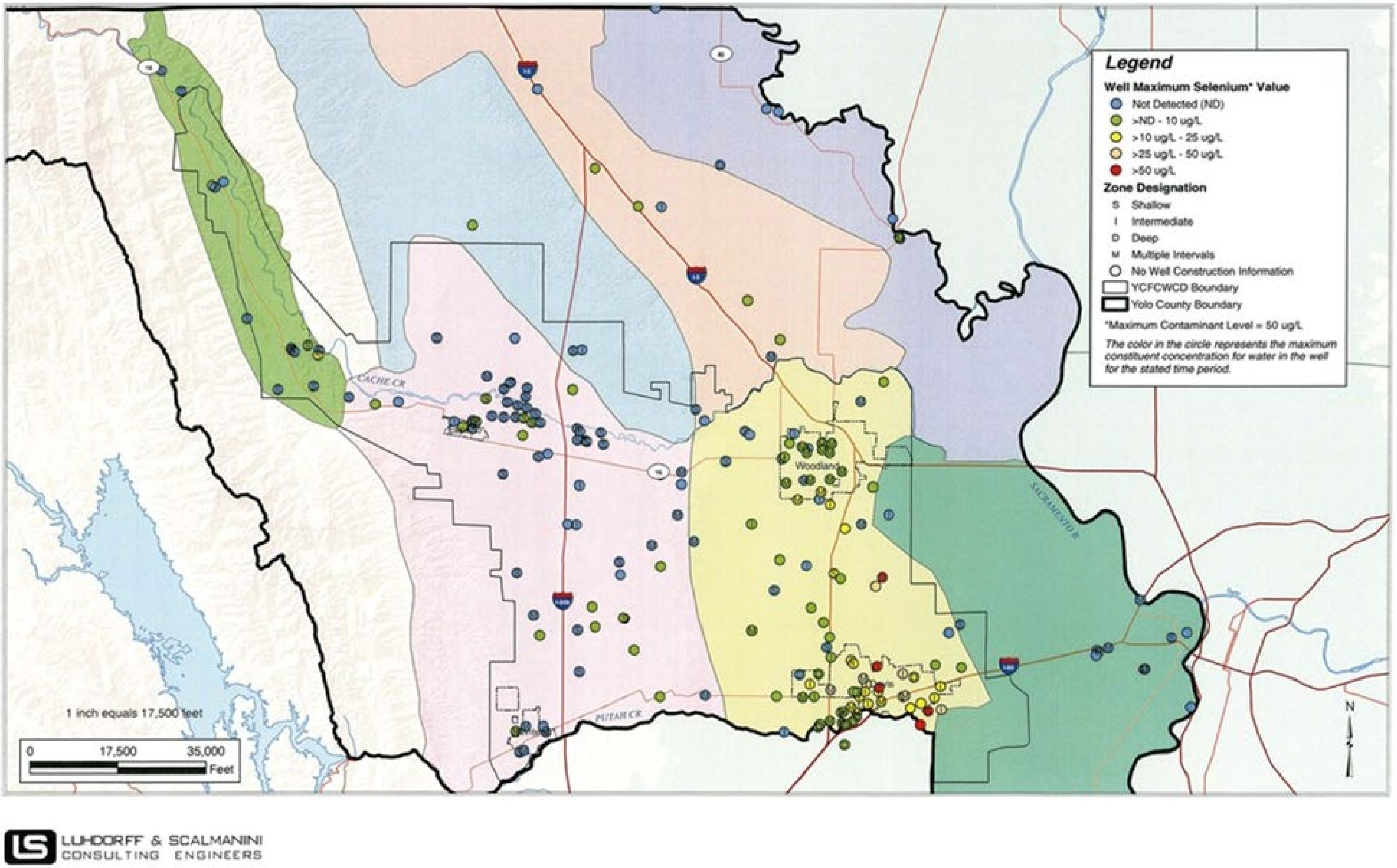

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Figure 2-38. Maximum Observed Selenium Concentrations, 1969-2004.

2.2.4.4 Public Water Systems

While land use within Yolo Subbasin is roughly 60-percent agricultural, there are 83 public water systems that are identified through GAMA and SDWIS. Seventeen of the 83 public water systems are classified as community water systems, meaning that there are at least 15 service connections, or 25 year-round residents are served. The remaining public water systems are either Non-Transient Non-Community (NTNC) or Transient Non-Community water systems (TNC). These classifications are generally designated for businesses who supply water to their employees, or a transient (pass through) population. Therefore, a separate groundwater quality assessment was conducted to evaluate community water systems. **Table 2-12** lists the community public water systems with a brief description and estimated population served. **Figure 2-39** shows where the community public water systems are located within the Yolo Subbasin.

Water quality data from regulated drinking water systems is available through SDWIS. NTNC water systems are required to test for most regulated constituents at least once every 3 years. TNC systems have reduced monitoring requirements and typically only test for nitrate and bacteria on a regular basis.

Table 2-12. Community Public Water Systems within Yolo Subbasin

Water System #	Water System Name	Population Served	Service Area	Number of Wells
CA5700700	Cacheville Community Services District	400	Residential	2
CA5700712	Cal-American Water Company – Dunnigan	400	Mobile Home Park	2
CA5700554	Campers Inn – RV & Golf Course	120	Mobile Home Park	1
CA5710001	City of Davis	71,311	Residential	9
CA5710003	City of West Sacramento	55,000	Residential	2*
CA5710005	City of Winters	7,417	Residential	5
CA5710006	City of Woodland	60,292	Residential	8
CA5710007	Esparto Community Services District	3,108	Residential	4
CA5710004	Knights Landing Community Services District	1,300	Residential	3
CA5700571	Madison Community Services District	876	Residential	2
CA5700797	Monroe/Leinberger Center/Waters	800	Institution	1
CA5700788	North Davis Meadows County Service Area	314	Residential	3
CA5700707	Rolling Acres Mutual Water Company	40	Residential	1
CA5710009	University of California, Davis	48,828	School	6
CA5710011	Wild Wings County Service Area	1,115	Residential	2
CA5710012	Woodland-Davis Clean Water Agency	129,820	Wholesaler	0
CA5700615	Yolo Co. Housing Authority – El Rio Villa	432	Residential	2

Note: * Wells are inactive

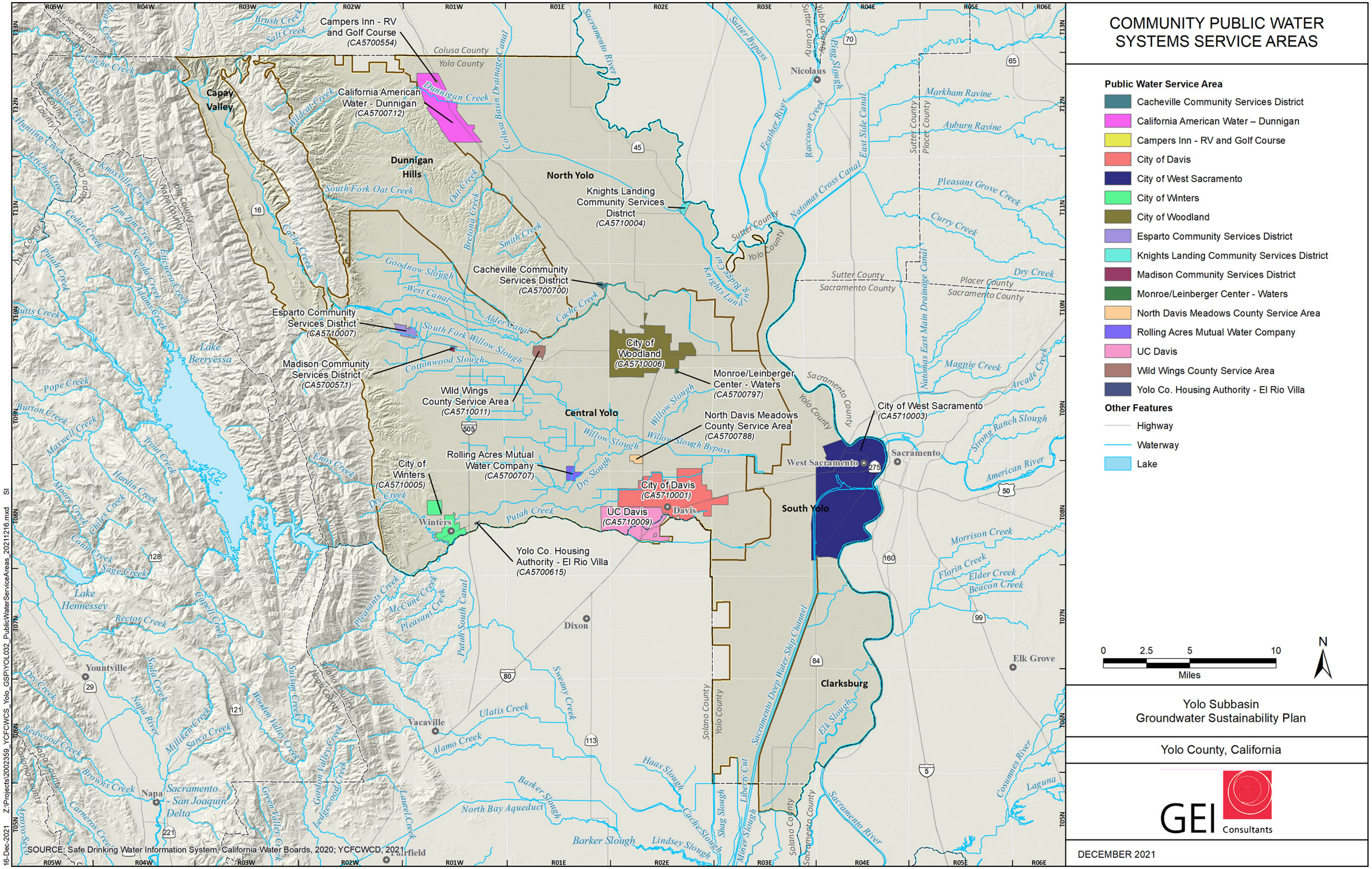

Figure 2-39. Community Public Water Systems Within Yolo Subbasin.

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2.2.4.5 Water Quality Evaluation of Public Community Water Systems

Several groundwater quality constituents are of particular concern for public community water systems within the Subbasin and are summarized in the following sections, including salinity, nitrate, boron, arsenic, and total and hexavalent chromium.

Public water systems were identified through GAMA and water quality data was extracted from SDWIS for the period of 2010 to 2020. Since most of the water systems identified are businesses, monitoring requirements are sometimes less extensive than municipalities serving residential communities. Therefore, this section is a summary of the water quality from the public water systems in the Yolo Subbasin.

All available water quality data was evaluated to identify constituents of concern. Not all constituents that are commonly found in the Subbasin, as identified in **Table 2-11**, are at concerning concentrations in community water systems. Therefore, only boron, hexavalent chromium, chloride, and sodium are addressed as constituents of concern.

It is important to note that this water quality evaluation of public water systems does not include NTNC, TNC, or domestic well information. NTNC and TNC water systems do not regularly report water quality data to SDWIS. Many domestic wells exist throughout the Subbasin for which water quality data is limited. Water quality in domestic wells is a data gap of the current monitoring network identified in **Section 4.6 – Groundwater Quality**.

2.2.4.5.1 Salinity – Public Water Systems

Based on drinking water standards, the recommended secondary maximum contaminant level of TDS is 500 ppm with an upper limit of 1,000 ppm and chloride is 250 ppm with an upper limit of 500 ppm. There is no drinking water standard for sodium; however, Water Quality Goals for Agriculture, published by the Food and Agriculture Organization of the United Nations in 1985, has set agricultural goals for TDS, sodium, and chloride at 450, 69, and 106 ppm, respectively. The criteria identified are protective of various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since land use in the Yolo Subbasin is roughly half irrigated lands, the agricultural goals for TDS, sodium, and chloride are referenced as the appropriate value rather than drinking water standards.

TDS is comprised of several dissolved minerals (calcium, phosphates, nitrates, sodium, potassium, and chloride), most of which have minimal impact on beneficial uses of the groundwater. Throughout the Subbasin, sources of salinity identified include a combination of naturally occurring marine deposits; infiltration from produced water disposal ponds; perched water subject to evaporative pumping; or agricultural drainage ponds.

Sodium and chloride ions contribute to TDS and in this region are more important to evaluate due to its impact to the agricultural industry. Both sodium and chloride show similar trends in the wells evaluated; therefore, some sections of the water quality evaluation collectively refer to these ions as salinity. Since sodium concentrations are an important measurement to crop yield, the focus of salinity level discussion will be on sodium.

Table 2-13 summarizes sodium concentrations among the community water systems within the Yolo Subbasin. Sodium data was not available for any wells within North Davis Meadows water system. About 75 percent of the wells either have sodium concentration greater than half or over the agricultural goal of 69 ppm. Since managing sodium concentrations to meet agricultural goals is important to the land uses within Yolo Subbasin, management actions that will slow or reverse the increasing sodium trend should be considered. Studies conducted through CV-SALTS, and the projects that are planned, will aid in salinity management.

Table 2-13. Summary of Sodium Prevalence Among Community Water Systems[33].

Water System	Sodium Concentrations		
	0-34 ppm	35-69 ppm	>70 ppm
Cacheville Community Services District		2	
Cal-American Water Company – Dunnigan	2		
Campers Inn – RV & Golf Course	1		
City of Davis			9
City of Winters	5		
City of Woodland	2	6	
Esparto Community Services District		4	
Knights Landing Community Services District		1	2
Madison Community Services District		2	
Monroe/Leinberger Center/Waters		1	
North Davis Meadows County Service Area	n/a		
Rolling Acres Mutual Water Company		1	
University of California, Davis			6
Wild Wings County Service Area			2
Yolo Co. Housing Authority – El Rio Villa		2	
Total Wells	**10**	**19**	**19**

2.2.4.5.2 Nitrate – Community Water Systems

Even though nitrate is not considered a concern for community water systems, which most likely have deeper wells and annular seals, it is mentioned in this evaluation for potential future references from the ILRP or CV-SALTS programs. There is a primary drinking water standard of 10 ppm for nitrate (as N). An agricultural goal is not available. Nitrate contamination is a significant concern in rural communities, particularly where agriculture is the predominant land use. However, a significant

[33] The city of West Sacramento is a public water system, No. CA5710003, that was not considered in this table. Information about the city's water system and water use can be found in its recently adopted 2020 Urban Water Management Plan.

source of nitrate also comes from septic systems used in these rural communities. Since municipal services (drinking water or wastewater collection systems) may not be available in rural areas of the Yolo Subbasin, all domestic and public wastewater disposal is through onsite septic systems.

Nitrate can be naturally present at low concentrations in groundwater, typically less than 2 ppm. Moderate and high concentrations generally occur because of human activities. Septic systems typically contribute moderate concentrations between 5 and 15 ppm of nitrate as nitrogen. Typically, higher concentrations (> 20 ppm) are associated with applying fertilizers to crops. Nitrate contamination is a significant public health concern because it has acute health effects. High concentrations of nitrate are typically found in shallow groundwater, such as those in the unconfined aquifer. Among the community water systems, one well has nitrate over the drinking water MCL for nitrate. **Table 2-14** shows the summary of number of wells of nitrate prevalence (source water) in community water systems. Data for **Table 2-14** represents water quality data for the period of 2010 to 2020, which was accessed in September 2020 from DDW's SDWIS.

Table 2-14. Summary of Nitrate Prevalence Among Community Water Systems[34].

Water System	Nitrate Concentrations[1]		
	0-5 ppm	**6-10 ppm**	**>11 ppm**
Cacheville Community Services District	2		
Cal-American Water Company – Dunnigan	1	1	
Campers Inn – RV & Golf Course		1	
City of Davis	5	4	
City of Winters	5		
City of Woodland	3	5	
Esparto Community Services District	4		
Knights Landing Community Services District	3		
Madison Community Services District		2	
Monroe/Leinberger Center/Waters	1		
North Davis Meadows County Service Area		2	1
Rolling Acres Mutual Water Company	1		
University of California, Davis	6		
Wild Wings County Service Area	2		
Yolo Co. Housing Authority – El Rio Villa		2	
Total Wells	**33**	**17**	**1**

Note: [1]Data accessed in SDWIS in September 2020.

[34] The city of West Sacramento is a public water system, No. CA5710003, that was not considered in this table. Information about the City's water system and water use can be found in its recently adopted 2020 Urban Water Management Plan.

2.2.4.5.3 *Boron – Public Water Systems*

There is no federal or state MCL for boron. However, California does have a Notification Level of 1,000 ppb, and there is an agricultural goal of 700 ppb. The agricultural goal is set to protect various agricultural uses of water, including irrigation of various types of crops and stock watering. These levels are used as a baseline to compare against and are not intended to represent an acceptable maximum value for the Subbasin. Since land use in the Subbasin is about half irrigated lands, the agricultural goal for boron is used as a reference point, rather than the drinking water Notification Level. The most prevalent sources of boron in drinking water are from leaching of rocks and soils, wastewater, and fertilizer/pesticides applications.

According to the USGS Scientific Investigations Report 2011-5002 (Bennett et al. 2011) boron is a trace element that occurs naturally in many minerals, primarily borax. Most elevated boron detections above the Notification Level were found in the Southern Sacramento Valley Study Unit, which includes Yolo Subbasin. High concentrations in wells along Cache and Putah creeks are likely associated with old marine sediments from the Coast Ranges (YCFC&WCD 2007).

Table 2-15 summarizes boron concentrations among the community water systems within the Yolo Subbasin. Boron data was not available for 12 of 51 wells. About 33 percent of the wells have boron concentrations over the Notification Level.

2.2.4.5.4 *Hexavalent Chromium – Public Water Systems*

There is no federal MCL for hexavalent chromium. In July 2014, California adopted a primary MCL of 10 ppb, which was invalidated as of September 2017. While DDW is repeating the regulatory process for adopting a new MCL, the federal MCL of 50 ppb for total chromium applies. There is no agricultural goal for hexavalent chromium.

Hexavalent chromium can come from anthropogenic and natural sources. Anthropogenic sources include discharges of dye and paint pigments, wood preservatives, chrome-plating liquid wastes, and leaching from hazardous waste sites into the environment. Naturally occurring chromium is a metal found in ore deposits containing other elements, mostly as chrome-iron ore. Chromium is also prevalent in soil and plants: the phenomenon of releasing chromium into groundwater is believed to be similar geochemical processes to arsenic. Generally, natural chromium in the environment occurs as trivalent chromium (Cr3) then is oxidized to a hexavalent state (Cr6+). This typically occurs in oxidizing conditions such as alkaline pH range (between 8 and 14 units) or in the presence of manganese dioxide; in these conditions, naturally occurring hexavalent chromium is likely to exist.

The presence of manganese oxide minerals within ultramafic and serpentinite derived soils and/or sediments can trigger the oxidation of chromium, leading to the presence of naturally occurring hexavalent chromium in the aquifers (State Water Board; Groundwater Information Sheet 2017). While studies have not been conducted on the types of soils and sediments in the Subbasin where hexavalent chromium is present, the relatively low concentrations (typically in the range of 5-13 ppb) indicate the source is naturally occurring (GAMA). **Table 2-16** summarizes hexavalent concentrations among the community water systems within the Yolo Subbasin. Hexavalent chromium data was not available for 4 of 51 wells. About 68 percent of the wells have hexavalent chromium concentrations over 10 ppb.

Table 2-15. Summary of Boron Prevalence Among Community Water Systems[35].

Water System	Boron Concentrations[1]		
	0-500 ppb	501-1,000 ppb	>1,001 ppb
Cacheville Community Services District	n/a		
Cal-American Water Company – Dunnigan	2		
Campers Inn – RV & Golf Course	1		
City of Davis		9	
City of Winters	4		
City of Woodland			6
Esparto Community Services District	2		
Knights Landing Community Services District			3
Madison Community Services District			2
Monroe/Leinberger Center/Waters	n/a		
North Davis Meadows County Service Area	n/a		
Rolling Acres Mutual Water Company		1	
University of California, Davis		5	
Wild Wings County Service Area			2
Yolo Co. Housing Authority – El Rio Villa		2	
Total Wells	**9**	**17**	**13**

Note: [1]Data accessed in SDWIS in September 2020.

[35] The city of West Sacramento is a public water system, No. CA5710003, that was not considered in this table. Information about the City's water system and water use can be found in its recently adopted 2020 Urban Water Management Plan.

Table 2-16. Summary of Hexavalent Chromium Prevalence Among Community Water Systems.

Water System	Hexavalent Chromium Concentrations		
	0-5 ppb	6-10 ppb	>11 ppb
Cacheville Community Services District	n/a		
Cal-American Water Company – Dunnigan			2
Campers Inn – RV & Golf Course			1
City of Davis	3	2	4
City of Winters		1	4
City of Woodland			8
Esparto Community Services District			4
Knights Landing Community Services District	3		
Madison Community Services District			1
Monroe/Leinberger Center/Waters			1
North Davis Meadows County Service Area			2
Rolling Acres Mutual Water Company			1
University of California, Davis		4	2
Wild Wings County Service Area	2		
Yolo Co. Housing Authority – El Rio Villa			2
Total Wells	**8**	**7**	**32**

2.2.4.6 Groundwater Quality Findings

Based on data evaluated in this groundwater quality characterization of community water systems; boron, hexavalent chromium, nitrate, and salinity are the primary constituents of concern for the Yolo Subbasin. While arsenic is not identified as a constituent of concern for community water systems, it has been included as a constituent to be monitored for since there is a set drinking water standard and a potential for concern. Findings for community water systems are based upon the data available for the area, consisting of supply wells for the public community water systems for the period of 2010 to 2020. Additionally, basin wide conditions were assessed using best available data from WRID and data collected under other regulatory programs such as CV-SALTS and ILRP. At the time of the basin wide conditions evaluation, data in the WRID after 2004 were not easily accessible. Consequently, future evaluation of water quality in the Yolo Subbasin should include any updated data from the WRID to be more comprehensive.

Nitrate is a primary drinking water standard with acute health effects. Although a review of public community water systems did not show nitrate being a constituent of concern, brief discussion is included. One well has nitrate levels over the drinking water MCL of 10 ppm. About 33 percent have nitrate levels between 5 to 10 ppm. As discussed in the basin wide assessment, elevated nitrate is typically present in the shallow groundwater zone and tend to be of lower concentrations since nitrate is a surface contaminant. Thus, wells with shallow screened intervals or annular seals typically show the highest levels of contamination. Community water system wells tend to have deeper screens and annular seals, which most likely explains nitrate levels below the drinking water standard in most of the water systems in this evaluation. However, this is most likely not the case for private domestic wells, which tend to have shallower depths and annular seals. Sacramento Valley Water Quality Coalition's 2018 Annual Groundwater Monitoring Results from the Fall 2018 sampling event for compliance with ILRP indicated three of 21 wells had nitrate concentrations over the MCL. To comply with the Human Right to Water, nitrate levels will need to be closely monitored and management actions will need to be in place to comply with the nitrate drinking water standard.

Salinity under the basin-wide conditions assessment tends to be higher in the shallow and intermediate groundwater zones. Elevated TDS is observed in the agricultural areas surrounding Woodland, Davis, and the Capay Valley. Salinity levels over the agricultural goal were found in most community water systems. About 75 percent of the wells either have sodium concentration greater than half or over the agricultural goal of 69 ppm. Constituents related to salinity have a greater impact to agriculture, which explains the lower limits established for agricultural industry than the secondary drinking water standards. Since land use in the Yolo Subbasin is about half agricultural land, management actions that will slow or reverse the increasing sodium trend should be considered. CV-SALTS program and goals will address salinity concerns in the Yolo Subbasin.

Boron and hexavalent chromium are considered elevated in the water quality evaluation of public community water systems. About 33 percent of the municipal wells that were sampled have boron levels over the Notification Level. USGS studies indicate boron to be naturally occurring and elevated levels tend to be in wells near the Cache and Putah creeks. Hexavalent chromium is also considered to be naturally occurring in the Yolo Subbasin. About 68 percent of the municipal wells sampled have hexavalent chromium levels above 10 ppb.

While other groundwater contaminants commonly found throughout the Yolo Subbasin were evaluated, there was limited presence of most constituents. Water quality data used in the Community Water System evaluation was collected between 2010 and 2020. Most wells showed stable trends of evaluated constituents. Overall, there is high-quality water in the portion of the aquifer that public community water systems draw from.

2.2.5 Land Subsidence

Land subsidence has been measured in the Yolo Subbasin since at least the late 1960s and has been subject to various technologies, including terrestrial (optical, laser) surveys, periodic surveys of numerous stations *via* the global position [satellite] system (GPS) since 1999, two continuous GPS stations since 2004, two extensometers, and by Interferometric Synthetic-Aperture Radar (InSAR). Subsidence includes an elastic component that fluctuates in response to changes in hydrostatic pressure among other factors and an inelastic component that manifests when the hydrostatic pressure decreases enough to allow the aquifer structure to collapse, primarily in the fine-grained layers within the aquifer and the aquitards.

Land deformation occurs as both surface subsidence and surface uplifting and the Subbasin experiences both processes. The following sections provide an overview of previous studies of subsidence performed within the Yolo Subbasin. There are several different methodologies and time periods available for evaluation. In general, steady levels of subsidence have been documented in the east portion of the Central Yolo MA and much of the North Yolo MA, and in the western portion of the Central Yolo MA a slight amount of uplift has been observed.

2.2.5.1 Yolo Subbasin Network Monitoring Events

Since 1999, several GPS surveys have been conducted for the Subbasin on behalf of the WRA, including 1999, 2002, 2005, 2008, and 2016. These surveys utilized over 50 stations throughout the Subbasin, including several continuous GPS stations, to define the magnitude and extent of subsidence. The results of these surveys are available at the WRA's website[36]. The accuracy of a GPS survey is dependent on the equipment and survey duration at each station, and these surveys used criteria that varied between 2 and 5 centimeters for the various attributes of each survey.

The latter surveys define a roughly diamond-shaped area of subsidence encompassing Davis, Dunnigan, Zamora, Woodland, and Madison (**Figure 2-40**). The greatest amount of subsidence occurred in pockets near Zamora and Woodland, where subsidence varied from 0.20 to 0.27 meters at three locations. According to Frame (2016), subsidence rates, "…have averaged as much as 3 cm per year in the most heavily affected locations during the 2008 to 2016 period" or up to 1.18 inches per year. The tabulated data for the stations (Appendix H of the Frame report) confirm the maximum subsidence value of 0.27 meters (0.9 feet) for the 8-year period, which is similar to the DWR value of 1.1 feet for a similar, overlapping 9-year period, as discussed below. Total subsidence in these two pocket areas was found to range between 6 and 11 inches between 2008 and 2016.

The earlier surveys utilized a mix of other stations and the 1999 survey used an alternate survey approach so comparable data are limited to 41 stations with complete sets of triennial data. Between 1999 and 2008, a total of 25 stations showed an overall increase in ground surface elevation, over 2 inches higher, while 16 stations showed an overall decrease in ground elevation, as much as 6 inches lower. Of this latter group, Frame (2009) identified six stations in the vicinity of Woodland and Zamora where the decreasing trends were indicative of subsidence and probably could have included a seventh station. Ground elevations at the other nine stations did not decrease as much and/or showed a variable trend. The maximum amount of subsidence was nearly 0.5 feet between 1999 and 2008 and the average annual maximum rate of subsidence is calculated to have been 0.6 inches. Subsidence appears to be a relatively new impact on the Yolo Subbasin, since the 1990s, based on the variable GPS survey results (increasing and decreasing elevations) in the early data (1999-2008) and the lower average annual maximum rate *versus* more consistent data thereafter (2008-2016) and the doubling of the average annual subsidence rate (1.3 *vs.* 0.6 inches per year). The 1999 survey occurred during the last year of 5-year period of wet conditions, which would have "inflated" the elastic character of the aquifer.

[36] http://www.yolowra.org/

2.2.5.2 Stanford InSAR Study

InSAR is an aerial- and space-based technology that has been used to evaluate ground surface elevation and deformation since the early 1990s. More recently, InSAR has been used to evaluate subsidence, including much of the County between 2007 and 2011. InSAR measures ground elevation using microwave satellite imagery data. This effort, headed by scientists from Stanford University, observed subsidence across much of the central-eastern portion of the Subbasin, stretching from Davis in the south to Dunnigan in the north (**Figure 2-41**). Within this area, maximum deformation was measured in the area between Zamora and Woodland, at a rate of up to 3 cm per year (Crews et al., 2017). Many areas in the south and east of the Subbasin display positive gains in surface elevation, which may be indicative of elastic rebound from subsidence due to a "wet" WY in 2011 after 4 preceding drought WYs (dry, critical, dry, below normal). Crews (2017) recommended the use of InSAR to define subsidence at a recurring interval of 3 to 4 years coupled with a reduced cycle of GPS surveys, from a 3-year cycle to a 9- or 10-year cycle.

2.2.5.3 Sacramento Valley Subsidence Survey

The 2017 GPS Survey of the Sacramento Valley Subsidence Network (DWR 2018a) presented the change in surface elevation between 2008 and 2017 using measurements from more than 50 surface elevation monuments across the Subbasin. Subsidence values ranged from 0.1 to 1.1 feet (median: 0.3 feet, mean: 0.4 feet). Twelve stations showed subsidence values of 0.19 feet or less, and one station (COTT) showed a slight increase in elevation (< 0.1 feet). These low value stations are mostly located on the southeastern side of the Subbasin and, to a lesser extent, along the western side. Subsidence was evident in the northeastern portion of the Subbasin near Zamora and Woodland (**Figure 2-42**), where five stations showed more than 12 inches of subsidence and five stations showed at least 9 inches. Of all the areas surveyed in the report, the County showed "the largest spatial extent" of subsidence within the Sacramento Valley (DWR 2018a). For the 9-year period between the GPS surveys (2008-2017), the rate of subsidence varied up to 1.5 inches per year (in/yr) with a median value of 0.4 in/yr and a mean value of 0.6 in/yr.

2.2.5.4 Continuous GPS Stations

Three continuous GPS stations are located in the Yolo Subbasin and provide "real-time" data on subsidence in the Subbasin, as discussed below. Two stations are part of the broad GPS network within California. GPS data have been acquired daily since 2004 and 2005; and these data are readily available from the University NAVSTAR Consortium (UNAVCO) website. One UNAVCO station (P265) is located near the southwestern corner of the Subbasin, east of Winters, on the western flank of the Sacramento Valley and the second station (P271) is located on the southeast side of Woodland, near the axis of the Sacramento Valley. A third continuous GPS station (UCD1) is located at the University of California in Davis, along the southern boundary of the Subbasin, midway toward the center of the Sacramento Valley. UCD1 is part of the Bay Area Regional Deformation Network, which provide daily values since 1996 as a text file. Note that the antenna has been changed twice, most recently in November 2019, which created a baseline shift of the vertical data.

Figure 2-43 illustrates the change in ground elevation at these three stations, including daily values and annual mean values, and compares these data to WY indices. The figure shows that daily values are variable at the three stations, increasing during the wet winter months and decreasing during the dry summer months. During the 2006 to 2011 WYs, both P265 (blue/black symbols) and P271 (orange/rust symbols) showed similar rates of decline (-0.16 and -0.19 in/yr, respectively), while UCD1 (green symbols) showed a higher rate of decline (~3X). The amplitude of annual change, which is related to the elasticity of the aquifer, was least at P265 and greatest at UCD1. This 6-year period included 2 wet years at the beginning and end and an overall dry period in the middle.

Beginning in 2012, the P271 rate of decline increased 5-fold during the historic 5-year drought period and diverged from P265, which continued to decline at roughly the same rate. Similarly, UCD1 continued its decline. In addition, the annual amplitude of P271 increased substantially due to the rapid decline in elevation during the latter part of each WY. These steep declines resulted in a 2-inch decrease in elevation during 2014 due to inelastic subsidence, and a 1-inch decrease during 2016. Conversely, the amplitudes of P265 and UCD1 remained relatively consistent with their respective previous values, although both stations showed an overall decrease in their elevation.

The 2012-16 drought was followed by a historic wet WY during 2017, the second highest of the 114-year record, a below-normal WY during 2018, and another wet WY during 2019. This improved WY period flattened the decline considerably at P265 and UCD1 and lessen the decline at P271. However, subsidence was still occurring to some degrees at these locations during WY 2019.

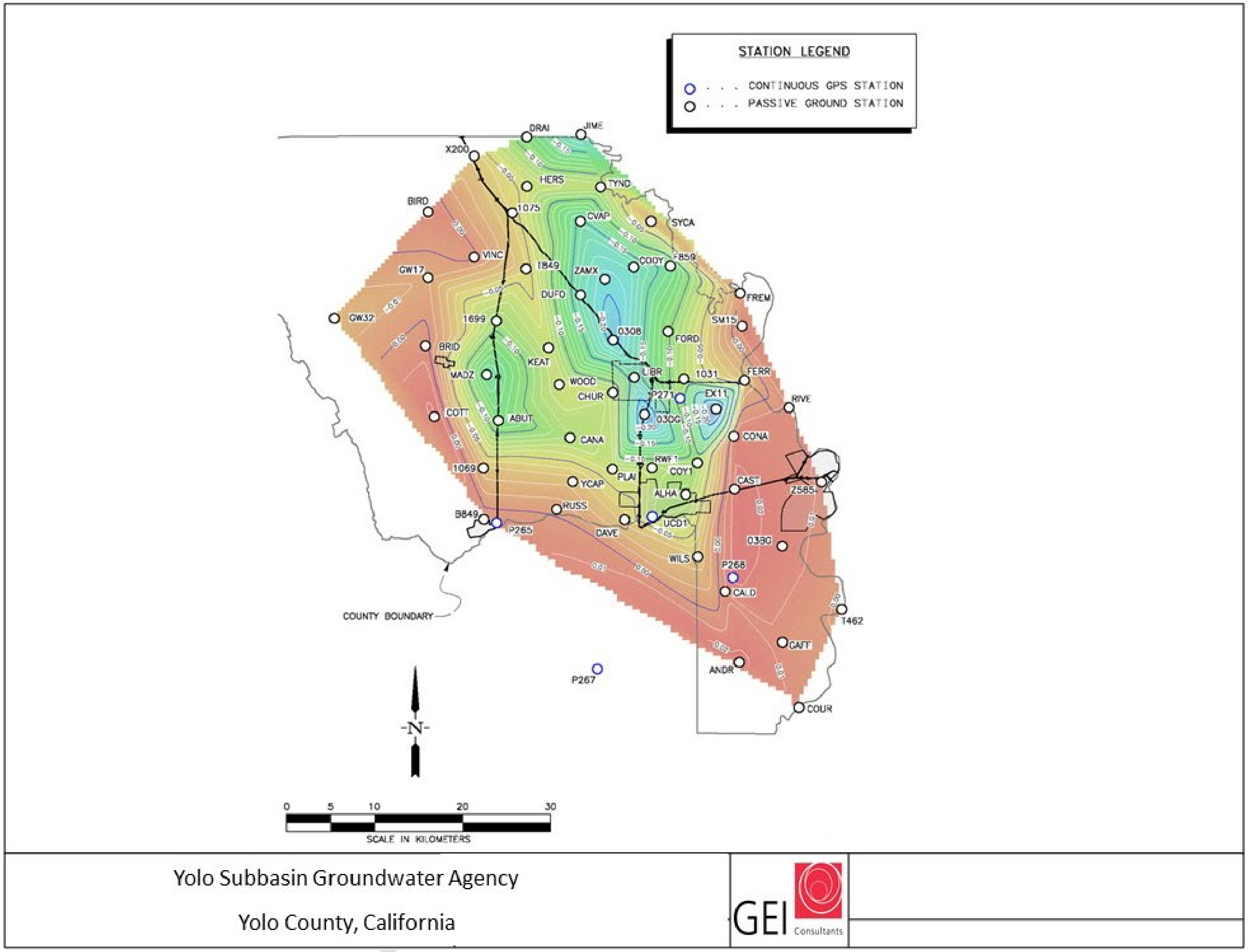


Figure 2-40. Yolo Subsidence Network Recorded Subsidence, 2008-2016. (Frame 2017).

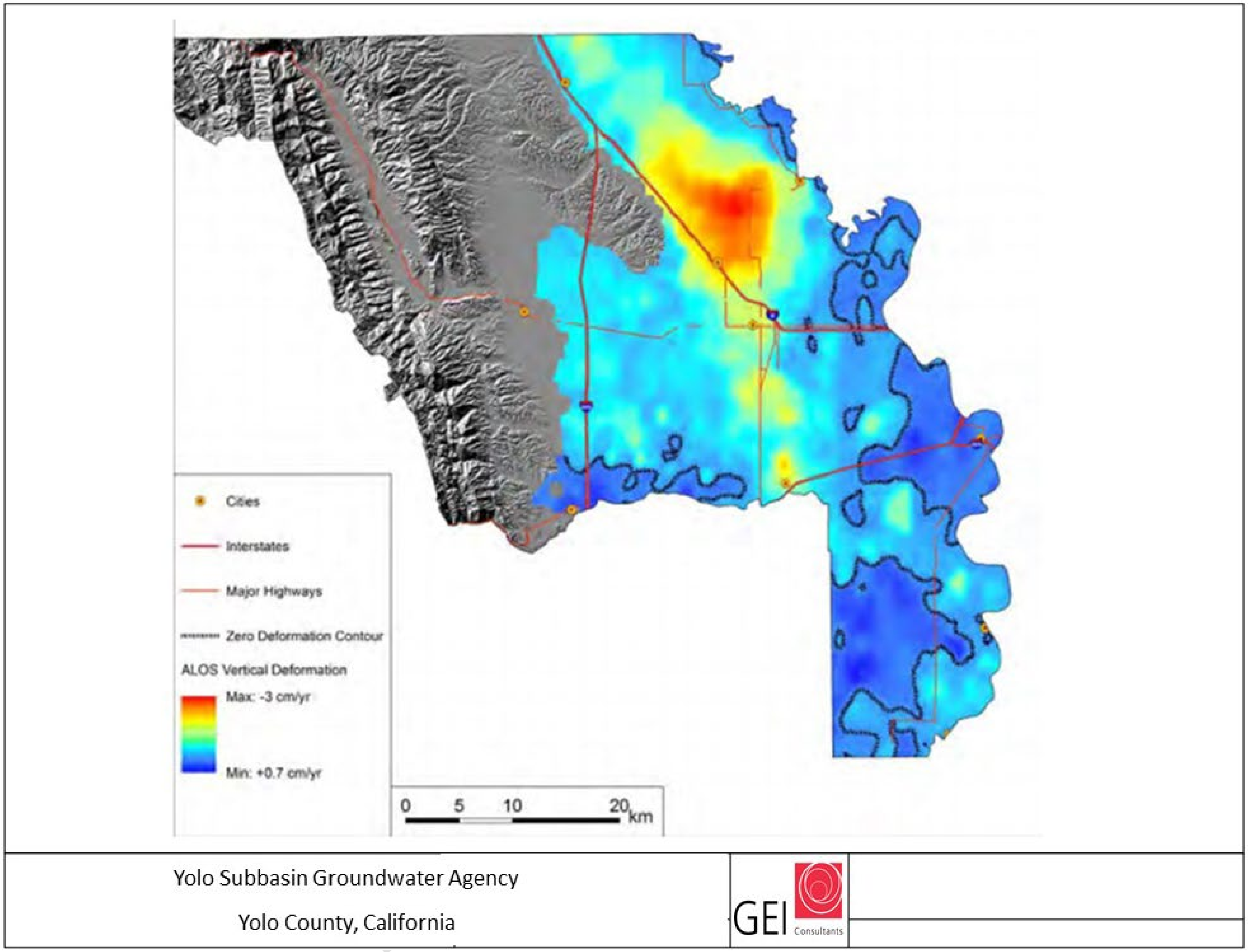
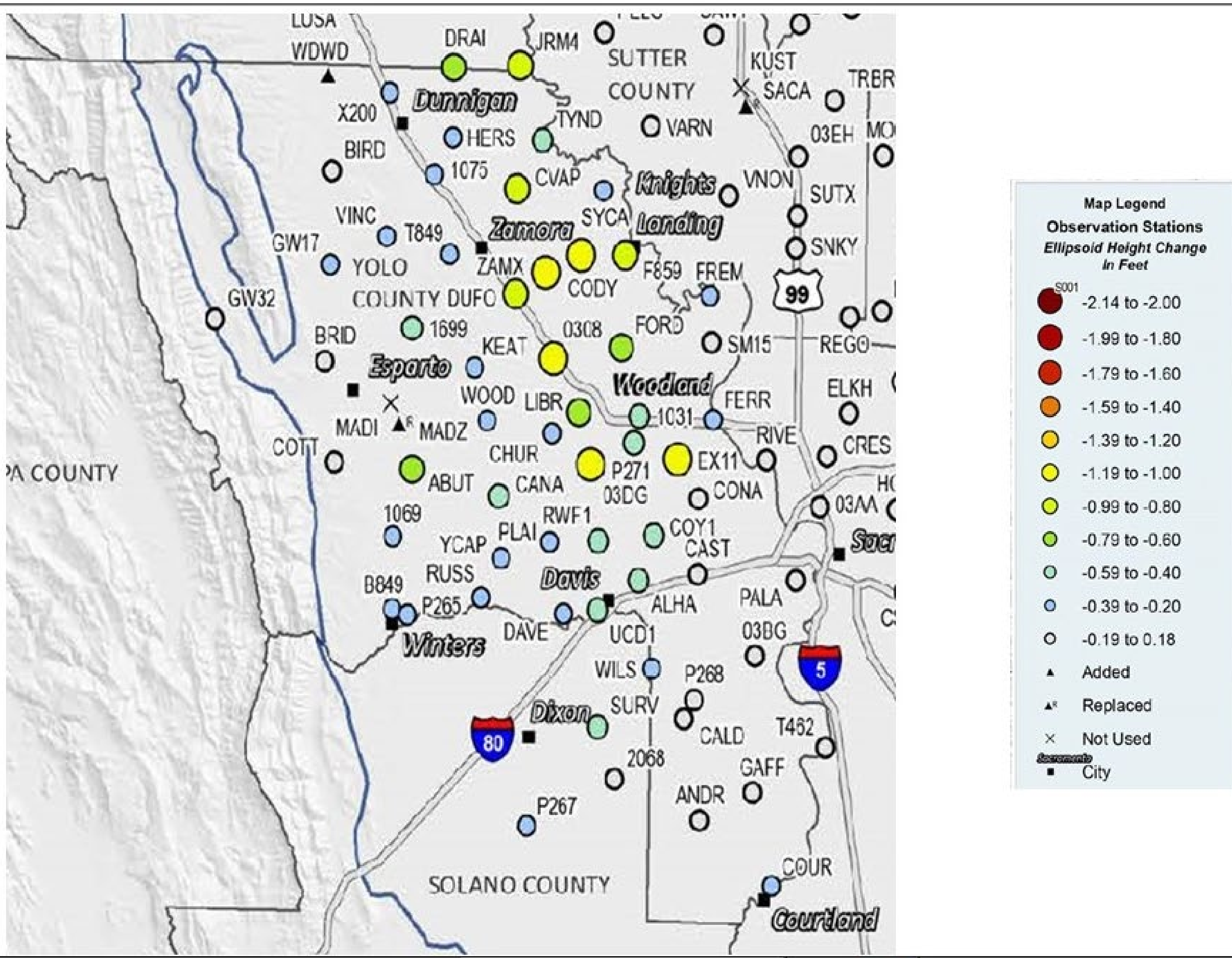


Figure 2-41. Stanford InSAR Subsidence in Yolo Subbasin, 2007-2011 (Crews 2017).



Yolo Subbasin Groundwater Agency

Yolo County, California

GEI Consultants

Figure 2-42. DWR's 2017 GPS Survey of Sacramento Valley Subsidence Network, 2008-2017.

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A third continuous GPS station (UCD1) is located at the University of California in Davis, along the southern boundary of the Subbasin, midway toward the center of the Sacramento Valley. UCD1 is part of the Bay Area Regional Deformation Network, which provides daily values since 1996 as a text file. Note that the antenna has been changed twice, most recently in November 2019, which created a baseline shift of the vertical data.

Figure 2-43 illustrates the change in ground elevation at these three stations, including daily values and annual mean values, and compares these data to WY indices. The figure shows that daily values are variable at the three stations, increasing during the wet winter months and decreasing during the dry summer months. During the 2006 to 2011 WYs, both P265 (blue/black symbols) and P271 (orange/rust symbols) showed similar rates of decline (-0.16 and -0.19 in/yr, respectively), while UCD1 (green symbols) showed a higher rate of decline (~3X). The amplitude of annual change, which is related to the elasticity of the aquifer, was least at P265 and greatest at UCD1. This 6-year period included 2 wet years at the beginning and end and an overall dry period in the middle.

Beginning in 2012, the P271 rate of decline increased 5-fold during the historic 5-year drought period and diverged from P265, which continued to decline at roughly the same rate. Similarly, UCD1 continued its decline. In addition, the annual amplitude of P271 increased substantially due to the rapid decline in elevation during the latter part of each WY. These steep declines resulted in a 2-inch decrease in elevation during 2014 due to inelastic subsidence, and a 1-inch decrease during 2016. Conversely, the amplitudes of P265 and UCD1 remained relatively consistent with their respective previous values, although both stations showed an overall decrease in their elevation.

The 2012-16 drought was followed by a historic wet WY during 2017, the second highest of the 114-year record, a below-normal WY during 2018, and another wet WY during 2019. This improved WY period flattened the decline considerably at P265 and UCD1 and lessened the decline at P271. However, subsidence was still occurring to some degrees at these locations during WY 2019.

2.2.5.5 Extensometers

Two extensometers were installed in the Subbasin during 1992 in association with the installation of two nested monitoring wells. Details of the construction are not available but, in general, an extensometer pipe (2-inch in diameter is anchored in a cement grout at a particular depth below a protective casing relative to a reference table over the pipe at the ground surface. Changes in the distance between the extensometer and table occur due to subsidence, earthquakes, and other tectonic factors.

The first installation is located east of Woodland and includes an extensometer (CON Ext, 09N03E08C004M) to a depth of 716 feet and completion at three depths. The second installation is located east of Zamora and includes an extensometer (ZAM Ext, 11N01E24Q008M) to a depth of 1,000 feet and completed at four depths.

Figure 2-44 illustrates the change in ground elevation at these two extensometers, including mean daily values and annual mean values, and compares these data to WY indices. The figure shows that daily values are variable at the two installations, increasing during the early part of each WY, concurrent with wet winter months, and decreasing during the latter part of the WY after the dry summer months. However, the two extensometers exhibit very different data due to their different locations and depth settings but do react to variations in the WY indices (type).

CON Ext data show a relatively low-amplitude annual cycle of ground movement (elastic), starting in WY 1993 through WY 2012. The amplitudes were minimal during the wet WYs of the middle to late 1990s, and gradually increased with time along with the relatively small, overall decline (inelastic) in the ground surface, as shown by the annual mean values. During the middle 3 years of the historic 5-year drought, ground surfaces dropped rapidly (0.3 ft/yr or ¾-foot of inelastic subsidence) and the annual amplitude increased substantially, especially during WY 2014. This rapid decline is likely related to groundwater pumping in the area. After the drought, the rate of subsidence at CON Ext decreased 10-fold, but at a higher rate than before the drought, and continued to fluctuate according to WY type.

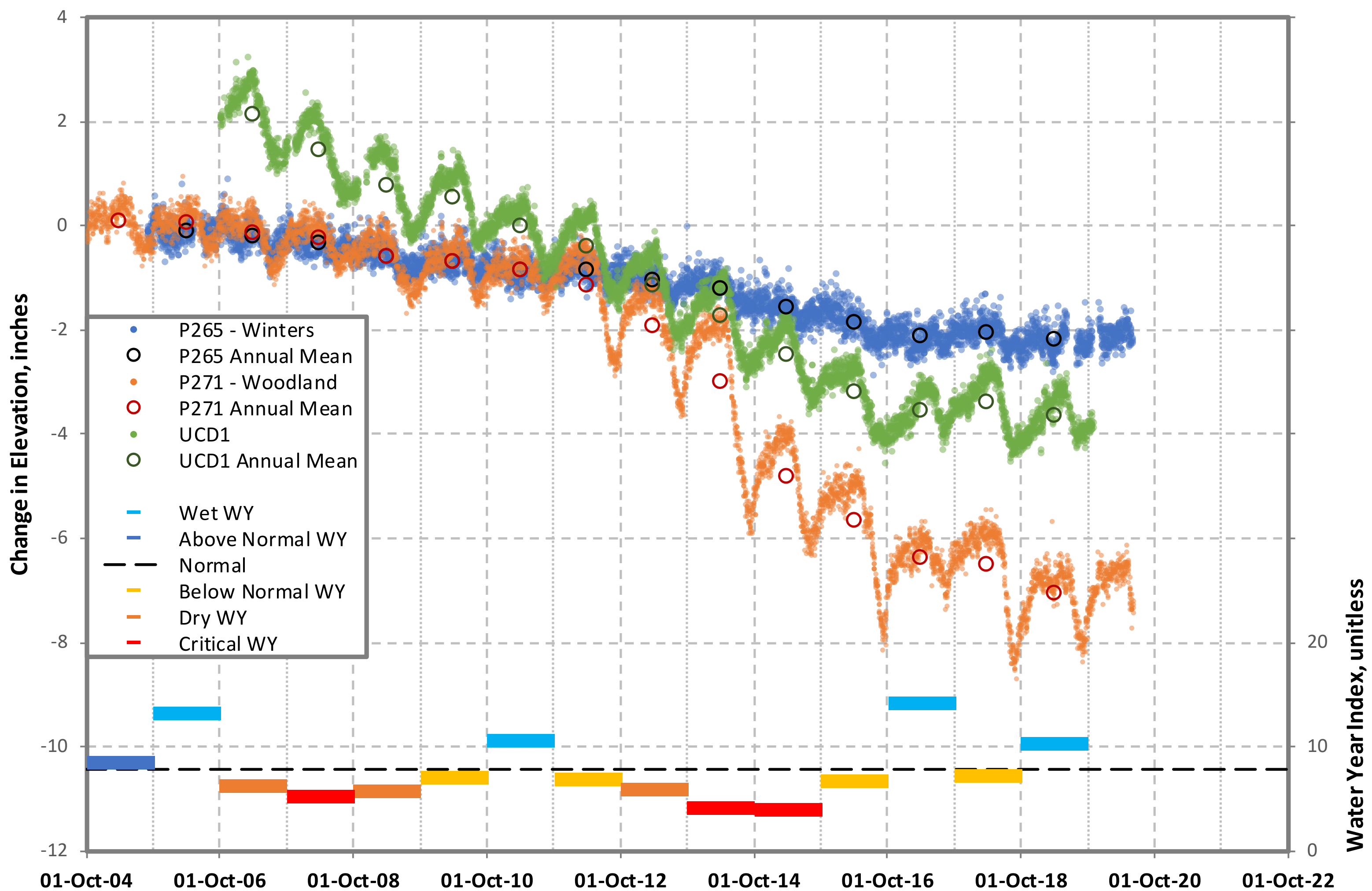
ZAM Ext data show a higher-amplitude and a more uniform annual cycle of ground movement (elastic) throughout much of its history. During the first 3 years of operations, the ground surface rose about one inch and was then followed by an overall long-term decline that is probably related to groundwater pumping. Some variability in the decline appears to be related to WY type, and the rate of decline doubled during the middle years of the drought. After the drought, the rate of subsidence at ZAM Ext decreased 10-fold but continue to decline at a lesser rate than before the drought.

2.2.5.6 DWR InSAR Subsidence Mapping

Subsidence can be estimated for the Subbasin using InSAR data provided by DWR for medium- and high-priority basins across California. The DWR website includes an interactive mapping application (SGMA Data Viewer) that covers the Subbasin and depicts land subsidence as 1) cumulative totals for various time periods beginning with June 2015 and extending monthly through September 2019 and 2) annual rates of subsidence beginning with July 2015-16 and proceeding monthly through September 2018-19. These InSAR data were obtained from European Space Agency (ESA) Sentinel-1A satellite and were processed by TRE ALTAMIRA Inc.

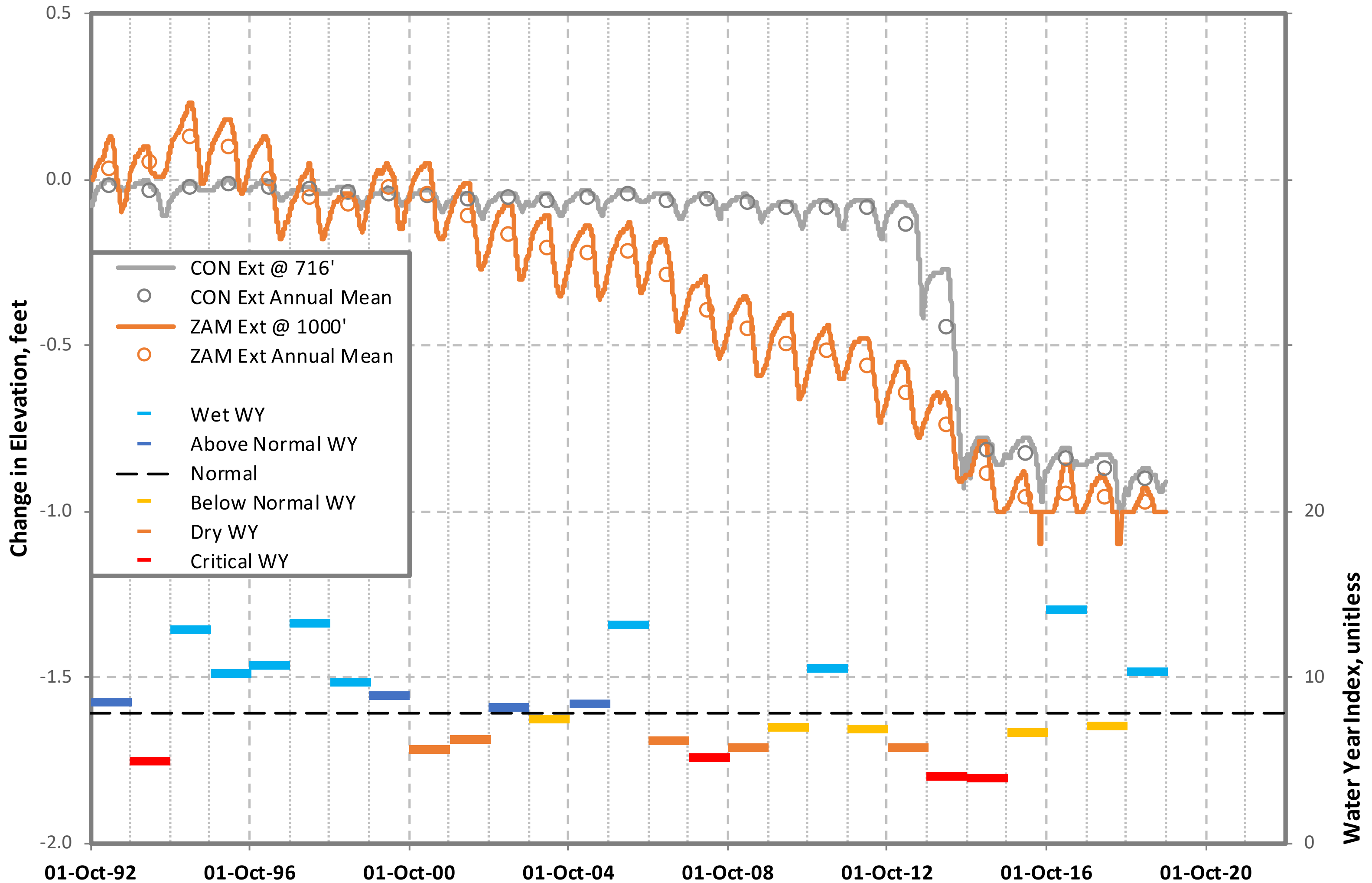
These DWR InSAR data were calibrated with continuous GPS data from 232 stations and then checked against 160 continuous GPS stations not associated with the calibration as well as 21 calibration stations in northern California. Nevertheless, the InSAR data are subject to measurement error, and DWR has stated that the total vertical displacement measurements are subject to two error sources (Brezing, personal communication, June 2019):

1) The error between InSAR data and continuous GPS data is 16 mm (0.052 feet or 0.63 inches) with a 95% confidence level for January 1, 2015 – September 19, 2019.
2) The measurement accuracy when converting from the raw InSAR data to the maps provided by DWR is 0.048 feet (0.58 inches) with 95% confidence level.



Yolo Subbasin Groundwater Sustainability Plan	GEI Consultants	Ground Elevation Variations at Continuous GPS Stations
Yolo Subbasin Groundwater Agency		June 2020

Figure 2-43. Ground Elevation Variation at Continuous GPS Stations.



Yolo Subbasin Groundwater Sustainability Plan	GEI Consultants	**Ground Elevation Variations at Extensometers**
Yolo Subbasin Groundwater Agency		June 2020

Figure 2-44. Ground Elevation Variation at Extensometers.

Simply adding the two sources of errors produces a combined potential error of 0.1 foot (or 1.2 inches). As such, land surface changes of less than 0.1 foot are therefore within the noise of the data and are equivalent to no subsidence in this GSP.

The DWR interactive mapping tool also includes numerous 'data points' for vertical displacement that link to a detailed map with an interactive time-series plot and a tabulation of monthly displacement values (feet). The data points are distributed throughout the Subbasin in various configurations – single 2.5-acres squares (330 by 330 feet) to linear and blocky arrangements of the squares. Interpolated displacement values are available in areas without squares.

Figure 2-45 shows the InSAR-measured subsidence in the Subbasin for the period June 2015 to June 2018. The green area denotes a ground surface rise or drop of less than 0.1 feet, which is within the measurement error and therefore is an area of no subsidence. The blue areas signify an increase in surface elevation from 0.1 to 0.3 foot. These measurements likely reflect areas subject to elastic subsidence, where relatively wetter conditions in recent years have facilitated groundwater recharge, expanding the aquifer structure and leading to an increase in surface elevation. The red areas reflect a drop in ground surface between 0.1 and 0.3 foot. These locations correspond spatially to areas that exhibited high levels of subsidence in previous surveys.

In contrast to previous surveys discussed above, recent InSAR results display a relatively low level of subsidence across much of the Subbasin, and even some recovery in the area between Davis and Winters. However, the northeastern portion of the Subbasin, including the area of high subsidence between Zamora and Woodland noted in previous studies, continues to experience subsidence. Ongoing subsidence over many years could add up to a more significant ground surface drop. It should also be noted that the climate from 2015 to 2018 was relatively wetter than some other previous time periods during which survey measurements were taken, and the associated increase in recharge may have slowed or reversed elastic subsidence in some areas.

2.2.6 Interconnected Surface Water Systems

Surface waters form some of the boundaries of Yolo Subbasin, including the Sacramento River as the east boundary and Putah Creek for part of the southern boundary. Numerous other creeks and sloughs (streams) emanate from the mountains and hills along the western boundary and flow eastward toward the Sacramento River, most notably Cache Creek from the Capay Valley. The Yolo Bypass is located to the west of the Sacramento River and is used for flood mitigation during the winter. The bypass drains into the Sacramento River at the Delta. Several man-made water features cross or traverse the Subbasin, including Colusa Basin Drain Canal, Tule Canal, and the Sacramento River Deep Water Ship Channel.

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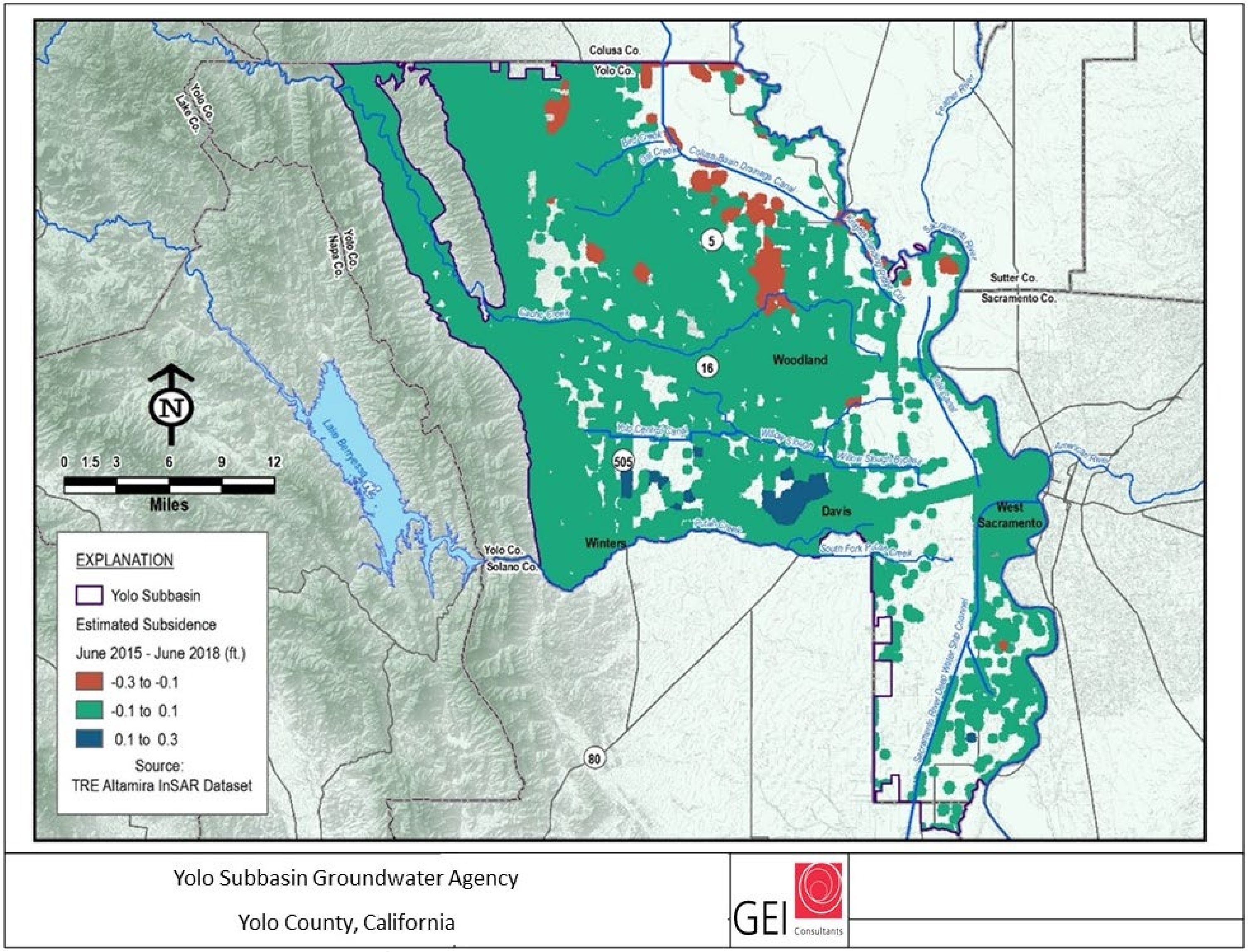

Figure 2-45. DWR InSAR Subsidence in Yolo Subbasin, 2015-2018.

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In general, rivers, streams, canals, and sloughs can be considered 'disconnected' from or 'connected' to groundwater. While the groundwater table is at or above the elevation of the streambed, the stream is considered connected. When the groundwater table is above the stream surface, the connected reach will be 'gaining' and receive upwelling groundwater as a supplement to flow. When the groundwater table is lower than the stream surface, the connected reach will be 'losing': a losing reach leaks water out of the bottom of the channel and loses water to groundwater. While a stream is connected to groundwater, a lowering of groundwater levels either (1) reduces the rate of exchange from groundwater to the stream in a gaining reach, (2) increases the rate of exchange from the stream to groundwater in a losing reach, or (3) changes the reach from gaining to losing. When the streambed and groundwater table are separated by an unsaturated zone, the stream is disconnected. While a stream is disconnected, changes in groundwater elevation do not change the rate of depletion from the stream.

Streams are also categorized by flow regime as perennial, intermittent, and ephemeral. Perennial streams have water flowing in them year-round either, from natural sources or releases from upstream reservoirs, and can be connected to or disconnected from groundwater. Intermittent streams flow seasonally and may display wet and dry reaches. These seasonal streams flow when upstream waters provide flow and when gaining water from groundwater, and are connected to groundwater, with some spatial and temporal variation. Ephemeral streams flow only after precipitation events and receive most of their water from runoff; they are generally disconnected.

Figure 2-46 shows the existing stream gaging stations within the Yolo Subbasin. Stations are operated by various agencies, including the DWR, the County of Sacramento, Solano County Water Agency (SCWA), Sutter County, USGS, and YCFC&WCD. The majority of this data is publicly available on the California Data Exchange Center (CDEC)[37], USGS Water for the Nation[38], and SCWA's website[39].

2.2.6.1 Identification of Interconnected Surface Water Bodies

Figure 2-47 characterizes the connection of the major streams in the Subbasin to groundwater. The methodology for this analysis is adapted from The Nature Conservancy's ICONS: Interconnected Surface Water in Central Valley dataset, available at icons.codefornature.org (The Nature Conservancy 2021). Based on the principles of groundwater-surface water interaction described above, the maximum groundwater elevation from WYs 2006 to 2015 was intersected with the stream surface elevations. Stream surface is estimated from a 1-meter resolution Digital Elevation Model (DEM). Gaining, losing, uncertain, and disconnected reaches are calculated according to **Table 2-17.**

This approach categorizes the water bodies using an estimate of stream bed elevation and groundwater depth as a proxy to determine if the water body is hydraulically connected, and therefore represents a likelihood that contains some uncertainty. A representation of that uncertainty

[37] https://cdec.water.ca.gov/
[38] https://waterdata.usgs.gov/nwis
[39] https://www.scwa2.com/putah-creek/

is shown in the yellow areas on **Figure 2-47**. For the purposes of this GSP, reaches categorized as "uncertain" are considered connected to groundwater to ensure a conservative approach.

Because the DEM provides an estimate of the stream surface elevation, stream bottom elevation was conservatively estimated as in the approach of ICONS. The stream bottom of perennial streams is assumed to be 20 feet below the stream surface, with a conservative 30-foot uncertainty range (The Nature Conservancy 2021). Because intermittent and ephemeral streams in the Subbasin are generally much shallower, a 5-foot window was assumed to reach the stream bottom, with a conservative 15-foot window of uncertainty.

Table 2-17. Classification of Interconnected Surface Waters.

Reach Classification	Perennial Streams	Intermittent/Ephemeral Streams
Connected - Gaining	Groundwater elevation at or above stream surface	Groundwater elevation at or above stream surface
Connected - Losing	Groundwater elevation 0-20 ft below stream surface	Groundwater elevation 0-5 ft below stream surface
Uncertain	Groundwater elevation 20-50 ft below stream surface	Groundwater elevation 5-20 ft below stream surface
Disconnected	Groundwater elevation > 50 ft below stream surface	Groundwater elevation > 20 ft below stream surface

2.2.6.2 Description of Interconnected Surface Water Systems

Most major water bodies in the Subbasin are connected to groundwater. The following section provides an overview of the state of local knowledge regarding the major connected water bodies, including:

- Sacramento River area
- Putah Creek area
- Cache Creek area
- Other canals, sloughs, and streams in the Yolo Subbasin

2.2.6.2.1 Sacramento River Area

In the Subbasin, areas along the Sacramento River are generally irrigated with surface water from the river; however, if there is any increased groundwater use in close proximity to the Sacramento River there is potential to reduce surface water flows by drawing water from the Sacramento River.

2.2.6.2.2 Putah Creek Area

Putah Creek channel lies on a perched alluvial fan, with no tributaries to the Creek as it flows eastward from the Winters, CA to the east of Highway 80. The historical hydrology of Putah Creek has been altered, beginning with a new south channel alignment and abandonment of the original channel near Davis, CA in 1871. In 1955, Putah Creek was dammed upstream of Winters, CA, further altering its hydrology.

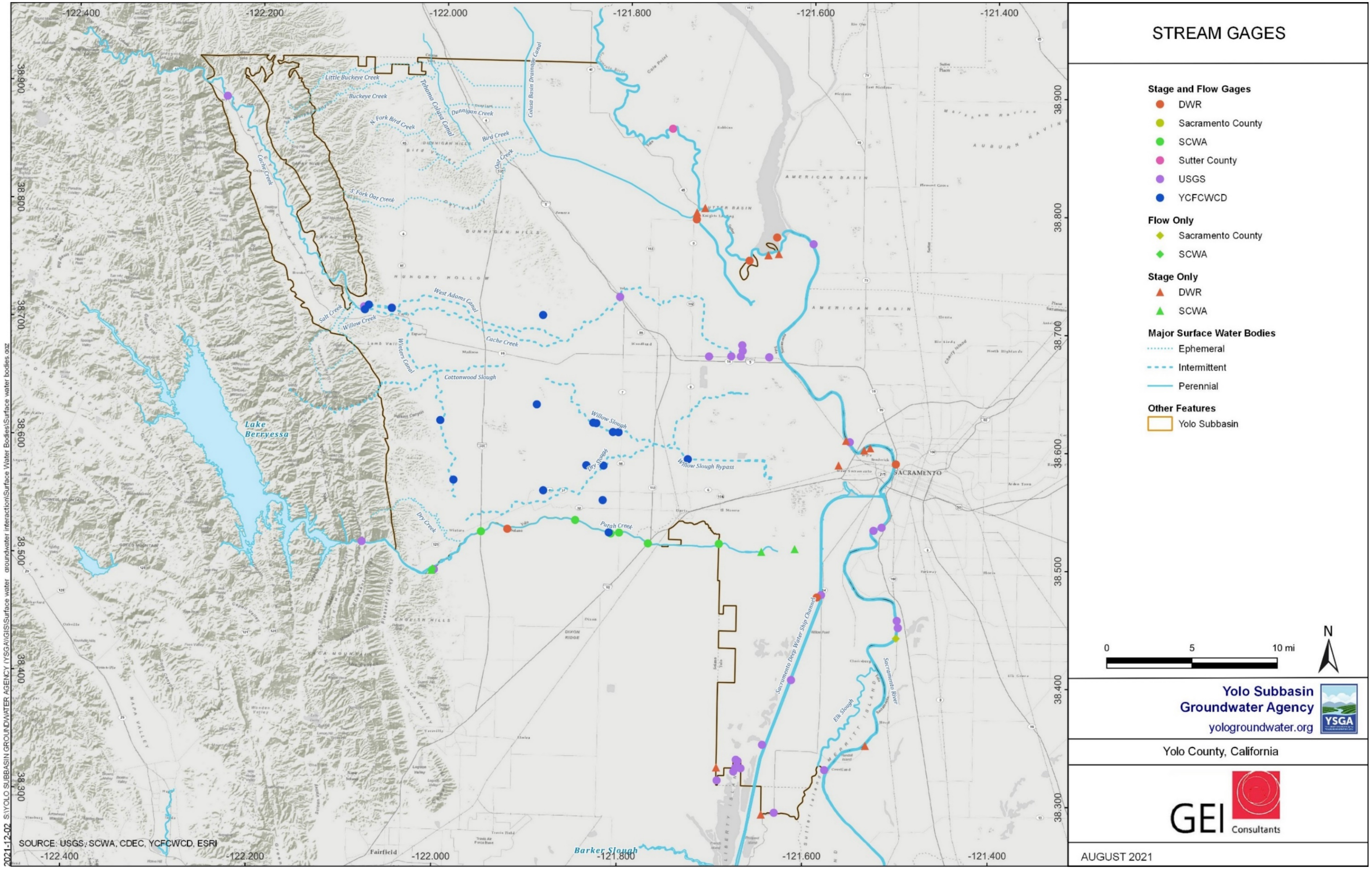

Figure 2-46. Yolo Subbasin Stream Gages.

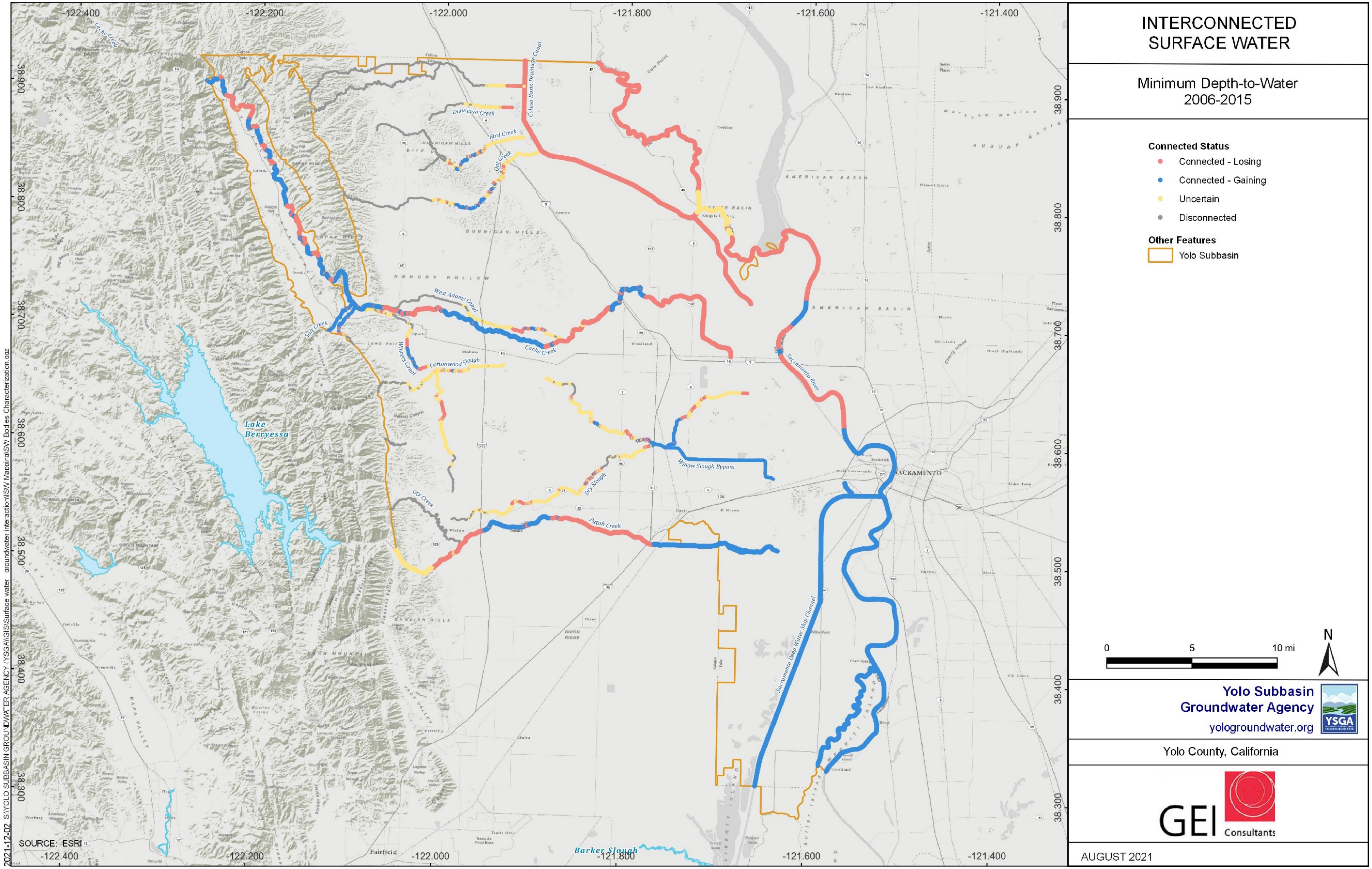

Figure 2-47. Interconnected Surface Water Bodies Under the Maximum Groundwater Elevation 2006-2015.

While Putah Creek historically was an ephemeral stream, a lawsuit in 2000 made releases of water required for permanent flows. According to the Conceptual Framework of the Lower Putah Creek Riparian Water Availability Forecasting Model, reaches of the creek regularly dried up during the summer months, while isolated pools persisted near Stevenson Bridge. These isolated pools were supported by rising groundwater directed by the Plainfield Ridge (Sanford 2005).

The "Lower Putah Creek Riparian Water Availability Forecasting Model" was developed to determine where riparian water would occur in the absence of dam releases, and where Putah Creek would normally have been dry. The Putah Creek portion of the YSGA model is calibrated with the information from this model. The most up-to-date results of the model for 2020 can be accessed on Solano County Water Agency's website[40].

In 2010, Luhdorff & Scalmanini Consulting Engineers (2010) conducted a review of over 50 documents regarding streamflow, seepage gains and losses, and stream-aquifer interactions in Putah Creek to evaluate the ability to predict streamflow's in Lower Putah Creek from groundwater levels. Putah Creek Council also maintains a bibliography of technical documents related to Putah Creek, that can be accessed online[41].

Putah Creek defines the border between the Yolo and Solano subbasins. The Solano GSA is taking the lead role in technical analysis of Putah Creek, with a supporting role from the YSGA. Additional information about Solano GSA can be found at their website[42].

2.2.6.2.3 Cache Creek Area

Cache Creek flows generally southeast through the Capay Valley and exits into the Sacramento Valley near the town of Esparto, where it then heads due east towards Woodland and eventually to the Cache Creek Settling Basin. Downstream of Capay, Cache Creek is an intermittent stream and is dry in some reaches during the summer, like the historic behavior of Putah Creek. The Cache Creek channel is located on a perched alluvial fan, also like Putah Creek, so there are no tributaries to the Creek east of Esparto, CA, except for the Salisbury Spill at Gordon Slough.

Two reservoirs are located upstream in the Cache Creek watershed – Clear Lake and Indian Valley Reservoir. These reservoirs are managed for the irrigation season and limited flood control purposes. Releases into Cache Creek travel approximately 70 miles downstream to the Capay Diversion Dam. The Capay Diversion Dam has no storage and is used to direct water into the 165 miles of canals operated by the YCFC&WCD. Upstream of the Capay Diversion Dam, the creek is generally perennial due to releases from storage. The Capay IGSM Model, developed by RMC Water and Environment for YDWN, describes the gaining and losing reaches of Cache Creek in the Capay Valley at a finer scale than the YSGA Model (RMC 2016). Further coordination

[40] https://www.scwa2.com/putak-creek-riparian-forecast/
[41] https://docs.google.com/spreadsheets/d/11ZPRLudIi4ebLbXRxnzlJ2LpSZtsE38YJ5rAALKzu4M/edit#gid=0
[42] https://www.solanogsp.com/

between the two modeling efforts is planned to increase the accuracy of the YSGA Model (*see* Project 64 in **Table 6 1 – YSGA Projects and Management Actions**.).

Downstream of the Capay Dam, Cache Creek is intermittent. During the summer, losing and gaining reaches create dry and wet sections. Wetted sections caused by gaining reaches can generally be found in the vicinities of I-505, Moore's Siphon, and County Road 94B. There is no regular monitoring program that has documented gaining and losing reaches over time. Stream gages on Cache Creek are spaced too far apart to be useful to determine gaining and losing stretches.

Gravel mining has occurred in Cache Creek since the late 1800's, as described in the Cache Creek Resources Management Plan. Over time, as mining increased, degradation (lowering) of the Creek bottom occurred. Multiple bridges were also constructed spanning Cache Creek. This constricted the channel, increasing water velocity during floods, further scouring the Creek bed and causing more degradation of the Creek bed. By the early 1990's environmental concerns about in-channel gravel mining resulted in the "Gravel Wars." An agreement between the County and the aggregate mining companies resulted in the end of in-channel mining and the creation of the Cache Creek Resources Management Plan (Yolo County 2019). Part of the plan was the installation of a network of dedicated shallow groundwater monitoring wells at the aggregate mine sites. This well network encompasses 30 years of valuable near-stream groundwater level and water quality data. The YSGA would like to work with the mining companies and the County to allow the monitoring well network to be preserved for future management of water resources along Cache Creek.

Upwelling groundwater can be a problem in urban areas during hydrologically wet periods. In Woodland, the East Beaman Street undercrossing of Highway 5 is below grade and has a dedicated electric pump to remove upwelling groundwater. In the mid-2000s, City of Woodland was spending more than $1,000,000 per year on electricity expenses to pump out groundwater that was flooding Dubach Park, which was an old gravel-mine pit. It has since been converted to a wakeboarding water park with a permanent lake.

The cities of Davis, Woodland, and the campus of UC Davis historically relied on groundwater pumping for all municipal and industrial needs. In 2016, a new water treatment plant and new pipeline from the Sacramento River was constructed to bring up to 45,000 acre-feet of river water per year to the cities and campus. Groundwater simulation models from 2011 show that, due to imported river water, groundwater levels will rise underneath the cities. This will also cause increased surface water flows in Cache Creek. Other scenarios in the model showed that theoretical increases in groundwater pumping could decrease the flows in Cache Creek and impact or deplete interconnected surface water; however, recharge would also increase, and extended overdraft conditions would be avoided.

2.2.6.2.4 Canals, Sloughs, and Streams in the Yolo Subbasin

Canals and sloughs in the Subbasin typically flow through the summer due to surface water deliveries and runoff from irrigated agriculture and go dry otherwise, except during times of rain. Most of the 165 miles of canal in the YCFC&WCD service area are unlined to promote groundwater recharge, and lose about 25 percent of summertime water deliveries (15,000-65,000 acre-feet per year [AFY]) to groundwater (YCFC&WCD 2012b). New wells continue to be drilled adjacent to the YCFC&WCD canal system, possibly causing direct depletion of the canals. Further study of the issue is necessary to understand the location and magnitude of these depletions.

Other canals and sloughs in the Subbasin are also earthen-lined and operated in a similar manner to YCFC&WCD canals. Although recharge estimates are not available, most are earthen channels that lose to groundwater during the irrigation season and are dry otherwise, with a few exceptions. The Colusa Basin Drainage Canal and Knight's Landing Ridge Cut are generally perennial; over 1 million acres are drained into the canal, providing a year-round flow of water (Colusa County RCD 2012). In the southern end of the Subbasin, the Yolo Bypass area and Clarksburg MA generally experience consistently high groundwater levels. Canals and ditches in the area are often gaining groundwater, remaining wet year-round. Fields in the area often need to pump groundwater out rather than apply it.

There are several smaller creeks in the Subbasin, such as Oat Creek in the Dunnigan Hills, which are considered ephemeral and only flow immediately following rainfall events. Information about groundwater levels in the area and the timing and quantity of flow in the creeks is limited and considered a data gap of this GSP.

2.2.6.2.5 Quantification and Timing of Depletion of Interconnected Surface Waters

The quantity and timing of depletions of interconnected surface waters is described by the YSGA Model (*see* **Section 2.3.1 – Model Overview**). **Table 2-18** summarizes the average monthly and annual stream seepage values in acre-feet. Generally, gains are greater, and losses are less in the spring than in the fall due to elevated groundwater levels.

The YSGA Model was calibrated from existing studies on Putah and Cache creeks and the Yolo Bypass area. Other streams in the Subbasin are uncalibrated and thus contain significant uncertainty. More information about the calibration and sources of uncertainty in the Model can be found in the **Appendix E – Yolo SGA Model Documentation**.

Table 2-18. Simulated Average Seepage Values from the YSGA Model.

		Stream Reach										
	Month	Lower Cache Creek	Upper Cache Creek	Colusa Basin Drain	Putah Creek	Upper Sacramento River	Lower Sacramento River	Knights Landing Ridge Cut	Sacramento Weir	Willow Slough	Yolo Bypass	Deepwater Ship Channel
Average Monthly Seepage (Acre-Feet/Month)	Jan	-4,900	400	0.12	-1,400	-110	-50	130	1.6	-0.31	2,300	160
	Feb	-4,100	530	0.12	-1,300	-100	-51	120	1.6	-0.30	2,100	140
	Mar	-3,700	730	0.15	-1,700	-100	-59	130	1.8	-0.26	2,400	160
	Apr	-2,100	810	0.16	-1,400	-64	-37	130	1.8	-0.10	2,400	150
	May	-720	820	0.16	-1,000	-36	-22	130	1.8	-0.13	2,500	150
	Jun	-1,200	660	0.15	-1,100	-26	-15	130	1.8	-0.13	2,600	150
	Jul	-2,200	590	0.15	-1,300	-24	-16	130	2.0	-0.17	2,900	160
	Aug	-2,800	530	0.15	-1,100	-22	-14	140	2.0	-0.16	2,900	170
	Sep	-2,400	520	0.14	-740	-29	-12	130	1.9	-0.080	2,700	170
	Oct	-3,800	770	0.14	-860	-19	-3.0	130	1.8	-0.040	2,600	160
	Nov	-4,100	550	0.12	-1,200	-41	-11	120	1.7	-0.12	2,300	150
	Dec	-4,700	410	0.12	-1,300	-91	-38	130	1.7	-0.25	2,300	150
Avg Annual Seepage (Acre-feet per year)		**-37,000**	**7,300**	**1.7**	**-15,000**	**-670**	**-330**	**1,500**	**21**	**-2.1**	**30,000**	**1,900**

2.2.7 Groundwater Dependent Ecosystems

GDEs within the Yolo Subbasin are identified in accordance with §354.16(g) of the Groundwater Sustainability Plan regulations. The Subbasin ecosystem is diverse. Within the Subbasin, GDEs have been identified and characterized. A GDE, as defined in the GSP regulations, "are ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." *23 CCR §351(m).* As described in the Nature Conservancy's *Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act* (Rohde et al. 2018), a GDE's dependence on groundwater relates to species and/or ecological communities' reliance on groundwater for all or a portion of their water needs.

GDEs within the Yolo Subbasin have been identified and characterized. Potential effects of current and future groundwater conditions on these GDEs have been evaluated. GDEs have been considered during the establishment of sustainability management criteria. Biological and hydrologic data has been incorporated into the YSGA monitoring network to better identify GDE conditions and their relation to groundwater conditions. Projects and management actions have been identified to maintain the baseline conditions of groundwater dependent ecosystems in the Yolo Subbasin.

2.2.7.1 Identification and Characterization of GDEs

Indicators of groundwater dependent ecosystems (iGDEs) were identified and mapped utilizing the Natural Communities Commonly Associated with Groundwater (NCCAG) database. The NCCAG dataset was created by the California Department of Fish and Wildlife (CDFW), DWR, and The Nature Conservancy. The NCCAG dataset was developed using publicly available state and federal data to identify iGDEs based on the presence of wetlands, vegetation, springs, and seeps. Similar criteria were used to evaluate a connection to groundwater for both subsets of data. In the vegetation iGDE dataset, 12,642 acres were evaluated. In the wetland iGDE dataset, 11,734 acres were evaluated.

Additional datasets that were utilized in the GDE identification and analysis process were:

- *Plant Rooting Depth database*[43] – rooting depth data for vegetative species
- *GDE Pulse*[44] (Klausmeyer et al. 2019) – data on spatial indices that are proxies for vegetative health (Normalized Difference Vegetation Index [NDVI] and Normalized Difference Moisture Index [NDMI])
- *California Protected Areas Database*[45]
- *US Fish and Wildlife Services Critical Habitat*[46]

[43] https://groundwaterresourcehub.org/sgma-tools/gde-rooting-depths-database-for-gdes
[44] https://gde.codefornature.org/#/home
[45] https://www.calands.org/
[46] https://ecos.fws.gov/ecp/report/table/critical-habitat.html

- *CDFW's Biogeographic Information and Observation System*[47] *and California Natural Diversity Database (CNDDB)*
- CDFW's *Areas of Conservation Emphasis (ACE)*[48]

2.2.7.2 Establishing a Connection to Groundwater

iGDEs that were included in the NCCAG dataset were evaluated to determine a connection to groundwater. The evaluation of these iGDEs resulted in the creation of three categories: connected, disconnected, and uncertain. The criteria utilized to determine an iGDE's category are described below.

2.2.7.2.1 Depth to Water

The depth to groundwater used in this analysis was created using the maximum groundwater elevation of the wells that were utilized in the YSGA model. There are 1,089 wells in this dataset, and the period of record was between 1929 and 2016. This groundwater elevation surface was subtracted from a DEM with 30-meter resolution to create a minimum depth to groundwater for the Yolo Subbasin. Using the minimum depth to groundwater over the period of record attempts to include GDEs that may only be connected to groundwater in years where the water table is elevated. The periodic connection and disconnection of GDEs to groundwater is a condition that has historically existed in the Subbasin and is a regime that supports the current presence of GDEs.

Vegetation iGDEs where depth to groundwater was less than 30 ft were generally retained– except in the limited cases where the additional evaluation criteria suggested a connection to groundwater did not exist.

iGDEs where the depth to water was greater than 30 ft, were further evaluated based on an evaluation of the rooting depth of the dominant species within that polygon. Valley Oaks (*Quercus lobata)*, for example, have a maximum rooting depth of nearly 25 ft. Studies suggest that the Valley Oak may be able to access groundwater much deeper, and up to nearly 80 ft in fractured rock ecosystems (Burgy 1964). For vegetative polygons where 30 ft was more than double the dominant vegetations rooting depth, 30 ft depth to water was used as the cutoff for establishing a connection to groundwater. For vegetative polygons where 30 ft was less than double the rooting depth of the dominant vegetative species, depth to water was compared to double the rooting depth of the dominant vegetative species. For example, if a vegetative iGDE polygon's primary vegetation was Valley Oak and the historic minimum depth to water was 48 ft, it would be considered a GDE. Historic minimum Depth to water greater than 50 ft was the cutoff for a connection to groundwater, with the exception of Valley Oak iGDEs. Based on the Burgy study, and based on recommendations from The Nature Conservancy, the depth to water delineation for Valley Oak GDEs is 75 ft.

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[47] https://apps.wildlife.ca.gov/bios/
[48] https://wildlife.ca.gov/Data/Analysis/Ace

For the ‘wetland’ iGDE polygons in the NCCAG dataset, Depth to water was evaluated using two criteria. The first consideration was if the wetland iGDE existed on a surface water body that was determined to be ‘connected’ as a result of the analysis for Interconnected Surface-Water Depletion. If the iGDE existed along a ‘connected’ stretch of a surface water body in this analysis, it was kept as a GDE. All springs and seeps identified in the dataset used were kept. The process to determine the status of a surface water body is described in **Section 2.3.6 – Groundwater Storage**. If the wetland iGDE was along an ‘uncertain’ body of water, the iGDE was placed into the ‘uncertain’ category. The second criteria depth to water that was used to determine the status of an iGDE was depth to water. For the wetland iGDEs that were not within 500 ft of a surface water body, polygons where depth to water was less than 30 feet were retained.

Depth to water data is limited in the Dunnigan Hills and in the southern most portion of the Yolo Subbasin. In the Dunnigan Hills, there are a handful of polygons that are uncertain due to limited data. There are 110 acres of vegetation iGDEs that fall into this category. There are 32 acres of wetland iGDEs that fall into this category.

Depth to water in the Yolo Bypass and near Clarksburg is known to be shallow, and generally less than 30 ft. The iGDEs in this area are considered as being GDEs because of the shallow depth to water in this area.

2.2.7.2.2 Summer Normalized Difference Vegetation Index (NDVI)

NDVI is an index that is commonly used to represent the greenness of vegetation. NDVI and NDMI are both commonly used as proxies to understand vegetation health and temporal trends in groundwater-dependent vegetation (Rouse et al. 1974 and Jiang et al. 2006 as cited in Klausmeyer et al. 2018). NDVI values were utilized to determine if a vegetative iGDE was disconnected from groundwater. The NDVI data that was used to evaluate vegetative iGDEs was downloaded from GDE Pulse. The GDE Pulse tool contains NDVI and NDMI values for iGDE polygons where greater than 50 percent of the NDVI cell overlaps an iGDE polygon. This dataset contains annual average NDVI values from Landsat data between July 9 and September 7 from 1985 to 2018. To determine whether a vegetative iGDE had a connection to groundwater, the maximum NDVI value between 2000 and 2018 was obtained for each polygon. If the maximum NDVI value for a given polygon was less than 0.2 between 2000 and 2018, it was inspected using arial imagery. If the iGDE polygon had a maximum summer NDVI of less than 0.2 and it did not appear to be a GDE from the current arial imagery, it was removed. This process removed 151 acres of vegetation iGDEs.

2.2.7.2.3 Additional Removal Criteria

Some additional polygons were removed for reasons that did not fall under the categories of NDVI and Depth to Water. These reasons include:

- **Wetland iGDEs within lined surface water bodies** (Colusa Basin Drain, < 1 acre)
- **Vegetation iGDEs in the medians of paved roads** (city of Davis, < 1 acre)

A summary of this work is shown in **Table 2-19**, **Table 2-20**, **Figure 2-48,** and **Figure 2-49**. The total acreage that was removed from the Vegetation and Wetland iGDEs dataset is a little over 1 percent.

Table 2-19. Acreage Status of iGDEs.

Wetland iGDE - Status	Wetland *Acreage*	Vegetation iGDE - Status	Vegetation *Acreage*
Retained	11123	*Retained*	12279
Removed – DTW	99	*Removed -DTW & Rooting Depth*	86
		Removed -NDVI	151
Uncertain	513	*Uncertain*	123

Table 2-20. Depth to Water and NDVI trends within HUC 12s in the Yolo Subbasin.

GDE Unit No.	GDE Unit Name	Average DTW 2000-2015	Average DTW 1975-1990	DTW Trend	NDVI 1985-1995	NDVI 2000-2015	NDVI Trend
1	Bird Creek	34.7	50.6	Limited Well Data	0.254	0.286	Positive
2	Brooks Creek-Cache Creek	22.7	20.4	Steady	0.335	0.436	Positive
3	Buckeye Creek	88.3	121.1	Limited Well Data	0.297	0.338	Positive
4	Bulkley Ranch	12.7	23.0	Positive	0.415	0.433	Steady
5	Chickahominy Slough-Dry Slough	36.2	36.6	Steady	0.381	0.433	Positive
6	Clarks Ditch-Colusa Basin Drainage Canal		80.0	Limited Well Data	0.358	0.462	Positive
7	Cottonwood Slough	19.6	17.8	Steady	0.349	0.386	Positive
8	Dry Creek	76.5	59.3	Negative	0.380	0.459	Positive
9	Dunnigan Creek-Colusa Basin Drainage Canal	51.6	63.3	Limited Well Data	0.355	0.457	Positive
10	Glide Ranch	19.1	21.1	Steady	0.415	0.406	Steady
11	Goodnow Slough-Cache Creek	45.4	45.1	Steady	0.342	0.426	Positive
12	Hamilton Creek-Cache Creek	59.9	27.1	Negative	0.364	0.433	Positive

GDE Unit No.	GDE Unit Name	Average DTW 2000-2015	Average DTW 1975-1990	DTW Trend	NDVI 1985-1995	NDVI 2000-2015	NDVI Trend
13	Knights Landing Ridge Cut	28.7	37.0	Steady	0.465	0.556	Positive
14	Lamb Valley Slough-South Fork Willow Slough	32.7	32.9	Steady	0.324	0.381	Positive
15	McCune Creek-Putah Creek	59.0	44.0	Negative	0.431	0.533	Positive
16	Natomas Main Drainage Canal-Sacramento River	N/A	N/A	Limited Well Data	0.405	0.480	Positive
17	Oat Creek	39.8	32.5	Steady	0.283	0.340	Positive
18	Packer Lake-Sacramento River	N/A	N/A	Limited Well Data	0.404	0.494	Positive
19	Putah Creek-South Fork Putah Creek	43.4	39.7	Steady	0.400	0.472	Positive
20	Salt Creek	N/A	N/A	Limited Well Data	#N/A	#N/A	#N/A
21	Salt Creek 2	29.3	19.3	Steady	0.344	0.393	Positive
22	Sand Creek	N/A	N/A	Limited Well Data	#N/A	#N/A	#N/A
23	Smith Creek-Colusa Basin Drainage Canal	47.7	48.3	Steady	0.369	0.456	Positive
24	South Fork Buckeye Creek	N/A	N/A	No Well Data	0.295	0.339	Positive
25	South Fork Ditch-Willow Slough	35.6	39.2	Steady	0.373	0.426	Positive
26	Sycamore Slough	18.9	2.7	Negative	0.424	0.447	Steady
27	Toe Drain-Cache Slough	8.7	17.0	Steady	0.397	0.442	Positive
28	Tule Canal-Toe Drain	38.6	41.2	Steady	0.401	0.479	Positive
29	Union School Slough	12.3	14.8	Steady	0.306	0.391	Positive

GDE Unit No.	GDE Unit Name	Average DTW 2000-2015	Average DTW 1975-1990	DTW Trend	NDVI 1985-1995	NDVI 2000-2015	NDVI Trend
30	Willow Spring Creek-Colusa Basin Drainage Canal	48.3	38.0	Negative	0.291	0.353	Positive

2.2.7.3 Characterization of GDE Condition

iGDE polygons where a connection to groundwater was established are referred to as GDEs. GDEs were evaluated for trends in hydrologic and ecologic data. This was done by consolidating GDEs into larger *GDE units* based on their proximity to each other, GDE type, and association to the same aquifer. Individual GDEs were aggregated together based on the USGS' 12-digit Hydrologic Unit Code polygons (HUC 12s). A number of other methods were considered for aggregation, but HUC 12s were decided on due to their spatial scale and availability of ecologic data. Using the HUC 12s, 30 GDE units were created.

Within these 30 HUC12s, trends in hydrologic and ecologic condition were evaluated, the GDEs that exist within each HUC 12 are referred to as GDE units. In general, as described in this section, groundwater levels in the Yolo Subbasin have been relatively stable. Historical groundwater elevation data was aggregated for wells in each HUC 12 and the average between the period 1975 to 1990 was compared to the average between 2000 and 2015. Changes in groundwater elevation were then broken into three categories: steady, positive, negative. Steady refers to a change in average groundwater elevation in the two periods of less than 10 feet in either direction. Positive refers to an increase in groundwater elevation of 10 feet or more between the two periods. Negative indicates a decrease in groundwater elevation of 10 feet or more between the two periods. **Figure 2-50** is a map that shows the depth to water trend in the Yolo Subbasin based on the above definition.

NDVI data was aggregated for each vegetative GDE by HUC 12, shown in **Figure 2-51**. This NDVI data only encompasses GDEs, it does not include agriculture or other systems that are not connected to groundwater. This NDVI data was then assessed for historical trends. NDVI values from 1985 to 1995 and from 2000 to 2015 were compared to determine trends. NDVI values in each HUC 12 were aggregated and averaged annually, and the two ranges of years were compared. Trends were broken into two categories: steady or positive, or negative. The steady category refers to an increase or decrease in NDVI of less than 0.025. The positive category refers to an increase in NDVI of greater than 0.025. In the Yolo Subbasin, there was only one GDE Unit where the average GDE NDVI between 1975 and 1990 greater than the GDE NDVI value between 2000 and 2015, GDE Unit #10. In GDE Unit#10, the change in NDVI between the two datasets was less than 0.01.

The NDVI trends in these GDE Units suggests that summer greenness in GDEs in the Yolo Subbasin is steady or increasing. This does not mean that individual GDE polygons have all remained steady or have had a positive trend, but when aggregated at the HUC 12 level, NDVI trends are steady or positive.

Exploration of trends in individual GDE polygons was done using the GDE Pulse Interactive Map. When viewing individual GDE polygons in this interactive tool, there are very few individual GDE polygons in the Yolo Subbasin that exhibit a negative trend in NDVI over the 1985 to 2015 time period. The majority of GDE Units in the Yolo Subbasin are not indicating a negative trend in depth to water or NDVI when evaluated using the criteria described above. The GDE Units with negative depth to water trends in this analysis are: Dry Creek (8), Hamilton Creek-Cache Creek (12), McCune Creek-Putah Creek (15), Sycamore Slough (26), and Willow Spring Creek-Colusa Basin Drainage Canal (30).

In the Hamilton Creek-Cache Creek GDE Unit, this trend is the result of deeper wells being added in the more recent time period. This trend is not evident when looking only at the set of wells that are included in both periods.

Dry Creek, McCune Creek-Putah Creek, Sycamore Slough, and Willow Spring Creek-Colusa Basin Drainage Canal exhibit a greater than 10 feet increase in depth to water when comparing the two periods. The NDVI trend in these GDE falls into the 'positive' category with the exception of the Sycamore Slough GDE Unit.

2.2.7.4 Additional Ecological Data

To further understand groundwater dependent ecosystems in the Yolo Subbasin, additional ecologic data was compiled. The California Freshwater Species Database was utilized to inventory species present in each GDE Unit/HUC 12. The total number of freshwater species, the number of listed species, the number of vulnerable species, and the number of endemic species present in the California Freshwater Species Database is shown in **Table 2-21**. Groundwater dependent species identified by the California Freshwater Species Database [49]as being located in the Yolo Subbasin are included in **Appendix G – Groundwater Dependent Species in the Yolo Subbasin**.

Additionally, CDFW 's ACE Species Biodiversity dataset [ds2769][50] was used to summarize the GDE Units in the Yolo Subbasin. The biodiversity dataset combines three measures of biodiversity:

- Native species richness
- Rare species richness
- Irreplaceability, a weighted measure of endemism.

This dataset displays biodiversity relative to the whole state of California (Gogol-Prokurat 2018). **Figure 2-52** displays the State Biodiversity Rank within the Yolo Subbasin. The State Biodiversity

[49] https://tnc.app.box.com/s/h0qd2ilqw2908uprt7qhkhif0b2ujn35
[50] https://gis.data.ca.gov/datasets/CDFW::species-biodiversity-ace-ds2769-1/explore

value, "…ranks of 1-5 assigned to the statewide normalized biodiversity values, with all zero values removed and remaining values broken into 5 quantiles" (Gogol-Prokurat 2018). **Figure 2-52** and **Table 2-21**, as well as the underlying data can be used as proxies to better understand, characterize, and inventory ecological conditions within the Yolo Subbasin

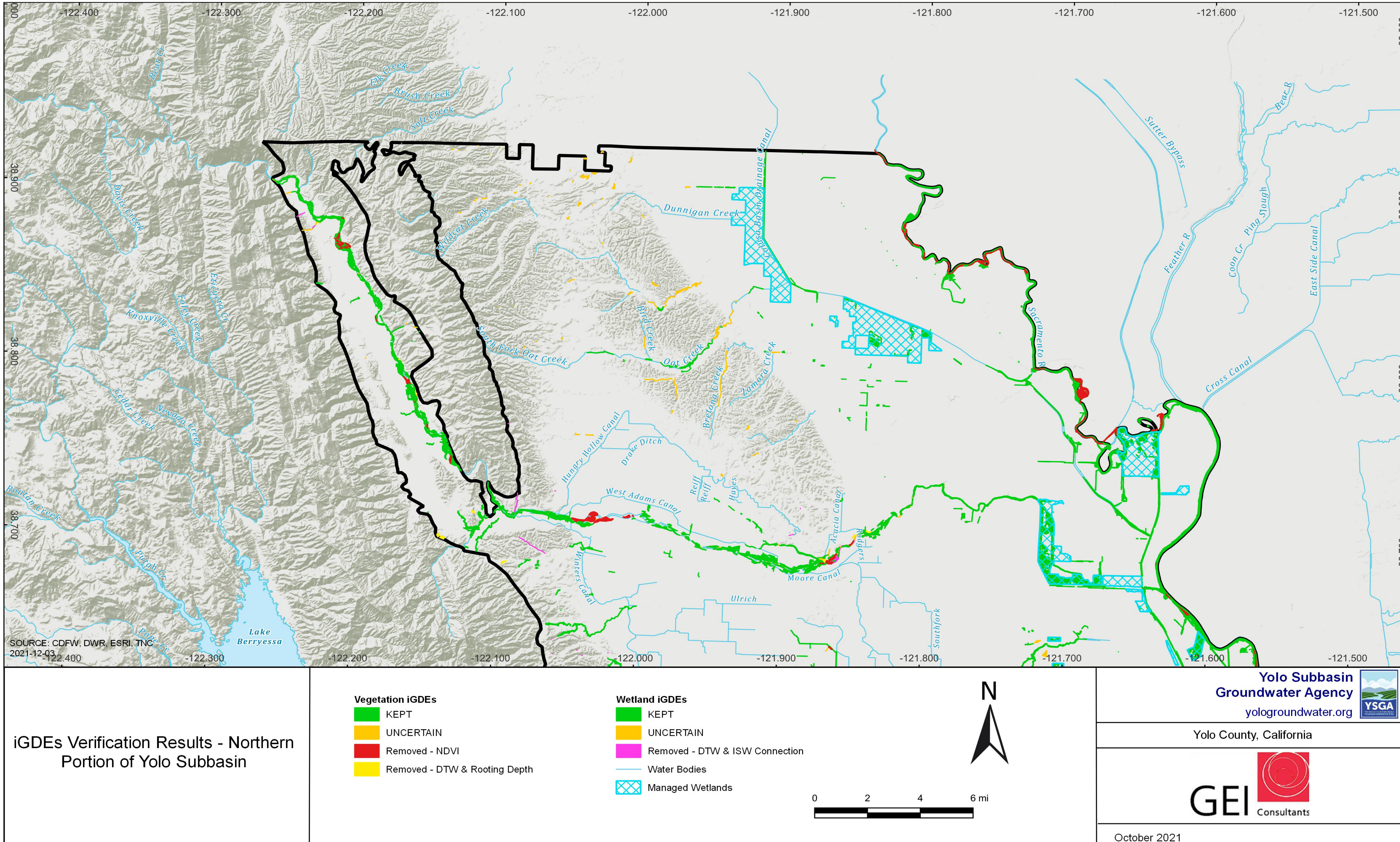

Figure 2-48. iGDEs and Status in the Northern Portion of the Yolo Subbasin.

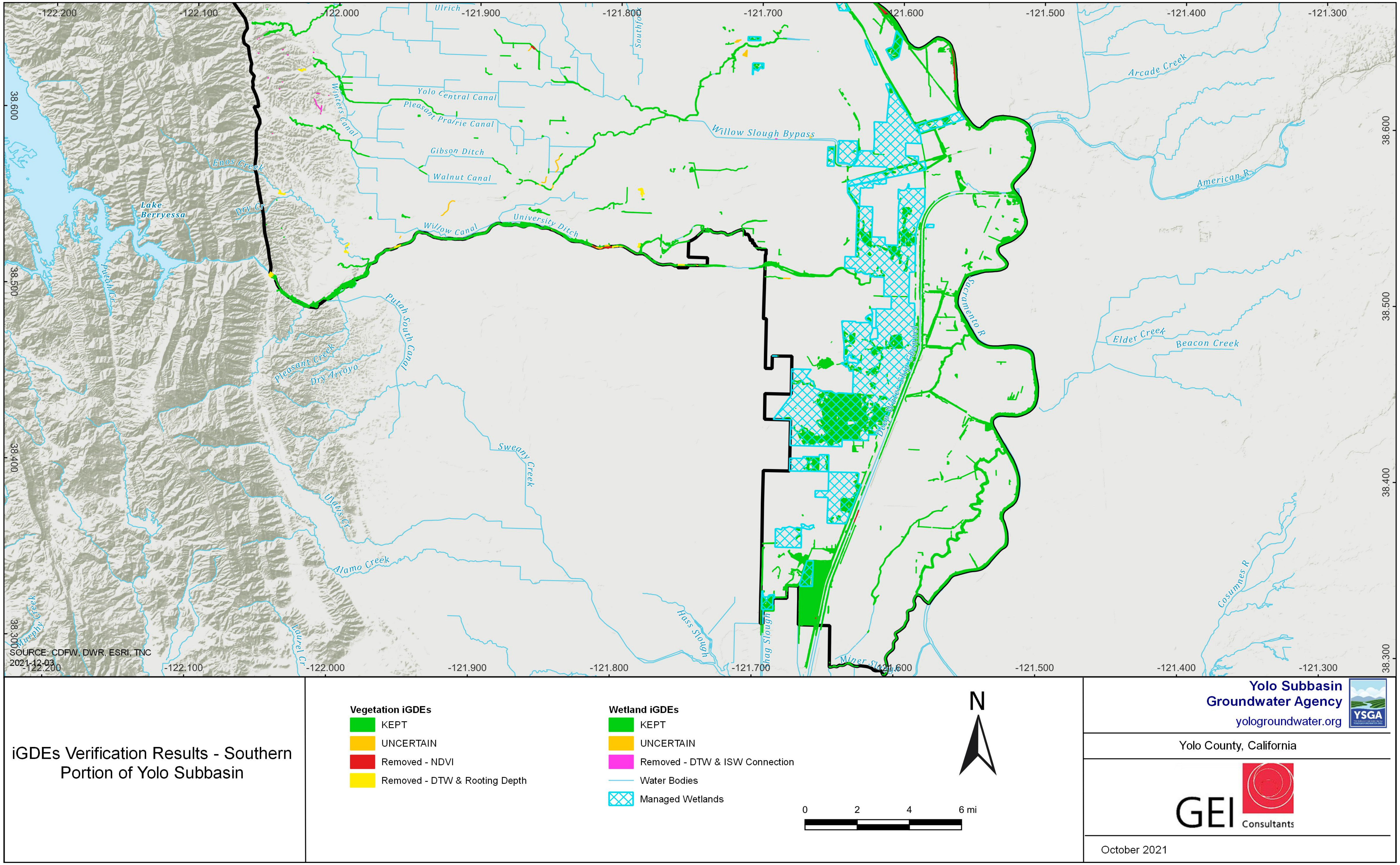

Figure 2-49. iGDEs and Their Status in the Southern Portion of the Yolo Subbasin.

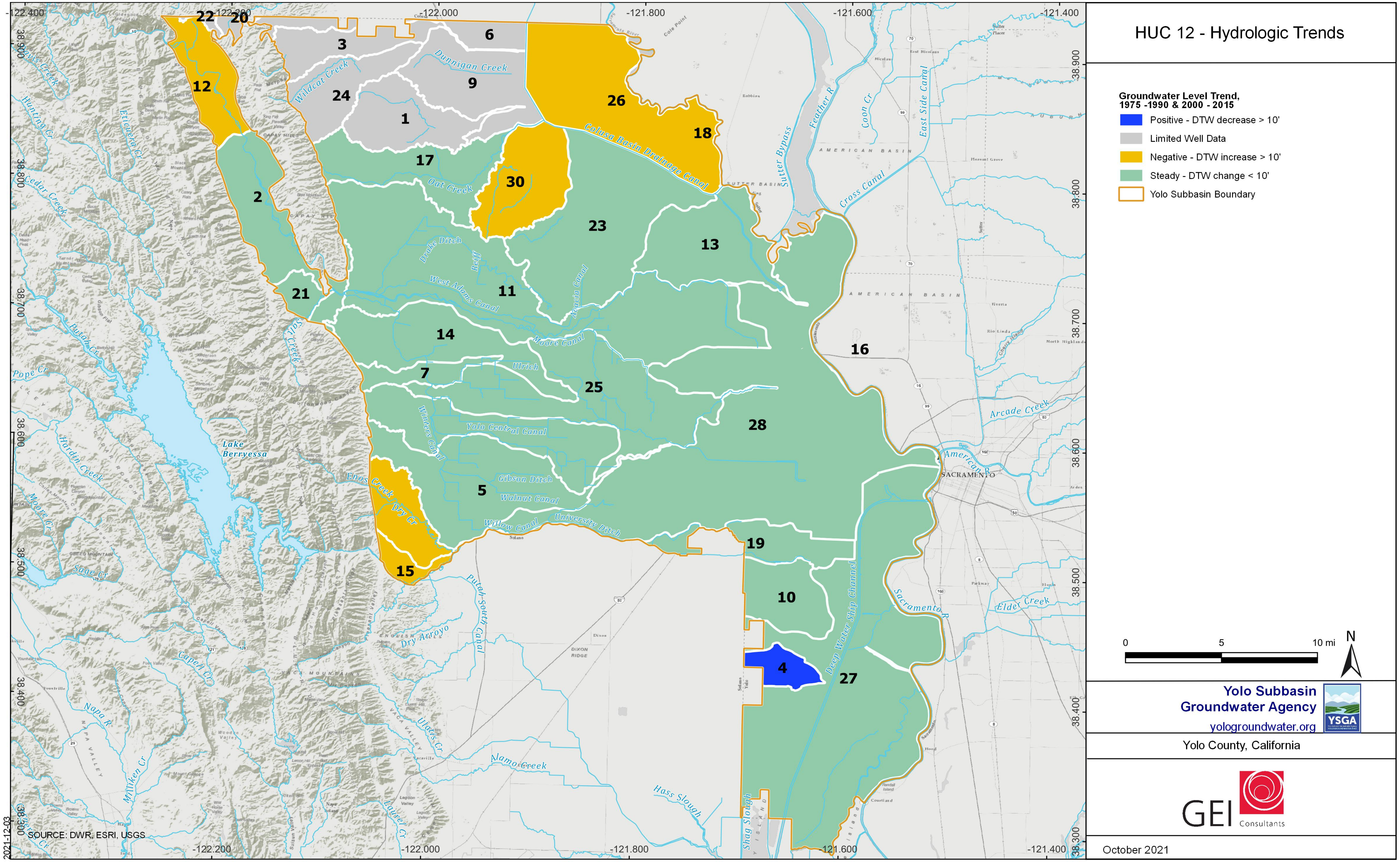

Figure 2-50. Hydrologic Trends of Groundwater Elevation in Each HUC 12 in the Yolo Subbasin.

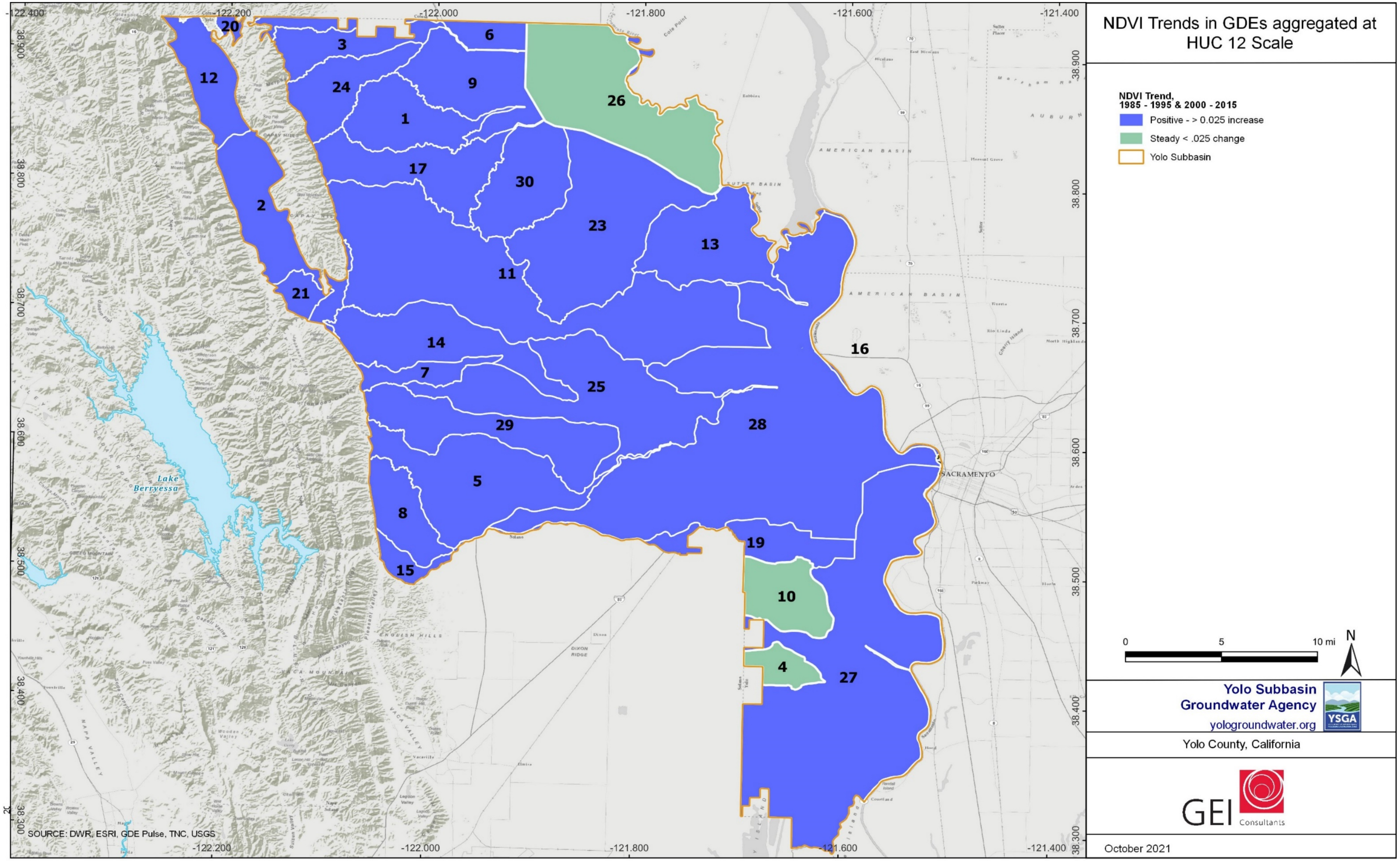

Figure 2-51. NDVI Trends in GDE polygons within each HUC 12 in the Yolo Subbasin.

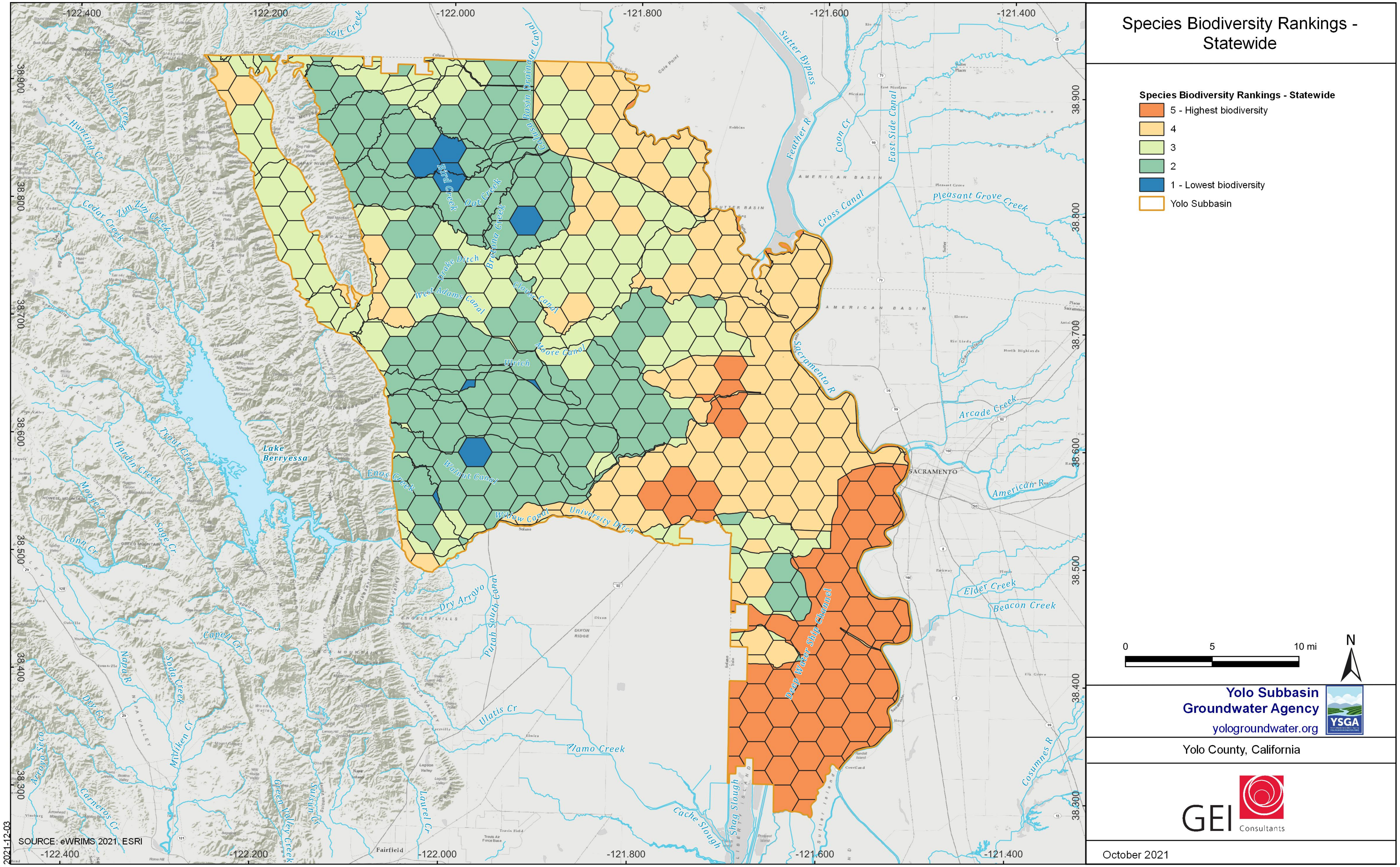

Figure 2-52. Biodiversity Rankings in the Yolo Subbasin.

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Table 2-21. Species present in California Freshwater Species Database, aggregated at the GDE Unit Scale.

GDE Unit Number	GDE Unit Number	Species Count	Listed Species	Vulnerable Species	Endemic Species
1	Bird Creek	27	4	15	15
2	Brooks Creek-Cache Creek	61	6	30	20
3	Buckeye Creek	37	5	19	16
6	Clarks Ditch-Colusa Basin Drainage Canal	263	9	62	52
7	Cottonwood Slough	41	5	21	13
9	Dunnigan Creek-Colusa Basin Drainage Canal	36	4	16	16
11	Goodnow Slough-Cache Creek	131	9	48	28
12	Hamilton Creek-Cache Creek	93	5	29	18
13	Knights Landing Ridge Cut	76	6	32	18
14	Lamb Valley Slough-South Fork Willow Slough	64	5	29	18
17	Oat Creek	37	4	22	17
18	Packer Lake-Sacramento River	132	13	47	21
20	Salt Creek	43	5	25	17
22	Sand Creek	54	4	22	16
23	Smith Creek-Colusa Basin Drainage Canal	94	8	37	17
24	South Fork Buckeye Creek	27	4	17	16
25	South Fork Ditch-Willow Slough	103	7	37	20
26	Sycamore Slough	96	9	39	19
28	Tule Canal-Toe Drain	211	13	57	33
29	Union School Slough	46	6	25	18
30	Willow Spring Creek-Colusa Basin Drainage Canal	42	4	20	15

GDE Unit susceptibility and prioritization can be categorized by evaluating the ecological significance of GDEs and trends in depth to water and spatial indices.

For example, GDE Unit 26 – Sycamore Slough, has a statewide biodiversity ranking of between three and four. GDE Unit 26 also has nine listed freshwater species, 39 vulnerable freshwater species, and 19 endemic species. NDVI has been steady in GDE Unit 26, and the average depth to water between the two sets of wells has increased between the two periods described previously.

2.2.7.5 Sustainable Management Criteria relating to GDEs

GDEs were considered in the establishment of sustainable management criteria in the Yolo subbasin. Sustainable management criteria and the rationale for selection are described in **Section 3 – Sustainable Management Criteria**.

2.2.7.6 GDE Monitoring

GDEs are considered within the Groundwater Monitoring Program. Widely available remote sensing datasets will be used to evaluate the health of GDEs through time. GDEs will experience natural fluctuations in greenness that will be captured in these remote-sensing metrics. Depth to water, and the relationship to GDEs will be monitored using the network of wells related to groundwater-level declines and interconnected surface-water depletions. These two sets of wells will provide information about vegetative and wetland GDEs throughout the Yolo Subbasin – along surface water bodies and terrestrial.

A relationship between NDVI and depth to water may be evaluated in the future to improve the understanding of the connection between groundwater levels and GDE health.

GDE data gaps – primarily in the Dunnigan Hill MA – coincide with data gaps in the monitoring network and are addressed in **Section 4 – Monitoring Networks**. Addressing data gaps in the monitoring network will help to improve the understanding of GDEs in areas where these data gaps are present.

2.3 Water Budget Information

This section describes the water budget information of the Yolo Subbasin. Water budgets quantify all inflows and outflows of the area of interest with surrounding boundaries, and within the area of interest boundary at a spatial and temporal resolution that balances data and resource (human, financial, and time) availability with the overall goals of the water budget.

Historical, present, and future land surface and groundwater budgets were estimated at catchment, MA, and Subbasin scale. This section of the GSP provides a summary of the water budgets at the Subbasin-scale; *please see* **Appendix F – Yolo Subbasin Water Budget Documentation** for additional details on water budget at the subbasin and MA scale and **Appendix E – Yolo SGA Model Documentation**, for technical information of model documentation.

Land surface water budgets quantify all the inflows and outflows to a specified area, from the bottom of the root zone (including water in the root zone), up to the land surface. Land surface inflows in the Subbasin are dominated by precipitation, surface water supply, and groundwater supply to meet multiple water demands (primarily agricultural and municipal water needs). Applied water re-use and recycled water are relatively minor inflows, quantitatively. Land surface outflows in the Subbasin are dominated by evapotranspiration (of precipitation and applied water), deep percolation (i.e., groundwater recharge), and surface runoff. Managed aquifer recharge is a quantitatively small land surface outflow for the Subbasin as a whole. The difference between these inflows and outflows represents the net change in land surface storage.

Groundwater budgets show all the inflows and outflows to the aquifer from the bottom of the root zone, down through all aquifer layers. Water in the root zone that percolates into the groundwater system is included as an inflow into the shallow aquifer. Much of the Subbasin is underlain by an aquifer with three layers, as described in **Section 2.1.5 – Geology**. Groundwater inflows in the Subbasin are dominated by deep percolation from the overlying land surface, followed by smaller contributions as recharge from the YCFC&WCD's unlined, earthen canal system. Groundwater outflows are largely comprised of pumping (for irrigation and municipal uses). Lateral flows (exchanges with neighboring subbasins) include groundwater exchanges with surface water bodies like rivers and creeks, and other smaller groundwater outflows from the Subbasin. The difference between groundwater inflows and outflows represents the net change in groundwater storage.

In the Subbasin, groundwater storage changes are positive in wet years and negative in dry years, with no significant trend (decline or increase) over the past 50 years.

Please *see* Section 1.3.7 – Evaluating Water Budget Estimates, in **Appendix F – Yolo Subbasin Water Budget Documentation** to learn more about the uncertainty in the water budgets and YSGA model overall.

2.3.1 Model Overview

The YSGA model is a linked surface water-groundwater model developed using Water Evaluation and Planning (WEAP)[51] and USGS' modular finite-difference flow model (MODFLOW)[52]. The YSGA model includes not only the Yolo Subbasin but also portions of the Cache Creek watershed upstream of the Capay Valley (including Clear Lake and Indian Valley Reservoir. **Figure 2-53** shows the spatial domain of the YSGA model.

The YSGA Model uses inputs such as climate variables, land use, irrigation information, urban water plans, and groundwater and surface water hydrologic conditions to estimate historical and future land surface and groundwater budgets. **Table 2-22**, below, provides the details of the data sources, assumptions, and the model's use of each variable. Additional information about model inputs, model calculations, model calibration, and model performance in different subregions of the Basin is available in **Appendix E – Yolo SGA Model Documentation**. The YSGA model relies on a 48-year historical period, which covers a large spread of WY types: significant and contiguous drought and wet periods. The YSGA model runs at a monthly time step from WY 1971 to 2018. WY 2018 is treated as the current period within the model and documentation – climate and water

[51] WEAP is an integrated surface water-groundwater modeling tool, which integrates rainfall-runoff hydrology, reservoir operation, water demands from cities and crops, and allocations of water to those demands from surface water and groundwater supplies.
[52] MODFLOW is a finite-difference groundwater modeling tool developed by the USGS, which simulates the groundwater budget of the Yolo Subbasin's three-layer aquifer and was built using the inputs, aquifer parameters, boundary conditions, and aquifer representation from a Yolo County Integrated Water Flow Model (IWFM).

rights data is updated to 2018; however, land use data was only available for 2016 (land use data from 2016 was kept constant until 2018).

Table 2-22. YSGA Model Data Sources.

	Variable	Historical Scenario		Future Projections	
		Sources	**Model use**	**Sources**	**Model use**
Climate	Precipitation	PRISM[1]	Input data	Historical, modified by Climate Change factors provided by DWR	Input data
	ETo	CIMIS[2]	Calibration	Historical, modified by Climate Change factors provided by DWR	Input data
	Minimum Temperature	PRISM[1]	Input data	NA	
	Maximum Temperature	PRISM[1]	Input data	NA	
	Wind speed	(Livneh et al. 2013); CIMIS[2]	Input data	NA	
	Humidity	PRISM[1]	Input data	NA	
Land Use	Agricultural land use	DWR Land Use Surveys[3]; Yolo County Annual Agriculture Commissioner Reports; DWR SGMA Portal (LandIQ dataset)	Input data	Agricultural land use kept constant to Current Year	Input data
	Non-agricultural land uses	DWR Land Use Surveys[3];	Input data	Growth projections from urban master plans[6]	Input data
Irrigation	Schedule	Sacramento-San Joaquin basin Study[4] (Reclamation 2015)	Input data	Same as historical	Input data
	Crop coefficients	Sacramento-San Joaquin basin Study[4] (Reclamation 2015)	Input data; Calibration	Same as historical	Input data
	Irrigation efficiency	NA	Calibration	Same as historical	Input data
	Applied Water	DWR Applied Water Estimates[5], Groundwater management plans and personal communication[6]	Calibration	NA	Model output
	Water sources and supply	State Water Board eWRIMS water rights database[7], personal communication[6]	Input Data	Same as historical	Input Data
Urban	Water demand, including population	Urban water plans and personal communication[6]; CA Department of Finance Population data[8]	Input data	Growth projections from urban master plans[6]	Input data
	Water sources and supply	Urban water plans and personal communication[6];	Input data (water rights)	Urban water plans[6]	

	Variable	Historical Scenario		Future Projections	
		Sources	Model use	Sources	Model use
		State Water Board eWRIMS water rights database[7]			Input data (water rights)
Hydrology	Stream flows	USGS[9]; CDEC[10]	Calibration	NA	Model output
	Stream flows	USGS9; CDEC[10]	Input Data	Same as historical	Input data
	Initial groundwater conditions	WRID[11]; SGMA[12]; IWFM model (Flores Arenas 2016)	Input data	Historical model end-of simulation set as future model run initial conditions	Input data
	Groundwater boundary conditions	IWFM model (Flores Arenas 2016)	Input data, calibration	NA	Input data
	Groundwater elevations (time series)	WRID[11]; SGMA[12]; WDL [13];	Calibration, Model output	NA	Model output
	Reservoir operations (storage levels, outflows)	CDEC[10]; Conversations with and data supplied by YCFC[6]	Calibration, Model output	NA	Model output
	In-stream flow requirements	CDEC[10]; Conversations with and data supplied by YCFC[6]	Input data	Same as historical	Input data

1 http://www.prism.oregonstate.edu/explorer/ Accessed 5.19.2019
2 https://cimis.water.ca.gov/Default.aspx . Accessed 5.19.2019
3 https://gis.water.ca.gov/app/CADWRLandUseViewer/ Accessed 9.1.2020
4 https://www.usbr.gov/watersmart/bsp/docs/finalreport/sacramento-sj/Sacramento_SanJoaquin_TechnicalReport.pdf Accessed 9.1.2020
5 https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Agricultural-Land-And-Water-Use-Estimates Accessed 2.1.20
6 A complete list of entity-specific data sources and personal communication is provided in Appendix E – Yolo SGA Model Documentation, and in spreadsheet format to the YSGA
7 https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/
8 http://www.dof.ca.gov/Forecasting/Demographics/Estimates/
9 https://waterdata.usgs.gov/nwis/sw
10 https://cdec.water.ca.gov/
11 Yolo County Water Resources Information Database (https://wrid.facilitiesmap.com/Login.aspx)
12 SGMA Data Viewer https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels
13 California Water Data Library https://wdl.water.ca.gov/GroundWaterLevel.aspx

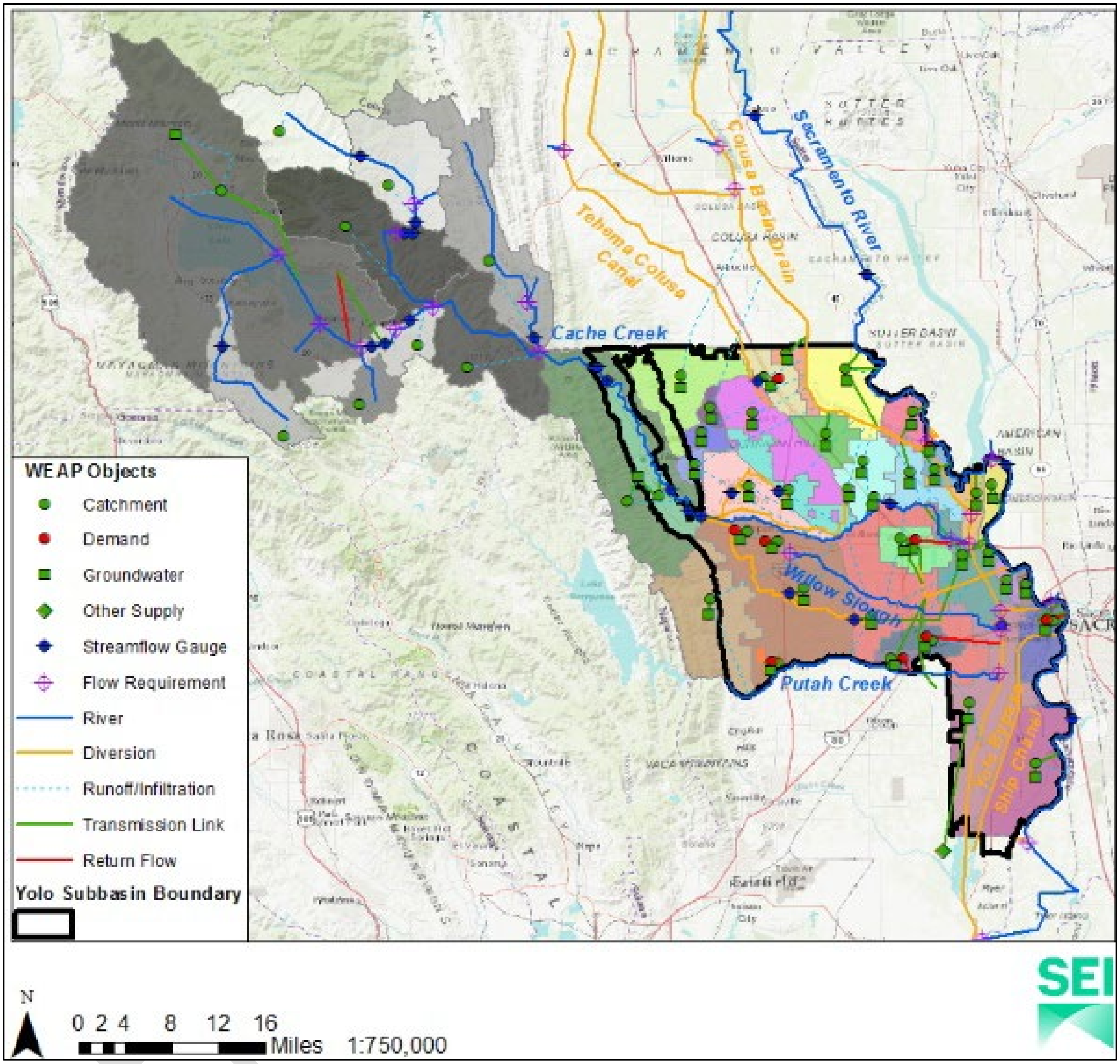


Figure 2-53. YSGA Model Spatial Domain.

Future projections in the YSGA model capture climate change projections based on climate change model simulations centered around the mid-2030's and mid-2070's. Five future scenarios exist in the model. Urban demand in these five scenarios is based on Urban Water Management Plan (UWMP) projections. The total urban demand is the same across the five modeled scenarios. Land use in the five future scenarios is held constant at the 2016/2018 land use values. The differences between five future modeling scenarios are driven by the effect of the climate changes impacting irrigation demand, precipitation, and surface water supply availability.

The five scenarios are as follows:

1. 'Future_baseline' – Urban demand increasing; irrigated crops constant; climate same as historical
2. 'Future_2030' – Climate representing the central tendency from many downscaled climate models, centered around 2030
3. 'Future_2070' – Climate representing the central tendency from many downscaled climate models, centered around 2070
4. 'Future_2070_DEW' – Climate representing the central tendency from many downscaled climate models, centered around 2070
5. 'Future_2070_WMW' – Climate representing wetter-moderate warming from many downscaled climate models, centered around 2070

The precipitation and evapotranspiration for the Yolo Subbasin are both higher in all climate projections, compared to that in the 'Historical' scenario. The model has four climate projections: Future_2030, Future_2070, 'Future_2070_DEW', and 'Future_2070_WMW'. The 'Future_baseline' scenario is not a climate change projection and models the future water budgets based on historical climate. The land surface and groundwater budgets can be compared between scenarios in **Tables 2-27, 2-28,** and **2-29.**

The four climate change scenarios use 'change factors' for precipitation and reference evapotranspiration, based on the methods presented in DWR's Climate Change Data and Guidance for Use During Groundwater Sustainability Plan Development (DWR 2018b). Additional information on Climate Change and the assumptions about climate change can be found in **Appendix F – Yolo Subbasin Water Budget Documentation** and **Appendix E – Yolo SGA Model Documentation**.

2.3.2 Land Use

Landcover in the Subbasin is dominated by agriculture and native vegetation. **Table 2-23** below shows the acreage and proportion of the main categories of Subbasin-wide land use for specific years where GIS data were available (1989, 1997, 2008, and 2016). Within each land use category, each crop is modeled with its own coefficient of water use. Native vegetation is modeled as its own category distinct from irrigated crops. More details on specific land use types and crop coefficients are available in **Appendix E – Yolo SGA Model Documentation**.

An important feature of land use changes in the Subbasin is an increasing acreage of perennial crops (deciduous, subtropical, and vines), which have partly replaced field crops, and brought previously uncultivated area into production in some regions. The Future Baseline and Historical scenarios have the same climate, but different land use inputs; Future Baseline holds 2016 land use constant, while the Historical scenario relies on the historical land use datasets in **Table 2-23**. Comparing the Future Baseline scenario to Historical demonstrates the impact of the increased perennial acreage in 2016 relative to historical land use data. Perennial acreage is generally associated with more efficient irrigation practices. Because these crops are permanent, they also decrease the flexibility of water demand ("demand hardening"). Another important change in land use is the conversion of agricultural areas to urban areas. Throughout the following sections, the comparison of the Future Baseline and Historical scenarios demonstrate the effects of this changing land use, largely in evapotranspiration and deep percolation. A model scenario incorporating future changes in land use is outside the scope of the current modeling effort but will be developed in future improvements of the YSGA model.

Table 2-23 Modeled Land Use in Historical Scenario.

	Land Use (ac)				Land Use (Percent)			
	1989	1997	2008	2016	1989	1997	2008	2016
Entire Basin	**639,089**	**639,089**	**639,089**	**639,089**				
Deciduous	17,550	18,406	30,717	59,434	3	3	5	9
Field Crops	96,679	108,427	36,475	41,446	15	17	6	6
Grain	80,354	57,993	52,369	27,200	13	9	8	4
Managed Wetlands	0	483	459	0	0	0	0	0
Native Vegetation	288,058	284,997	319,938	330,463	45	45	50	52
Pasture	42,612	44,822	63,801	33,129	7	7	10	5
Rice	22,652	24,754	35,056	38,847	4	4	5	6
Subtropical	118	135	1,331	3,670	0	0	0	1
Truck Crops	56,953	55,160	46,968	46,930	9	9	7	7
Urban	26,347	29,153	33,220	33,270	4	5	5	5
Vine	2,543	9,536	13,384	19,329	0	1	2	3
Water	5,222	5,222	5,372	5,372	1	1	1	1

2.3.2.1 Natural Vegetation

Natural vegetation covers large areas of the Yolo sub-basin, especially in north-western Yolo County (*see* **Table 2-23** for acreages). **Table 2-24** below summarizes the subbasin wide consumptive use of natural vegetation.

Table 2-24. Modeled Evapotranspiration of Natural Vegetation.

Scenario	ET Actual Average Annual (acre-feet)
Historical	399,434
Future_Baseline	437,359
Future_2030	446,687
Future_2070	448,710
Future_2070_DEW	426,354
Future_2070_WMW	452,683

Natural vegetation ET is almost one-third of basin-wide ET in the historical period.

Natural vegetation ET increases in all future scenarios, peaking in the extreme wet scenario. Relatively drier soils in the extreme-dry scenario reduce ET slightly. Native vegetation ET differences across future scenarios are relatively small (approximately 6%).

The YSGA model outputs, as for every other land cover class, ET data for every catchment-land cover combination. The detailed consumptive water use for native vegetation is provided separately as Excel spreadsheets, allowing YSGA to investigate water requirements for multiple uses at a more refined spatial scale than listed for the basin above.

2.3.2.2 Managed Wetlands

In the YSGA model, managed wetlands appear as a landcover class in RD 2035. As described in the **Appendix E – Yolo SGA Model Documentation**, RD 2035 local data provided acreages of managed wetlands from 1996 to 2008. The acreages ranged from 93 to 790 acres, averaging 411 acres. For 2018, managed wetlands acreage was available from the Land IQ derived land cover dataset, at 55 acres.

In future model scenarios, the last available acreages were used for all land cover classes (as described earlier) – hence all model runs for future scenarios have 55 acres of managed wetlands.

In the **Table 2-25** below, 2018 acreages and ET. Actual volumes are used for the historical summary this allows a more straightforward comparison among all scenarios. As the table shows, consumptive use of managed wetlands can be expected to increase in all climate change scenarios, with the highest increase in the extreme dry climate change scenario.

Table 2-25. Modeled Evapotranspiration of Managed Wetlands.

Scenario	ET Actual (acre-feet)	Area (Acres)	ET Actual (acre-feet/Acre)
Historical	302	55	5.5
Future_Baseline	295	55	5.4
Future_2030	308	55	5.6
Future_2070	321	55	5.8
Future_2070_DEW	338	55	6.1
Future_2070_WMW	309	55	5.6

The portrayal of managed wetland acreages is a recognized weakness of this model. The challenges in constructing a robust, continuous long-term spatial landcover dataset for the Yolo Subbasin have been described earlier. None of the earlier DWR land and water use surveys, nor agricultural commissioner's reports, included managed wetlands as a category. The recent DWR commissioned Land IQ datasets may be under-estimating managed wetlands, or may be accurate enough for 2018, but no information is available about future acreages.

For future GSP and YSGA model updates, the TAC will work to harmonize historical managed wetland data and operations, as well as to guide future scenarios for their possible evolution in the future.

For now, the YSGA model indicates the high per acre water needs of managed wetlands, that should be considered when evaluating the impacts of YSGA projects and management actions.

2.3.3 Water Demand and Supply

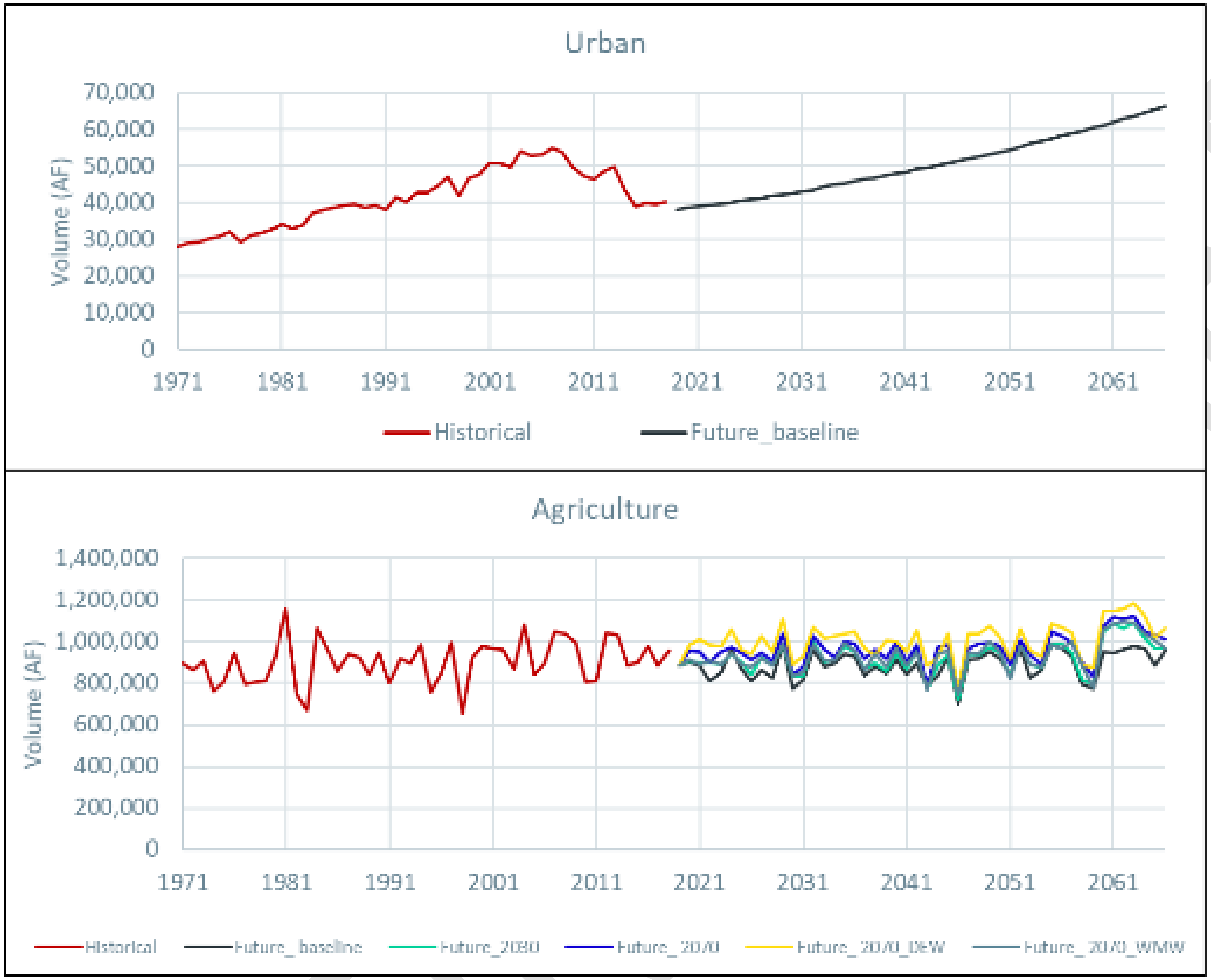
Total water demands for each of the five scenarios are presented in **Figure 2-54**. Urban water demands (based on UWMPs) rise steadily but remain small relative to irrigation demand. Irrigation demand in the future scenarios stays within the range of historical simulations, but averages are higher than in the historical scenario.

The supply sources for the 'Historical' and 'Future_baseline' scenarios shown in the pie charts in **Figure 2-54** illustrate that supply sources are expected to be about the same: Woodland Davis Clean Water Agency's water supply accounts for the increase in urban surface water supply in the 'Future_baseline' scenario. Overall, the average annual water demand increases from 945 thousand acre-feet (TAF) to a maximum of 1,055 TAF from the 'Historical' to the 'Future_2070_DEW'' (dry-extreme warming) scenario. **Figure 2-54** shows the average annual urban demand for the future scenarios as 50,270 AFY. In the future scenarios, the urban demand rises steadily, resulting in modeled urban demand that is higher at the end of the future period than at the beginning.

The modeled time period of WY 1971 to 2018 covers a large spread of WY types, significant and contiguous drought periods (WY 1976-1977, WY 1987-1992, WY 2007-2009, and WY 2012-2016), and significant and contiguous wet periods of note (WY 1971-1975, WY 1982-1984, WY 1995-2000, and WY 2005-2006). **Table 2-26** shows the WY Index (Sacramento Valley) and the WY Types for the historical to current WY type. The WY Index and WY Type are provided from DWR, and "provide a classification to assess the amount of annual precipitation in a basin" *23 CCR §351(an)*. Additional information on the WY Index for the Sacramento Valley can be viewed in DWR's *Sustainable Groundwater Management Act Water Year Type Dataset Development Report* (DWR 2021)

WY 2018 – the last year of the model simulation in the historical period – is treated as the current period. This is the most recent year for which almost all datasets are available. Climate and water rights data are updated to WY 2018 in the YSGA model. Land use data, however, is only available to 2016 (the LandIQ dataset provided by DWR in the SGMA Data Viewer[53]). Hence, 2016 land use data is used and kept constant through WY 2018.

[53] See https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#waterbudget; Accessed 8.31.2018



Average Annual Demand (Acre Feet)	
Urban	
Historical	41,102
Future(all scenarios are equal)	50,270
Agriculture	
Historical	904,090
Future_baseline	888,139
Future_2030	922,000
Future_2070	961,712
Future_2070_DEW	1,005,341
Future_2070_WMW	931,403

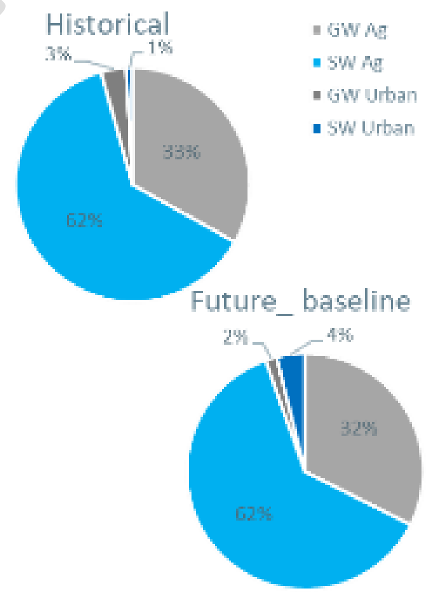


Figure 2-54. Water Demand for Historical and Future Scenarios.

Table 2-26. Historical Sacramento Valley Water Year Index and Water Year Type.

Water Year	Water Year Index	Water Year Type	Water Year	Water Year Index	Water Year Type
1971	10.37	W	1995	12.89	W
1972	7.29	BN	1996	10.26	W
1973	8.58	AN	1997	10.82	W
1974	12.99	W	1998	13.31	W
1975	9.35	W	1999	9.80	W
1976	5.29	C	2000	8.94	AN
1977	3.11	C	2001	5.76	D
1978	8.65	AN	2002	6.35	D
1979	6.67	BN	2003	8.21	AN
1980	9.04	AN	2004	7.51	BN
1981	6.21	D	2005	8.49	AN
1982	12.76	W	2006	13.2	W
1983	15.29	W	2007	6.19	D
1984	10.00	W	2008	5.16	C
1985	6.47	D	2009	5.78	D
1986	9.96	W	2010	7.08	BN
1987	5.86	D	2011	10.54	W
1988	4.65	C	2012	6.89	BN
1989	6.13	D	2013	5.83	D
1990	4.81	C	2014	4.07	C
1991	4.21	C	2015	4.00	C
1992	4.06	C	2016	6.71	BN
1993	8.54	AN	2017	14.14	W
1994	5.02	C	2018	7.14	BN

Note: Additional information on the Water Year Index for the Sacramento Valley can be viewed in DWR's Sustainable Groundwater Management Act Water Year Type Dataset Development Report (DWR 2021).

2.3.4 Land Surface Water Budget

Figure 2-55 shows the annual historical land surface water budget, and **Table 2-27** shows the historical and projected annual average inflows and outflows in the land surface water budget. The key results for the future average land surface water budget are discussed below:

- In all scenarios, overall land surface mass balance is maintained (total inflows = outflows).

- Compared to the Historical scenario, the Future Baseline scenario results in more evapotranspiration and less deep percolation, demonstrating the effect of increased perennial acreage.
- In all 4 climate scenarios, the effect of climate change results in more evapotranspiration than the Historical and Future Baseline scenarios.
- All climate scenarios besides Future_2070_WMW have less deep percolation than the historical scenario. When comparing the future scenarios, the deep percolation is less in the 'future baseline' (historical climate with 2016/2018 land use) than it is in the climate change scenarios.

Table 2-27. Average Annual Land Surface Water Budget

Average Annual Land Surface Water Budget (TAF)														
	Outflows							Inflows						
	Evapotranspiration	Deep Percolation	Surface Runoff	Urban Consumption	YCFC Canal Recharge	Treated WW Outflow	Total Outflows	Precipitation	Pumping: Urban	Pumping: Irrigation	SW Supply: Urban	SW Supply: Irrigation	Tailwater Reuse: Irrigation	Total Inflows
Entire Basin														
Historical	-1,227	-353	-459	-18	-33	-13	-2,102	1,147	33	313	9	591	10	2,102
Future_Baseline	-1,274	-308	-437	-23	-37	-16	-2,095	1,147	16	304	34	584	10	2,095
Future_2030	-1,314	-321	-471	-23	-39	-16	-2,184	1,201	15	322	35	600	11	2,184
Future_2070	-1,345	-340	-519	-23	-40	-16	-2,282	1,259	15	343	36	619	11	2,282
Future_2070_DEW	-1,346	-323	-549	-23	-37	-16	-2,293	1,229	15	385	35	620	9	2,293
Future_2070_WMW	-1,326	-424	-692	-23	-43	-16	-2,523	1,530	14	311	37	620	11	2,524

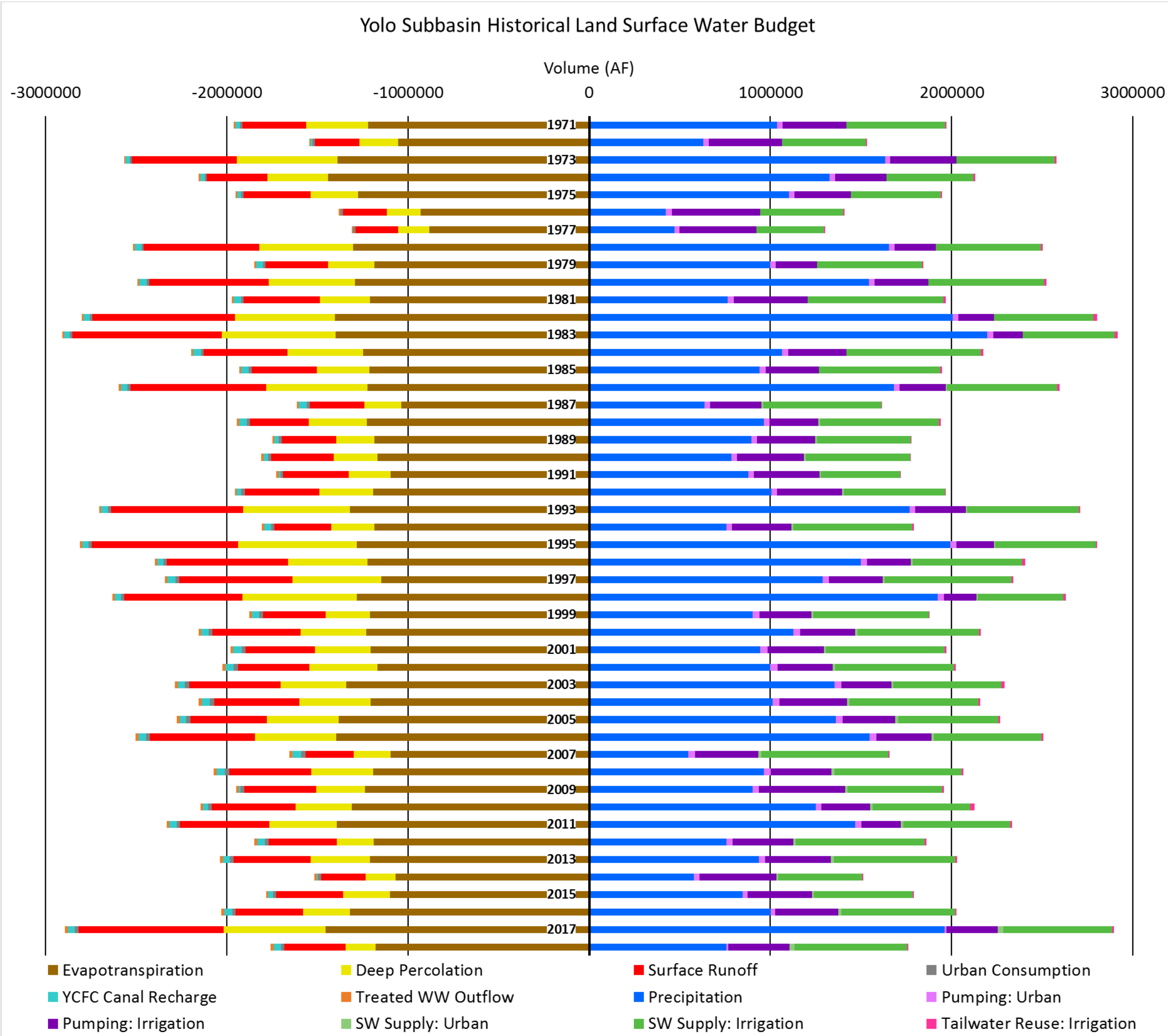


Figure 2-55. Yolo Subbasin Historical Land Surface Water Budget.

2.3.5 Groundwater Budget

Figure 2-56 shows the historical groundwater budget, and the key findings are as follows:

- Inflows to the Yolo Subbasin are dominated by deep percolation.
- Pumping (urban and irrigation) is the largest groundwater outflow.
- Groundwater-surface water exchange is on average positive; more water is lost to groundwater than gained by the modeled streams.
- The net lateral exchange with neighboring basins is negative; on average, lateral flow is leaving the Subbasin.

- Some fluxes are 0 in some years. For example, the 1976-77 and 2014 droughts led to no surface water deliveries.

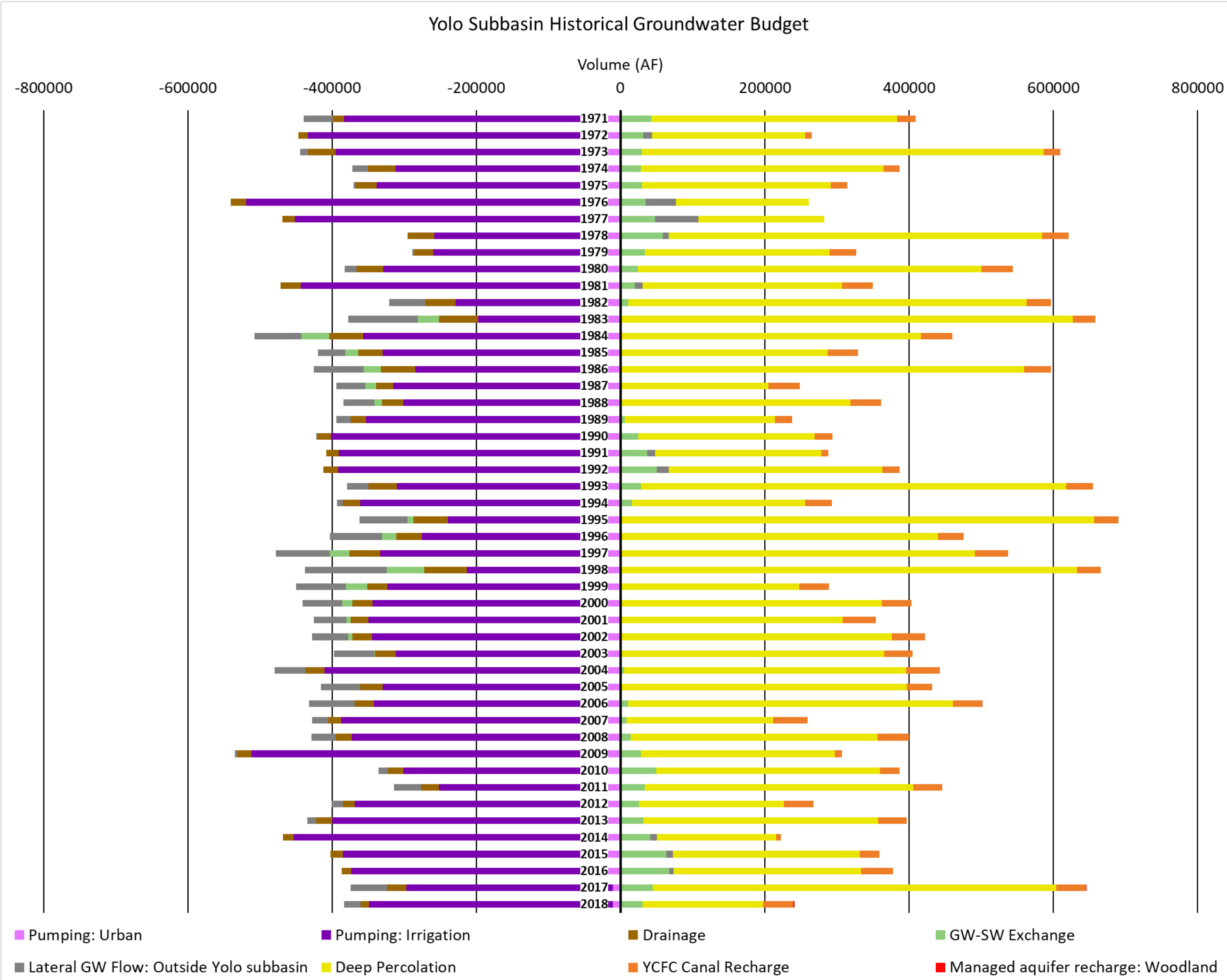


Figure 2-56. Yolo Subbasin Historical Ground Water Budget.

Table 2-28 below includes the average annual groundwater budget for the historical and five scenarios evaluated. The key findings for the <u>future</u> average groundwater budgets are as follows:

- The Future Baseline scenario predicts less deep percolation than historical and slightly more outflow than inflow, reflecting increased perennial acreage and changing irrigation management.
- In the Extreme Dry scenario, climate change causes an increase in deep percolation and reduced groundwater storage. In the central tendency scenarios, budgets remain balanced. In the Extreme Wet scenario, climate change causes an increase in groundwater storage.
- Every scenario except the Extreme Wet scenario shows less inflows into the groundwater system than historical (far right column of **Table 2-28**).

Table 2-28. Average Annual Groundwater Budget.

Average Annual Groundwater Budget (TAF)												
	Outflows				Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer recharge:	Total Inflows
Entire Basin												
Historical	-33	-313	-28	-374	15	-28	0.0	-13	353	33	0.04	386
Future_Baseline	-16	-304	-16	-336	25	-40	0.0	-15	308	37	1.37	346
Future_2030	-15	-322	-15	-352	23	-37	0.0	-15	321	39	1.43	361
Future_2070	-15	-343	-15	-373	22	-35	0.0	-13	340	40	1.31	381
Future_2070_DEW	-15	-385	-13	-413	46	-6	0.0	39	323	37	1.30	360
Future_2070_WMW	-14	-311	-24	-348	-29	-79	0.0	-108	424	43	1.40	468

Notes: In the historical scenario: GW-SW exchange is positive with Cache Creek (29 TAF), Putah Creek (13.9 TAF), Sacramento River (0.9 TAF) and negative with Yolo bypass (25.7 TAF), Knights Landing Ridge Cut (1.5 TAF) and Colusa Basin Drain (2 TAF). Other GW-SW exchanges are minor.

Table 2-29 below provides another way to view the average annual groundwater fluxes by observing the delta, or difference, from the 'Historical' scenario.

Table 2-29. Average Annual Groundwater Budget Relative to Historical Scenario.

Historical Average Annual Groundwater Budget (TAF)												
	Outflows				Varying Flows				Inflows			
	Pumping: Urban	Pumping: Irrigation	Drainage	Total Outflows	GW-SW Exchange	Lateral GW Flow: Outside Yolo subbasin	Lateral GW Flow	Total Varying Flows	Deep Percolation	YCFC Canal Recharge	Managed aquifer recharge: Woodland	Total Inflows
Entire Basin												
Historical	-33	-313	-28	-374	15	-28	0	-13	353	33	0.04	386
	Delta from Historical				Delta from Historical				Delta from Historical			
Future_Baseline	17	9	12	38	10	-12	0	-2	-45	4	1.33	-40
Future_2030	18	-9	13	22	8	-9	0	-2	-32	6	1.39	-25
Future_2070	18	-30	13	1	7	-7	0	0	-13	7	1.27	-5
Future_2070_DEW	18	-72	15	-39	31	22	0	52	-30	4	1.26	-26
Future_2070_WMW	19	2	4	26	-44	-51	0	-95	71	10	1.36	82

2.3.6 Groundwater Storage

Changes in groundwater storage over time are the aggregate (net) outcome of the individual inflows and outflows from the aquifer. The MODFLOW portion of the YSGA model estimates basin-wide groundwater storage capacity at 13.7 MAF. This is consistent with Clendenen & Associates (1976), which estimated the available groundwater storage in the County (20 to 420 feet bgs), as 14 MAF.

Modeled basin groundwater storage is presented as cumulative change from initial storage in September 1970, as shown in the **Figure 2-57**. Groundwater is lost from storage in dry years and recharge occurs in wet years to allow basin-wide recovery. Deep groundwater storage declines following the deep droughts and storage recovery follows in the intervening wet periods. **Over the past 50 years, there is no evidence of basin-wide overdraft.** Additionally, as previously mentioned, the dominant shift in land use in the Yolo Subbasin over this historical period has been from annual to perennial crops. **The groundwater storage trace implies that the climate signal has dominated over this historical period at the basin-wide level.**

Groundwater extraction increases over the past decade were driven by the extended drought and acceleration of perennial acreage. Despite these factors, a wetter 2017 appears to have helped the Basin storage recover almost to initial levels (at the end of the simulation in the historical period, modeled Basin groundwater storage is lower than the initial level by 86 TAF).

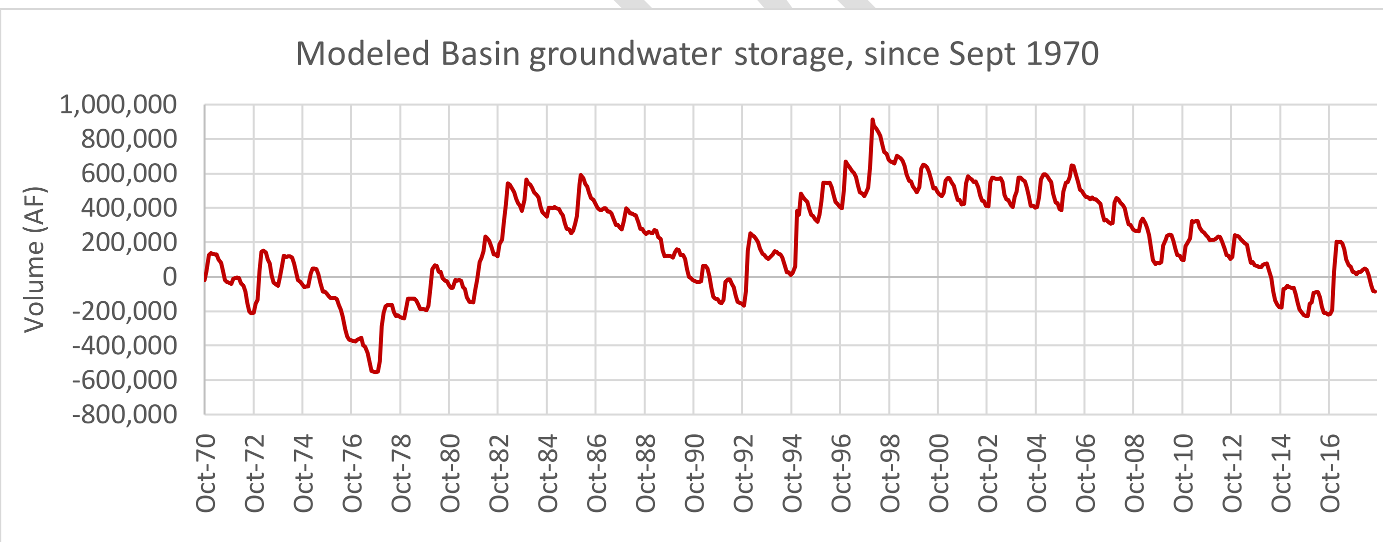


Figure 2-57. Modeled Basin Groundwater Storage.

Decadal changes in storage are summarized below in **Table 2-30** to further illustrate the fluctuation of groundwater storage in different wet and dry decades. These decadal changes represent the *historical* scenario; the groundwater storage predicted in *future* scenarios is based on future climate signals and is presented in **Figure 2-58**.

Figure 2-58 illustrates the change in groundwater storage for each of the future scenarios relative to the 'Historical' scenario (red line). Groundwater storage patterns follow the precipitation and temperature trends among scenarios, such as the following:

- The most groundwater storage declines occur in the driest, warmest scenario ('Future_70_DEW')
- Groundwater storage shows an overall increase in 'Future_70_WMW' scenari
- There is not much difference in groundwater storage between the central tendency scenarios ('Future_30' and 'Future_70') and the 'Future_baseline'
- The 'Historical' and 'Future_baseline' have the same climate input and comparing them shows the sensitivity to current cropping patterns and irrigation management

Table 2-30. Change in Groundwater Storage by Decade.

Decade	Change in Storage (AF)
WY 1971-1980	-24,806
WY 1981-1990	17,992
WY 1991-2000	521,671
WY 2001-2010	-390,769
WY 2011-2018	-208,710

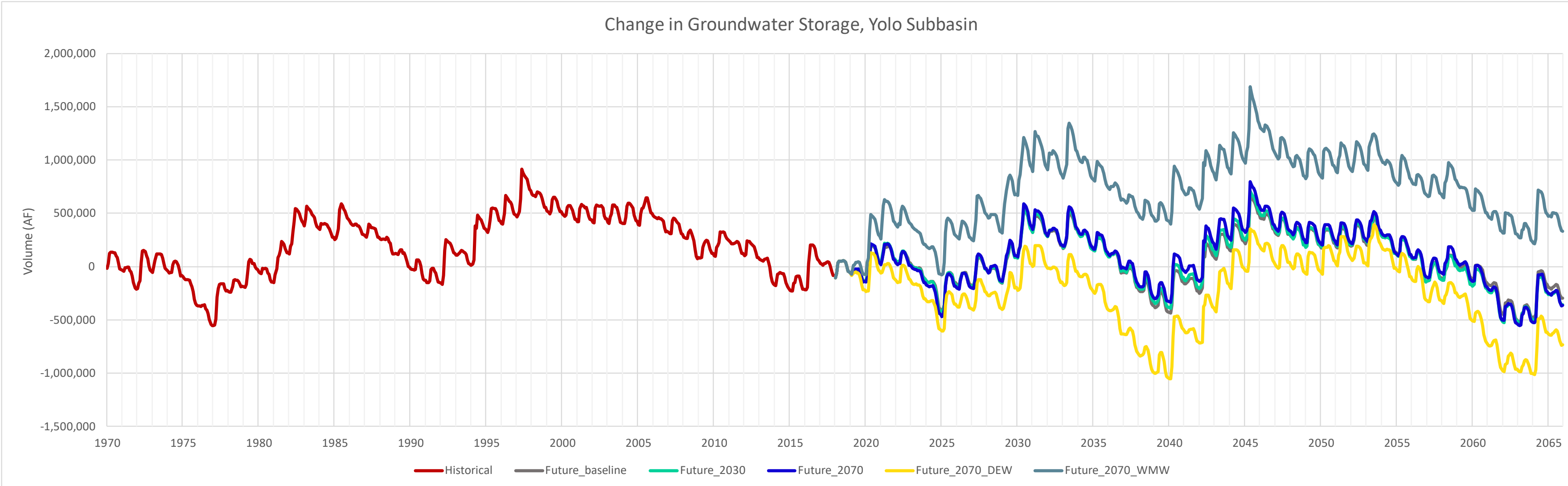


Figure 2-58. Basin-wide Change in Groundwater Storage for All Scenarios.

2.3.7 Sustainable Yield

SGMA describes 'Sustainable Yield' as the amount of groundwater that can be withdrawn annually without causing undesirable results. Section 354.18(b)(7) of the GSP Regulations requires that an estimate of the basin's sustainable yield be provided in the GSP. This sustainable yield estimate can be helpful for estimating the projects and programs needed to achieve sustainability. Note that SGMA does not incorporate sustainable yield estimates directly into sustainable management criteria. "Basinwide pumping within the sustainable yield estimate is neither a measure of, nor proof of, sustainability. Sustainability under SGMA is only demonstrated by avoiding undesirable results for the six sustainability indicators" (DWR 2017).

The results presented above show that the Yolo Subbasin has historically been sustainable (for the 48 years between WY 1971-WY 2018). Groundwater observations and the YSGA model results during this period show that while groundwater is lost from storage in drought years, it is replenished in wet years. As a result, groundwater storage and observed elevations have almost recovered by end of WY 2018 to initial storage and elevations. These results show that the Yolo Subbasin has not been overdrafted. The conjunctive use of surface water and groundwater – especially due to surface water available from Indian Valley Reservoir and to some extent the Tehama Colusa Canal; improved irrigation practices toward low-volume irrigation methods (Orang et al. 2008); and improved urban water conservation practices in the past decade have all contributed to recovering groundwater elevations. This appears to be a marked improvement from groundwater conditions in the decades before 1971, when the Yolo Subbasin was estimated to be in a state of overdraft (Clendenen & Associates 1976).

From the literature available for the County, the closest definition to 'sustainable yield' is an estimate for perennial yield provided in the County groundwater investigation from 1976 (Clendenen & Associates 1976; Scott and Scalmanini 1975). These investigators defined 'perennial yield' as "the amount of water which can be pumped annually from that basin, with no net change in storage over a selected period of time". This definition is materially the same as the SGMA definition mentioned earlier. **Perennial yield for Yolo County, for the period 1963 to 1972, was calculated at 304.5 TAF.**

With the above in mind, this GSP proposes that:

1. The average annual pumping over WY 1971 – WY 2018 as the sustainable yield for the Yolo Subbasin: **346 TAF per year**. The estimated annual pumping varies widely over the historical period, from 197-519 TAF/year. The following should be noted:
    a. The proposed sustainable yield of 346 TAF is based on a longer period of time, more data, and from a period of additional surface water availability than was available back in the 1960's and early 1970's. Indeed, safe yield for Indian Valley reservoir is estimated at 50 TAF (Max Stevenson, personal communication Nov. 11, 2020), which when added to the earlier perennial yield estimate from the 1970's, independently approximates the proposed 346 TAF value.

b. An analysis of model scenarios created for the GSP supports this estimate. In **Figure 2-59** the average annual groundwater pumping and change in groundwater storage are plotted. A regression line fit to the data has a y-intercept corresponding to zero change in groundwater storage of 336 TAF.

2. In the spirit of adaptive planning, the sustainable yield should be re-visited – and updated if needed – for each 5-year GSP update.

Based upon the analysis above, a sustainable yield of 346 TAF seems reasonable and justified.

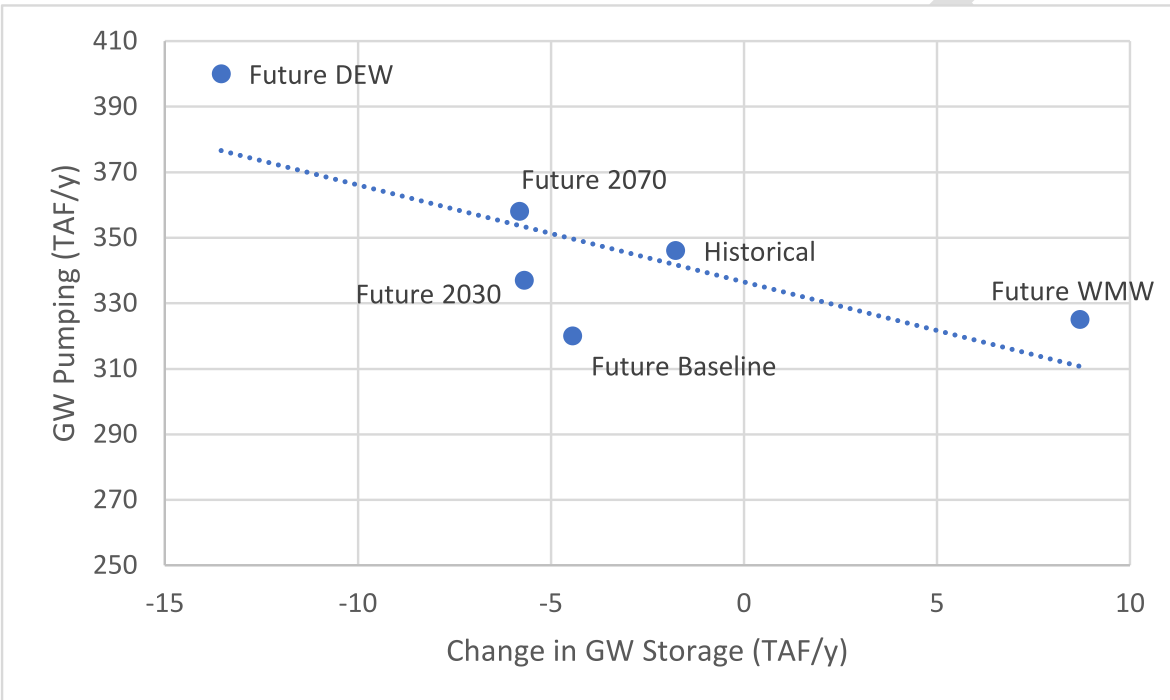


Figure 2-59. Annual Average Groundwater Pumping and Change in Storage for Each Model Scenario.

For further comparison, **Figure 2-60** shows the modeled pumping time series for the historical period, and for the future scenarios; the proposed Sustainable Yield of 346 TAF/year is shown as a horizontal reference line. **Figure 2-60** shows that Basin-wide groundwater storage, in all the investigated scenarios except for the DEW scenario, recovers to close to or above initial storage levels.

The data in **Figure 2-60** is aggregated in a different way in **Table 2-31**, showing the number and percent of years, for each scenario, when the proposed Sustainable Yield is exceeded. In all except the Dry Extreme scenario, the frequency is close to or smaller than in the Historical scenario.

Table 2-31. Modeled Pumping Versus Sustainable Yield.

Scenario	No. of Years	Precent
Historical	25	52
Future_Baseline	14	29
Future_2030	17	35
Future_2070	26	54
Future_DEW	37	77
Future WMW	14	29

2.3.8 Model Evaluation

All models are simplified abstractions of reality, and therefore water budgets will always exhibit uncertainty (Loucks and van Beek, 2017). Uncertainty in model outputs arise from uncertain or missing input data, model parameter uncertainty, differing model structures, natural variability (in climate, hydrology, geology, land use), and measurement errors (California DWR, 2020). For example, large uncertainties are likely to exist in model estimates of groundwater levels in Buckeye Creek simply because of inadequate – or complete lack - of groundwater data. These uncertainties directly affect model outputs.

As described in more detail in Section 3.3 of **Appendix E – Yolo SGA Model Documentation**, the largest uncertainties in the Yolo Basin arise from:

Land use interpretation, and related irrigation management (variations in planting and harvest dates across space and time, for example) exhibit relatively large uncertainty. The land use uncertainty affects all components of a water budget[54]. Details of crop acreage uncertainties rising from different data sources are in Section 2.1 of **Appendix E – Yolo SGA Model Documentation**.

Surface water supply in several areas of the Yolo Basin is not well known, as in some of the Reclamation Districts; and in the Willow Slough drainage, in the Clarksburg MA and Yolo Bypass and Colusa Basin Drain region. Assumptions were made, which largely allowed surface water use to take precedence over groundwater pumping.

Groundwater levels and trends are uncertain in some areas like in north-west Yolo. Additionally, reference point elevations and screening depths from well logs are uncertain, and in many cases, missing. The latter made it challenging to ascertain which aquifer layer was being pumped; and the former directly impacted calibration statistics.

Geology and stratigraphy are uncertain in the Dunnigan Hills area (WRIME 2006).

[54] This is true of all Basins

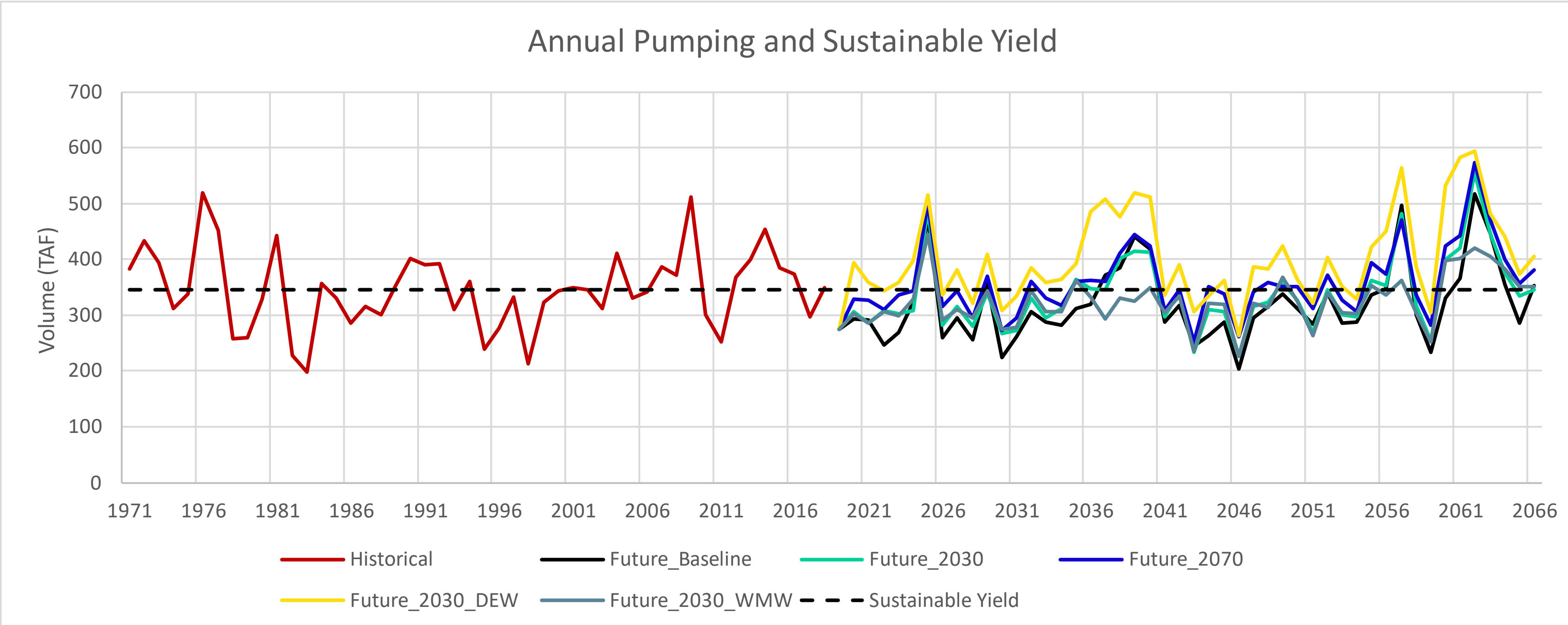


Figure 2-60. Sustainable Yield and Annual Pumping for Historical and Future Scenarios.

An evaluation of the YSGA model in relation to previous modeling efforts is available in **Section 1.3.7** of **Appendix F – Yolo Subbasin Water Budget Documentation**. In summary, total demand from these different efforts appear to be within 10 percent of each other. The YSGA model's estimate of pumping is higher than the 1970's estimate (Clendenen & Associates 1976), and lower than the IGSM model (WRIME 2006). The YSGA model estimates of percolation are lower than that of the IGSM model (WRIME 2006).

Finally, the details and full results of the model's calibration with observed data are presented in Section 3 of **Appendix E – Yolo SGA Model Documentation**. On average, the model under predicts groundwater elevations by about 2 ft. Seventy eight percent of the simulated values are within 20 ft of observed, 47 percent are within 10 ft, and 25 percent are within 5 ft of observed. These results vary among different areas of the Subbasin. The North Yolo area displays the least amount of bias in simulated values, while the Dunnigan Hills area displays the highest amount of bias due to lack of observation wells.

2.4 Management Areas

Six MAs have been established within the Subbasin for implementation of project and management actions to achieve groundwater sustainability. In developing these MAs, YSGA considered geologic, aquifer, and topographic characteristics. The groundwater bearing deposits in the County are contained in the Sacramento Valley Basin (DWR 1978). This report utilizes a subdivision of the County groundwater-bearing area into six informal hydrologic units, or MAs. MAs were developed based on prior investigations, which delineated somewhat different subbasin areas, and have been adapted for the purpose of this GSP. To prevent undesirable results in adjacent MAs, consistent minimum thresholds and measurable objectives have been developed as discussed in **Section 3 – Sustainable Management Criteria**. For purposes of this report, the six MAs are described below and shown on **Figure 2-61**, including:

- Capay Valley
- Dunnigan Hills
- North Yolo
- Central Yolo
- South Yolo
- Clarksburg

During the formation of the GSA, the delineations for these subunits were modified. Specifically, the Northern Sacramento River and Buckeye/Zamora subunits were combined to form the North Yolo MA. The Western Yolo and Lower Cache-Putah subunits were combined to form the Central Yolo MA, and the Southern Sacramento River subunit was divided into the South Yolo and Clarksburg MAs. Furthermore, certain YSGA entities were transferred to a neighboring MA, namely RD 1600, which moved from the North Yolo MA to the South Yolo MA. Beyond this, geologic units in the area, features such as the Capay Dam, and YSGA entities were used to adjust the MA boundaries.

In coordination with DWR several steps occurred to develop consistent MA nomenclature. The Western Yolo subunit, part of the Central Yolo MA, referenced in this report is described as including two subunits in the IRWM Plan. These subunits include the Hungry Hollow unit located north of Cache Creek and the Upper Cache-Putah unit located south of Cache Creek. Similarly, this report refers to the Buckeye/Zamora subunit located north of Cache Creek and east of the Dunnigan Hills. This subunit was originally planned to be further divided into two MAs. This plan has since been altered and the Buckeye/Zamora subunit has merged with the Northern Sacramento River subunit to form the North Yolo MA.

2.4.1 Dunnigan Hills Management Area

To the northwest, the Dunnigan Hills represent a low hilly area of uplifted Tehama Formation or nonmarine deposits with a thickness of up to 2,000 feet. These deposits appear to contain fresh groundwater, but previous reports indicate that aquifer material may be largely lacking. Historically little groundwater development has occurred in the hills. In the past 15 years, however, many thousands of acres olives, grapes, and almonds have been planted. Many new wells have been drilled to service these new plantings.

2.4.2 North Yolo Management Area

The North Yolo MA consists of the Buckeye/Zamora and Northern Sacramento River subunits. To the northeast, the Buckeye/Zamora subunit underlies the Valley floor east of the Dunnigan Hills. The area is considered to be underlain by alluvium and nonmarine deposits similar to those seen further south. Future detailed hydrogeologic study may be considered as a potential objective to better define the aquifer system in the County area. The Northern Sacramento River subunit encompasses the northernmost portion of the eastern part of the County and contains the flood plain/basin and Sacramento River area. The area is underlain by alluvium and nonmarine deposits. While at least some of the sand sequences occur in the MA, there is also a component of eastern sourced alluvial plain and/or tributary fluvial deposits in the nonmarine section. In addition, northeast of Woodland, a lower concentration of sand units occurs in the Tehama Formation.

2.4.3 Capay Valley Management Area

The Capay Valley MA is a small, structurally controlled valley of Cache Creek bound by faulted marine deposits to the east in the Capay Hills and the Coast Range to the west. Alluvium and the Tehama Formation are present in the valley floor with a thickness up to 1,000 feet. The valley appears to be connected to the larger groundwater basin through downstream alluvium and the underlying Tehama Formation along Cache Creek. The northern end of the valley is separated by a topographic divide of the Tehama Formation, although some groundwater connection may be possible north to Colusa County. According to DWR's WCR database[55], approximately one-third of wells in the MA are less than 100 feet deep, representing a significant use of the shallow aquifer zone. 5 of the 10 groundwater levels representative wells (**Section 4.4 – Chronic Lowering of**

[55] https://data.cnra.ca.gov/dataset/well-completion-reports

Groundwater Levels and Reduction of Groundwater Storage) in this MA are less than 100 feet deep, capturing the interests of the shallow groundwater users in the area.

2.4.4 Central Yolo Management Area

The Central Yolo MA consists of the Western Yolo and Lower Cache-Putah subunits. The Western Yolo subunit is defined on the north and east by the alluvial plains lying west of the roughly north-south line extending from the western edge of the Dunnigan Hills north of Cache Creek, just east of the mapped Tehama Formation exposures near the Woodland-Watts Airport area and Plainfield Ridge and south to Putah Creek. This MA is bound on the south by Putah Creek and extends to the western edge of the mapped Tehama Formation in the low hills marginal to the Coast Range. The exposures of the Tehama Formation may be an important source of recharge for the Tehama Formation further east. The gentle alluvial plain area is underlain by thin alluvium overlying the Tehama Formation. These nonmarine deposits appear to be sand poor except in the vicinity of Putah Creek. Deep test hole control is relatively poor in this MA, and additional geologic study using water well data may be warranted to examine shallow and intermediate zone stratigraphic relationships.

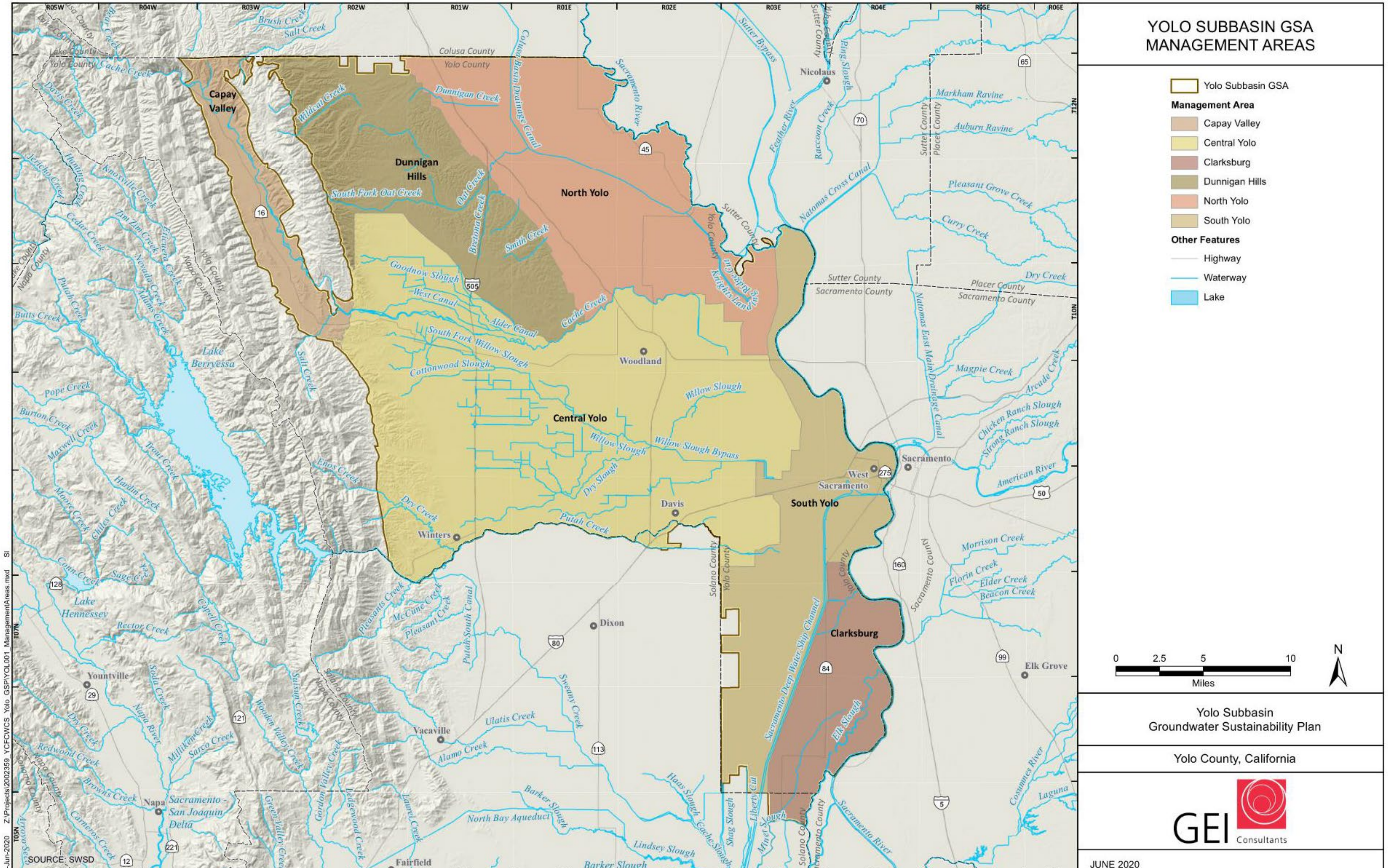


Figure 2-61. Yolo Subbasin Management Areas.

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In the Central Yolo MA, two Areas of Special Concern have been identified. These Areas of Special Concern are areas where trends in groundwater levels differ from the rest of the subbasin. The two Areas of Special Concern in the Central Yolo MA are roughly described as: (1) the general vicinity around the city of Winters and (2) the Hungry Hollow. In these two areas, there has been an emerging trend in some wells with declining levels. Further investigation is needed to determine the extent and cause of the declining water levels in the wells in these areas.

2.4.5 South Yolo Management Area

The South Yolo MA encompasses a portion of the southeastern section of the county. It contains the middle swath of the flood plain/basin, Yolo Bypass, and the Sacramento River area within the County. The area is underlain by alluvium and nonmarine deposits. While at least some of the sand sequences occur in the MA, there is also a component of eastern sourced alluvial plain and/or tributary fluvial deposits in the nonmarine section. The City of West Sacramento (City) is in the South Yolo MA. The City historically delivered groundwater to its customers as the exclusive source of water for many years before building its surface water diversion and treatment facilities. The City continues to preserve and use groundwater in its service area for various purposes and is looking to improve its groundwater system to provide necessary system redundancy to ensure safe and reliable water supplies for all of the City's residents and businesses.

The Yolo Bypass Wildlife Area, and other public and private wetland easements, make up a large part of this MA and provide important habitat for migratory birds, fishes, and other key species. The Wildlife Area is managed by the CDFW according to the Yolo Bypass Wildlife Area Land Management Plan (CDFW 2008).

2.4.6 Clarksburg Management Area

The Clarksburg MA encompasses the southernmost portion of the eastern part of the County and contains the flood plain/basin and Sacramento River area. The area is underlain by alluvium and nonmarine deposits. While at least some of the sand sequences occur in the MA, there is also a component of eastern sourced alluvial plain and/or tributary fluvial deposits in the nonmarine section.

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3.0 Sustainable Management Criteria

Under SGMA, the sustainable management criteria (SMC) define conditions for sustainable groundwater management that are used to guide sustainability in the Yolo Subbasin. SMC includes characterization of the sustainability goal for the Subbasin and the establishment of undesirable results, minimum thresholds, and measurable objectives for applicable Subbasin sustainability indicators. SMC concepts captured in this section are outlined below and provide a basis of understanding for the development of sustainable groundwater management in the Subbasin.

- **Sustainability Goal:** The sustainability goal guides sustainable groundwater management across all MAs in the Subbasin by providing qualitative descriptions of the objectives and desired conditions.
- **Undesirable Results:** Undesirable results are established for each applicable sustainability indicator and constitute as significant and unreasonable groundwater conditions in the Subbasin.
- **Minimum Thresholds:** Minimum thresholds are the quantitative values that represent groundwater conditions at a representative monitoring site that, when exceeded, in combination with exceeded minimum thresholds at other representative monitoring sites, may cause an undesirable result in the subbasin. Minimum thresholds are set for each applicable sustainability indicator at each representative monitoring site using the same metrics as the measurable objectives. This section defines the minimum thresholds at each representative monitoring site for applicable sustainability indicators considering interests of beneficial uses and users of groundwater in the Subbasin.
- **Measurable Objectives:** Measurable objectives are quantitative goals that reflect the Subbasins' desired groundwater conditions and allows the MAs within the Yolo Subbasin to be managed sustainably through the 20-year Implementation Period. In the Subbasin, the quantitative goals expressed as the measurable objectives are currently met and are intended to continue to be met. Measurable objectives are set for each applicable sustainability indicator. Measurable objectives are set such that there is a reasonable margin of operational flexibility that will anticipate recoverable fluctuations due to droughts, climate change, conjunctive use operations, or other groundwater management activities.
- **Interim Milestones:** Interim milestones are target values representing measurable groundwater conditions, in increments of 5 years, set to ensure that the Subbasin moves towards its sustainability goal over the 20-year Implementation Period. As the Subbasin is already meeting its sustainability goal, the interim milestones are set at the measurable objective for the applicable sustainability indicators.

  In the Yolo Subbasin, interim milestones are set equal to measurable objectives for all sustainability indicators for which minimum thresholds and measurable objectives have been set. As described in this plan, the YSGA is establishing sustainable management criteria to be equal to recent historical conditions. Therefore, provided a normal range of hydrology, the groundwater basin is expected to maintain its historical regime and from the outset of the plan is expected to operate within a reasonable range of established measurable objectives.

- **Undesirable Results Watch Area:** An undesirable result watch area is a MA that has triggered the exceedance criteria for an undesirable result for a given sustainability indicator, but where the number of MAs exceeding the criteria has not been reached. An undesirable result watch area triggers responses from the YSGA and its member agencies to address the local conditions of exceeding minimum threshold values to avoid triggering the criteria for a basin-wide undesirable result.

3.1 Sustainability Goal

As required by SGMA, a sustainability goal is to be defined for the basin (CWC §10727(a)). This is further clarified as a basin-wide basis in DWR's GSP emergency regulations. The sustainability goals for the Yolo Subbasin are as follows:

- *Achieve sustainable groundwater management in the Yolo Subbasin by maintaining or enhancing groundwater quantity and quality through the implementation of projects and management actions to support beneficial uses and users.*
- *Maintain surface water flows and quality to support conjunctive use programs in the Subbasin that promote increased groundwater levels and quality.*
- *Operate within the established sustainable management criteria and maintain sustainable groundwater use through continued implementation of a monitoring and reporting program.*
- *Maintain sustainable operations to maintain sustainability over the implementation and planning horizon.*

3.2 Criteria for Sustainable Management Criteria

Through a collaborative process, undesirable results have been developed for each sustainability indicator. In compliance with DWR's GSP emergency regulations, these undesirable results are defined as Subbasin-wide condition representing non-sustainable management relative to the sustainability indicators (23-CCR § 354.20). The definitions of "undesirable results" provide guidance and flexibility for each MA within the Subbasin to define minimum thresholds that constitute significant and unreasonable impacts to the beneficial uses and users of groundwater within the specific MAs.

Undesirable results can occur for each sustainability indicator when minimum thresholds are exceeded at multiple representative monitoring sites within Subbasin. The exceedance of a minimum threshold at one representative monitoring site does not constitute an undesirable result for the entire Subbasin. An undesirable result occurs when the required number of monitoring sites in the

Subbasin exceed their minimum threshold, where the required number of monitoring sites is defined for each MA and for each sustainability indicator.

The following sections describe the criteria for determining undesirable results for each sustainability indicator.

3.3 Chronic Lowering of Groundwater Levels

3.3.1 Undesirable Results

The basin-wide definition of "undesirable results" for the chronic lowering of groundwater levels is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by depth or elevation of ground water, affect the reasonable beneficial use of, and access to, groundwater by overlying users.*
>
> *An undesirable result occurs when the minimum threshold criteria is exceeded in* ***51 percent or more*** *of representative monitoring wells in* ***two (2) MAs****.*

This 51 percent value was selected to allow for interim projects and management actions to take place within the subbasin. This value was selected and agreed to by the YSGA member entities and the YSGA Board. No minimum threshold has been established for the Clarksburg MA due to the lack of significant groundwater use in this MA. However, YSGA intends to monitor this MA for changes in groundwater uses and land use to identify the potential for changes in groundwater conditions. If conditions change in a manner that could influence groundwater conditions, the MA will be reevaluated and minimum thresholds for Chronic Lowering of Groundwater Levels will be considered in the future.

3.3.1.1 Potential Cause of Chronic Lowering of Groundwater Levels

Section 354.26(b)(1) of the GSP Emergency Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Potential causes of chronic lowering of groundwater levels vary throughout the Subbasin but can most likely be attributed to increased groundwater pumping during dry periods, reduction in surface water use, reduced groundwater inflows from adjacent areas, and/or climate change related impacts that result in more frequent dry years.

3.3.1.2 Potential Effects of Chronic Lowering of Groundwater Levels

Section 354.26(b)(3) of the GSP Emergency Regulations requires identification of potential effects of an undesirable result for each sustainability indicator. Potential effects of chronic lowering of groundwater levels include groundwater well dewatering and increased pumping lift. These effects would lead to increased maintenance costs and higher energy use, respectively. Lowering of groundwater levels would have an increased economic impact since reduced groundwater levels lead to increased pumping costs, additional well wear, and reduced well efficiency. In addition to the impact on groundwater production, the chronic lowering of groundwater levels can also impact surface water-groundwater interactions along Subbasin waterways, such as Putah and Cache creeks, and groundwater availability for GDEs.

3.3.2 Minimum Thresholds

3.3.2.1 Criteria for Establishing Minimum Thresholds

Minimum thresholds for the chronic lowering of groundwater levels were established through a collaborative process with local stakeholders and interested parties. As summarized in **Section 2 – Basin Setting**, the Yolo Subbasin is a relatively stable basin, with groundwater levels maintaining a relatively consistent long-term average elevation or depth to groundwater. While groundwater levels decline during dry conditions due to reduced recharge from precipitation, local runoff and seepage, and continued reliance on groundwater for agricultural and municipal demands, groundwater levels substantially recover during wet years.

To establish the minimum thresholds and measurable objectives for the Yolo Subbasin, the YSGA reviewed available well data and selected a subset of Representative Wells that would be used to establish minimum threshold values. These Representative Wells, shown in **Figure 3-1**, were selected because the well maintained a sufficient period of record to be representative of surrounding groundwater conditions and included sufficient spring and fall elevation data for the period of 2001 to 2011. Representative Wells were reviewed with stakeholders from the MA in which they are located to ensure the selected wells represented the best available data and were representative of local groundwater conditions.

Based on historic, current, and projected groundwater conditions in the Subbasin, the YSGA developed several methodologies for establishing the minimum threshold value for each representative well, based on MA boundaries. The hydrographs for all Representative Wells used to establish minimum thresholds and measurable objectives are provided in **Appendix H – Yolo Subbasin Hydrographs of Representative Wells**. The methodology for each MA is described below.

3.3.2.1.1 Capay Valley, Dunnigan Hills, Central Yolo, and South Yolo:

> *A well violates the minimum threshold when the groundwater elevation exceeds the historic (pre-2016) minimum elevation in the period of record of each Representative Well in two consecutive fall measurements.*

The minimum threshold established with this methodology protect groundwater levels from chronically lowering to levels below the historical experience and recognize that groundwater conditions in these MAs is expected to behave similarly to historic conditions. No significant decreases in groundwater conditions are expected under future projected conditions. Minimum thresholds for groundwater levels and groundwater storage will be evaluated using static water levels.

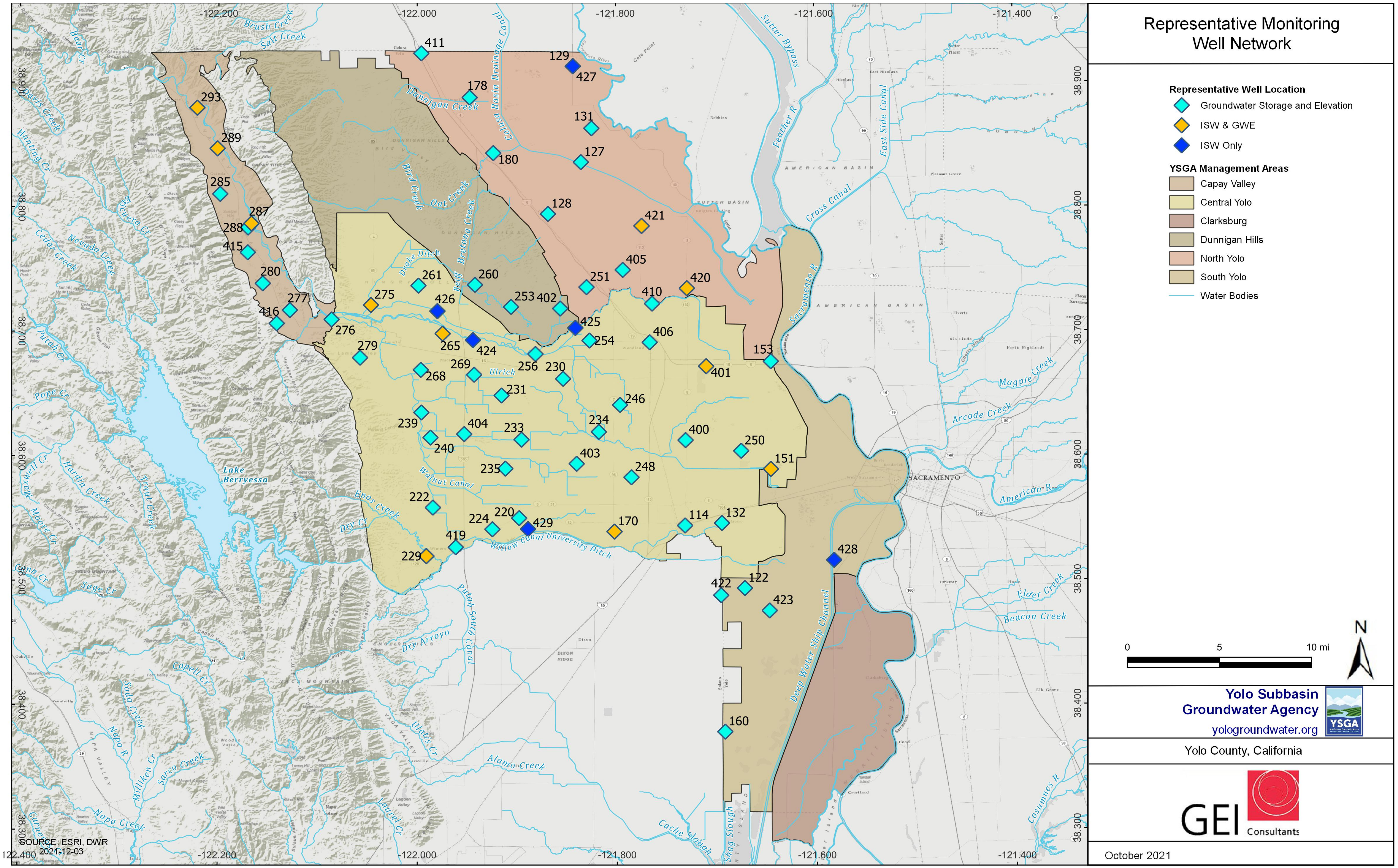

Figure 3-1. Yolo Subbasin Representative Wells.

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3.3.2.1.2 North Yolo:

A well violates the minimum threshold when the groundwater elevation exceeds the historic minimum elevation in the period of record (pre-2016) of each Representative Well ***plus*** *20 percent of the depth between the historic maximum and historic minimum elevation for the period of record (pre-2016) of the Representative Well in two consecutive fall measurements.*

The minimum thresholds for the North Yolo MA are set lower than historical conditions recognizing that water districts, such as RD 108, in this area may experience reductions in surface water deliveries from the Sacramento River as the Voluntary Agreements with the State Water Board are implemented. The Voluntary Agreements are expected to reduce surface water deliveries to Sacramento Water Rights Contractors during certain year types, requiring that water users increase their reliance on local groundwater during the same year types. Historical performance of the North Yolo MA shows that groundwater levels typically recover to a long-term average during wet periods. Therefore, setting the minimum threshold lower than the historical low is not expected to create long-term undesirable effects on groundwater elevations. Minimum thresholds for groundwater levels and groundwater storage will be evaluated using static water levels.

3.3.2.1.3 Clarksburg:

No minimum threshold has been established for the Clarksburg MA due to the lack of groundwater usage in the MA. The YSGA will annually monitor groundwater conditions in the Clarksburg MA to determine if groundwater conditions or usage changes to the degree that minimum thresholds are required to ensure sustainable management of this portion of the Subbasin.

3.3.2.2 Minimum Threshold Values

The minimum threshold values for chronic lowering of groundwater levels have been established for each MA as described above. **Table 3-1** shows the minimum threshold values and measurable objective values for each of the Representative Wells in the Subbasin. **Figure 3-2** shows a contour map of minimum threshold elevations for all representative wells used to establish minimum thresholds and measurable objectives. The groundwater elevation contour of minimum thresholds allows for the evaluation of minimum threshold values across the region. Where a discontinuity of minimum groundwater elevations is seen (e.g., large vertical differences between minimum groundwater elevations of adjacent representative wells) corrective action can be made to adjust minimum elevations to compatible values among adjacent wells. Variations of **Figure 3-2** have been developed throughout the development of this GSP and have been reviewed with stakeholders for input leading to refinement of minimum threshold values.

3.3.3 Measurable Objectives

3.3.3.1 Criteria for Establishing Measurable Objectives

To establish the measurable objectives for the Yolo Subbasin, the YSGA utilized the representative wells identified for minimum thresholds, shown in **Table 3-1** and **Figure 3-1**, to determine the measurable objectives for chronic lowering of groundwater levels. Based on historic, current, and projected groundwater conditions in the Subbasin, the used the following criteria for establishing measurable objectives at all MAs, with the exception of the Clarksburg MA:

> *Measurable objective is equal to the average fall (Sep.-Dec.) groundwater elevation for the water year period of 2000 to 2011 at each Representative Well. Performance of the measurable objective will be measured as the five (5) year running average of the minimum fall (Sep.-Dec.) groundwater elevation.*

Due to the lack of significant groundwater use in the Clarksburg MA no measurable objective has been established in the MA.

The hydrographs for all Representative Wells used to establish minimum thresholds and measurable objectives are provided in **Appendix H – Yolo Subbasin Hydrographs of Representative Wells**.

3.3.4 Interim Milestones

Interim milestones for the Chronic Lowering of Groundwater Levels are set equal to measurable objectives.

3.4 Reduction of Groundwater Storage

Historically, DWR has utilized changes in groundwater elevations to estimate changes in groundwater storage. Similarly, the YSGA intends to use groundwater levels as a proxy for the change in groundwater storage that will be calculated by evaluating the volumetric difference between changes in groundwater surfaces created based on groundwater level data collected at representative monitoring wells and reported to DWR, per SGMA reporting requirements.

As a result, the sustainable management criteria for reduction of groundwater storage are tied to the criteria for chronic lowering of groundwater levels. The minimum threshold and measurable objectives for chronic lowering of groundwater levels are identical to those of chronic lowering of groundwater levels, as groundwater elevation serves as the proxy for groundwater storage.

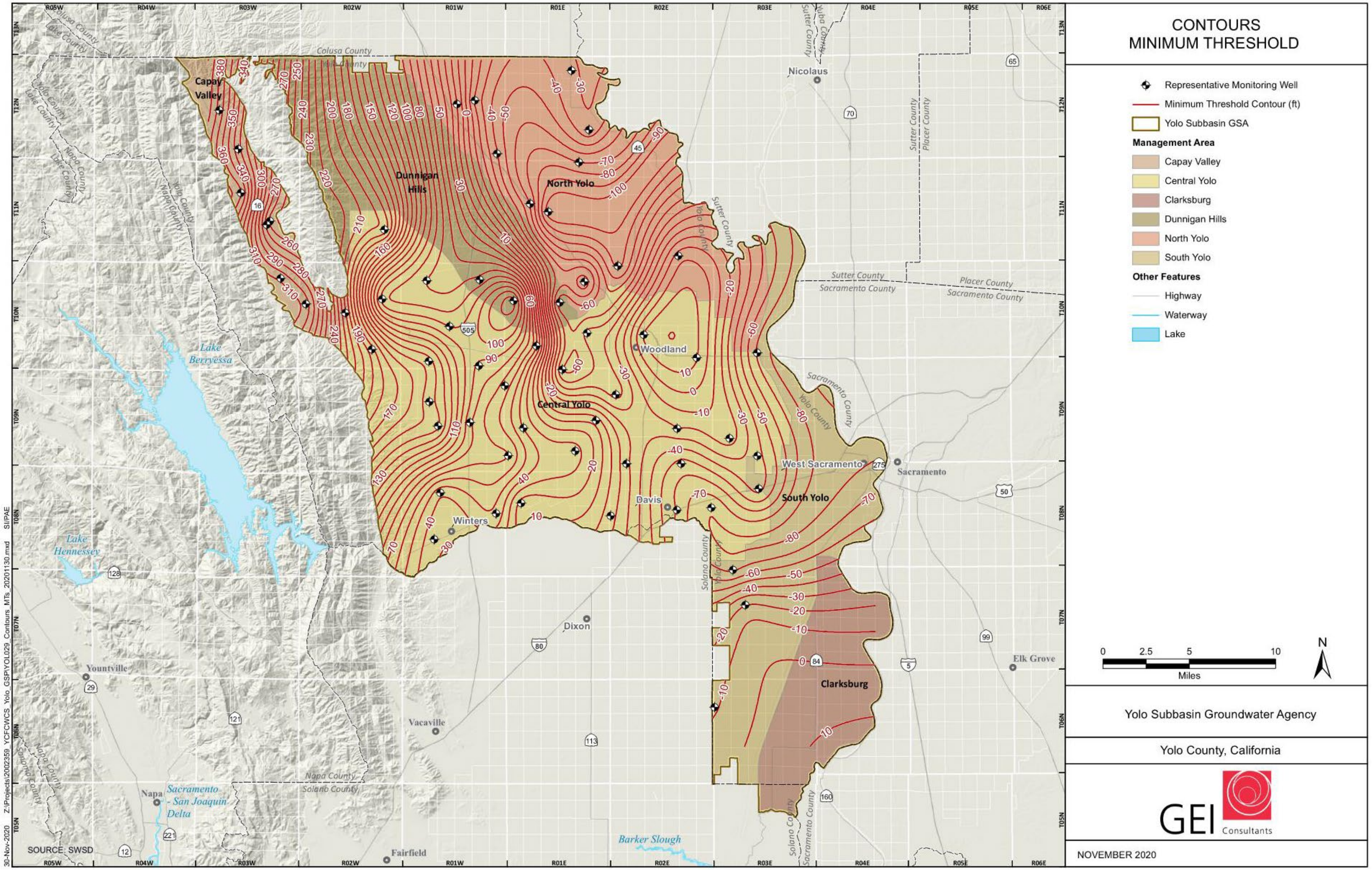

Figure 3-2. Yolo Subbasin Minimum Threshold Elevation Contour.

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Table 3-1. Yolo Subbasin Representative Wells and Minimum Threshold and Measurable Objective Values.

Management Area	YSGA Representative Well Number	State Well Number	Measurable Objective (ft)		Minimum Threshold (ft)	
			Depth to Water	*Groundwater elevation*	*Depth to Water*	*Groundwater elevation*
Capay Valley	276	10N02W16R001M	14.4	215.0	21.9	207.7
	277	10N02W18F001M	20.4	315.6	31.8	304.2
	280	10N03W02R002M	18.7	319.5	29.9	308.2
	285	11N03W09Q001M	20.4	383.7	48.3	355.8
	287	11N03W23L001M	15.2	296.0	23.6	287.6
	288	11N03W23N001M	32.9	287.3	49.1	271.0
	289	11N03W33F001M	19.8	351.2	29.6	341.2
	293	12N03W20D001M	19.8	382.8	26.2	376.4
	415	11N03W35D003M	28.6	280.7	36.3	273.0
	416	10N03W24B002M	65.4	324.8	109.1	281.1
Central Yolo	114	08N02E15A002M	71.5	-25.1	107.7	-61.3
	132	08N03E07N500M	58.3	-22.0	114.3	-78.0
	151	09N03E33B002M	16.2	4.7	56.1	-35.3
	170	08N02E18M002M	48.1	20.4	67.0	1.5
	220	08N01E07R001M	25.3	82.3	91.0	16.5
	222	08N01W09C001M	57.3	110.9	127.9	40.3
	224	08N01W13G003M	37.7	80.0	69.9	47.8
	229	08N01W20R005M	79.8	72.8	116.2	36.4
	230	09N01E03C003M	81.7	19.3	157.4	-56.4
	231	09N01E07D001M	13.4	111.1	56.2	68.3
	233	09N01E20E001M	10.0	104.8	47.7	67.1
	234	09N01E24D001M	17.2	52.2	61.7	7.6
	235	09N01E31D001M	13.4	104.6	49.8	68.3
	239	09N01W08Q001M	13.8	185.1	46.7	152.2
	240	09N01W21E001M	11.9	163.4	30.5	144.7
	246	09N02E07L001M	46.1	24.7	116.2	-45.4
	248	09N02E32M001M	31.9	29.1	68.0	-7.0
	250	09N03E19R002M	17.6	6.7	38.3	-14.1
	254	10N01E23Q002M	65.0	26.8	134.8	-43.0
	256	10N01E29K001M	34.9	77.8	54.4	58.4
	261	10N01W08B001M	41.3	139.5	107.6	73.3
	265	10N01W21J001M	33.8	127.5	70.4	90.9
	268	10N01W32E001M	18.9	169.9	44.3	144.5
	269	10N01W35Q001M	20.8	120.5	48.4	93.0
	275	10N02W14A001M	69.9	137.8	116.5	91.1
	279	10N02W26P001M	112.6	241.7	141.7	212.7

Management Area	YSGA Representative Well Number	State Well Number	Measurable Objective (ft)		Minimum Threshold (ft)	
			Depth to Water	*Groundwater elevation*	*Depth to Water*	*Groundwater elevation*
	406	10N02E29A001M	21.5	35.7	47.4	9.9
	400	09N02E22H002M	16.1	22.9	63.8	-24.8
	401	10N02E36E001M	8.1	22.1	21.2	9.0
	403	09N01E26N001M	8.4	71.7	48.0	32.2
	404	09N01W23D001M	10.5	135.8	63.4	82.9
	419	08N01W22G500M	59.6	71.9	125	6.5
North Yolo	127	11N01E02D001M	41.5	-13.3	116.5	-88.3
	128	11N01E16P001M	88.6	-33.1	185.3	-129.8
	129	12N01E03R002M	23.2	9.1	76.6	-44.3
	131	12N01E26A002M	30.1	-4.2	72.0	-46.1
	153	10N03E33B011M	21.0	3.8	98.0	-73.3
	178	12N01W14M001M	37.0	10.5	78.4	-30.9
	180	12N01W36K002M	48.2	-7.7	90.2	-49.7
	251	10N01E02Q002M	45.2	32.1	109.8	-32.6
	405	10N02E06B001M	34.7	26.0	146.4	-85.7
	411	12N01W05B001M	94.4	49.5	169.2	-25.3
	410	10N02E09N001M	48.5	12.9	125.0	-63.7
	420	10N02E03R002M	30.6	12.2	81.9	-39.2
	421	11N02E20K004M	24.7	28.8	85.1	-31.6
South Yolo	122	08N03E32L001M	30.5	-1.9	100.3	-71.8
	160	06N03E07M001M	9.0	9.9	29.7	-10.8
	422	08N03E31N001M	40.6	-7.0	82.8	-49.3
	423	07N03E04Q001M	24.0	0.5	51.6	-27.1
Dunnigan Hills	253	10N01E18C001M	51.4	143.1	61.6	132.8
	260	10N01W02Q001M	66.5	128.3	121.2	73.6
	402	10N01E15D001M	76.9	17.5	164.0	-69.6

3.4.1 Undesirable Result

The basin-wide definition of "undesirable results" for the reduction of groundwater storage is as follows:

> *The point at which significant and unreasonable impacts over the planning and implementation horizon, as determined by the amount of groundwater storage in the Yolo Subbasin, affect the reasonable and beneficial use of, and access to, groundwater by overlying users. In the Subbasin groundwater elevations serve as a proxy for groundwater storage.*

A groundwater storage undesirable result occurs under the same definition as the chronic lowering of groundwater levels. As with the chronic lowering of groundwater levels, no sustainable management criteria are established for the Clarksburg MA, due to the lack of significant groundwater use in the MA.

3.4.1.1 Potential Cause of Reduction of Groundwater Storage

Section 354.26(b)(1) of the GSP Emergency Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Potential causes for reduction of groundwater storage are generally the same for that of lowering of groundwater levels. Therefore, the causes listed above for the lowering of groundwater levels are applicable to causes of undesirable results due to the reduction of groundwater storage.

3.4.1.2 Potential Effects of Reduction of Groundwater Storage

Section 354.26(b)(3) of the GSP Emergency Regulations requires identification of potential effects of an undesirable result for each sustainability indicator. Potential effects of reduction of groundwater storage includes the potential for limited groundwater availability during a prolonged drought for the various Subbasin uses and users of groundwater, including environmental users.

3.4.2 Minimum Threshold

The minimum threshold values for reduction of groundwater storage have been established for each MA and are based on and identical to the minimum threshold values established for chronic lowering of groundwater elevations.

3.4.3 Measurable Objective

The measurable objective values for reduction of groundwater storage have been established for each MA and are based on and identical to the measurable objective values established for chronic lowering of groundwater elevations.

3.4.4 Interim Milestones

Interim milestones for the Chronic Lowering of Groundwater Levels are set equal to measurable objectives.

3.5 Degraded Water Quality

The YSGA is only establishing sustainable management criteria for total dissolved solids and has elected to not establish specific sustainable management criteria for other constituents of concern identified within the Subbasin at this time. For all constituents of concern except total dissolved solids, the Subbasin will rely on current and future water quality standards established for drinking water and agricultural water uses by state and County regulatory agencies. The YSGA will annually review water quality monitoring data, in collaboration with regulating agencies, to determine if water quality is being negatively affected by groundwater management activities. In the future, where significant negative impacts to water quality associated with groundwater management activities are identified, the YSGA will coordinate with stakeholders and regulatory agencies to establish appropriate sustainable management criteria that can be used to define the occurrence of basin-wide undesirable results for specific water quality constituents.

The YSGA has identified a list of water quality constituents of concern, including those constituents whose presence, distribution, or concentration can be influenced by groundwater management activities. The list of water quality constituents of concern for the Subbasin includes:

- Total Dissolved Solids
- Nitrate
- Arsenic
- Boron
- Hexavalent Chromium (VI)

3.5.1 Undesirable Result

The basin-wide definition of "undesirable results" for degraded water quality is as follows:

> *The point at which water quality is degraded to the extent of causing significant and unreasonable impacts from groundwater management actions in the Yolo Subbasin, that affect the reasonable and beneficial use of, and access to, groundwater by overlying users.*
>
> *An undesirable result occurs when the minimum threshold criteria is exceeded in* **50 percent or more** *of representative monitoring wells monitored for total dissolved solids.*

The YSGA will also perform an annual qualitative analysis of water quality conditions for all identified constituents of concern to determine whether water quality conditions are being impacted by groundwater management activities. In the event that clear linkages between degraded water quality conditions (i.e., unacceptable concentrations of constituents of concern) and groundwater management activities are identified, the YSGA will create a process for establishing minimum thresholds and measurable objectives for those constituents consistent with concentration limits established by responsible regulating agencies.

3.5.1.1 Potential Causes of Degraded Water Quality

Section 354.26(b)(1) of the GSP Emergency Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Potential causes of undesirable results due to Degraded Water Quality within the Subbasin include the addition or movement of constituents of concern (COCs) *via* groundwater processes that are related to water management or land use activities. These potential processes include:

- Deep percolation of precipitation, seepage from various natural and man-made channels, and recharge from spreading basins.

- Irrigation system backflow into wells and flow through well gravelpack and screens from one formation to another.
- Deep percolation of excess applied irrigation water and other water applied for cultural practices (e.g., for soil leaching). Potential COCs include salinity (i.e., TDS), nitrate, and agricultural chemicals.
- Lateral migration from adjacent areas with poorer quality groundwater. Potential COCs include salinity and other natural constituents (e.g., chloride and sulfate).
- Leaching from internal sources such as fine-grained, clay-rich interbeds. Potential COCs include arsenic and other constituents associated with fine-grained depositional environments.

In the case of deep percolation of excess applied irrigation and leaching water, such activities are regulated separately under the CVRWQCB's ILRP and CV-SALTS. For the last two items listed above, the underlying cause can be related to hydraulic gradients and heads (groundwater levels), and thus linked to changes in groundwater levels. Currently, the leaching or movement of COCs related to groundwater gradients is not a documented issue in the Subbasin.

3.5.1.2 Potential Effects of Degraded Water Quality

Section 354.26(b)(3) of the GSP Emergency Regulations requires identification of potential effects of an undesirable result for each sustainability indicator. The potential effects of undesirable results caused by degraded water quality on beneficial uses and users of groundwater may include: increased costs to treat groundwater to drinking water standards if it is to be used as a potable supply source; increased costs to blend relatively poor-quality groundwater with higher-quality sources for agricultural and non-agricultural uses; limitations on viable crop types or crop yield depending on crop sensitivity and tolerance to COCs in groundwater used for irrigation; and potential reduction in "usable storage" volume of groundwater in the basin if large areas of an aquifer are impacted to the point that they cannot be used to support beneficial uses and users.

3.5.1.3 Annual Water Quality Review

The YSGA will rely on current and future water quality standards established for drinking water and agricultural water uses by state and County regulatory agencies. *See* **Table 4-2** for current agricultural and drinking water standards for California in 2021.

To determine whether groundwater management activities are impacting the quality of groundwater, the YSGA will monitor levels of total dissolved solids in select RMWs and will review water quality data collected by other responsible regulating agencies.

Annually the YSGA will:

- Review water quality monitoring data, in collaboration with responsible regulating agencies, to determine if water quality is being negatively affected by groundwater management activities.

- Where future significant negative impacts to water quality associated with groundwater management activities are identified, the YSGA will coordinate with stakeholders and regulatory agencies to establish appropriate sustainable management criteria to avoid the occurrence of basin-wide undesirable results.
- YSGA's annual review of water quality conditions and determination of impacts associated with groundwater management activities will be provide to DWR in the YSGA's required annual report. This report will also be available for review by local stakeholders.

3.5.2 Minimum Threshold

The YSGA has established a minimum threshold for total dissolved solids as follows:

> *A representative monitoring well violates the minimum threshold when the total dissolved solids concentration exceeds 1,000 ppm over a three (3) year rolling average.*

3.5.3 Measurable Objective

The YSGA has established a measurable objective for total dissolved solids as follows:

> *A representative monitoring well violates the measurable objective when the total dissolved solids concentration exceeds 750 ppm over a three (3) year rolling average.*

3.5.4 Interim Milestones

Interim milestones for the Degraded Water Quality are set equal to measurable objectives.

3.6 Land Subsidence

3.6.1 Undesirable Result

The basin-wide definition of "undesirable results" for land subsidence is as follows:

> *The point at which the rate and extent of subsidence in the Subbasin causes significant and unreasonable impacts to surface land uses or critical infrastructure.*
>
> *An undesirable result occurs when the minimum threshold value is exceeded over 25 percent of the management or sub-MA in three (3) or more management or sub-MAs in the same reporting year.*

Within the Yolo Subbasin, a management or sub-MA will be considered an undesirable result watch area when that MA exceeds its minimum threshold value, identified below. Sub-MAs have been established for the purposes of assessing undesirable results of land subsidence and are shown in **Figure 3-3**. If three or more undesirable result watch areas exist, as defined above, the Subbasin would be considered to be experiencing an undesirable result relative to land subsidence.

3.6.1.1 Potential Causes of Land Subsidence

Section 354.26(b)(1) of the GSP Emergency Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Land subsidence can be caused by several mechanisms, but the mechanism most relevant to sustainable groundwater management is the long or short-term depressurization of aquifers and aquitards due to lowering of groundwater levels, which can lead to compaction of compressible strata and lowering of the ground surface. Therefore, the potential causes of Undesirable Results due to land subsidence are generally the same as the potential causes listed above for undesirable results due to chronic lowering of groundwater levels.

3.6.1.2 Potential Effects of Land Subsidence

Section 354.26(b)(3) of the GSP emergency regulations requires identification of potential effects of an undesirable result for each sustainability indicator. Potential effects of land subsidence on beneficial uses and users of groundwater and overlying land uses within the Subbasin would include damage to gravity-driven water conveyance infrastructure, and groundwater well casings, and other public infrastructure, such as roadways and utility infrastructure.

3.6.1.3 Criteria for Establishing Minimum Thresholds and Measurable Objectives

The YSGA reviewed the level of subsidence in the Subbasin based on a number of studies as reviewed in **Section 2.2.5 – Land Subsidence**. Land deformation occurs as both surface subsidence and surface uplifting and the Subbasin experiences both processes. In the east portion of the Central Yolo MA and nearly the entire North Yolo MA steady levels of subsidence have been documented. In the western portion of the Central Yolo MA a slight amount of uplift has been observed. For additional details, *refer to* **Section 2.2.5**.

Subsidence in the Subbasin has occurred at a steady rate according to available studies and occurs even in years when groundwater levels are stable or increasing. The rate of subsidence does not substantially increase during years when groundwater levels are declining. The cause of subsidence can be attributed to other tectonic activities, and not solely groundwater extractions. To fully understand the exact causes of subsidence additional data is needed to identify where in the substrata subsidence occurs.

The YSGA recognizes that, while the exact causes of subsidence in the Subbasin are not fully understood, subsidence can cause significant impacts to surface infrastructure and is often caused by increasing groundwater extractions. The YSGA and its member agencies have also established groundwater level minimum threshold and measurable objective values at levels consistent with historic conditions. Therefore, future subsidence rates could be expected to continue at rates similar to current rates. Through a collaborative process with YSGA member agencies and stakeholders the minimum threshold and measurable objectives for subsidence have been set at approximately the current rate of subsidence in the various parts of the Subbasin.

The YSGA is committed to continued evaluation of subsidence and identification of impacts associated with subsidence. The YSGA will work with local and state agencies to evaluate subsidence in the Subbasin and will:

- Require continued monitoring and reporting of the level of land subsidence occurring in the Subbasin
- Require annual monitoring and reporting of potential impacts to land uses, critical infrastructure, and wells (domestic, production and municipal)
- Continue to refine the understanding of the causes of subsidence based on observed data (water management vs tectonic)
- Quantify the amount of subsidence which causes impacts to infrastructure
- Using observed data consider establishing future subsidence thresholds as maximum amount of subsidence in critical areas of the Subbasin based on observed data

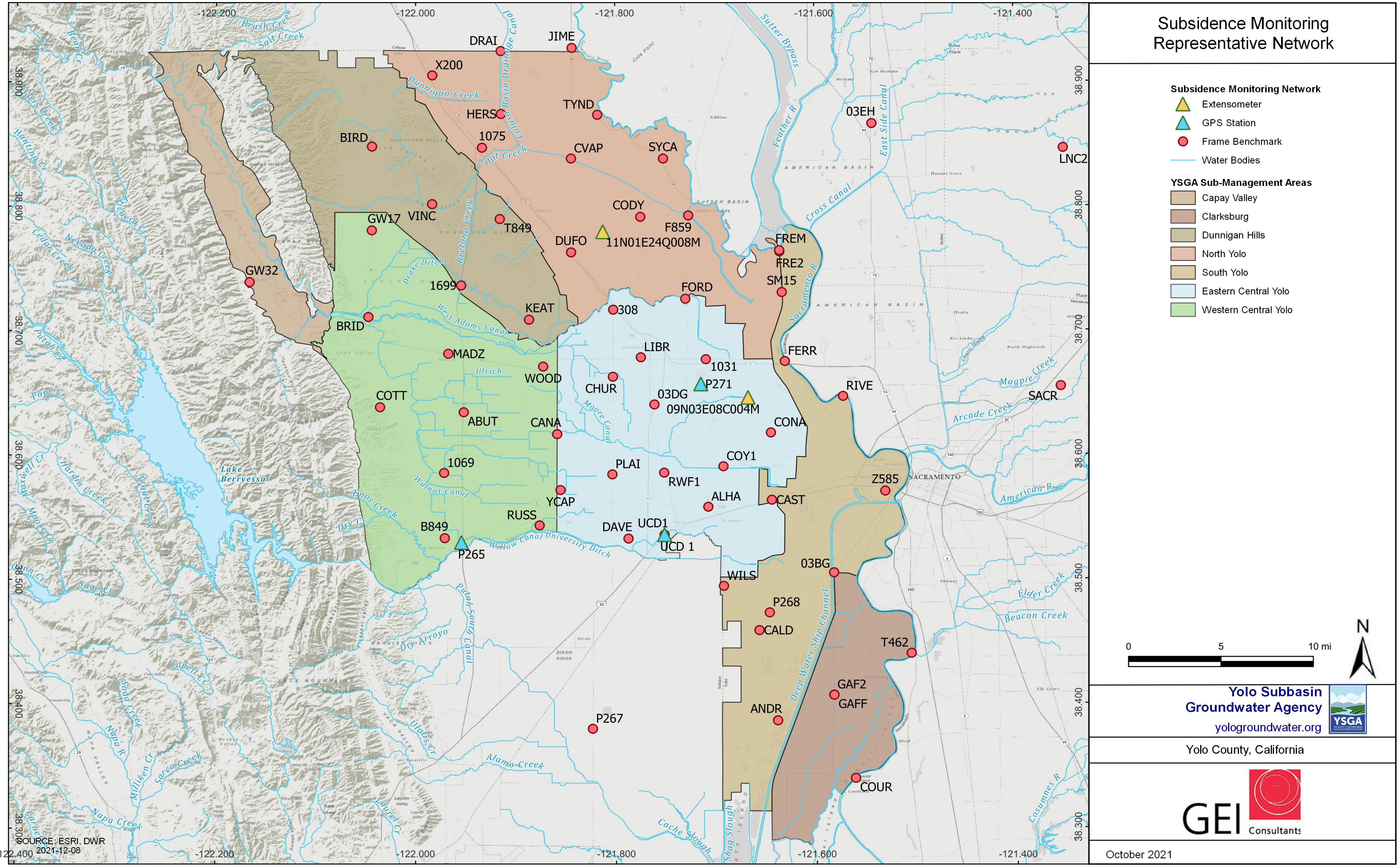

Figure 3-3. Yolo Subbasin Sub-Management Area for Subsidence Sustainability Indicator.

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3.6.2 Minimum Threshold Values

The minimum threshold values for land subsidence have been established for each management or sub-MA as shown in **Table 3-2**.

Table 3-2. Minimum Thresholds for Land Subsidence.

Management / Sub-Management Area	Running Average	Max Subsidence Rate	Max Percent of Area
Capay Valley	TBD	TBD	TBD
Dunnigan Hills	5-year	1.8 cm/year	25%
North Yolo	5-year	3.0 cm/year	25%
East Central Yolo	5-year	2.5 cm/year	25%
West Central Yolo	5-year	1.8 cm/year	25%
South Yolo	5-year	0.0 cm/year	25%
Clarksburg	5-year	0.0 cm/year	25%

3.6.3 Measurable Objectives Values

The measurable objectives values for land subsidence have been established for each management and sub-MA as shown in **Table 3-3**.

Table 3-3. Measurable Objective Thresholds for Land Subsidence.

Management / Sub-Management Area	Running Average	Max Subsidence Rate	Max Percent of Area
Capay Valley	TBD	TBD	TBD
Dunnigan Hills	3-year	1.8 cm/year	25%
North Yolo	3-year	3.0 cm/year	25%
East Central Yolo	3-year	2.5 cm/year	25%
West Central Yolo	3-year	1.8 cm/year	25%
South Yolo	3-year	0.0 cm/year	25%
Clarksburg	3-year	0.0 cm/year	25%

3.6.4 Interim Milestones

Interim milestones for the Land Subsidence are set equal to measurable objectives that are generally equal to current levels of subsidence. The YSGA's objective for land subsidence, as for most sustainability indicators, is to maintain groundwater levels and conditions at those experienced during recent historical conditions, generally since 2000. Therefore, SMCs for land subsidence are set at conditions similar those recently experienced.

3.7 Seawater Intrusion

Seawater intrusion has been determined to not be a concern in the Yolo Subbasin with no potential for seawater intrusion to occur under water quality management objectives in the Sacramento-San

Joaquin Delta or changes in water management activities in the Subbasin. Accordingly, no definitions of undesirable results, minimum thresholds, or measurable objectives have been developed.

3.8 Depletion of Interconnected Surface Water

The YSGA intends to use groundwater levels at shallow near-stream representative monitoring wells as a proxy for the rate and volume of depletion of interconnected surface waters caused by groundwater use.

There are many uncertainties associated with directly quantifying and measuring the rate and volume of surface water depletions caused by groundwater use. With the current state of knowledge, the YSGA lacks the ability to directly measure such depletions. There are streamflow gages throughout the basin; however, the gages are influenced by many other factors, and surface water management makes it difficult or impossible to see the effects of depletion. Second, separating depletion caused by reduced natural seepage to the groundwater basin from changing climate signals or other factors is a difficult task. The YSGA's integrated WEAP/MODFLOW model (YSGA Model) provides estimates of the quantity and timing of groundwater-surface water exchange; however, the model contains uncertainties such that setting thresholds based around model outputs is not appropriate. More information about model uncertainties is provided in the **Appendix E – Yolo GSA Model Documentation**. Improvements in the model's calibration parameters and portrayal of interconnected surface water systems are planned as a future Management Actions to update the YSGA Model.

Therefore, groundwater levels at the representative monitoring wells (RMW)s are being used as a proxy for the rate and volume of depletion of interconnected surface waters caused by groundwater use. The correlation between shallow groundwater levels and the depletion of interconnected surface waters is described by the YSGA Model. While the near-stream groundwater levels are higher than the elevation of the stream bottom, a lowering of groundwater levels either (1) reduces the rate of exchange from groundwater to the stream in a gaining reach, (2) increases the rate of exchange from the stream to groundwater in a losing reach, or (3) changes the reach from gaining to losing. This relationship holds in the reverse direction with an increase in groundwater elevations. While the near-stream groundwater levels are below the stream bottom elevation, the stream is considered disconnected, and a change in groundwater levels has no effect on depletion. For more details about groundwater-surface water interaction in the model, *please refer to* Modeling Surface Water-Groundwater Interaction with MODFLOW: Some Considerations (Brunner et.al. 2010).

Development of sustainable management criteria for the depletion of interconnected surface waters was constrained by limited groundwater data and available previous studies of stream-aquifer interaction. Additional investigations of stream-aquifer interactions and additional groundwater monitoring data in the Yolo Subbasin may necessitate a future change in the sustainable management criteria for this sustainability indicator.

3.8.1 Undesirable Results

The basin-wide definition of "undesirable results" for interconnected surface water is as follows:

> *The point at which significant and unreasonable impacts to the surface waters affect the reasonable and beneficial use of those surface waters by overlying users, including associated ecosystems.*
>
> *An undesirable result occurs when the Minimum Threshold is exceeded in over 50 percent of the interconnected surface water representative monitoring wells in two (2) or more interconnected surface water MAs in the same reporting year.*

Within the Yolo Subbasin, an interconnected surface water management zone will be considered an *"undesirable result watch area"* when 50 percent or more of the RMW's in that management zone exceed their minimum threshold value, identified below. If multiple undesirable result watch areas meet the criteria for depletion of interconnected surface waters undesirable result, as defined above, the Subbasin will be experiencing an undesirable result relative to depletion of interconnected surface waters. Interconnected Surface Water Management Zones are defined as follows:

- Upper Cache Creek – Cache Creek upstream of Capay Dam (coincident with the Capay Valley MA)
- Lower Cache Creek – Cache Creek downstream of Capay Dam to the Cache Creek Settling Basin, including RMW's up to 1 mile away from the creek
- Upper Sacramento River Reach – Sacramento River from the northern Subbasin boundary to the southern boundary of the North Yolo MA, including RMW's up to 5 miles away from the river. Also includes the Colusa Basin Drain
- Lower Sacramento River Reach – Sacramento River from the southern boundary of the North Yolo MA to the southern Subbasin boundary, including RMW's up to 5 miles away from the river
- Putah Creek –Putah Creek from the western Subbasin boundary to its drainage in the Yolo Bypass Wildlife Area, including wells up to 2 miles away from the creek

3.8.1.1 Potential Causes of Depletion of Interconnected Surface Water

Section 354.26(b)(1) of the GSP Emergency Regulations requires identification of potential causes of an undesirable result for each sustainability indicator. Potential causes of depletion of interconnected surface water include increased excessive groundwater pumping, which can draw on surface water; depleted streamflow; and increased surface water diversions.

3.1.1.1 Potential Effects of Depletion of Interconnected Surface Water

Section 354.26(b)(3) of the GSP Emergency Regulations requires identification of potential effects of an undesirable result for each sustainability indicator. Potential effects of depletion of interconnected surface water may include reduced stream or surface water flows, subsidence, and degraded groundwater quality. The reduction of surface water flows can reduce suitable aquatic habitat through increased temperature and reduced stream depth, flow velocity, cover, and dissolved oxygen.

3.8.2 Minimum Thresholds

3.8.2.1 Criteria for Establishing Minimum Thresholds

Minimum thresholds for the chronic lowering of groundwater levels were established through a collaborative process with local stakeholders and interested parties. To establish the minimum thresholds and measurable objectives for the Yolo Subbasin, the YSGA reviewed available well data and selected Representative Wells that could be used to establish minimum threshold values for interconnected surface waters. These Representative Wells, shown in **Figure 3-1**, were selected based on proximity to interconnected surface waters and well depth. More details about representative well selection can be found in **Section 4.8 – Depletion of Interconnected Surface Water.**

Based on historic, current, and projected conditions in the Subbasin, the YSGA developed several methodologies for establishing the minimum threshold value for each representative well, based on Interconnected Surface Water Management Zones. The primary sustainability criteria for establishing minimum thresholds for interconnected surface waters is to maintain interconnection of the local groundwater system to the critical surface water body at levels consistent with recent conditions (1971-2018). In this manner the YSGA is establishing sustainable management criteria that protects the existing level and frequency of interconnection, which in turn supports existing habitat and ecosystem conditions associated with critical surface water bodies, while preventing further degradation. The habitat associated with interconnected surface water bodies is supported by both surface flows (much of which is managed) and periodic connection to groundwater. The goal of the YSGA is to maintain conditions experienced in the past and to cause no degradation of habitat from the Subbasin's current baseline. Historically this condition included periods when groundwater elevations were below the level needed to support connection to surface water bodies. However, groundwater elevations recover during wet periods to reestablish connections between groundwater and surface water bodies. This regime of fluctuating and periodically recovering groundwater levels supports the current level of habitat in interconnected surface water bodies and for GDEs. The hydrographs for all Representative Wells used to establish minimum thresholds and measurable objectives are provided in **Appendix H – Yolo Subbasin Hydrographs of Representative Wells**. The methodology for each Interconnected Surface Water Management Zone is described below.

3.8.2.1.1 Lower Cache Creek:

The Minimum Threshold for depletion of interconnected surface water is the recurrence of the spring (March-May) average measurement for 1975 to present in at least one spring in every seven (7) years.

Lower Cache Creek is an intermittent water body with a known connection to groundwater, that supports sensitive ecosystems, recreation, and surface water uses. The creek experiences connection to, and disconnection from, groundwater that varies in space and time. The intention of the established minimum threshold is to ensure that no depletion occurs in excess of what has been experienced since 1975, and to ensure that groundwater levels rise at regular intervals to maintain the stream's connection to groundwater.

Historically, near-stream groundwater levels have fluctuated on both an annual and inter-annual basis. Within the range of historical inter-annual variation in near-stream groundwater levels, undesirable results have not been documented.

Because of the construction of Indian Valley Reservoir in 1975, many of the near-stream hydrographs showed steep declines prior to 1975 and significantly higher levels afterwards. Because the pre-1975 hydrographs showed significant declines contrary to the management goal of the basin, the period-of-record for calculation of minimum thresholds and measurable objectives for lower Cache Creek was shortened to 1975-2018. This ensures that the pre-1975 declines observed in these hydrographs are not repeated.

At each RMW, the average 1975 to present spring (March-May) groundwater elevation was calculated. The hydrograph was then evaluated for the longest period of time that groundwater elevations had remained below that value. The 7-year threshold represents the average of this period of time in all designated RMW's for Lower Cache Creek. In different areas of the creek, this value ranged from 4 to 11 years. The 7-year designation thus provides conservative preservation of the hydrologic regime throughout the entire lower creek area.

3.8.2.1.2 Upper Cache Creek, Putah Creek, and Lower Sacramento River:

Minimum Threshold value is equal to the minimum elevation for the period of record at the RMW, exceeded in 2 consecutive years.

Upper Cache Creek, Putah Creek, and the Sacramento River are perennial waterways that support a variety of beneficial uses. The effect of groundwater extraction on streamflow is difficult to determine due to flow management practices. However, hydrographs of monitoring wells adjacent to perennial water bodies display much less inter-annual variation than those of Lower Cache Creek. Generally, water levels are more stable, reflecting both the availability of surface water in the area and the replenishment of groundwater levels by the water body. Because groundwater levels at these wells generally rebound every spring, it is not appropriate to set a multi-year threshold. The minimum threshold is a single value aimed at limiting the rate of depletion from the water body. No undesirable results have been documented within the historical period of evaluation. Therefore, the minimum threshold is set to the historic minimum elevation for the period of evaluation at the representative monitoring well. The exceedance of this value in 2 consecutive years represents a departure from the historical near-stream hydrology, and if it occurs at a subbasin wide scale may lead to an undesirable result. The established minimum thresholds have been established to maintain interconnection of local groundwater systems to the adjacent water body at levels consistent with recent conditions, thereby, supporting existing habitat and ecosystem conditions associated with the water bodies, while preventing further degradation.

3.8.2.1.3 Upper Sacramento River:

Exceedance of the historic minimum elevation in the period of record of each RMW plus 20 percent of the depth between the historic maximum and historic minimum elevation for the period of record of the RMW in 2 consecutive years.

The minimum thresholds for the North Yolo MA are set lower than historical conditions recognizing that water districts, such as RD 108, in this area may experience reductions in surface water deliveries from the Sacramento River as potential Voluntary Agreements with the State Water Board are implemented. The Voluntary Agreements are expected to reduce surface water deliveries to Sacramento River Settlement Contractors during certain year types, requiring that water users increase their reliance on local groundwater during the same year types.

The minimum threshold is lower in this reach to provide operational flexibility to the beneficial users of groundwater in the region. However, the YSGA intends to manage towards the measurable objective, which seeks to maintain historical groundwater levels. In the long-term, groundwater levels will stay at their historically sustainable levels, and no undesirable results are predicted to occur.

3.8.2.2 Minimum Threshold Values

The *Minimum Threshold* values for depletion of interconnected surface water have been established for each RMW in the interconnected surface water management zone, as described above, and are provided in **Table 3-4**. The *Minimum Threshold*s will be measured at specific RMWs representative of the surrounding area and capture groundwater conditions in the area that influence surface waters.

3.8.3 Measurable Objectives

3.8.3.1 Criteria for Establishing Measurable Objectives

To establish the measurable objectives for the Yolo Subbasin, the YSGA utilized the representative wells identified for minimum thresholds, shown in **Table 3-5**, to determine the measurable objectives for chronic lowering of groundwater levels. Based on historic, current, and projected groundwater conditions in the Subbasin, the used the following criteria for establishing measurable objectives at representative monitoring wells:

Measurable Objective is equal to the average spring (March-May) groundwater elevation for water years 2000-2011 at the RMW. Performance of the Measurable Objective will be measured as the five (5) year running average of the maximum spring (March-May) groundwater elevation.

This measurable objective ensures that groundwater levels continue to rebound in spring, maintaining connection to and preventing undesirable depletion of interconnected surface waters.

Table 3-4. Interconnected Surface Water Minimum Thresholds.

YSGA Representative Well Number	State Well Number	Interconnected Surface Water Management Zone	Minimum Thresholds Value Depth to Water (Ft)	Minimum Thresholds Value Groundwater Elevation (Ft msl)	Minimum Thresholds Evaluation
265	10N01W21J001M	Lower Cache	29.7	131.6	1 in 7 years
275	10N02W14A001M	Lower Cache	64.4	143.2	1 in 7 years
424	10N01W23P001M	Lower Cache	28.6	116.7	1 in 7 years
425	10N01E22H500M	Lower Cache	29.4	55.1	1 in 7 years
426	10N01W16G500M	Lower Cache	36.1	132.6	1 in 7 years
151	09N03E33B002M	Lower Sacramento	56.1	-35.3	Single exceedance
401	10N02E36E001M	Lower Sacramento	21.2	9.0	Single exceedance
428	08N04E19N001M	Lower Sacramento	19.3	-1.3	Single exceedance
170	08N02E18M002M	Putah Creek	67.0	1.5	Single exceedance
229	08N01W20R005M	Putah Creek	116.2	36.4	Single exceedance
429	08N01E17F001M	Putah Creek	47.7	56.1	Single exceedance
287	11N03W23L001M	Upper Cache	23.6	287.6	Single exceedance
289	11N03W33F001M	Upper Cache	29.6	341.2	Single exceedance
293	12N03W20D001M	Upper Cache	26.2	376.4	Single exceedance
420	10N02E03R002M	Upper Sacramento	81.9	-39.2	Single exceedance
427	12N01E03R003M	Upper Sacramento	73.7	-35.4	Single exceedance
421	11N02E20K004M	Upper Sacramento	85.1	-31.6	Single exceedance

3.8.3.2 Measurable Objective Values

The measurable objective for depletion of interconnected surface waters has been established for each RMW in the interconnected surface water management zone, as described above. The Measurable Objectives will be measured at specific RMWs representative of the surrounding area and capture groundwater conditions in the area that influence surface waters

3.8.4 *Interim Milestones*

Interim milestones for the depletion of interconnected surface waters are set equal to measurable objectives that are generally equal to current conditions. The YSGA's objective is to maintain groundwater levels and conditions at those experienced during recent historical conditions, as detailed above.

Table 3-5. Interconnected Surface Water Measurable Objectives

YSGA Representative Well Number	State Well Number	Interconnected Surface Water Management Zone	Measurable Objectives Value Depth to Water (Ft)	Measurable Objectives Value Groundwater Elevation (Ft msl)
265	10N01W21J001M	Lower Cache	28.6	132.7
275	10N02W14A001M	Lower Cache	62.2	145.4
424	10N01W23P001M	Lower Cache	29.5	115.8
425	10N01E22H500M	Lower Cache	23.3	61.2
426	10N01W16G500M	Lower Cache	30.6	138.0
151	09N03E33B002M	Lower Sacramento	5.1	15.7
401	10N02E36E001M	Lower Sacramento	3.3	26.8
428	08N04E19N001M	Lower Sacramento	9.3	8.7
170	08N02E18M002M	Putah Creek	38.8	29.7
229	08N01W20R005M	Putah Creek	61.0	91.6
429	08N01E17F001M	Putah Creek	27.8	76.0
287	11N03W23L001M	Upper Cache	12.5	298.7
289	11N03W33F001M	Upper Cache	16.5	354.3
293	12N03W20D001M	Upper Cache	17.4	385.2
420	10N02E03R002M	Upper Sacramento	18.9	23.9
427	12N01E03R003M	Upper Sacramento	9.0	29.3
421	11N02E20K004M	Upper Sacramento	20.0	33.5

4.0 Monitoring Networks

The monitoring network and protocols described in this section are designed to collect data of sufficient quality, frequency, and distribution to characterize groundwater conditions and water budget components in the Yolo Subbasin, and to evaluate changing conditions due to local hydrology, water management actions, and water supply projects. This section describes the objectives, design, rationale, monitoring protocols, and data reporting requirements of the monitoring network, along with a plan for future improvement to the monitoring network to fill identified data gaps. The YSGA has established this SGMA representative monitoring network with those wells or sites that will be used to report the Subbasin's performance for each of the sustainability indicators. Within the Subbasin many hundreds of additional wells are also monitored for purposes other than SGMA reporting.

Since 2004, the Yolo Subbasin has maintained an established groundwater-level and water quality monitoring database known as the County WRID[56] that includes more than 190,000 records from thousands of agricultural, domestic, municipal and dedicated monitoring wells that have been monitored for groundwater levels, water quality and subsidence. In addition, members of the YSGA and more than 40 other agencies also maintain and monitor wells throughout the Subbasin. The subset of wells that are included in the Subbasin's SGMA monitoring network for specific sustainability indicators are detailed in the following sections. Not all monitoring wells are included in the SGMA monitoring network. They are, nevertheless, important for monitoring conditions in the Subbasin and will continue to be monitored. All current and historic monitoring data on the WRID is available online for scientists and engineers. For more accessible public access, all currently active monitoring wells (418 as of August 2021) are available to the public at sgma.yologroundwater.org.

SGMA representative monitoring wells or sites are discussed for each of the sustainability indicators in the following sections along with evidence that the wells are reflective of conditions in the principal aquifers.

4.1 Objectives

The representative monitoring network in the Subbasin is designed to meet the following objectives of this GSP:

- Monitor impacts of groundwater pumping on beneficial uses and users of groundwater
- Monitor progress toward measurable objectives and minimum thresholds
- Collect data to quantify annual changes in water budget components of the Subbasin

[56] https://wrid.facilitiesmap.com/

- Monitor changes in groundwater conditions relative implementation of projects and management actions

The representative monitoring network design relative to these four objectives are discussed in this section. These objectives will monitor the following pertinent sustainability indicators:

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Degraded groundwater quality
- Land subsidence
- Depletion of interconnected surface waters

The following sections provide a description of the 1) entire monitoring network, 2) selected representative monitoring network along with its justification, and 3) frequency of measurement for each of the sustainability indicators.

4.2 Monitoring Progress Toward Measurable Objectives

The monitoring network will inform progress of the Subbasin to operate to interim milestones and measurable objectives and ensure avoidance of minimum thresholds. As described in **Section 3.3 – Chronic Lowering of Groundwater Levels**, groundwater levels are the primary indicator for which minimum thresholds have been set for the evaluation of the Subbasin's sustainable management. Groundwater levels serve as the measure for chronic lowering of groundwater levels, reduction of groundwater storage, and depletion of interconnected surface waters. However, as groundwater levels change, effects on other indicators will also be evaluated. Tracking the progress of water levels as well as other indicators will inform the effectiveness of water management actions, implemented projects, and quantification of water budget components.

Monitoring for degraded water quality will rely on ongoing, existing water quality monitoring programs and the specific monitoring wells and criteria established in those programs. Land subsidence in the Subbasin will rely upon existing and planned surface subsidence monitoring points and extensometers located in the subbasins, as well as periodic subsidence evaluations conducted in the Subbasin.

Monitoring the Subbasin's performance to interim milestones and measurable objectives will provide information needed to evaluate whether adjustments to management actions and monitoring networks are required. As stated in §354.34(g)(3), minimum thresholds, measurable objectives, and interim milestones will be established at each monitoring site or representative monitoring site. Where needed, interim milestones and minimum thresholds for groundwater levels or other sustainability indicators may be adjusted in the 5-year updates to maintain the objectives of this GSP.

4.2.1 Monitoring for Water Budget Components

One of the objectives of the monitoring network is to quantify or estimate water budget components to quantify the change in water budget over time. This aspect of the network will rely on local monitoring stations for water levels, but also regional weather stations, remote sensing methods for consumptive use, or estimates for seepage or other groundwater inflow outflow components. In addition, water supply import and export accounting is required for the water budget. These aspects of the network are briefly described below.

4.2.1.1 Subbasin Inputs

As described in **Section 2.3 – Water Budget Information**, water inputs to the Subbasin include:

- Diverted surface water (both imported and natural), that satisfies consumptive use, or becomes managed or unmanaged direct recharge to the Subbasin
- Precipitation
- Channel seepage
- Subsurface inflow

4.2.1.1.1 Surface Water Diversions

Surface water diversion provide a sources water to meet the agricultural and municipal demands in the Subbasin, and to a less extent as a source of direct groundwater recharge. As a component of the water budget diversions from local waterways, such as Cache Creek, or imports, through water rights or contractual agreements, from the Sacramento River will be monitored and quantified annually to support required water budget analysis and reporting.

4.2.1.1.2 Precipitation

Depending on the WY, precipitation may account for recharge as well as satisfying a portion of consumptive use in the Subbasin. It is a component of water budget accounting that is monitored by weather stations in the Subbasin. The following weather stations (**Table 4-1**) will be used for monitoring purposes in the Subbasin.

4.2.1.1.3 Subsurface Inflows

Historical quantities of groundwater inflow to the Subbasin underlying the study area have been estimated with the Subbasin's regional model and estimated by water budget accounting methods. Subsurface inflows include deep percolation, YCFC&WCD canal recharge, and managed aquifer recharge.

As the groundwater model of the study area continues to be refined, groundwater inflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data that can support estimates of groundwater inflow in the future.

Table 4-1. Weather Stations within the Subbasin.

Station Type	ID	Latitude	Longitude	Elevation (feet msl)	Other
CIMIS	Bryte	38.599158	-121.54041	40	
CIMIS	Davis	38.535694	-121.77636	60	
CIMIS	Esparto	38.691786	-122.01381	174	Inactive
CIMIS	Woodland	38.672722	- 121.81172	82	
CIMIS	Zamora	38.808758	-121.90754	50	Inactive
NCDC	Davis 2 WSW Exp Farm	38.5349	-121.7761	60	
NCDC	Winters	38.525	-121.978	135	
NCDC	Woodland 1 WNW NCDC	38.6829	-121.794	69	
Touchtone	Davis	38.53	-121.76	60	
Touchtone	Winters	38.53	-121.96	135	

4.2.1.2 Subbasin Outputs

As described in **Section 2.3 – Water Budget Information**, water leaving the Subbasin includes:

- Consumptive use from crop demand, other vegetation, evaporation, and other beneficial use such as water recreation, domestic use, municipal or industrial use, etc.
- Surface outflows
- Subsurface outflow

4.2.1.2.1 Consumptive Use

Sources of water for consumptive use include surface water, precipitation, and groundwater. As described in the water budget section of this GSP, consumptive use from crop demand, other vegetation, and evaporation has been calculated at the basin level using remote sensing techniques.

4.2.1.2.2 Surface Outflows

Surface outflows include surface flows leaving the boundaries of the Subbasin, typically as flows into the Sacramento River, Yolo Bypass, or the Delta.

4.2.1.2.3 Subsurface Outflow

Historical quantities of groundwater outflow from the Subbasin underlying the study area have been estimated in various regional models and estimated by water budget accounting in the past.

As a model of the study area is refined, groundwater outflow calculations may become more accurate. In addition, annual water budget accounting as well as semiannual water elevation monitoring, contouring and gradient estimating, will continue to provide data to support estimates of groundwater outflow in the future.

4.3 Monitoring Network Design

The monitoring network design considers the use of the WRID monitoring network and monitoring maintained by other local and state agencies. Network coverage includes areas within the Subbasin with current and projected groundwater use to adequately demonstrate the short-term, seasonal, and long-term trends in groundwater and related surface conditions.

The YSGA shall adjust the monitoring frequency and/or density to provide an adequate level of detail under circumstances including drought; minimum threshold exceedances; highly variable spatial or temporal conditions; impacts to beneficial uses and users of groundwater; and the potential to adversely affect the GSP implementation of adjacent subbasins.

4.3.1 Monitoring Frequency Design

The monitoring frequency is specified for sustainability indicators. In general, monitoring will occur semiannually for groundwater levels, land subsidence, and depletion of interconnected surface waters. Monitoring for water quality will occur at least semiannually, as determined by the water quality monitoring program responsible for collection of the water quality data. The frequency of monitoring will provide sufficient short-term, seasonal, and long-term data to evaluate the effectiveness of management actions. Further details on monitoring frequency are outlined in the discussions pertinent to each sustainability indicator.

4.3.2 Spatial Density Design

The spatial density of the monitoring network design accounts for the six MAs in the Subbasin that have been established to better implement and monitor sustainable groundwater management. These six MAs are described in more detail in **Section 2.4 – Management Areas**. The monitoring network has been designed to provide the best possible coverage of beneficial uses and users of groundwater, restricted by the current data gaps of this GSP. The representative monitoring network in relation to key beneficial users (DACs, domestic wells, GDEs, and Tribal lands) is presented in **Figure 4-1.** Please *refer to* the sections below for additional details on the monitoring spatial density for each of the sustainability indicators.

4.3.3 Rationale for Design

Rationale regarding the design of the monitoring network is provided in the sections below dedicated to each sustainability indicator. In general, monitoring stations were chosen based on the following scientific rationale:

- Aquifer representation – Per DWR Emergency Regulations §354.34, monitoring wells were chosen to represent each underlying aquifer under the boundaries of the Subbasin.
- Potential impacts to beneficial users of groundwater

- Access to monitoring location and monitoring data
- Availability of site-specific historical data and technical information
- Spatial and vertical representation
- Identification of dedicated monitoring wells
- Site accessibility

Additionally, data gaps within the monitoring network have been identified and a monitoring improvement plan (**Section 4.11 – Monitoring Network Improvement Plan**) has been developed, which identifies locations for supplemental (or future) monitoring sites for each sustainability indicator, as appropriate.

4.4 Chronic Lowering of Groundwater Levels and Reduction of Groundwater Storage

4.4.1 Representative Monitoring Network

The subbasin has 62 wells spread across the six MAs that have been designated as the representative monitoring wells for chronic lowering of groundwater levels. The selected representative monitoring network is a subset of all monitoring wells currently monitored in the Subbasin. The representative monitoring wells have been selected because they have a period of record that supports analysis required to develop measurable objectives and minimum thresholds for this sustainability indicator, and whose locations are representative of surrounding groundwater levels. The representative monitoring wells will identify groundwater level responses, during the implementation period (2022-2042), to monitor the Subbasin's performance to this sustainability indicator. As shown in **Figure 4-2**, these 62 wells have been spatially distributed to provide adequate coverage throughout the Subbasin. **Table 3-1** identifies these monitoring wells by each MA.

As explained in **Section 4.1 – Objectives**, groundwater levels are the key to informing the progress of the GSP's objectives. Historically, DWR has utilized changes in groundwater elevations to estimate changes in groundwater storage. Similarly, the Subbasin will use groundwater levels as a proxy for the change in groundwater storage that will be calculated by evaluating the volumetric difference between changes in groundwater surfaces created based on groundwater level data collected in the spring of each year.

As a result, representative monitoring wells for chronic lowering of groundwater levels will serve as a proxy for reduction in groundwater storage. Similarly, monitoring frequency and spatial density will be the same as for chronic lowering of groundwater levels, as described below.

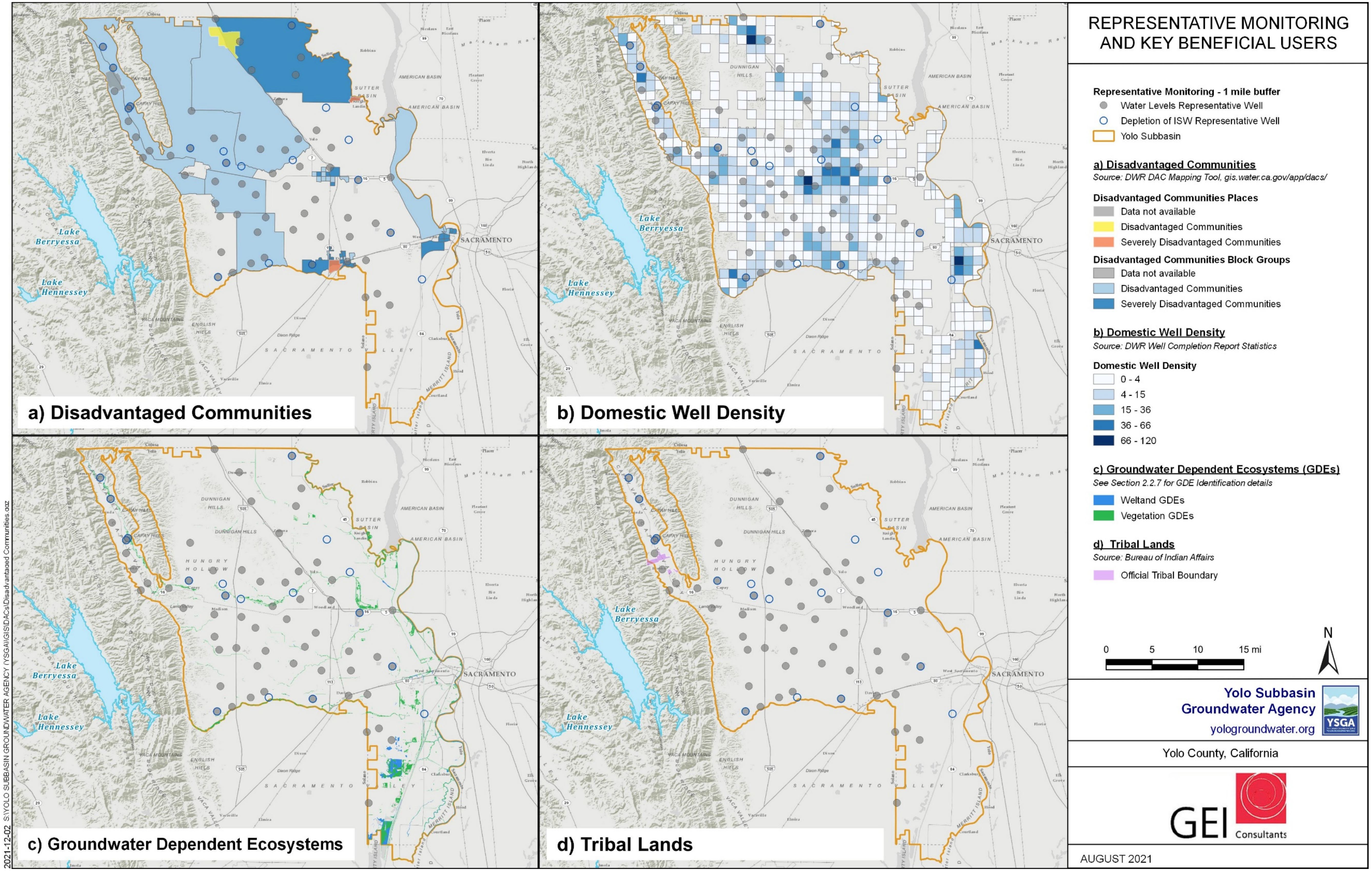

Figure 4-1. Monitoring Network for Key Beneficial Users.

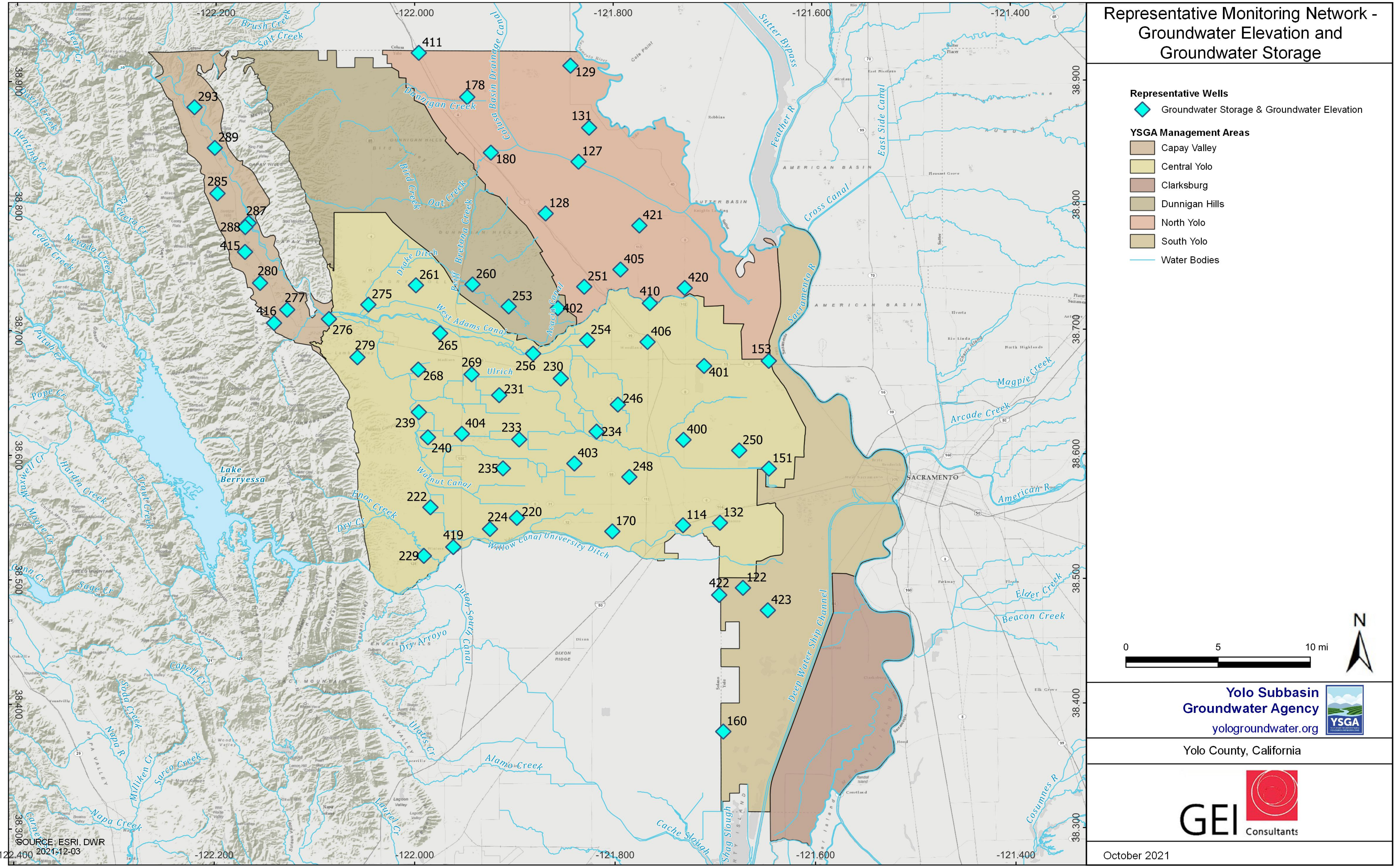

Figure 4-2. Yolo Subbasin Groundwater Elevation Representative Monitoring Wells.

4.4.2 Rationale

Representative monitoring wells were selected to represent the general conditions of the area surrounding the monitoring well and where minimum thresholds and measurable objectives have been established. The design and site selection for monitoring the groundwater levels was based on the same rationale outlined in **Section 4.3.3 – Rationale for Design**.

Monitoring will also continue for all other non-representative wells currently being monitored in the Subbasin to ensure a robust collection of data and thorough analysis of groundwater conditions in the Subbasin. As appropriate, representative monitoring wells may be modified to reflect:

- Improved understanding of the groundwater conditions
- Changes in land use conditions that warrant an increase or decrease and the spatial distribution of monitoring wells
- Changed conditions at the monitoring site (including well access)
- Establishment of nearby and equally representative dedicated monitoring wells

4.4.3 Monitoring Frequency

Frequency of groundwater level monitoring is cited in the Monitoring Networks and Identification of Data Gaps Best Management Practice (DWR 2016) which presents guidance on monitoring frequency based on the type of monitoring, aquifer type, confinement, recharge rate, hydraulic conductivity, and withdrawal rate. Historically, DWR has monitored groundwater levels on a semi-annual basis.

Based on the analysis of groundwater level condition and seasonal variations in the Subbasin, dating back several decades, it was determined that semi-annual groundwater level measurements at representative monitoring wells was sufficient to identify groundwater level trends in the Subbasin for changes in groundwater levels at the wells in the monitoring network shown on **Figure 4-2**.

Semi-annual groundwater levels will be collected in the spring (seasonal high prior to summer irrigation demands) and fall (seasonal low after the summer irrigation demands). In the spring, groundwater levels are typically higher than any other time of the year and groundwater pumping stresses are usually minimal. Fall measurements are taken after the heaviest pumping has occurred during the dry season and before substantial recharge has occurred from precipitation. The fall measurements are typically considered to be the regional minimum groundwater level for a given year.

Monitoring at representative wells will be completed during a 2-week window on either side of target dates (March 15 and October 15) to accommodate inclement weather and scheduling conflicts. The YSGA will also consult data from other Subbasin wells to confirm that data collected at representative wells is consistent with annual high and low groundwater level periods for the Subbasin. This spring/fall frequency of monitoring is sufficient to demonstrate seasonal, short-term (1-5 years), and long-term (5-10 years) trends in groundwater and related surface conditions and yield representative information about groundwater conditions as necessary to evaluate plan implementation.

A well impact analysis has also been conducted and is included in **Appendix I – Well Impact Analysis**. This well impact analysis can be utilized to evaluate potential impacts to beneficial users of groundwater.

4.4.4 Spatial Density

A groundwater level well monitoring density goal ranges from 0.2 to 10 wells per 100 square miles (DWR 2016). The monitoring well density goals can also be based on the amount of groundwater use. For basins where groundwater pumping exceeds 10,000 AFY per 100 square miles, four wells per 100 square miles is recommended. Professional judgement is also essential to determining an adequate level of monitoring, frequency, and density based on the need to observe aquifer response near high pumping areas, cones of depression, significant recharge areas, and specific projects.

The Yolo Subbasin extends over an area of approximately 844 square miles and supplies about 320,000 acre-feet of groundwater annually. This equates to about 38,000 AFY per 100 square miles. There are 62 representative monitoring wells selected to monitor for chronic lowering of groundwater levels and reduction of groundwater storage in the Subbasin or a density of about seven wells per 100 square miles. The density of the representative monitoring wells exceeds the recommended density goals and are sufficient to provide representative groundwater levels throughout the Subbasin.

4.4.5 Data Gaps

As shown in **Figure 4-2**, there is an adequate density of monitoring wells in the Capay Valley, North Yolo, Central Yolo, and South Yolo MAs. However, data gaps are present in Dunnigan Hills and Clarksburg MAs. The YSGA will seek to add additional monitoring wells in the Dunnigan MA as irrigated agriculture increases in the area and new wells are installed. These additional wells will enable the YSGA to better assess groundwater conditions and to monitor performance to sustainability indicators. The Clarksburg MA is considered a monitoring area for chronic lower of groundwater and reduction of groundwater storage, due to the very limited amount of groundwater used in the area. In the event that land uses change or groundwater production increases in a manner that will affect local groundwater conditions, new monitoring wells will be sited in this MA.

4.5 Seawater Intrusion

As stated previously, in **Section 2.2.3 – Seawater Intrusion**, the Subbasin is more than 50 miles inland from the Pacific Ocean and seawater intrusion into the Delta is now controlled for freshwater management. Therefore, seawater intrusion is not likely to occur in the vicinity of the Subbasin and a representative monitoring network and monitoring is not required for this sustainability indicator.

4.6 Groundwater Quality

The representative monitoring network for groundwater quality consists of existing monitoring programs in the Subbasin. YSGA will review water quality monitoring data on an annual basis to monitor for potential changes in groundwater quality.

4.6.1 Representative Monitoring Network

As discussed in **Section 2.2.4 – Groundwater Quality**, groundwater quality monitoring and reporting is conducted through numerous public agencies. Rather than developing a new monitoring program, the YSGA will rely on existing programs to monitor water quality in the Subbasin. Specifically, the representative monitoring network will consist of public water system wells regulated by the State Water Board's DDW and YCEH; participating agricultural and on-farm domestic drinking water wells monitored by the Coalition under ILRP; and potential private domestic wells under the CV-SALTS Nitrate Control Program. **Table 4-2** provides an overview of these programs and the limits monitored for each constituent of concern identified in the Subbasin.

Other groundwater quality monitoring programs that exist within the YSGA boundary will be tracked by the YSGA, but not discussed in detail here, as hundreds of constituents are tested on a regular basis. These programs include GAMA managed by the USGS, the DPR's Groundwater Protection Program[57], and LUSTs[58], among others. For a detailed review of the various groundwater quality monitoring programs active in the YSGA area *please see* the 2016 Groundwater Quality Assessment Report (ch2m 2016b).

Table 4-2. Yolo Subbasin Existing Monitoring.

		Drinking Water Standard			Monitoring Entity/Program		
Constituent	Units	Limit	Type	Agricultural Water Quality Thresholds	DDW/Yolo County Health	ILRP	CV-SALTS[3]
Arsenic	ppb	10	Primary	100	X		
Boron[1]	ppb	1,000	State Notification Level	700	X	X	
Hexavalent Chromium (VI)[2]	ppb	n/a	n/a	n/a	X		
Nitrate	ppm	10	Primary	n/a	X	X	X
Total Dissolved Solids	ppm	500	Secondary	450	X	X	

[1]Unregulated chemical without an established MCL but monitoring is required if detected in initial source sampling or from Unregulated Contaminant Monitoring Rule (UCMR 1).
[2]No current MCL; however, MCL of 10 ppb was adopted in 2014 but rescinded in 2017 with anticipation that a new standard will be adopted and regulated in the future by DDW.
[3]Yolo Subbasin is a Priority II Subbasin under CV-SALTS Nitrate Control Program with Notice to Comply letters expected to be sent out January 2022.

[57] https://www.cdpr.ca.gov/docs/emon/grndwtr/gwp_sampling.htm
[58] https://www.waterboards.ca.gov/ust

4.6.1.1 DDW Public Water Systems

Water quality monitoring is currently conducted for the Subbasin's 83 public water systems through DDW. Data for these systems is publicly available through the SDWIS and will be reviewed by YSGA on an annual basis. Majority of this annual effort will focus on the 16 community water systems with regulated wells followed by the remaining non-community water systems consisting of NTNC or TNC water systems. *Refer to* **Table 2-12** for an overview of community water system wells within the Subbasin.

4.6.1.2 ILRP On-Farm Drinking Water Wells

There are approximately 32 agricultural and on-farm domestic drinking water wells that are monitored for various constituents including boron, nitrate, and TDS by the Coalition under the ILRP. Nitrate monitoring results are publicly available through GeoTracker. For TDS and boron, the YSGA will coordinate with the Coalition to obtain and will review results on an annual basis.

4.6.1.3 CV-SALTS Nitrate Control Program Private Wells

The Yolo Subbasin is classified as a Priority II Subbasin for the CV-SALTS Nitrate Control Program with Notice to Comply letters from CVRWQCB expected to be sent out January 2022. A residential sampling program is a requirement of the CV-SALTS Nitrate Control Program and is designed to assist in identifying residents affected by nitrate within a Management Zone. Private well owners may request to have their well tested for nitrate by the Management Zones. Upon implementation of the Nitrate Control Program in the Subbasin, the YSGA will coordinate with the Management Zones to obtain nitrate results and may include sampled wells as part of the groundwater quality monitoring network.

4.6.2 Monitoring Network Information

Figure 4-3 shows existing monitoring network sites for nitrate, arsenic, TDS, and boron in the Yolo Subbasin. These are not all of the wells that are monitored for water quality in the Subbasin, but a subset of Public Water System wells with publicly available data[59].

Table 4-3 shows the GAMA ID for these wells, their latitude/longitude, a local well description, and their status within the nitrate, arsenic, TDS, and boron monitoring networks.

[59] https://gamagroundwater.waterboards.ca.gov/gama/gamamap/public/

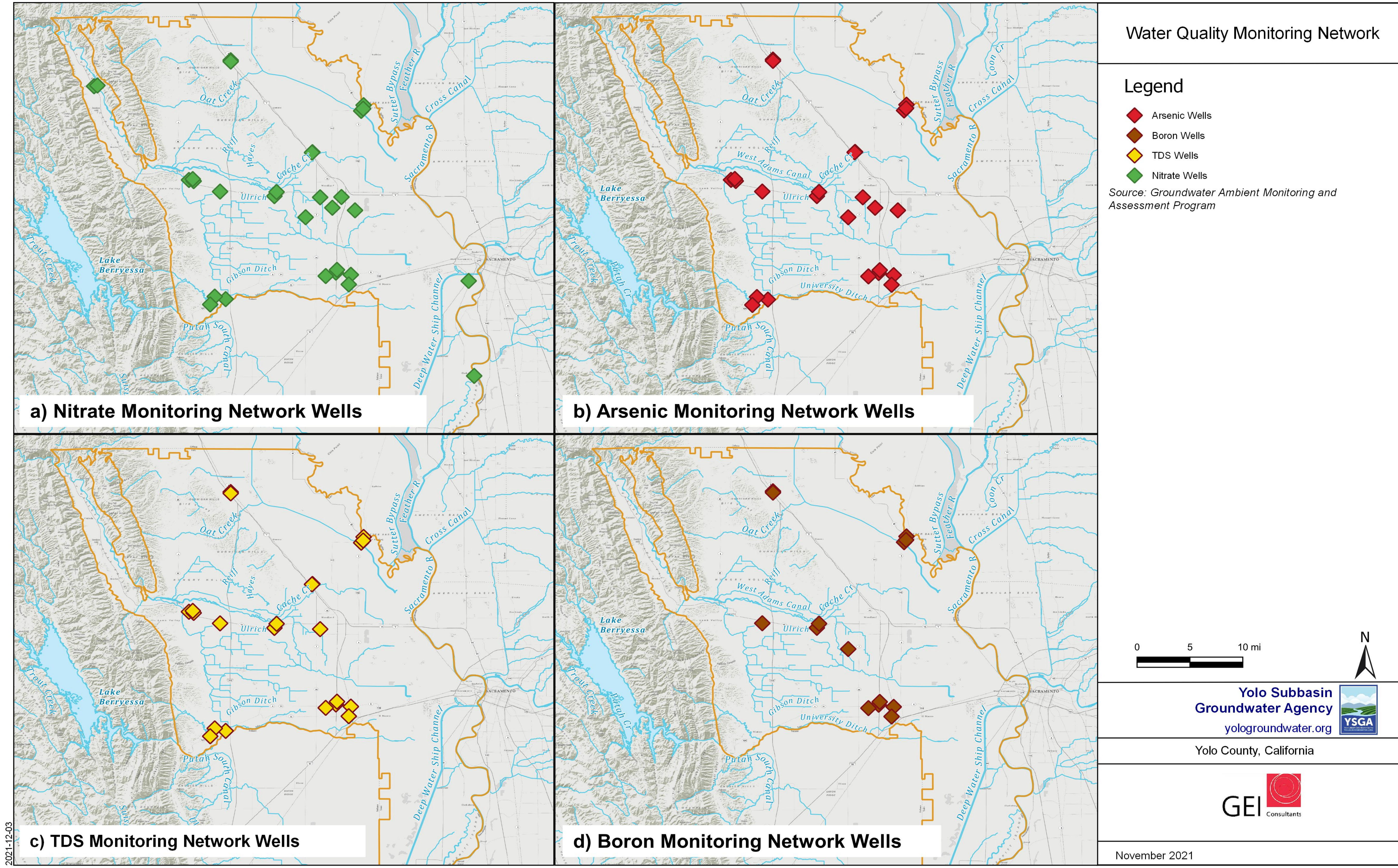

Figure 4-3. Monitoring Network for Nitrate, Arsenic, TDS, and Boron in the Yolo Subbasin.

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Table 4-3. Monitoring Network for Nitrate, Arsenic, TDS, and Boron in the Yolo Subbasin

GAMA WELL ID	Latitude	Longitude	Local Well Description	Monitoring Network Nitrate	Monitoring Network Arsenic	Monitoring Network TDS	Monitoring Network Boron
5710011-002	38.67242	-121.87596	Wildwings - Pintail Well	X	X	X	X
5710011-001	38.67829	-121.87212	Wildwings - Canvas Back Well	X	X	X	X
5710004-005	38.80071	-121.71942	Knights Landing Well 05 - Third Street Well	X	X	X	X
5710004-004	38.79259	-121.72364	Knights Landing Well 04 - Ridge Cut Well	X	X	X	X
5710004-003	38.79567	-121.72021	Knights Landing Well 03 - Railroad Street Well - RAW	X	X	X	X
5710001-052	38.56106	-121.7426	City of Davis - Well 33 (Lewis)	X	X	X	X
5710001-030	38.56411	-121.7687	City of Davis - Well 31	X	X	X	X
5710001-028	38.55936	-121.78653	City of Davis - Well 30	X	X	X	X
5710001-025	38.56809	-121.76683	City of Davis - Well 27	X	X	X	X
5710001-018	38.54746	-121.74632	City of Davis - Well 23	X	X	X	X
5700712-012	38.86453	-121.95231	Dunnigan Well 02	X	X	X	X
5700712-001	38.86263	-121.95225	Dunnigan Well 01	X	X	X	X
5700571-012	38.67891	-121.971	Madison Well 03	X	X	X	X
5710007-006	38.69533	-122.02543	Esparto Well 06	X	X	X	
5710007-001	38.69369	-122.01718	Esparto Well 01-A	X	X	X	
5710005-007	38.52695	-121.96128	City of Winters - Well 06	X	X	X	
5710005-006	38.53054	-121.98036	City of Winters - Well 05	X	X	X	
5710005-005	38.5194	-121.98829	City of Winters - Well 04	X	X	X	
5700643-001	38.64253	-121.82144	Plainfield Well 01	X	X		X
5710006-024	38.65213	-121.73501	Woodland - Well 24 (Town Center Well)	X	X		
5710006-015	38.65586	-121.77465	Woodland - Well 16 College Ave	X	X		
5710006-048	38.67096	-121.75867	Well 15S - RAW	X			
5710007-007	38.6966	-122.0188	Esparto Well 05 RAW	X	X	X	
5710006-056	38.67062	-121.79593	Woodland - Well 30 (ASR)	X	X	X	
5700700-002	38.73453	-121.80925	Yolo - Washington St Well	X	X	X	
5700700-001	38.73386	-121.81003	Yolo - Sacramento St Well	X	X	X	
5700552-001	38.41747	-121.52819	Clarksburg Well	X			
5700728-001	38.82758	-122.19181	Guinda Well 01	X			
5700713-003	38.82869	-122.18598	Guinda Well 02	X			
5700575-001	38.55178	-121.53689	West Sac - Jefferson BLVD	X			

Notes: ARS = Aquifer Storage and Recovery

Figure 4-3 and **Table 4-3** include wells that have been actively monitored by other programs or entities, primarily DDW. The selected wells shown are not necessarily the same wells that will be monitored moving forward, depending on the requirements of the existing programs. The YSGA will review the wells that have been monitored for water quality within the Yolo Subbasin on an annual basis and will provide an update on water quality in the annual reports.

Additional sources of data for domestic wells have been identified. The ILRP will begin testing domestic wells for water quality in 2022. The County currently requires a water quality test when a new domestic well is drilled. These one-time measurements, when aggregated, can provide useful information about trends in water quality data.

4.6.3 Rationale

To prevent duplicating monitoring efforts in the Subbasin, the YSGA has elected to utilize existing monitoring programs under DDW, ILRP, and future monitoring efforts under CV-SALTS. By utilizing existing programs, monitoring is more effective and spatially available across the Subbasin, allowing for more water quality monitoring coverage.

4.6.4 Monitoring Frequency

Evaluation of water quality results will be conducted annually by YSGA and published in the annual reports. Results will be obtained from public databases including SDWIS, GAMA, and GeoTracker. Data not publicly available will be obtained by the YSGA through coordination with monitoring entities. Monitoring is expected to expand once the Nitrate Control Program under CV-SALTS begins implementation.

4.6.5 Data Gaps

The YSGA will review water quality results for each system annually and will consider expanding the monitoring network if additional coverage is needed. Currently, water quality monitoring for domestic wells is considered a data gap in the monitoring network.

4.7 Land Subsidence Monitoring Network

4.7.1 Representative Monitoring Network

Land subsidence has been measured in the Yolo Subbasin since the late 1960s and has been subject to various technologies. This includes:

- Terrestrial (optical, laser) surveys
- Surveys of numerous stations *via* GPS on behalf of the WRA, in 1999, 2002, 2005, 2008, and 2016 (http://www.yolowra.org/projects_subsidence.html)
- Three continuous GPS stations
- Two extensometers

- DWR InSAR mapping

Of these, continuous GPS stations, extensometers and InSAR mapping are planned to be continued. As a result, YSGA intends to utilize these stations as the subsidence representative monitoring network for Yolo Subbasin.

4.7.1.1 Continuous GPS Stations

Three continuous GPS stations are located in the Yolo Subbasin as shown in **Figure 4-4** and provide "real-time" data on subsidence in the Subbasin. Two stations, P265 and P271 are part of the broad GPS network within California with data acquired daily since 2004 and 2005 respectively. Third station UCD1 is part of the Bay Area Regional Deformation Network and provides daily values since 1996.

Figure 4-4 shows the locations of these three continuous GPS stations. Station P265 is located near the southwestern corner of the Subbasin, east of Winters, on the western flank of the Sacramento Valley and the second station (P271) is located on the southeast side of Woodland, near the axis of the Sacramento Valley. This data is readily available from the UNAVCO website. Station UCD1 is located at UC Davis, along the southern boundary of the Subbasin, midway toward the center of the Sacramento Valley.

4.7.1.2 Extensometers

In general, an extensometer pipe (2-inches in diameter) is anchored in a cement grout base at a particular depth below a protective casing relative to a reference table over the pipe at the ground surface. Changes in the distance between the extensometer base and reference table occur due to compaction of soils between the base and reference table. Two extensometers were installed in the Subbasin during 1992 in association with the installation of two nested monitor wells. The first installation is located east of Woodland and included an extensometer (CON Ext, 09N03E08C004M) to a depth of 716 feet and a 3-completion monitor well. The second installation is located east of Zamora and included an extensometer (ZAM Ext, 11N01E24Q008M) to a depth of 1,000 feet and a 4-completion nested monitor well. **Figure 4-4** also shows the locations of these two extensometers.

4.7.1.3 DWR InSAR Subsidence Mapping

DWR monitors subsidence for medium- and high-priority basins across California using InSAR data obtained from ESA Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. This InSAR data was calibrated with continuous GPS data from 232 stations and then checked against 160 continuous GPS stations not associated with the calibration as well as 21 calibration stations in northern California. At present, the DWR website includes an interactive mapping application that covers the Subbasin and depicts land subsidence as:

- Cumulative totals for various time periods beginning with June 2015 and extending monthly through September 2019

- Annual rates of subsidence beginning with July 2015-16 and proceeding monthly through September 2018-2019

4.7.2 Rationale

Continuous GPS stations that are currently part of the broad GPS network within California and the Bay Area Regional Deformation Network; two extensometers currently monitored and maintained by DWR. InSAR subsidence mapping data is planned to continue monitoring in the future. YSGA will utilize these stations to monitor subsidence in the Subbasin.

4.7.3 Monitoring Frequency

Data from continuous GPS stations, extensometers and DWR InSAR subsidence mapping will be downloaded in the spring and fall of each year coinciding with the semi-annual groundwater level data collection period and responsive to SGMA reporting requirements. This data will be plotted annually with the groundwater levels to assess changes in subsidence relative to established minimum thresholds and measurable objectives.

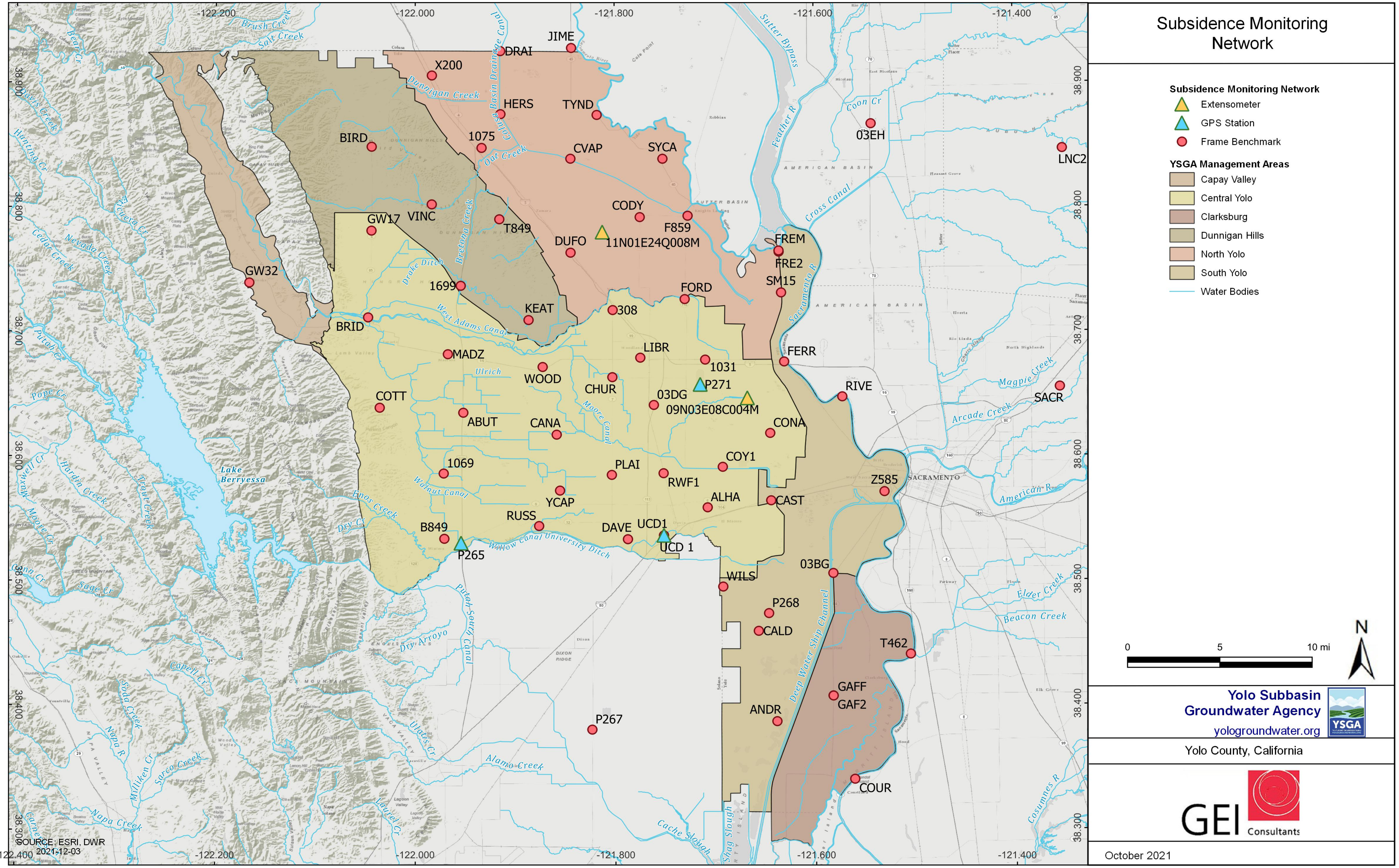

Figure 4-4. Yolo Subbasin Subsidence Representative Monitoring.

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4.7.4 Data Gaps

The exact causes of all subsidence in the Subbasin are not clearly understood. While certainly a portion of subsidence can be attributed to dewatering of compactable soils during dry years, there have also been reports of tectonic related subsidence in the region. In fact, a portion of the basin is experiencing modest uplifting, which would be an effect of tectonic activities. To better understand the effects of groundwater pumping on subsidence additional extensometers will be needed to determine the extent of subsidence that occurs within the groundwater pumping zone. This is especially important in areas where more aggressive groundwater pumping is expected to occur in the future.

4.8 Depletion of Interconnected Surface Water

4.8.1 Representative Monitoring Network

The subbasin has 17 near-stream, shallow wells that have been designated as the representative monitoring wells for depletion of interconnected surface waters. The selected representative monitoring network is a subset of all wells currently monitored in the Subbasin. The representative monitoring wells have been selected because they have a period of record that supports analysis required to develop measurable objectives and minimum thresholds for this sustainability indicator, and whose locations are representative of surrounding groundwater levels. The representative monitoring wells will identify groundwater level responses, during the implementation period (2022-2042), to monitor the Subbasin's performance to this sustainability indicator. **Table 4-5** and **Figure 4-4** identify the monitoring wells by each interconnected surface water management zone. As shown in **Figure 4-5**, these 17 wells have been spatially distributed to provide adequate coverage of major interconnected surface water bodies. The representative monitoring network for depletion of interconnected surface waters is divided into five groups, corresponding to the Interconnected Surface Waters Management Zones described in the Undesirable Results section.

4.8.2 Rationale

As described in **Section 2.2.6 – Interconnected Surface Water Systems**, groundwater levels at near-stream, shallow monitoring wells will be used as a proxy for the depletion of interconnected surface waters. *Addressing Regional Surface Water Depletions in California* (EDF 2018)[60], describes the rationale behind this approach, and provides recommendations for selecting representative wells. Based on Darcy's Law, "…the exchange of water between an aquifer and hydraulically connected surface waters is determined by the gradient across the boundary between the stream and the aquifer" (EDF 2018). Managing and monitoring this gradient allows for the management of the depletion of interconnected surface waters caused by groundwater extraction. Under this approach, the ideal monitoring location is at an intermediate distance from the stream, outside the direct influence of river stage and between the stream and the area of extensive groundwater development.

[60] https://www.edf.org/sites/default/files/documents/edf_california_sgma_surface_water.pdf

Wells were selected with the above approach in mind, according to the following criteria:

- A period of record that supports analysis required to develop measurable objectives and minimum thresholds for this sustainability indicator.
- Screened within, or close to, the shallow aquifer as defined in the hydrogeologic conceptual model. Wells shallower than 220 feet were preferred, with the deepest selected well drilled to a depth of 350 feet. Water levels at wells within the top portion of the intermediate zone are still considered to affect surface water bodies because both the shallow and intermediate zones are largely alluvial and there is no evidence showing a confining layer between the two zones.
- At locations representative of the hydraulic gradient between interconnected surface water bodies and the center of pumping, as described by EDF (2018).
- Wells with a historical variation in water levels of greater than 10 feet, and ideally a range of 50 feet or more. This ensures that the water levels at the RMW are not dominated by the influence of river stage.

Only a small subset of active monitoring wells in the Subbasin were selected as RMWs for monitoring depletion of interconnected surface waters. The many active monitoring wells not selected will continue to be monitored to ensure a robust collection of data and thorough analysis of groundwater conditions in the Subbasin.

Streamflow monitoring within interconnected surface water bodies will continue. Streamflow gages are maintained and monitored by several agencies, summarized in **Table 4-4**. While sustainable management criteria are not directly linked to this data, the YSGA will compile this data on an annual basis. Any observed changes in streamflow will be compared to known changes in surface water management and observed changes in groundwater levels. If consistent correlation between streamflow and groundwater levels is observed, these streamflow sites may be incorporated as representative sites or used to revise existing sustainable management criteria. Proximity to stream gages will be prioritized when siting additional shallow monitoring wells.

Table 4-4 Selected Stream Gages in the Yolo Subbasin.

Cache Creek			
Name	*Operator*	*Site Code**	*Type*
Cache Creek at Yolo	USGS	CCY	Stage and Flow
Cache Creek at Rumsey Bridge	USGS/DWR	RUM	Stage and Flow
Putah Creek			
Name	*Operator*	*Site Code**	*Type*
Headworks	SCWA		Flow
I-505	SCWA		Stage and Flow
I-80	SCWA		Flow
Pedrick Rd.	SCWA		Stage and Flow
Stevenson Bridge	SCWA		Stage and Flow
Mace Blvd	SCWA		Stage and Flow
University Spill	SCWA		Stage and Flow
Putah C Nr Winters	USGS	11454000	Stage and Flow
Putah South Cn Nr Winters	USGS	11454210	Stage and Flow
Putah Creek	DWR NCRO	PTC	Stage and Flow
Putah Creek	SCWA	PTF	Flow
Sacramento River			
Name	*Operator*	*Site Code**	*Type*
Sacramento R A Sherwood Harbor Nr W Sacramento	USGS	383155121314101	Stage and Flow
Delta Rmp Sacr-015	USGS	383205121310901	Stage and Flow
Sacramento R A Freeport	USGS	11447650	Stage and Flow
Sacramento R A Sherwood Harbor Nr W Sacramento	USGS	383155121314101	Stage and Flow
Byron Jackson Pumps	Sutter County	BJP	Stage and Flow
Sacramento River at I Street Bridge	DWR NCRO	IST	Stage and Flow
Sacramento River at Freeport	USGS	FPT	Stage and Flow
Sacramento R at Fremont Weir (Crest 32.0')	DWR NCRO	FRE	Stage and Flow
Sacramento River at Verona	USGS/DWR	VON	Stage and Flow
Sacramento River at Freeport Aux	USGS	FPX	Stage and Flow
Deep Water Ship Channel			
Name	*Operator*	*Site Code**	*Type*
Sacramento R Deep Water Ship Channel Nr Clarksburg	USGS	11455136	Stage and Flow
Sacramento R Deep Water Ship Channel Nr Freeport	USGS	11455095	Stage and Flow

Notes: * 3-letter site codes correspond to data on CDEC (cdec.water.ca.gov); numerical site codes correspond to data on USGS's NWIS (waterdata.usgs.gov/nwis)

Table 4-5. Yolo Subbasin Depletion of Interconnected Surface Waters Monitoring Wells.

Interconnected Surface Water Management Zone	YSGA Representative Well Number	State Well Number
Upper Cache Creek	287	11N03W23L001M
	289	11N03W33F001M
	293	12N03W20D001M
Lower Cache Creek	265	10N01W21J001M
	424	10N01W23P001M
	420	10N02E03R002M
	425	10N01E22H500M
	275	10N02W14A001M
Upper Sacramento River	420	10N02E03R002M
	427	12N01E03R003M
	421	11N02E20K004M
Lower Sacramento River	401	10N02E36E001M
	151	09N03E33B002M
	428	08N04E19N001M
Putah Creek	170	08N02E18M002M
	429	08N01E17F001M
	229	08N01W20R005M

As appropriate, representative monitoring sites may be modified in the future to reflect:

- Improved understanding of the groundwater conditions and/or the connection between surface water and groundwater
- Changes in land use conditions that warrant an increase or decrease in the spatial distribution of monitoring wells
- Changed conditions at the monitoring site (including well access)
- Establishment of nearby and equally-representative dedicated monitoring wells

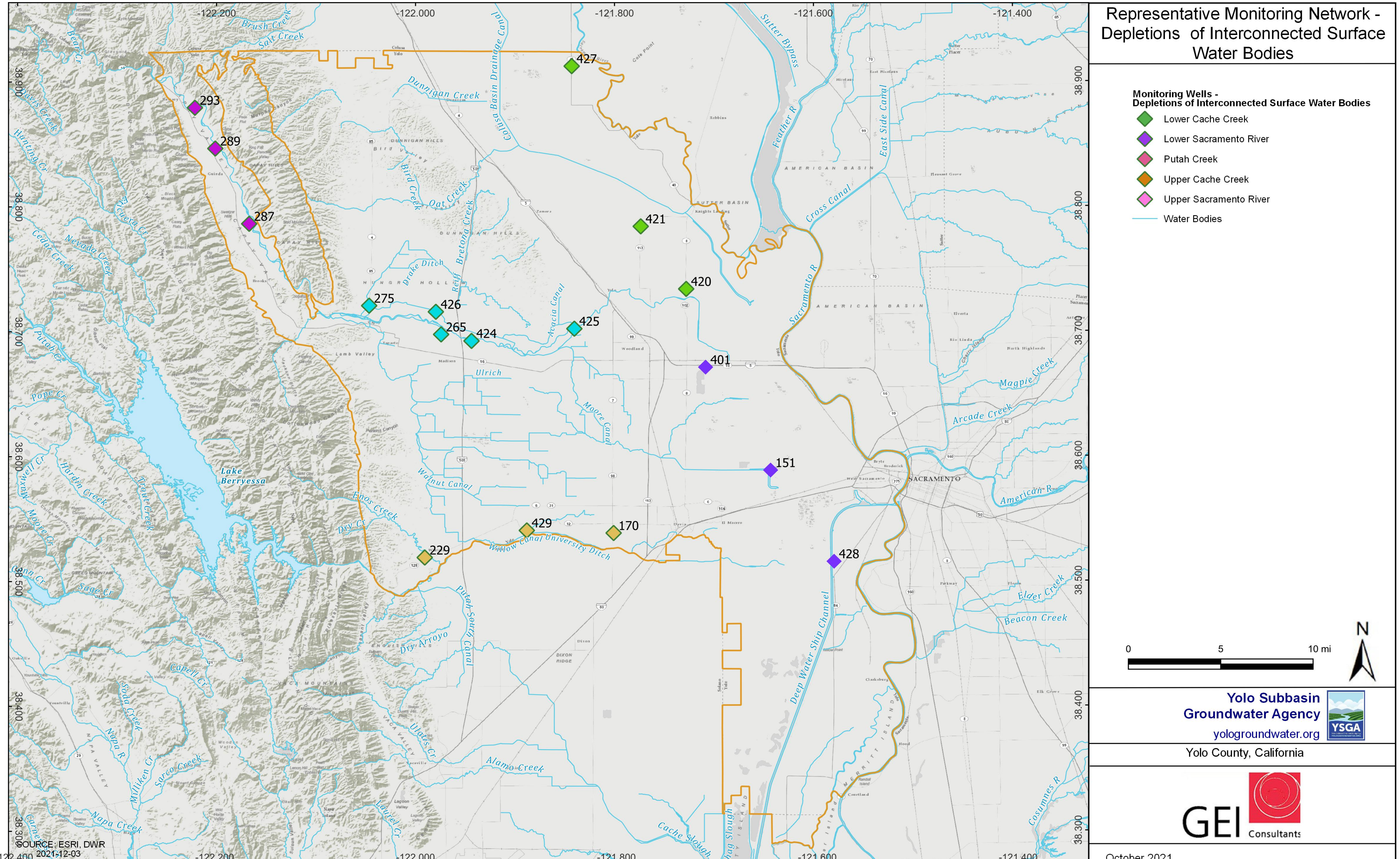

Figure 4-5. Yolo Subbasin Interconnected Surface Water Representative Monitoring Wells.

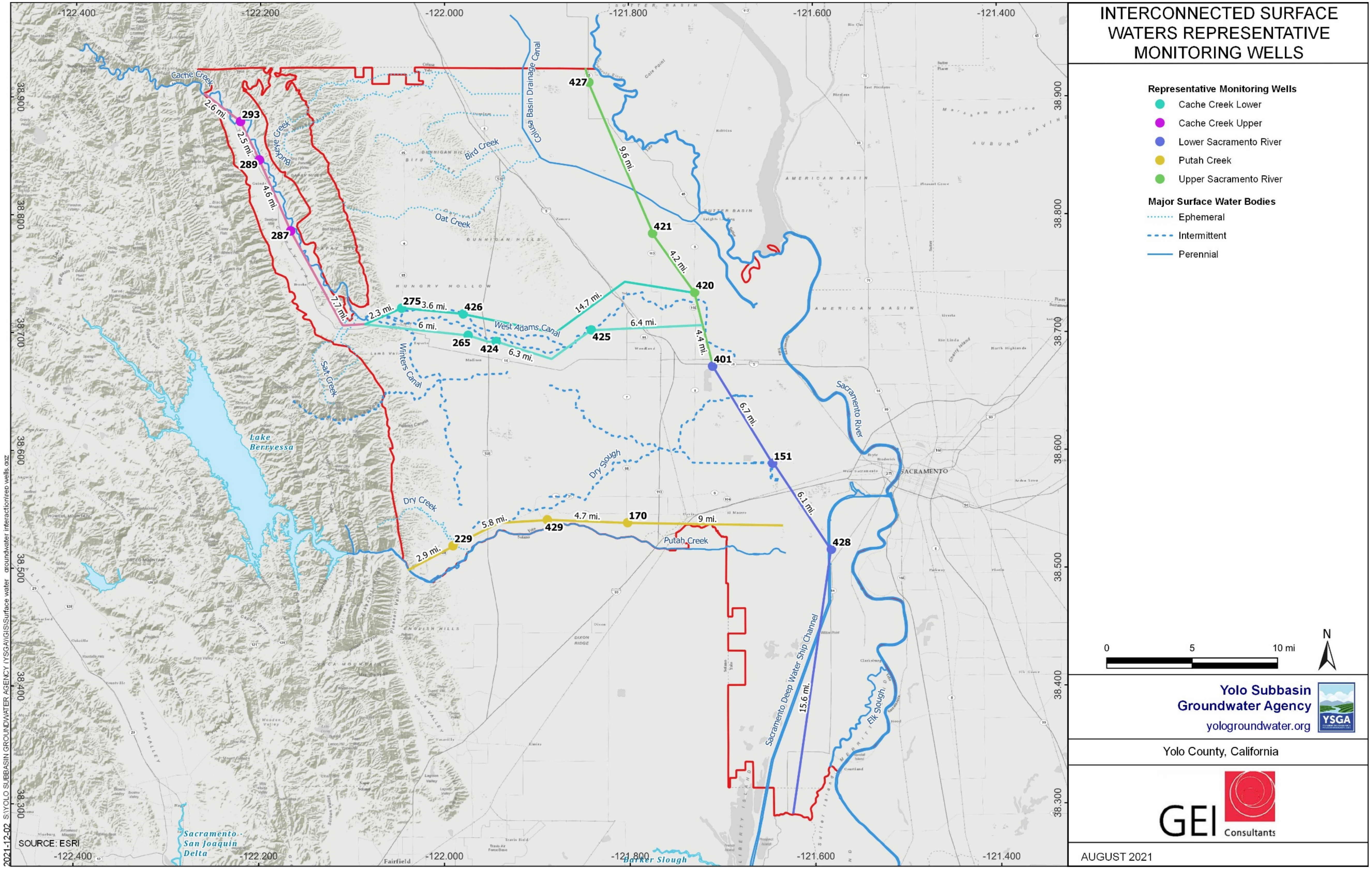

Figure 4-6. Distribution of Yolo Subbasin Interconnected Surface Water Representative Monitoring Wells.

4.8.3 Monitoring Frequency

The monitoring of groundwater levels for the depletion of interconnected surface waters will follow the same protocols and monitoring frequency outlined in **Section 4.4.3 – Monitoring Frequency**. Semi-annual measurements in spring and fall are intended to capture the full seasonal variation of groundwater levels, and therefore capture seasonal variation in surface water depletion. This frequency of monitoring is sufficient to demonstrate seasonal, short-term (1-5 years), and long-term (5-10 years) trends in groundwater levels, and by proxy, depletion of interconnected surface waters and yield representative information about groundwater conditions as necessary to evaluate plan implementation.

4.8.4 Spatial Density

Representative monitoring wells were selected to produce a good spatial distribution along major interconnected surface water bodies, ideally one well for every 4 to 6 miles along the stream (*see*: *Addressing Regional Surface Water Depletions in California*, EDF 2018). The representative monitoring network is designed around this methodology.

4.8.5 Data Gaps

The ephemeral streams in the Dunnigan Hills area, namely Oat Creek, Bird Creek, Dunnigan Creek, Buckeye Creek, and Little Buckeye Creek, are not well described. There is high uncertainty about when the streams are flowing, the groundwater levels and aquifer properties in the area, and how the streams may or may not be connected to groundwater. The YSGA will seek to add additional monitoring wells in the area and increase understanding of aquifer properties, surface water flow regimes, and potential groundwater-surface water interaction.

Due to a lack of significant groundwater development in the southern region of the Subbasin, coincident with the Clarksburg MA, the area is considered a monitoring area for depletion of interconnected surface waters. In the event that land use changes occur or groundwater production increases in a manner that will affect local groundwater conditions, new monitoring wells will be sited in this MA.

4.9 Monitoring Protocols and Reporting Standards

The YSGA has established monitoring protocols for collection of groundwater levels for the chronic lowering of groundwater, reduction in groundwater storage, and depletion of interconnected surface water. Separate protocols have been established for subsidence monitoring. Protocols for water quality samples will follow the protocols that have been established for the monitoring program that monitoring will occur, such as the State Water Board's DDW, Drinking Water Program; Yolo County's Environmental Health Division, Drinking Water Program; IRLP; and CV-SALTS.

4.9.1 Groundwater Level Monitoring Network Protocol and Standards

The monitoring network in the YSGA includes production wells, abandoned or unused production wells, and dedicated monitoring wells. Until enough dedicated monitoring wells are installed to fill data gaps, production wells will be used to provide the desired spatial coverage within the Subbasin.

As referenced in § 352.4 of the GSP emergency regulations, monitoring sites/wells will conform to a Best Management Practice (BMP) for geographic locations, identification, and details on well construction. **Table 4-6** provides the requested standards.

Table 4-6. DWR Standards for Required Monitoring Well Information.

	§ 352.4 Standards for Required Monitoring Well Information
Well Identification	Use the CASGEM well identification number. If a CASGEM well identification number has not been issued, appropriate well information shall be entered on forms made available by the DWR.
Well / Site Location	Geographic locations shall be reported in GPS coordinates by latitude and longitude in decimal degree to five decimal places, to a minimum accuracy of 30 feet, relative to NAD83, or another national standard that is convertible to NAD83. Reference point elevations shall be measured and reported in feet to an accuracy of at least 0.5 feet, or the best available information, relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described.
Well Type and Construction Details	A description of the well use/type, whether the well is active or inactive, and whether the well is a single, clustered, nested, or other type of well. Casing perforations, borehole depth, and total well depth shall be reported. WCRs will be provided, if available, from which the names of private owners have been redacted. Geophysical logs, well construction diagrams, or other relevant information will be provided, if available, including any other relevant well construction information, such as well capacity, casing diameter, or casing modifications.
Monitoring Zone	Identification of principal aquifer or aquifer zones monitored.

4.9.1.1 Monitoring Protocols

As referenced in §352.4 of the Emergency Regulations, "…monitoring protocols shall be developed according to BMPs. Monitoring protocols shall be reviewed at least every 5 years as part of the periodic evaluation of the Plan and modified as necessary."

As discussed in DWR's *Monitoring Protocols, Standards, and Sites BMP* (Monitoring Protocols BMP)[61]:

- All groundwater levels in a basin will be collected within as short a time as possible, preferably within a 1- to 2o-week period.

[61] https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/BMP-1-Monitoring-Protocols-Standards-and-Sites_ay_19.pdf

- Depth to groundwater will be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement will measure the depth to groundwater from the north side of the top of the well casing.
- The sampler will remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement will follow a period of time to allow the water level to equilibrate.
- Field measurements of depth to groundwater and land surface will be measured and reported in feet to an accuracy of at least 0.1 feet relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described (i.e., electric sounder, steel tape, plopper, transducer, acoustic sounder, or airline).
- The water level meter will be decontaminated after measuring each well.
- To assure that the same well is being measured each time, the YSGA will apply an outdoor-rated label to the well, including the SWN and contact information for the YSGA.
- The sampler will replace any well caps or plugs and lock any well buildings or covers.
- All data will be entered into the YSGA DMS (the WRID) as soon as possible. Care will be taken to avoid data entry mistakes and the entries will be checked by a second person for compliance with the data quality objectives.

4.9.1.2 Pressure Transducers

As per DWR's Monitoring Protocols BMP, groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers (or real-time telemetry) installed in monitoring wells. When installing pressure transducers, care will be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols will be followed when installing a pressure transducer in a monitoring well:

- The sampler will use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation.
- The sampler will note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers will be able to record groundwater levels with an accuracy of at least 0.1 foot. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers will be included in the evaluation.

- The sampler will note whether the pressure transducer uses a vented or non- vented cable for barometric compensation. Vented cables are preferred, but non- vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that data quality objectives are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.

The transducer data will periodically be checked against hand-measured groundwater levels to monitor electronic drift or cable movement. This will happen during routine site visits, at least annually or as necessary to maintain data integrity. The verification measurement will be recorded in the telemetry system and an offset will be applied, if needed.

The data will be downloaded as necessary to ensure no data is lost and entered into the YSGA's DMS following the Quality Assurance/Quality Control process described above. Data collected with non-vented data logger cables will be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data will be deleted from the data logger to ensure that adequate data logger memory remains. This step is not necessary for real-time telemetry connected transducers.

As mentioned above, for specific details regarding the monitoring network for groundwater level and change in groundwater storage for each MA, *please refer to* the respective individual sections. The data gaps and steps for improvement of the respective monitoring networks have also been identified in those sections.

4.9.2 Water Quality Monitoring Network Protocol and Standards

Water quality monitoring will be reliant on existing water quality monitoring programs for drinking water and irrigated lands. The existing programs in the Subbasin, include:

- State Water Board DDW, Drinking Water Program
- Yolo County Environmental Health Division, Drinking Water Program
- Irrigated Lands Regulatory Program
- CV-SALTS
- Other monitoring programs that may be implemented in the future

Data collection and analysis will continue to be the responsibility of the entities listed above. The YSGA will collect and review data from these entities to ensure that groundwater quality is not being affected by changes in groundwater management activities. The YSGA's annual review of water quality monitoring data and interpretation of linkages to groundwater management activities will be included as a component of it's the Annual Report to DWR and available for review by stakeholders.

To the extent possible the YSGA will coordinate with these existing water quality monitoring programs to include protocols and standards required in the GSP emergency regulations § 352.4 and the USGS *National Field Manual for the Collection of Water Quality Data* and DWR's *Groundwater Monitoring Protocols, Standards, and Sites BMP* (2016).

Groundwater quality sampling protocols will ensure that:

- Groundwater quality data are taken from the correct location
- Groundwater quality data are accurate and reproducible
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the data quality objectives
- All important information is recorded to normalize, if necessary, and compare data
- Data are handled in a way that ensures data integrity

4.9.3 Land Subsidence Monitoring Network Protocols

Per DWR's Monitoring Protocols BMP, various standards and guidance documents for collecting data include:

- Leveling surveys will follow surveying standards set out in the California Department of Transportation, *Caltrans Surveys Manual (2018).*
- GPS surveys will follow surveying standards set out in the California Department of Transportation, *Caltrans Surveys Manual (2018).*
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and will be utilized to the extent possible and where available: http://ca.water.usgs.gov/land_subsidence/california-subsidence- measuring.html
- Instruments installed in borehole extensometers will follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

4.10 Data Reporting

All collected groundwater data for Representative Monitoring Wells will either be reported to DWR's SGMA Portal or stored in the DMS developed for the Subbasin (WRID), or both. All elevation data will be in coordinate datum NAVD88. All measurement locations are geographically referenced.

The data will be analyzed and reported in annual reports and shared with stakeholders. The data will be used to provide annual updates and to support revisions to the groundwater model. Groundwater level data can be viewed real-time by stakeholders at https://sgma.yologroundwater.org/.

4.11 Monitoring Network Improvement Plan

4.11.1 Data Gaps

The following areas are the primary data gaps that have been identified in the development of the Yolo Subbasin GSP: 1) groundwater levels and storage, 2) subsidence, 3) interconnected surface waters, and 4) groundwater dependent ecosystems.

Data gaps exist for the groundwater levels in the Dunnigan Hills, South Yolo, and Clarksburg MAs, and west of the city of Winters.

Data gaps exist related to interconnected surface waters. These data gaps exist mainly on smaller tributaries and unlined canals, or in the areas that have limited groundwater levels data described above.

Additionally, it is recognized that managed wetlands are an important part of groundwater sustainability in the Yolo Subbasin. Accurate characterization of managed wetlands is currently identified as a data gap. According to the DWR's 2016 Statewide Crop Mapping, there are approximately 31,000 acres of managed wetlands within the Subbasin[62]. This includes areas such as the Yolo Bypass Wildlife Area, the Davis Demonstration Wetlands, Cache Creek Conservancy, and waterfowl habitat in the North Yolo MA.

GDEs are described in the **Section 2 – Basin Setting**. Verification, classification, and ground truthing of these GDEs is considered a data gap and will be improved with the best available data.

Determining the cause of any existing subsidence and extent of subsidence caused by groundwater is also identified as a data gap. A plan to address each of these data gaps has been developed and is detailed in the following section

4.11.2 Plan to Address Data Gaps

Improving the monitoring network will be an important area of focus within the Yolo Subbasin. The primary focus of monitoring network improvements will be on data gaps identified throughout this GSP. Specific projects that are dedicated to improving the monitoring network have been identified and are described in **Section 5 – Proposed Actions, Description, and Timeline to Address Data Gaps**. In general, the focus of monitoring network improvements will be on:

[62] https://data.cnra.ca.gov/dataset/crop-mapping-2016

- groundwater monitoring program improvements
- subsidence monitoring improvements
- surface water monitoring program improvements
- additional monitoring efforts near interconnected surface waters and GDEs
- Data gaps related to the hydrogeologic conceptual model

When identifying new representative monitoring wells in data gap areas, proximity to disadvantaged communities, domestic wells, Tribes, and GDEs will be prioritized.

4.11.2.1 Groundwater Levels Monitoring Network

Groundwater monitoring improvements are planned in areas identified as data gaps, areas of increasing development, and areas with low monitoring well density. This includes the Dunnigan Hills MA (data gap), the area surrounding the city of Winters (increasing development), and the South Yolo and Clarksburg MAs (low monitoring density).

To improve groundwater levels data in the Dunnigan Hills MA, several opportunities have been identified. Obtaining and digitizing existing monitoring data from wells in the Dunnigan Water District network would be beneficial. These wells are located along the northwest edge of the North Yolo MA and have long periods of record but aren't currently available digitally. This will also provide additional groundwater level data along Buckeye, Dunnigan, and Bird creeks.

Additional wells have been identified in Dunnigan Hills MA for the YSGA to consider incorporating into the monitoring network. Several existing wells have been identified with the landowners expressing interest in joining the monitoring program. Two wells north of Hungry Hollow, two wells west of Hungry Hollow, and several wells along Oat Creek have been identified that could be incorporated into the monitoring program. These wells do not have long periods of record but are beneficial for understanding current conditions and providing a baseline in case of future change. To incorporate these wells into the monitoring program, construction information may need to be obtained. The construction of dedicated monitoring wells may be considered in the Dunnigan Hills MA, depending on the well density that can be achieved with existing wells. Wells exist at the northern border of the Dunnigan Hills MA, at the southern border of the Colusa Subbasin; however, individual monitoring wells have not yet been identified in this area and will be considered moving forward. These additional wells at the Colusa boundary in the Dunnigan Hills would improve the understanding of boundary conditions and the classification of Buckeye Creek.

The Dunnigan Hills MA largely lacks baseline historical groundwater level measurements, making it difficult to evaluate current conditions. The YSGA will analyze historic water level measurements provided in the DWR's digitized WCR database[63]. The County of Yolo maintains a similar database of completed well permits and has recently added a field for static water level. Ongoing coordination

[63] https://data.cnra.ca.gov/dataset/well-completion-reports

with the County, and use of the WCR dataset, will allow the YSGA to gather one-time information about water levels in data gap areas and areas of rapid development.

In the area surrounding the city of Winters, existing monitoring wells have been identified. Wells with monitoring data exist northwest of the city of Winters at the wastewater treatment facility and at the landfill location northwest of Winters. An additional well west of Winters has been identified with data starting in 2000 and continuing to present. This well will be incorporated into the overall monitoring program, although designation as a SGMA Representative Monitoring Well still needs evaluation.

There are some wells in the Subbasin that have long-term depth to water measurements but are no longer monitored. Some of these wells could be monitored, but currently are not. Others are no longer able to be monitored due to obstructions, access issues, or a number of other reasons. The YSGA will attempt to identify wells with long-term data sets that can begin to be monitored again. Wells that can no longer be monitored and have long-term datasets will also be identified. For these wells that can no longer be monitored, the plan is to identify new monitoring wells that are near the old wells. Ideally, these newer wells will have similar well construction and will exhibit similar hydrology of the initial wells. Data will be recorded for these new wells, and a connection between the initial well and the new well will be evaluated. If the new well and the old well exhibit the same hydrology, the YSGA will consider establishing minimum thresholds and measurable objectives for these newer wells using a combination of the newly collected data and the data from the nearby historic well.

In the South Yolo MA and Clarksburg Monitoring Area, there are wells that have some historical measurements and can be seen on the SGMA data viewer. Some of these wells have long term data records, but recently stopped being monitored. These wells will be evaluated, and if possible, incorporated into the monitoring network. In order to incorporate these wells into the monitoring network, it will likely be necessary to communicate with the original monitoring entity to determine the reason that the well was dropped from their monitoring program.

In addition, the YSGA has recently installed a real-time sensor near the Cacheville Community Services District to provide additional water supply security for the Cacheville Community Services District since it is solely groundwater dependent. Improvements to the existing monitoring network will ensure the preservation of long data records and the ability to continue monitoring wells into the future. These improvements include (1) obtaining up-to-date contact information for all sites, (2) labeling of wells within the YSGA monitoring network to provide clear identification, and (3) establishing formal monitoring and/or access agreements with landowners and cooperating agencies to document access and data sharing procedures. These efforts are already underway and will continue into the future to maintain the robust, long-term monitoring of the Subbasin.

4.11.2.2 Well Construction Information Improvements

Some wells that are currently in the monitoring network lack known casing perforations, borehole depths, or total well depths. This information can be important to understand and manage groundwater in the basin, especially in areas where the alluvium is shallow. Efforts will be made to obtain well construction information for wells which do not have known casing perforations, borehole depths, or total well depths. These efforts may include videologging and a deeper investigation of existing WCRs.

4.11.2.3 Subsidence Monitoring Network

As InSAR data is published, it will be evaluated by the YSGA. Additionally, when DWR repeats their benchmark surveys, the results will be evaluated by the YSGA. Continuous GPS stations or extensometers are being evaluated to allow near real-time monitoring of subsidence, specifically in the North Yolo MA.

The YSGA will monitor impacts as a result of subsidence by creating and implementing a publicly accessible method of reporting subsidence impacts. In addition, creating an inventory of areas that are most susceptible to subsidence is a proposed project that would improve the subsidence monitoring network.

Subsidence in the Capay Valley is considered a data gap. InSAR data exists in Capay Valley. To improve the understanding of subsidence in the Capay Valley, when future GPS-based surveys are planned, the Capay Valley will be included.

4.11.2.4 Surface Water, Interconnected Surface Water, and Groundwater Dependent Ecosystem Monitoring Network

Improvements to the characterization of surface water bodies in the Yolo Subbasin can be made by improving monitoring of groundwater levels and surface water flows in areas with limited data. Additional streamflow gage(s) on Cache Creek may improve the quantification and timing of exchange with groundwater. In coordination with the Solano Subbasin, additional shallow, near-stream nested monitoring wells may be installed along Putah Creek. Characterization of surface water connection and GDE status of and near smaller creeks, sloughs, and canals may be improved with additional surface water monitoring and groundwater monitoring. Potential options to improve interconnected surface waters and classification of GDEs include seepage measurements, nested piezometers, and incorporation and analysis of existing streamflow gages.

GDEs in the Yolo Subbasin may be refined and characterized through a verification process that would include coordination with local entities, surveys, and additional field work. A process for monitoring wetland, aquatic, and vegetative GDE presence and health on an annual and inter-annual basis is being considered. This process would include utilization of TNC's GDE Pulse[64] and Point Blue's Water Tracker[65].

The YSGA water budget currently contains a data gap surrounding the consideration of managed wetlands. To ensure accurate representation of managed wetlands moving forward, additional analysis and coordination will occur. Wetland extent in a given year can be calculated using Point Blue's Water Tracker and a modified methodology from Ducks Unlimited's Seasonal and Permanent

[64] https://gde.codefornature.org/
[65] https://data.pointblue.org/apps/autowater/

Wetlands dataset (Petrik et.al. 2013). Audubon is developing a statewide managed wetlands dataset, which will be incorporated to improve the water budget's estimate of managed wetland acreage. The YSGA will coordinate with the managers of these wetlands to improve the modeled historical and projected water demand of managed wetlands.

Improving the understanding of groundwater surface water interaction along Cache Creek can be accomplished by utilizing stream flow gauges and nearby wells. Nearby monitoring wells exist, and data is regularly collected for the aggregate mining companies that exist along Cache Creek. The long-term records were obtained by the YSGA, state well numbers were assigned, and the data was entered into the WRID. There may be existing biological data that can be coupled with this water level data to improve the understanding and evaluate Minimum Thresholds and Measurable Objectives based on GDE and Interconnected Surface Water conditions observed historically. Additionally, communication with the Cache Creek TAC and utilization of the data collected and displayed on the Cache Creek Management Data website[66] would be beneficial for groundwater dependent ecosystems.

YCFC&WCD is working with the Solano County Water Agency, utilizing TSS funds from DWR, to install shallow monitoring wells on the north and south sides of Putah Creek. The shallow monitoring wells on the Solano side of Putah Creek should be drilled by the end of 2023.

4.11.2.5 Hydrogeologic Conceptual Model Data Gaps

Data gaps exist relating to aquifer characteristics and the bfw in the Yolo Subbasin. Reviewing upcoming and recent studies may yield beneficial information about the bfw. Airborne electromagnetic (AEM) surveys will also be utilized to improve the aquifer characteristics in the Yolo Subbasin.

4.11.2.6 Water Quality Data Gaps

Monitoring of domestic wells for water quality are currently considered a data gap. The ILRP program will be beneficial in addressing this data gap. Additionally, analysis of one-time water quality measurements on domestic wells is required by the County. This data may be useful for identifying trends in groundwater quality in the Yolo Subbasin. Additionally, the YSGA will work with the County to encourage implementation of a one-time required TDS test on all new wells.

[66] https://flowwest.shinyapps.io/cache-creek

4.11.3 Proposed Actions, Description, and Timeline to Address Data Gaps

Table 4-7 shows the potential actions that can be taken to address the known data gaps in the Yolo Subbasin.

Table 4-7. Proposed Actions and Timeline to Address Data Gaps.

Action Number	Data Gap Focus	Description	Affected Area	Timeline
1	Groundwater Monitoring	Obtain and digitize existing monitoring data from DWD	Dunnigan Hills	Within 5 years
2	Groundwater Monitoring	Incorporate existing wells into monitoring program	Dunnigan Hills, Hungry Hollow, Winters	Ongoing; completed within 5 years
3	Groundwater Monitoring	Outreach to expand voluntary monitoring program in data gap areas	All	Ongoing
4	Groundwater Monitoring	Utilize existing well completion databases to establish baseline groundwater levels	All	Within 5 years
5	Groundwater Monitoring	Continue monitoring of long-term monitoring wells with recent end to monitoring	Subbasin-wide- especially in South Yolo/Clarksburg	Ongoing, completed within 5 years
6	Groundwater Monitoring	Installation of additional real-time monitoring units	Yolo/Zamora	Ongoing
7	Groundwater Monitoring	Improvements to site access and well information for existing monitoring network	All	Ongoing
8	Groundwater Monitoring	Construction of additional monitoring wells	Interconnected Surface Waters, GDEs, Dunnigan Hills, data gaps	Ongoing, starting within 5 years
9	Groundwater Monitoring	Concentrated effort to link existing WCRs to current monitoring network	Subbasin-wide	Within 5 years
10	Groundwater Monitoring	Videologging of existing monitoring wells lacking screen intervals	Subbasin-wide	TBD
11	Subsidence Monitoring	Installation of continuous GPS stations or extensomenters	TBD	TBD
12	Subsidence Monitoring	Design and implemement accessible reporting of subsidence impacts	Subbasin-wide	Within 5 years
13	Subsidence Monitoring	Inventory areas most susceptible to subsidence	Subbasin-wide	TBD
14	Subsidence Monitoring	GPS-based surveys in the Capay Valley	Subbasin-wide/Capay Valley	Within 5 years
15	Surface Water & GDE	Additional streamflow gage(s) along Cache Creek	Cache Creek	Within 10 years

Action Number	Data Gap Focus	Description	Affected Area	Timeline
16	Surface Water & GDE	Additional shallow, nested monitoring wells along Putah Creek	Putah Creek	Within 5 years
17	Surface Water & GDE	Improve characterization of surface water and GDE status near smaller creeks, sloughs, and canals	Basinwide	Ongoing
18	Surface Water & GDE	Potential options to improve interconnected surface waters and classification of GDEs include seepage measurements, nested piezometers, and incorporation and analysis of existing streamflow gages.	Interconnected Surface Waters & GDEs	Ongoing
19	Surface Water & GDE	Refine and verify GDE dataset through coordination with local entities, surveys, and field work	Subbasin-wide	Ongoing
20	Surface Water & GDE	Develop and implement process for monitoring wetland, aquatic, and vegetative GDE presence and health	Subbasin-wide	TBD
21	Surface Water & GDE	Correct modeling of managed wetland acreage and water demands	Subbasin-wide	Within 5 years
22	HCM	Review upcoming and recent studies on base of freshwater	Subbasin-wide, North Yolo Management Area	Within 5 years
23	HCM	AEM surveys	Data Gaps, Capay Valley, Hungry Hollow, Western Edge	Within 5 years

5.0 Projects and Management Actions

This section describes projects and management actions proposed by the YSGA and its member agencies to meet the sustainability goal for the Yolo Subbasin. The projects and management actions presented here represent the best available engineering and analysis completed to-date. This list will be updated throughout the planning and implementation period (2022 to 2042) to reflect additional analyses and new and emerging opportunities.

As described in the Subbasin water budget in **Section 2.3 – Water Budget Information**, the Subbasin has an estimated Sustainable Yield of 346 TAF annually. Groundwater pumping under Subbasin future scenarios to support urban and agricultural demands and to maintain surface water – groundwater interactions at their current level are as follows:

- Future baseline 320 TAF
- Future 2030 337 TAF
- Future 2070 358 TAF
- Future 2070 DEW 400 TAF
- Future 2070 WMW 325 TAF

Based on the water budget information, the Subbasin will exceed its sustainable yield only in the Future 2070 and Future 2070 DEW scenarios. In all other scenarios the Subbasin will maintain a relative groundwater balance. However, the YSGA and its member agencies have identified a list of projects and management actions for implementation that will ensure that the Subbasin's groundwater resources and its beneficial users will not suffer undesirable results.

Throughout the remainder of this GSP, projects and management actions are referred to collectively as "management actions."

5.1 Management Actions Processes

The following sections describe the processes required for management actions to be implemented, the sustainability indicator addressed and overview of the expected benefits. A summary list of all management actions being considered by the YSGA are provided in **Table 5-1** and the detail related to the following management action information is presented in **Appendix J – Table of Projects and Management Actions**.

5.1.1 Goals and Objectives

Per Section 354.44 of DWR's GSP emergency regulations, GSPs are to include management actions to address any existing or potential undesirable results for the identified relevant sustainability indicators. The YSGA and its member agencies plan to implement management actions to protect against violating the minimum thresholds of the following sustainability indicators: (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) degraded water quality, (4) impacts to surface water – groundwater connections, and (5) land subsidence. **Table 5**-1 indicates the sustainability indicators that may be addressed by the proposed management actions.

5.1.2 Circumstances for Implementation

Management actions will be implemented as determined by the YSGA or its member agencies and certain management actions may be implemented as soon as 2022 following the adoption of this GSP. **Table 5-1** provides an estimated timeline for implementation of each management action and the circumstances for implementing.

5.1.3 Public Noticing

The public notice and outreach processes for the YSGA and its member agencies include public board meetings and the California Environmental Quality Act (CEQA) process each management action is required to undergo before implementation. The YSGA and its member agencies provide public noticing by publicly posting all board meeting notices, agendas, and minutes in accordance with Brown Act requirements. All projects funded or considered for implementation by the YSGA will be posted under a 'Projects' page on the yologroundwater.org website. The YSGA is committed to an open and transparent process in identifying and implementing projects and management actions.

5.1.4 Permitting and Regulatory Process

Permitting and regulatory requirements vary for the different management actions. Specific requirements will depend on the type of project, which could be recharge and infrastructure projects as well as administrative actions that improve data collection and analysis. The following is a list of the types of permitting at the federal, state, and county level that could apply, but not necessarily, to all management actions.

- Federal
  - If federal grants are used, National Environmental Policy Act documentation is required
  - National Pollution Discharge Elimination System stormwater program permit
- State
  - CEQA documentation may be required prior to implementation of some of the management actions. These documents include one or more of the following: Notice of Exemption, Initial Study, Negative Declaration, Mitigated Negative Declaration, and Environmental Impact Report
- Regional

    - Yolo-Solano Air Quality Management District permit and regulations
- Local/County
    - Encroachment Permits
    - Yolo County Grading Permit
    - Yolo County Well Permit

5.1.5 Implementation Timetable and Status

The current status of each management action is included in **Appendix J – Table of Projects and Management Actions**. Since most management actions are in the conceptual phase of development, the timelines for permitting and regulatory process requirements and other particulars are estimated and subject to change. The implementation of the proposed projects and management actions identified in **Table 5-1** will be done through an adaptive management process. Ultimately the YSGA will work its member agencies to manage the groundwater basin to avoid undesirable results, as described in the previous sections.

The status of each management action is also provided in **Appendix J – Table of Projects and Management Actions**. Each management action is designated as follows:

Conceptual: The management action is identified but has not undergone significant planning, engineer or feasibility analyses.

Not yet started: This management action as undergone some initial evaluations but has advanced to an implementation phase. The management action will likely require additional feasibility analyses.

Initiated: The management action has undergone initial planning and feasibility assessments and being advanced to implementation.

Ongoing: The management action is part of an ongoing effort and will continue to be implemented to meet the sustainability goals of the YSGA.

5.1.6 Expected Benefits

Table 5-1 provides the estimated benefits for each management. As previously stated, most of the proposed actions are in their conceptual phase of development; therefore, a range has been provided for the estimated benefits each action is expected to yield but is subject to change.

5.1.7 Source of Water

Some management actions require that the YSGA or its member agencies bring in supplemental water from outside the Subbasin to support its management actions. While not all management actions require water from outside the Subbasin, there are several that do. Where outside sources of water are required, the source of that water will be identified.

5.1.8 Legal Authority Required

The YSGA is a GSA and has the legal authority to implement projects and management actions in order to achieve groundwater sustainability. Member agencies of the YSGA, who will be leading the implementation of management actions, will do so under the authorities of that agency.

5.1.9 Estimated Costs and Funding

As previously stated, most of the projects are in a conceptual phase of development; therefore, costs may not available. Where costs have been estimated, they are subject to change as the management action undergoes more detailed analysis.

5.2 Management Actions Descriptions

Through the course of the implementation period, 2022 to 2042, the YSGA and its member agencies will implement a variety of management actions to protect groundwater sustainability. These management actions will include capital investment projects to develop additional water supplies to off-set groundwater pumping, a data collection and analysis program to better understand and manage the Subbasin, and improved outreach activities.

Many of the management actions will require additional planning, engineering, and environmental/regulatory analysis before they can be implemented. And the possibility exists that some project will not be feasible to implement. If the identified management actions cannot be implemented, the YSGA will consider additional management actions as needed to protect groundwater sustainability.

5.2.1 Projects and Management Actions

There are existing and on-going projects and management actions that contribute to sustainability in the Yolo Subbasin. Proposed future, existing, and ongoing projects and management actions are described below. **Table 5-1** includes ongoing and proposed projects, with a brief description of the relevant sustainability indicator, status, expected benefits, and ongoing costs. These projects and management actions are proposed by the YSGA for development over the 20-year implementation period. **Appendix J – Table of Projects and Management Actions** contains more detailed information for each of the projects and management actions listed in **Table 5-1**.

Table 5-1. YSGA Projects and Management Actions.

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
MA 1	Continued and Improved Groundwater Monitoring Program	Several groundwater monitoring programs exist within the Yolo Subbasin. Efforts to aggregate these monitoring programs include the Yolo County Water Resources Information Database (WRID) and DWR's Water Data Library. The WRID also receives well water level data from the cooperating agencies, monitoring about 550 wells distributed Countywide semi-annually. Most groundwater level data received or collected in the WRID is submitted to the state's Water Data Library. Existing programs monitor both water quality and water levels. Continuing to monitor groundwater conditions in the Yolo Subbasin is a critical component of a sustainable future. Improvements can be made to the current program by expanding monitoring efforts into data gaps, improving coordination between programs, and ensuring sustainable funding of monitoring efforts.	•	•	•	•
MA 2	Continue coordination efforts with other management and monitoring entities	Coordination efforts are ongoing related to groundwater management and monitoring in the Yolo Subbasin. Continuing these coordination efforts will yield better information and allow for a collaborative and conjunctive decision-making process. This includes evaluation of well permit applications and working with Yolo County in the well permitting process.	•	•	•	•
MA 3	Subsidence Monitoring Program	Continue to investigate subsidence and causes of subsidence in the Yolo Subbasin.			•	
MA 4	Preparedness through Increased Groundwater Recharge and Managed Aquifer Recharge Projects	This project encompasses all efforts to increase groundwater recharge in the Yolo Subbasin. This includes diversion of winter flows for groundwater recharge, increased groundwater infiltration from precipitation, aquifer storage and recovery projects, for example. Increased groundwater recharge efforts and winter diversions may result in creational of seasonal wetlands in some scenarios. YCFC&WCD proposes to divert winter flows from Cache Creek into the canal system to increase groundwater recharge. Groundwater recharge and recovery is central to good conjunctive management of surface and groundwater resources. Currently, by YCFC&WCD policy, 160 miles of surface water canals remain unlined, providing summertime groundwater recharge services that benefit the aquifer and riparian habitat. The recharged groundwater is used by beneficial users in the Subbasin. Utilizing TNC's Multi-Benefit Recharge Project Methodology Guidance Document will help make	•		•	

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
		these projects successful. Managed wetlands within the Subbasin already provide multi-benefit recharge services, and increased coordination with wetland managers will provide opportunity for information sharing and potential managed aquifer recharge projects. Additional methods of groundwater recharge that will be considered include flood water and drain flows in the Yolo Bypass, drain flows in the Colusa Basin Drain, and application of irrigation water in excess of crop evapotranspiration needs.				
MA 5	Conjunctive Water Use Program	This conjunctive water use project envisions using a variety of methods (recharge/recovery, off-stream storage and canal system modernization) to effectively store and conjunctively use groundwater in the District's service area. The new water that will be developed can be used to the benefit of agriculture, environmental and municipal interests. A significant amount of work has already been completed on this project including establishment of a groundwater monitoring program	•			
MA 6	Increased outreach and information sharing of groundwater resources and knowledge within the Yolo Subbasin.	Information sharing, collaboration, and communication will be an important part of groundwater sustainability in the Yolo Subbasin. This project will convey information, best practices, funding opportunities, data, and observations to as wide of a group as possible. This project relates to the Communication and Engagement Plan that the YSGA has created for the Yolo Subbasin.	•	•	•	•
MA 7	Domestic Well Impact Mitigation Program	The YSGA is working to create a domestic well impact mitigation program to mitigate any potential impacts to domestic well users. This program will identify potential funding sources for both temporary and permanent domestic water solutions in cases where domestic well users are impacted due to changing groundwater conditions as a result of groundwater management actions. The minimum thresholds and measurable objectives established in this document are generally protective of domestic well users in the Yolo Subbasin. The Domestic Well Impact Mitigation Program will provide resources and information in cases where management actions result in impacts to domestic well users.	•			
MA 8	Surface Water Monitoring Program	There is no coordinated Countywide surface water monitoring program at present. However, on-going monitoring programs are in-place on various waterways, and a large number of smaller temporary investigations have occurred over the years. These individual surface water monitoring efforts need to be consolidated to improve the value of the data for implementation of actions identified in this GSP.	•	•	•	•

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
MA 9	Management Consideration of Grey Areas in the Yolo Subbasin	During the formation of the GSA for the Yolo Subbasin, the eligible entities were identified based on SGMA's definition. Irrigated areas outside of water or irrigation district service areas were known as "white areas" since they did not have an eligible entity (other than the County) to form or become a GSA. The YSGA was formed in June 2017, with Yolo County serving as a member of the JPA to cover these "white areas". The YSGA now has the authority and responsibility for this area; however, there is still no formal mechanism for receiving revenues for SGMA implementation, which has made these areas slightly complicated, or now known as "grey areas". There is a desire for the YSGA to work closely with landowners in these "grey areas" to assess the best solution for implementing the GSP and ensuring future sustainability. Ideas for these areas include, annexing the property into an existing irrigation or reclamation district (as an "Area B" or an Improvement District); creating or forming a new water district; or simply implementing a county-wide assessment for all properties in the Yolo Subbasin.	•	•	•	•
MA 10	Coordination Efforts with Land Use Planning Entities	The YSGA and member entities will work on an as-needed basis with Yolo County and municipalities within the Yolo Subbasin to promote the sustainable use and protection of groundwater resources including GDEs and interconnected surface water bodies. These coordination efforts will include inputs to general plan updates in the future.	•	•	•	•
MA 11	Continued Investigation of subsurface geology and aquifer properties in the Yolo Subbasin	There are portions of the Yolo Subbasin where the geologic properties of the aquifer are well understood. Alternatively, there are areas where geologic conditions are not well described or understood. This Management Action would work to improve geologic information in areas of the subbasin where the aquifer is poorly described. This includes looking at existing geologic cross-sections, AEM surveys, and investigation of driller's reports.	•	•	•	•
MA 12	Coordinated Response to Minimum Threshold Exceedances	The YSGA will coordinate responses to minimum threshold exceedances. When a single well minimum threshold is exceeded, the YSGA will verify the exceedance, analyze causes and trends, and evaluate mitigation. When multiple wells exceed minimum thresholds, causes and trends will be evaluated by MA entities and potential mitigation actions (projects and management actions) will be identified. When wells exceed the minimum threshold for a MA, causes and trends will be evaluated, potential mitigation actions (projects and management actions) will be evaluated and a plan for implementation will be developed. This will involve basin-wide coordination.	•	•	•	•

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 1	Identification of Locations Vulnerable to Damage from Subsidence - Catalog of Infrastructure Damage Reports	This project would improve the ability to define and quantify the sustainable management criteria for subsidence. Sustainability indicators for subsidence could be better informed if the impacts caused by potential subsidence were catalogued. The sustainable management criteria for subsidence would be improved by identifying infrastructure that would be negatively impacted by subsidence.			•	
P 2	Groundwater Model Enhancement Program/YSGA Model Improvements	To better understand groundwater conditions in the Yolo Subbasin, the YSGA model can be used. This project would continue working with the YSGA model to calibrate and refine model inputs, outputs, and parameterization. Improved data on evapotranspiration could be utilized in enhancing the total water balance in the Subbasin. A primary groundwater model enhancement could be to improve the accuracy of crop ET through development local crop coefficients based on remote sensing/energy balance analyses. This project would include incorporating improved land use datasets for future scenarios and revising "managed wetlands" classifications in the current YSGA model. Additionally, there are other existing models with finer scale, specifically in the Capay Valley that might be useful to calibrate and parameterize the YSGA model. This will be a continuous project, and updates to the model can be made when improved input datasets are made available or created.	•	•	•	•
P 3	Water Resources Information Database Project	This project would include updates to the existing WRID system, and potential additional projects related to data storage and sharing. This project would improve the hosting, visualization, and storage of data related to the YSGA and the Yolo GSP.	•	•	•	•
P 4	Topographic Mapping (LiDAR Project)	This project would improve topographic mapping of the Yolo Subbasin, including surface water bodies.			•	•
P 5	Additional monitoring wells along ephemeral streams, interconnected surface water bodies, and near GDEs	Additional monitoring wells along ephemeral streams in the subbasin may improve understanding of surface water/groundwater of ephemeral streams in the subbasin.	•			•
P 6	Vegetative and aquatic surveys in related to groundwater dependent ecosystems	This project would Improve the ecological inventory of GDEs in the Yolo Subbasin.				•

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 7	AEM Flights to improve subsurface geology data	Airborne Electromagnetic (AEM) surveys can provide useful information about subsurface geology. This data could potentially be utilized to better understanding aquifer conditions in the Yolo Subbasin. The YSGA is proposing partnering with DWR to implement AEM surveys in areas where the data obtained will be particularly useful. From DWR's AEM Survey datasheet, "During an AEM survey, a helicopter tows electronic equipment that sends signals into the ground which bounce back. The process has been compared to taking an MRI of the ground subsurface. The data collected is used to create continuous images that are interpreted for underground geology. The resulting information will provide a standardized, statewide dataset that improves the understanding of aquifer structures. It can also help with the development or refinement of hydrogeologic conceptual models and can help identify areas for recharging groundwater."	•		•	•
P 8	Abandoned Well Incentive Program	Creation of an incentive program that would pay for the destruction of old, abandoned wells. There are other existing programs that could be the foundation for this proposal. The objectives of this program would be to provide landowners an incentive-based, volunteer program with the intent of protecting the quality of groundwater, eliminating the safety hazard of open wells to humans and livestock, and promoting the importance of water quality within the Yolo Subbasin.		•		
P 9	Modernization Project: Integrated Precision Water Management	YCFC&WCD will modernize 16 miles of its main canal. Automatic water control gates will allow the YCFC&WCD to operate its main system with more flexibility.	•			
P 10	Exchanges between CVP or SWP system and Cache Creek System	This project includes any potential surface water transfers between the CVP or SWP and the Yolo Subbasin. Potentially Sites Reservoir.	•			
P 11	Flood Monitoring Network Project	This project would install flow monitoring stations at canals and sloughs in order to optimize conveyance capacity for both agricultural operations and during rain events, which could occur at the same time. It is not known how much flow sloughs contribute to the canal systems during rain events.	•			
P 12	Yolo County Drains and Sloughs - Governance and Maintenance Study	YCFC&WCD and County will work together to develop a governance and maintenance study that will assist in providing effective rural storm water management responsibilities based on the defined governing bodies. Plan/investigation will initiate a legitimate storm water management program in Yolo County.	•			

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 13	Zamora area winter recharge from Cache Creek *via* China Slough	This project would be the development of groundwater recharge capacity by utilizing China Slough and conveying water to the Zamora area. Utilizing existing YCFC&WCD infrastructure would allow for water to reach China Slough and be conveyed to the Zamora area. This project is related to another proposed project - West Adams Canal Renovation and China Slough Rehabilitation. The rehabilitation of China Slough would likely need to occur prior to any successful groundwater recharge events occurring.	•		•	
P 14	Dunnigan Hills Winter Runoff Capture for Recharge	Runoff water in Dunnigan Hills and Hungry Hollow could be diverted into N Adams canal and sent to Yolo-Zamora for winter recharge. This project would utilize excess water in Dunnigan Hills and Hungry Hollow and send it east towards the Yolo Zamora area.	•			
P 15	Winter Diversions from Tehama-Colusa Canal	This project would divert excess winter water from the Tehama Colusa Canal to the Yolo-Zamora area for winter recharge.	•			
P 16	Bird Creek surface water storage	160TAF of potential storage exists in the Bird Creek basin. Installing a dam along Bird Creek would potentially decrease North Yolo MAs reliance on groundwater. Developing a reliable surface water supply would be beneficial to users in White Areas of the Subbasin and could be particularly beneficial to water users whose reliance on groundwater is high.	•			
P 17	Bird Creek, Oat Creek, Buckeye Creek, 2047 Canal groundwater recharge infrastructure improvements	This project is a proposal to improve groundwater recharge in the North Yolo MA. There are a couple options for doing this. Small weirs could be installed to increase the retention time of surface water in the creeks. Additionally, surface water that remains in the 2047 Canal during winter could be rediverted to a ditch with better percolation properties. Areas with high infiltration rates are known by local entities and operators; diversions for groundwater recharge could be directed to these areas.	•			
P 18	Hardwood Subdivision Recharge	CalTrans utilized a parcel on the SW side of the Hardwood Subdivision of Dunnigan to build the County Road 6 overpass of I-5. This parcel is owned by stakeholders in the Yolo Zamora area and may be suitable for recharge. The parcel is currently not utilized for agricultural production and may be an ideal location to develop a groundwater recharge site.	•		•	

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 19	Schaad Ranch/Buckeye Creek Recharge	Buckeye Creek runs through Schaad Ranch at approximately County Rd 88 where Buckeye Creek crosses it. There is a Dunnigan WD turnout nearby the stream course and several monitoring wells, including a DWR well nearby, also. 215 or other waters could be diverted into the stream course and small, temporary weirs placed or created to slow it and enable recharge.	•			
P 20	Trickle flow to ephemeral streams	The Tehama-Colusa Canal has several side gates used to dewater sections of the canal. These drain into ephemeral streams like Buckeye Creek in Yolo County. Additionally, there are several locations in Colusa and Glenn counties that may be suitable for similar projects. There is the potential to collaborate with CGA to streamline the permitting and regulatory process. Information on Buckeye Creek and the requirements for these side gates to be utilized are known. RD 108 and Dunnigan Water District are ideal partners to promote and implement this project.	•	•	•	•
P 21	Extension of Tehama Colusa Canal	This project would extend the existing Tehama Colusa Canal south. By extending the Tehama Colusa Canal, water users south of Bird Creek water users in the Yolo Zamora area of the North Yolo Management Area may be able to access additional surface water supplies in certain years. Easements may already exist on properties south of Bird Creek which would facilitate the extension of the TC canal.	•			
P 22	Conjunctive Use/groundwater recharge/surface water delivery extension to the area around Zamora	This project would enhance recharge, both actual and in-lieu, through extending surface water deliveries and exploring opportunities for enhanced recharge in the areas in and around Zamora.	•		•	•
P 23	Additional Extensometers in North Yolo MA	This project would help to better understand land subsidence in the North Yolo MA, additional extensometers are being proposed. This will provide a more complete understanding of where and when subsidence is occurring in this area.			•	
P 24	Add real time static level monitoring equipment to Washington Street well in Yolo	This project would help to better react to changes in available water and provide constant historical data that is shared directly to the GSA.	•	•	•	•
P 25	Add real time static level monitoring equipment to Ridgecut well in Knights Landing	This project would help to better react to changes in available water and provide constant historical data that is shared directly to the GSA.	•	•	•	•

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 26	Sites West Sac. Valley Water Filtration System	This would be a Domestic Water Use Filtration System for Sites Reservoir Sphere of Influence in West Sac Valley. Project could focus on Colusa and North Yolo counties or extend northward into Shasta County.	•	•		
P 27	Sutter Buttes and Willows Fault Arsenic and Saltwater Study	This is a Proposed USGS Study to Follow Up on “Future Work” detailed in the Masters’ Thesis of Stephen Springhorn entitled "Stratigraphic Analysis and Hydrogeologic Characterization of Cenzoic Strata in the Sacramento Valley Near the Sutter Buttes.	•	•	•	
P 28	Forbes Ranch Regulating Pond	This project would develop and construct a 200-acre-foot regulating pond to reduce drainage and flood waters through the town of Madison and District canal system. Divert stormwater flows to the pond through the existing conveyance. The regulating pond would provide storm water retention during the winter and would allow for groundwater recharge in the spring and summer when capacity and water is available. The regulating pond would provide water quality benefits.	•	•		
P 29	West Adams Canal Renovation and China Slough Rehabilitation	This project would result in the enlargement and improvement of the YCFC&WCD's West Adams, East Adams, and Acacia Canal system, and rehabilitation and improvement of China Slough (a natural storm drainage channel). YCFC&WCD's canal system could be modernized to allow for a “demand” system and to ensure no spills. China Slough would need to be cleaned, an operating road constructed, and installation of about eight check structures. Improvement of this system would increase capacity for groundwater recharge, both in-lieu and actual.	•			
P 30	Diaz in-line reservoir	The Diaz in-line reservoir project would include the creation of an in-line reservoir on Clover Canal. This would help with water use efficiencies and encourage increased conjunctive use by making surface water easier to utilize. This location could also possibly used for increased groundwater recharge.	•			

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 31	Magnolia Canal Loss Reduction and Extension Project	This is a proposed 1.5 miles of pipeline to extend and reduce loss in the Magnolia Canal system. This project might increase surface water usage in this area, and thus reduce groundwater demand. Currently, Magnolia Canal has high losses to groundwater, so this loss reduction project would likely decrease the current amount of surface water to groundwater recharge. Extending the canal, however, may allow for decreased reliance on groundwater at the end of Magnolia Canal. A cost-benefit analysis will be conducted prior to project implementation. Quantification of the changes in groundwater recharge will need to be made to determine the benefits of this proposed project.	●			
P 32	Demand Delivery on Yolo Central and Pleasant Prairie Canals	This project would Increase surface water usage by making it easier and more convenient for water users to use surface water on the Yolo Central and Pleasant Prairie Canals. This project should result in lower groundwater demands and lower reliance on groundwater. Infrastructure would need to be developed on these canals to allow water users to more easily utilize surface water supplies.	●			
P 33	North of Winters multi-use, stormwater, and water storage pond, Winters North Area Stormwater Pond'	This project proposes developing and constructing a 5,000 acre-feet storm water retention pond in the north area of Winters to reduce drainage and flood waters from the Chickahominy Slough. The retention pond would also be used for groundwater recharge in times when the capacity and water was available. The retention pond would provide water quality benefits by allowing the sediments in the runoff to settle and lessening the transfer of pollutants and chemicals downstream. The surrounding area would have native vegetation that would promote benefits for wildlife habitat, and the property would allow for groups to visit and learn about the multi-beneficial, multi-agency partnership. Similar to the District's Chapman Reservoir, the project would install automated gates and monitoring devices at the retention pond that would be connected to the District's SCADA system for real-time management.	●			
P 34	West Winters Aquifer Storage and Recovery (ASR) well field	Surface water from Putah Creek, or the YCFC&WCD canal system, could be injected west of Winters and extracted to blend with city of Winters wells exceeding arsenic or hex-chrome. Other city wells could be pumped directly to Putah Creek as in-lieu exchange for water injected to SARs field.	●			
P 35	Development of Surface Water Source for the city of Winters	Winters could purchase water from Solano Project, treat and blend with groundwater. Blending would reduce water quality issues and use of surface water would reduce reliance on groundwater. Long-term	●	●		

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
		contracts would be required and because Winters historically declined Solano Project water rights, this could be problematic.				
P 36	City of Davis - ASR	This project would include researching the potential for ASR – placing treated surface water into the intermediate aquifer during winter months and using the stored water to augment surface water supplies in summer months. A feasibility study has been completed and pilot testing is underway.	●			●
P 37	Upstream Flow Management to Prevent Madison Flooding and to Facilitate GW Recharge	YCFC&WCD proposes to manage high flows from Lamb Valley, Cottonwood and S. Fork Willow Sloughs using the existing canal system as well as other means such as upstream check dams. During storm events Willow Slough floods the Town of Madison. The Canal system can be used to convey water away from the Town of Madison and reduce flood levels while also managing peak flows through use of check dams, particularly in Lamb Valley Slough. This project would increase groundwater recharge during winter storm events.	●			
P 38	Madison Farmer Field Stormwater Capture and Groundwater Recharge	This is a proposed modification of farmer fields around Madison, specifically those next to Highway 16 and those that will capture upstream flows. The two options considered include 1) 1,200 acres of farmer field modification for rainfall capture (8-inch-berm) and 2) modification of a farmer field near Cache Creek for rainfall and storm water runoff capture a 3-foot-high storm water detention basin. This project will require farmer participation and advanced planning for field modification.	●			
P 39	City of Davis -Site Survey for Hardscape Conversion to Pervious Pavement	This project proposes surveying public parking lots that currently have impervious surfacing to assess the practicality of converting these locations to pervious pavement when they are in need of resurfacing, maintenance or redesign. Portions of the pathways near the sites could potentially highlight permeable pavers in addition to the parking lots. Projects could be planned with improvements to incorporate bioswales, low water use plants, and other low-impact design measures into any landscape changes.	●			
P 40	City of Davis - West Area Pond Redesign	This would be a redesign the West Area Pond (detention basin) to utilize agricultural summer flows to enhance aquatic wildlife habitat and improve water quality. This proposal involves redirecting existing agricultural runoff through the Stonegate drainage pond and pumping it into the West Area Pond. This would enhance aquatic habitat while improving any water discharges through retention, enhancing opportunities for infiltration, transpiration and evaporation.	●			

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 41	Sac River Water to Davis/Woodland	This project has already been implemented. The Woodland-Davis Clean Water Agency will continue to use Sacramento River water when available and supplement with groundwater when needed. The average surface water utilization is around 40,000 AFY. Effects of this project are being studied.	•			
P 42	City of Woodland - Well 31 ASR Project	The project involves the design and construction of a new municipal ASR well #31 near the site of the existing Well #6. The new ASR well will facilitate groundwater recharge by injecting treated surface water into the gravel layer approximately 500 feet below the surface when surplus Sacramento River water is available during winter months.	•	•		
P 43	City of Davis Leak Detection Survey	This project proposes hiring a consultant to use acoustical listening technology to survey water mains and laterals within the city of Davis water distribution area to detect and locate leaks. Prioritize leaks based on severity. Purchase leak detection equipment to install within distribution system to continuously monitor for potential leaks at key areas identified through the leak detection survey.	•	•		

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 44	Woodland Recycled Water Utility Expansion Project (Phase II)	The city of Woodland currently has tertiary treated Title 22 effluent from the City's Water Pollution Control Facility (WPCF) providing a firm capacity of approximately 2,700 gpm for recycled water. Woodland has an existing recycled water utility serving 2 City parks and a large industrial user in the industrial area northwest of the WPCF. The City has planned for an expansion of the recycled water utility into the Spring Lake Area of the City and also to serve the planned Woodland Research & Technology Park. There are several existing large water users that would use the recycled water for irrigation of parks and roadside landscaping. Businesses in the Research Park would utilize recycled water for cooling buildings. In addition, recycled water would be available to extend into new development areas for landscape irrigation. Portions of recycled water pipelines in Spring Lake have already been constructed by development projects. Providing recycled water to these areas would reduce demands on the potable water distribution system and reduce the demand on the groundwater aquifer. The recycled water pipeline would be constructed in the City's existing right of way. The City has recently completed a Mitigated Negative Declaration for the project. The expected initial demand for recycled water would exceed 110-acre feet per year. The Capital Cost for the Project is approximately $2.5M. The recycled water project includes construction of approximately 10,000 feet of 8-inch-diameter purple pipe and a 100,000-gallon storage tank. The project also provides recycled water for expansion (Phase III) to west of Highway 113.	•	•		

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 45	Woodland Recycled Water Utility Expansion Project (Phase III)	The city of Woodland currently has tertiary treated Title 22 effluent from the city's WPCF providing a firm capacity of approximately 2,700 gpm for recycled water. Woodland has an existing recycled water utility serving two city parks and a large industrial user in the industrial area northwest of the WPCF. The city has planned for an expansion of the recycled water utility into the Sports Park Area of the city and also to serve the planned SP1B and SP1C areas in the city's General Plan. There are several existing large water users that would use the recycled water for irrigation of parks and roadside landscaping. In addition, recycled water would be available to extend into new development areas for landscape irrigation. Providing recycled water to these areas would reduce demands on the potable water distribution system and reduce the demand on the groundwater aquifer. The recycled water pipeline would be constructed in the city's existing right of way. The city has recently completed a Mitigated Negative Declaration for the project. The expected initial demand for recycled water would exceed 70-acre feet per year. The Capital Cost for the Project is approximately $925,000. The recycled water project includes construction of approximately 4,300 feet of 8-inch-diameter purple pipe.	●	●		
P 46	City of Davis -Recycled Water Pump Station	With the completion of secondary and tertiary improvements, the City's Wastewater Treatment Plant is now capable of producing tertiary disinfected effluent that meets the requirements of Title 22 of the CCR for recycled water. However, a final component of these upgrades is a means of delivering the recycled water produced at the WWTP to potential future customers. New infrastructure is necessary to convey recycled water from the WWTP to potential	●	●		
P 47	YCFC&WCD Winter Recharge	This project increases winter recharge by utilizing YCFC&WCD sloughs and canals. This is an ongoing project and can only be conducted under certain circumstances. The water diverted into unlined district canals varies on an annual basis between a minimum of 0 AFY and a maximum of around 30,000 AFY.	●			
P 48	City of Winters Recycled Water Utilization	The city of Winters Waste Water Treatment Facility is secondary treatment. This water is currently discharged to 170 acres on two spray fields. No water leaves the facility, and none of the effluent comes in contact with any surface waterway. In 2020, 267.4 acre-feet of water were discharged for percolation and evaporation. In 2019, 240 acre-feet were discharged for percolation and evaporation. This project is ongoing. There may be opportunities to develop the groundwater recharge aspect of this project.	●			

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 49	Citrona Ditch Pressurization Project	This project would increase the adoption of surface water over groundwater when available. This is a 10-15 (cubic feet per second) cfs supply, for four customers on 10 fields.	•			
P 50	RD 2035 - Groundwater Studies	Reclamation District 2035's Ground Studies Project will consist of the identification and analysis of issues, if any, surrounding the quality and availability of groundwater within their district.	•	•	•	•
P 51	RD 2035 - Floodway Corridor Project	The project consists of piping (or lining) the Cross Bypass Canal and the installation of flow control and measurement devices to improve the conveyance system and increase water use efficiency.	•			
P 52	RD 2035 - Conjunctive Use Study	The project consists of the study and analysis of the coordinated use of surface and groundwater that could benefit the agricultural, urban, and environmental interests within, nearby and downstream of Yolo County, especially the North Delta region.	•			
P 53	Water Hexavalent Chromium (Cr6) Compliance Project	City of Winters Hexavalent Chromium related projects to improve water quality.		•		
P 54	UC Davis Arboretum Waterway Wetland Restoration and Enhancement	UC Davis is proposing to enhance the Arboretum Waterway, which captures stormwater discharge from 900 acres of the UC Davis campus, by establishing a wetland area to treat stormwater discharge and recycled water prior to discharge to Putah Creek.	•			
P 55	City of Woodland - North Regional Pond and Pump Station	This project involves the design and construction of an approximate 75-acre sedimentation pond and a pump station able to eventually accommodate a 120-cfs design flow. Project re-purposes an existing City evaporation pond that is no longer in use for any purpose. There may be some groundwater recharge benefits as a result of this project. The primary benefit is stormwater treatment and retention. This project is operational and is substantially completed.	•			
P 56	Improved hydrologic flows, increased runoff retention, and improved watershed health in the Capay Valley	These projects would improve groundwater levels, groundwater quality, and SW/GW Interaction in the Capay Valley Management Area. In the Capay Valley MA, this would include the creation of demonstration sites for capturing hillside run-off, process-based restoration in selected tributaries of Cache Creek, and improvement of overall watershed health to improve overall groundwater conditions. The processes established by these projects can be utilized throughout the subbasin.	•	•		•

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 57	Enhanced water infiltration *via* grazing management and crop production practices in the Capay Valley	For every 1% increase in soil organic matter, water holding capacity can increase by 20,000 gallons per acre. Some crop production practices are known to improve water infiltration and water-holding capacity. Pilot projects, scaling, and community adoption are all components of these projects. This type of project could be expanded to the entire subbasin, or other areas within the subbasin.	●			
P 58	Oak woodland, riparian, and chaparral restoration in the Capay Valley	Develop a restoration plan and demonstration sites. Then scale-up the demonstration sites to other areas in the Capay Valley MA. Improving the health of oak woodlands, riparian areas, and chaparral can improve the hydrological and ecological function of these areas. Similar projects can be created for other areas within the Yolo Subbasin.	●			●
P 59	Establish an equipment and knowledge hub in the Capay Valley	A one-stop-service Equipment and Knowledge Hub will be established to make available services and equipment that support the projects described above and their application into perpetuity. Services and equipment will be tailored to the needs of livestock managers, crop producers and habitat restorationists. The aim will be to make available the knowledge and tools that are not readily available as yet and are necessary for farmers/ranchers/others to adopt practices for improving groundwater management. If successful, this knowledge hub could be expanded to other areas within the subbasin.	●	●	●	●
P 60	Rumsey and Guinda Ditch Winter Recharge	Development of groundwater recharge capacity by utilizing Rumsey and Guinda ditch and conveying water to the Capay Valley.	●			
P 61	Guinda Ditch summer irrigation and pipelines from Cache Creek to other side of Highway 16	Guinda ditch could be reactivated to provide additional Cache Creek water during the irrigation season to Capay Valley	●			
P 62	Yocha Dehe Wintun Nation - expansion of Surface Water Diversion	This is the continuation of an existing project that allows the YDWN to utilize surface water resulting in in-lieu recharge of groundwater.	●			
P 63	Improve Subsidence data collection and analysis in the Capay Valley MA	This encompasses projects to improve the understanding of subsidence in the Capay Valley. This can be done by installing extensometers or securing funding to better understand land subsidence in the Capay Valley.			●	

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 64	Incorporation of Capay IGSM into the YSGA Model	This falls under the 'Updates to the YSGA Model' project that is applicable to the entire subbasin. The Capay Integrated Groundwater Surface water Model was developed by WRIME (now called RMC Water and Environment) in 2010 and updated by RMC in 2016. Components of this model may be incorporated into the YSGA Model to improve overall understanding of groundwater in the Capay Valley.	•			•
P 65	Yolo Bypass Conservation Projects	These are projects that relate to changes in land use, surface water flows, and groundwater use in the Yolo Bypass.	•			
P 66	Revisions to the YSGA Model for Urban Groundwater usage in the South Yolo MA	This project would ensure that the water budget for the South Yolo MA accurately reflects changes in urban groundwater usage in this area moving forward.	•	•	•	•
P 67	Methylmercury Impacts analyses for the Yolo Bypass	Yolo County proposes to collect data and analyze changes in methyl mercury production and bioaccumulation that could result from (1) a proposed Bay Delta Conservation Plan (BDCP) project to enhance fisheries habitat in the Yolo Bypass; and (2) a Central Valley Flood Protection Plan proposal to expand the Yolo Bypass to improve flood capacity		•		
P 68	West Sacramento Well Improvements that may Include ASR	Groundwater recharge and extraction project for groundwater storage, groundwater quality management, and system redundancy.	•	•		•
P 69	West Sacramento and city of Sacramento Intertie	Coordinate conjunctive use activities and provide emergency water supplies.	•	•		•
P 70	Dry well groundwater recharge on California Olive Ranch	*This proposed project would inject excess surface water* into the aquifer at a location on California Olive Ranch.	•			•
P 71	Projects to improve understanding of surface water/groundwater interaction around Oat Creek and Buckeye Creek/others in Dunnigan/North Yolo areas.	Additional streamflow monitoring and dedicated groundwater monitoring wells are proposed to better understand groundwater levels and surface water-groundwater interaction in the surface water bodies in the Dunnigan Hills area. Information from a recent pilot study on groundwater recharge in Oat Creek can be used to improve understanding of the creek's recharge potential.	•		•	

MA / Project Number	MA / Project Name	Summary Description	Relevant Sustainability Indicators Affected			
			GW Levels	GW Quality	Land Subsidence	GW/SW
P 72	Additional groundwater monitoring wells in the Dunnigan Hills MA	There are currently very few groundwater monitoring wells in the Dunnigan Hills MA. The addition of dedicated monitoring wells will improve the understanding of groundwater in this area. Few wells in this Management Area have long periods of record, but the YSGA has identified wells and landowners that would like to be involved in the groundwater monitoring program.	•	•	•	•
P 73	O'Halloran off-stream reservoir site	A proposed off-stream reservoir that would improve surface water delivery efficiency and conjunctive use. This project would also likely be utilized to generate peak-hour electricity.	•			
P 74	Additional groundwater monitoring wells in the Clarksburg MA	There are currently very few groundwater monitoring wells in the Clarksburg MA. The addition of dedicated monitoring wells will improve the understanding of groundwater in this area. This monitoring network would include water quality measurements in this area. There are few wells in this area with long periods of record, but monitoring could start now. Wells and landowners have been identified with interest in improving the groundwater monitoring network program.	•	•	•	•
P 75	Reclamation District 999 - Elk Slough Groundwater Quality Improvement and Flood Protection Project	Elk Slough is currently closed to the fresh water of the Sacramento River and is maintained by tidal inflows from Sutter Slough. Elk Slough water quality is typically similar to that of the river; however, when salinity intrusion increases during droughts, the slough water quality declines.	•	•		
P 76	Boards In Program	This would be a voluntary or financially incentivized program to have landowners keep the spill boards in their rice fields in during the winter. This would increase groundwater recharge in the subbasin and would be a multi-benefit project. Even though these fields tend to have low infiltration there would still be benefits out of this sort of program.	•			
P 77	Cover cropping, rangelands improvements, and other agricultural practices to improve groundwater recharge	Cover crops, compost application, and rangeland management strategies can provide multiple benefits, including increased groundwater recharge. This would be a landowner-based project, with potential incentives being created in the future.	•		•	•

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