J

CHOWCHILLA SUBBASIN

Sustainable Groundwater Management Act (SGMA)

Groundwater Sustainability Plan

Prepared by

Davids Engineering, Inc
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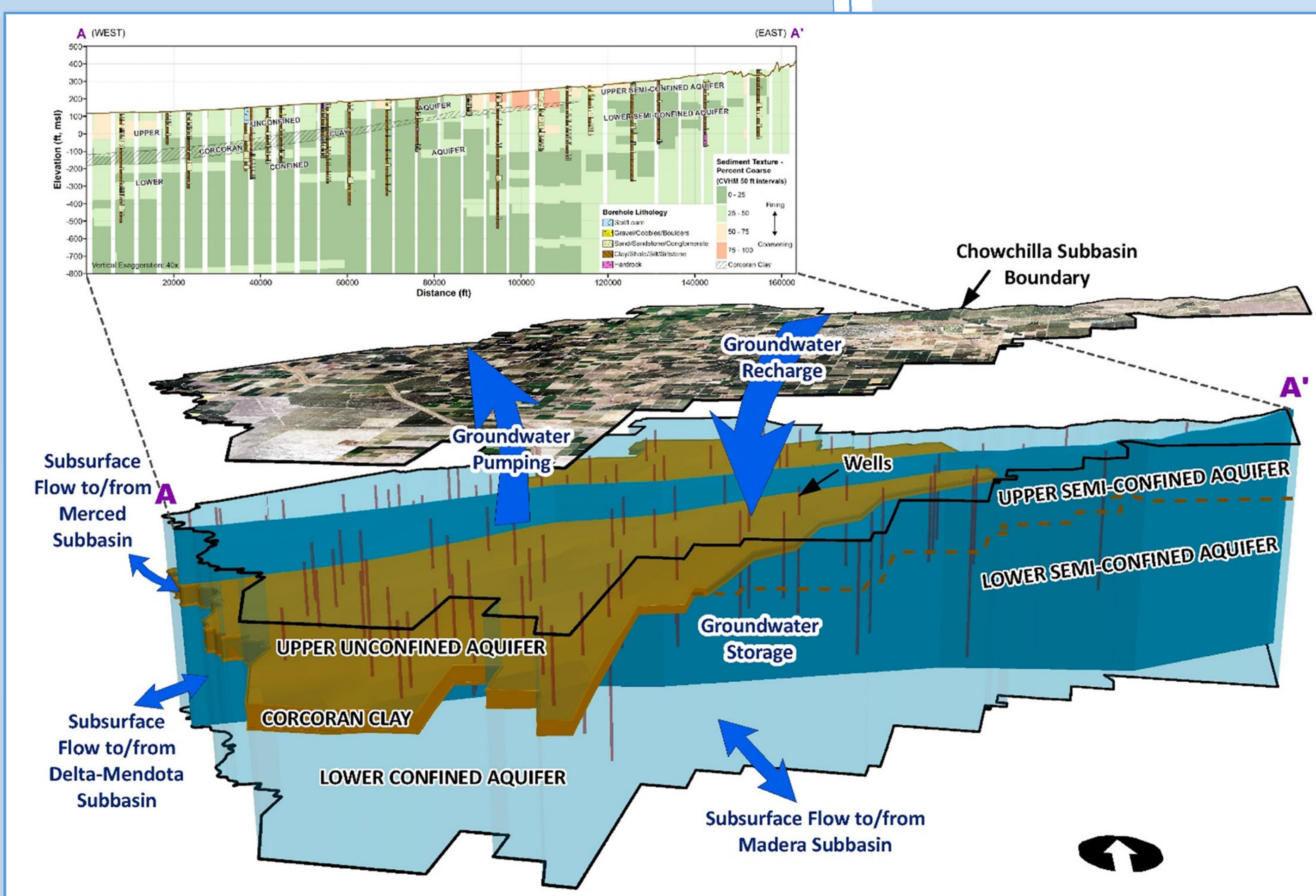
ERA Economics
Stillwater Sciences and
California State University, Sacramento

APPENDIX 2. PLAN AREA AND BASIN SETTING

Technical Appendices 2.A. through 2.F.

January 2020



FINAL

Chowchilla Subbasin

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Chowchilla Subbasin GSP Advisory Committee

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APPENDIX 2. PLAN AREA AND BASIN SETTING

APPENDIX 2.A. CHOWCHILLA SUBBASIN ANNUAL SPATIAL LAND USE

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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To support GSP development, land use areas in the Chowchilla Subbasin were identified from available data in Madera and Merced Counties, which include the entire Chowchilla Subbasin.

Annual land use estimates were primarily based on spatially distributed land use information from DWR Land Use surveys for Madera County (1995, 2001, and 2011) and Merced County (1995, 2002, and 2012), and Land IQ[1] remote sensing-based land use identification for 2014. County Agriculture Commission land use areas were used to interpolate between years with available spatial land use information. Lands in the District were assigned to one of 17 land use classes.

The following five steps were used to develop the county-wide annual, spatial land use datasets.

1.) Developed spatial land use coverages for:
Madera County: 1995, 2001, 2011, and 2014
Merced County: 1995, 2002, 2012, and 2014,
and made adjustments to the spatial coverage, including:
    a) Filled missing area from Land IQ coverage with 2011 DWR coverage (native, semi-agricultural, urban, and water account for 86% of the missing area in Madera County and 95% of missing area in Merced County)
    b) In Madera County: Used the water area from 2001 for the 1995 DWR survey (water surfaces were not included in the 1995 DWR survey).
2.) Calculated agricultural area:
    a) Assumed county data does not include idle land (county data has zero idle area in all years)
    b) Excluded idle land from DWR agricultural totals to be consistent with county totals
    c) Calculated the ratio of the DWR agricultural total area (not including idle lands) to county agricultural production area for years with DWR (or Land IQ) land use data
    d) Estimated agricultural area for missing years between the first and last available county data by interpolating the ratio calculated in step (c)
    e) Estimated agricultural area for missing years outside the available county data by extending the annual trend or estimating as equal to the nearest available county data
3.) Multiplied county agricultural acres for each crop by the ratio calculated in in step 2 (c) to adjust county agricultural areas for each crop scaling each crop area in each year by an estimate of the difference between the areas in the DWR land use surveys and County Commissioner reports. This procedure assumes DWR areas are the most accurate.
    a) Interpolated native, semi-agricultural, urban, and water land uses between DWR years.
    b) Calculated idle area as the remaining area (total DWR land use minus total cropped area)
4.) Reviewed calculated idle and crop area graphs and adjusted individual annual crop areas with abnormal area shifts based on professional judgement to eliminate calculated negative idle area.
Madera County:
    a) 1996 adjustments--replaced high miscellaneous truck areas with interpolated values between 1995 and 1997
    b) 2002, 2003, 2004 and 2005 adjustments--replaced high areas for mixed pasture and alfalfa between 2001 and 2011 DWR areas by interpolating areas between 2001 and 2011.
    c) 2012 adjustments--replaced high miscellaneous deciduous, field and truck with interpolated value between 2011 and 2013
Merced County:
    a) Almond acreage adjustments--interpolated years 2013 and 2015 using 2012 and 2014 land use coverages.
    b) Citrus and Subtropical acreage adjustments--interpolated between 2002 and 2015 using 2002, 2012, and 2014 land use surveys

[1] Land IQ is a firm that was contracted by DWR to use remote sensing methodologies to identify crops in fields.

c) Grain and Hay Crops--interpolated years 2013 and 2015 using 2012 and 2014 land use coverages
d) Grapes--interpolated between 1989 and 2015 using land use surveys
e) Miscellaneous Field Crops--replaced low acreage in 1991 by interpolating between 1990 and 1992
f) Miscellaneous Truck Crop--interpolated years 2006, 2009, 2010, 2013, and 2015 based on land use surveys
g) Water--assumed acreage from 1995 DWR survey for 1989 through 1994

5.) Implemented the DWR Land Use interpolation tool to create annual spatial cropping data sets for 1989 through 2017.

Table A2.A-1 summarizes the land use sector and average acreage of each land use class in the Chowchilla Subbasin based on the above land use analysis.

Table A2.A-1. Average Land Use Acreages in Chowchilla Subbasin, 1989 to 2014.

Land Use Sector	Land Use Class	Acres
Agricultural	Alfalfa	22,743
	Almonds	26,296
	Citrus and Subtropical	65
	Corn (double crop)	17,325
	Grain and Hay Crops	5,642
	Grapes	9,976
	Idle	6,624
	Miscellaneous Deciduous	3,791
	Miscellaneous Field Crops	14,377
	Miscellaneous Truck Crops	1,537
	Mixed Pasture	6,424
	Pistachios	3,951
	Walnuts	315
Native Vegetation	Native	17,702
	Water	1,397
Urban	Urban	4,691
	Semi-agricultural	3,467
Total		146,323

References

DWR. 2011. “Madera County land use survey data.” State of California, Department of Water Resources. Available online: https://water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Land-Use-Surveys. Also published in 1995 and 2001.

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Madera County. 2018. “Madera County Crop & Livestock Report.” Madera County Department of Agricultural Weights and Measures. Available Online: https://www.maderacounty.com/government/agricultural-commissioner-weights-and-measures/annual-crop-reports. Published annually.

Merced County. 2018. “Merced County Report on Agriculture.” Merced County Department of Agriculture. Available Online: https://www.co.merced.ca.us/151/Crop-Statistics-Reports. Published annually.

APPENDIX 2.B. ASSESSMENT OF GROUNDWATER DEPENDENT ECOSYSTEMS

Prepared as part of the

Groundwater Sustainability Plan
Chowchilla Subbasin

January 2020

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TECHNICAL APPENDIX ◦ NOVEMBER 2019

Assessment of Groundwater Dependent Ecosystems for the Chowchilla Subbasin Groundwater Sustainability Plan

PREPARED FOR

Groundwater Sustainability Plan
Chowchilla Subbasin

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1 GDE IDENTIFICATION

Groundwater dependent ecosystems (GDEs) are defined in California's Sustainable Groundwater Management Act (SGMA) as "ecological communities of 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 guidance for GDE analysis (Rohde et al. 2018), a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all or a portion of their water needs. In this section, we detail the information sources used, new information gathered, and methods applied to make determinations and to describe the conditions of GDEs identified in the Chowchilla Subbasin. We used Rohde et al. (2018) as well as the text of SGMA itself as primary guides.

1.1 GDE Mapping and Methods

We began the process of identifying the GDE units in the Chowchilla Subbasin using the California Department of Water Resources' (DWR) iGDE (GDE indicators) database, published online and referred to as the Natural Communities Commonly Associated with Groundwater dataset (Klausmeyer et al. 2018). We augmented these data with other relevant spatial vegetation data, aerial imagery, information on vegetation types, depth to groundwater, plant and animal species distributions in the area, plant species rooting depths, and field observations. Data analysis was conducted through a series of steps to augment, filter, classify and finalize the GDE units within the Chowchilla Subbasin.

1.1.1 Data sources

This section includes brief descriptions of the data and other information sources used to identify and aggregate potential GDEs into final GDE units.

Our starting point for GDE identification and analysis was the iGDE database (Klausmeyer et al. 2018). We downloaded the iGDE geodatabase from the DWR website (https://gis.water.ca.gov/app/NCDatasetViewer/#) and incorporated it into the project geographic information system (GIS) to create a preliminary map to serve as the primary basis for initial identification of potential GDEs. This data set is a combination of the best available data obtained from multiple publicly available sources:

- VegCAMP – Vegetation Classification and Mapping Program, California Department of Fish and Wildlife (CDFW 2018) – Areas mapped to the alliance level and with a minimum mapping unit (MMU) of 1.0 and 0.25 acres for natural uplands and wetlands/ riparian areas, respectively; mapped using 2012 imagery from the National Agriculture Imagery Program (NAIP) for the Southern San Joaquin Valley.
- NWI v2.0. – National Wetlands Inventory (Version 2.0), U.S. Fish and Wildlife Service (USFWS 2018); MMU = 0.5 acres.
- CalVeg – Landsat-based classification and assessment of visible ecological groupings, USDA Forest Service (March 2007) – vegetation mapping to the alliance level that is cross-walked to VegCAMP; MMU = 2.5 acres.

In addition, we added a more recent vegetation mapping source for the San Joaquin River riparian corridor, developed by Stillwater Sciences under contract with the Bureau of Reclamation for the San Joaquin River Restoration Program (Bureau of Reclamation 2014). This dataset represents an update to the Geographic Information Center's 2009 vegetation map, prepared for DWR's

Central Valley Flood Protection Program; this update used 2012 NAIP imagery and 2013 field observations. Vegetation was mapped to the alliance level with an MMU of 0.25 acres (Bureau of Reclamation 2014).

Klausmeyer et al. (2018) created the iGDE dataset as a starting point to identify potential GDEs across the state. Per the authors, this dataset requires careful review and refinement with local information since it was created at the state scale and broad decisions were made without consideration of local conditions. Thus, we reviewed all areas included in the iGDE dataset and scanned the full area of the Chowchilla Subbasin, using aerial imagery and existing vegetation mapping, to check for potential GDEs that might have been omitted or mischaracterized during creation of the statewide iGDE dataset.

To inform the assessment of GDE condition and potential effects (Sections 2 and 3), we obtained mapped plant community and wetland types detailed in the original VegCAMP, NWI, and CalVeg datasets as well as the San Joaquin River Riparian Vegetation dataset, the latter of which was available in-house. We evaluated and incorporated information on depth to groundwater and plant species rooting depth into this analysis to help inform subsequent assessment of potential sensitivity of vegetated GDEs to changes in groundwater. Published information on depth of rooting for riparian and wetland plant species was obtained in the form of a database (spreadsheet) collated and made publicly available online by TNC at The Nature Conservancy's Groundwater Resource Hub (https://groundwaterresourcehub.org/gde-tools/gde-rooting-depths-database-for-gdes/). Where data were missing, Stillwater's vegetation ecologists conducted literature searches to update this database for phreatophyte species occurring within the Chowchilla Subbasin. Depth to groundwater in the regional aquifer was estimated and mapped by LSCE based on existing well data, as described in Section 2.2.2 of this Groundwater Sustainability Plan (GSP) and provided as a geodatabase. Information on hydrogeology was used to better understand the distribution of other perched/mounded groundwater in the subbasin (Davids Engineering and LSCE 2017).

1.1.2 Procedure

In general, we followed the steps for defining and mapping GDEs outlined in Rohde et al. (2018). Throughout this process, we applied a decision tree to determine when species or biological communities were considered groundwater dependent based on definitions found in SGMA and Rohde et al. (2018). This decision tree, created to systematically and consistently address the range of conditions encountered, is summarized below, where the term 'unit' refers to an area with consistent vegetation and hydrology:

The unit is a GDE if groundwater is:

1. An important hydrologic input to the unit during some time of the year, AND
2. Important to survival and/or natural history of inhabiting species, AND
3. Associated with:
    a. A perched/mounded[1] unconfined aquifer, OR
    b. A regional aquifer used as a regionally important source of groundwater.

[1] The degree to which the shallow groundwater is perched or mounded atop shallow clay layers. Mounding is often pronounced underneath rivers which are often the source of the mounded water.

The unit is not a GDE if its hydrologic regime is primarily controlled by:

1. Surface discharge or drainage from an upslope human-made structure(s), such as irrigation canal, irrigated fields, reservoir, cattle pond, water treatment pond/facility.
2. Precipitation inputs directly to the unit surface. This excludes vernal pools from being GDEs where units are hydrologically supplied by direct precipitation and very local shallow subsurface flows from the immediately surrounding area.

For the Chowchilla Subbasin, shallow groundwater is perched/mounded above shallow clay layers rather than the regional aquifer. Specifics on these steps, as applied to the Chowchilla Subbasin, are provided below.

1.1.2.1 Identify communities supporting phreatophytic vegetation

After obtaining the relevant spatial data described above, we overlaid and evaluated these data in GIS to select the most recent and highest quality vegetation and water body mapping information. In this case, consistent with Klausmeyer et al. (2018), we prioritized the most recent and highest resolution mapping over earlier and coarser scale mapping information. Thus, the order of priority, from first to last, was: San Joaquin River Riparian (Bureau of Reclamation 2014), VegCAMP, NWI v2.0, CalVeg. The highest priority mapped vegetation type polygons that overlapped with the iGDE polygons were summarized by vegetation type and total acreage. These vegetation types were reviewed by one of our experienced wetland and riparian ecologists to remove vegetation types adapted to well drained, upland conditions (i.e., those not considered phreatophytes[2]) from the working GIS layer, such as blue oak woodland (*Quercus douglasii*).

1.1.2.2 Identify potential GDEs based on potential hydrologic connection to groundwater

GDEs rely on shallow groundwater in the Chowchilla Subbasin. For much of the subbasin, the regional aquifer is very deep, and the shallow groundwater that GDEs rely on is perched or mounded atop shallow clay layers. Because the potential hydrologic connection between the shallow groundwater and deep groundwater is often unknown, we conservatively assumed that shallow groundwater could potentially be influenced by pumping. We removed iGDEs without a potential hydrological connection to groundwater from the original dataset using spatially extrapolated or interpolated empirical measurements of depth to groundwater (DTW) for winter/spring of water years 2014 and 2016. DTW mapping for 2015 was not used due to limitations resulting from few available water level measurements. The 2014 and 2016 DTW data were the most accurate and recent DTW data available for the Chowchilla Subbasin. While the 2016 data represent conditions after the 2015 SGMA baseline, the use of shallow groundwater data from both years was deemed appropriate because it provided a more conservative (i.e., more inclusive) indicator of potential GDEs than the use of a data from a single year.

A DTW of 30 feet was used as one of the primary criteria in the initial screening of potential GDEs. The use of a 30-foot DTW criterion to screen potential GDEs corresponds to the maximum rooting depth of valley oak, *Quercus lobata* (Lewis and Burgy 1964), one of the species that compose iGDEs in the subbasin and is consistent with guidance provided by The Nature Conservancy (Rohde et al. 2018) for identifying GDEs. Potential GDEs were retained for

[2] A phreatophyte is a deep-rooted plant that obtains its water from the phreatic zone (zone of saturation) or the capillary fringe above the phreatic zone (Rohde et al. 2018). Phreatophytes grow where precipitation is insufficient for their persistence and groundwater is therefore required for long-term survival (Naumberg et al. 2005). Phreatophytes are often, but not always, found in riparian areas and wetlands.

further analysis if the underlying DTW in either winter/spring 2014 or winter/spring 2016 was equal to or shallower than 30 feet. In addition, we evaluated DTW under the San Joaquin and Chowchilla rivers during 2014 and 2016 in relation to river flow to assess the potential connection between surface flow and groundwater levels. If there was evidence that the surface water was connected to groundwater (i.e., a gaining stream), that reach would be eligible for inclusion as a potential GDE. Because the vast majority of rivers in the subbasin are not perennial and all are in a net-losing hydrological condition (i.e., losing water to the groundwater system), this criterion excluded most of the smaller river channels and associated terrestrial vegetation from consideration as GDEs. Thus, we generated a draft map of the potential GDEs that occur in areas where DTW was less than or equal to 30 feet in either water year 2014 or 2016. We used 2012 geospatial vernal pool mapping data (Witham et al. 2014) in combination with aerial photographic analysis to identify vernal pools mapped in the iGDE data set and remove them from the working GIS layer and draft map. Other surface water features such as stock ponds that we determined were not connected to groundwater were removed based on review of aerial photographs and other available information.

1.1.2.3 Refine potential GDE map

We reviewed for accuracy the mapped vegetation cover in remaining polygons identified as potential GDEs using visual analysis of Google Earth and NAIP imagery. These potential GDE polygons were primarily those dominated by terrestrial vegetation (i.e., vegetated potential GDEs). We removed from the potential GDE map those areas that had, since vegetation mapping occurred, changed land use from natural vegetation to developed uses (urban, roads, or agriculture). During this heads-up review of the potential GDEs, areas supporting riparian or wetland vegetation that were not in the original iGDE geodatabase, but were included in other high-quality datasets (e.g., VegCAMP or San Joaquin River Riparian mapping [Bureau of Reclamation 2014]) and have the potential to be hydrologically linked to groundwater (i.e., located in an area where the depth to water is less than or equal to 30 feet or along a gaining river or stream reach), were added to the potential GDE geodatabase and map. Polygons on the potential GDE map were labeled and color-coded as “kept,” “added” or “removed” from the original iGDE data set according to the above described criteria (Figure A2.B-1).

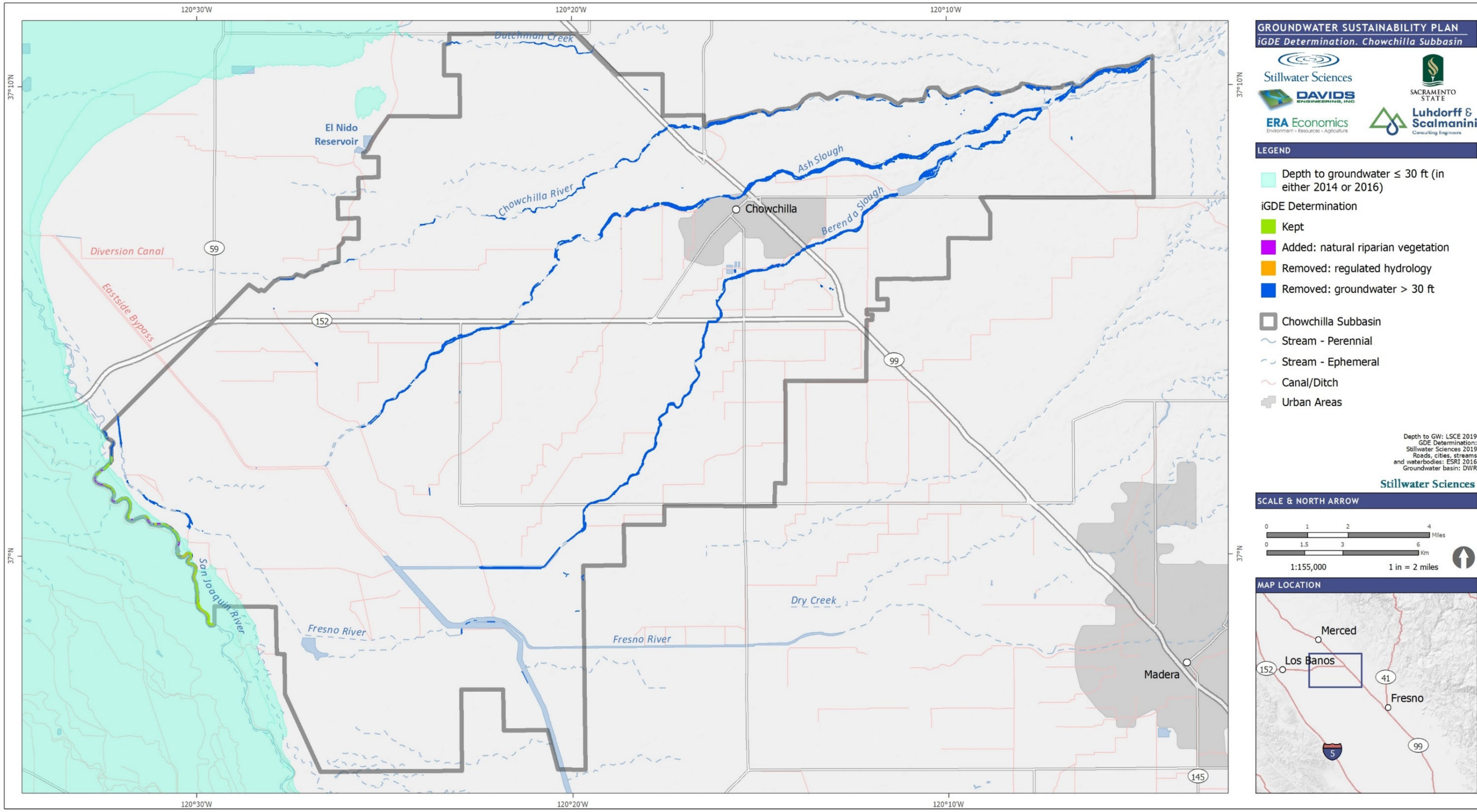

Figure A2.B-1. Potential GDEs in the Chowchilla Subbasin, showing iGDE polygons kept, added, or removed from the DWR Natural Communities Commonly Associated with Groundwater dataset.

1.1.2.4 Identify potentially associated sensitive species and community types

Stillwater Sciences' ecologists queried existing databases on regional and local occurrences and spatial distributions of special-status species. Databases accessed include CNDDB (2019), CNPS (2019), and eBird (2019). Spatial database queries were centered on the potential GDEs plus a 5-mile buffer. Stillwater's ecologists reviewed the database query results and identified species and community types with the potential to occur within or to be associated with the vegetation and aquatic communities in or immediately adjacent to the potential GDEs. Stillwater's ecologists then consolidated a list of these sensitive species and community types, along with summaries of habitat preferences and any known occurrence reports, for field review.

1.1.2.5 Ground truth vegetation type and condition in field surveys

On May 1, 2019, two Stillwater Sciences biologists, one with expertise in vegetation and the other in wildlife, performed a reconnaissance level survey of portions of the areas mapped as potential GDEs. The Stillwater team loaded spatial data on potential GDE locations, sensitive species occurrences, and DTW estimates onto a GPS equipped field tablet. The field crew also brought field maps and other information on potential special-status species to the field and visited a subset of the potential GDEs, selected to represent the range of potential GDE vegetation and hydrologic types in the subbasin. At each site, the field biologists recorded dominant vegetation types and plant species, estimates of percent cover for native and non-native plants by vegetation layer, indications of hydrologic connectivity with surface and/or groundwater, and indications of site alteration (e.g., cattle use, human disturbance, land use changes). Based on field observations, the field crew confirmed or refined mapped vegetation types, qualitatively evaluated the ecological condition, and qualitatively assessed habitat conditions for sensitive species at each representative site. The field crew recorded notes on the ecological conditions of each site visited, such as information on the proportion of live vs. senescent canopy, evidence of native species recruitment, and vegetation density. Habitat conditions for each species were assessed by comparing each species' habitat preferences (e.g., large trees, open water or herbaceous cover, etc.) to conditions present at the site. The field crew also recorded observations to help inform or verify potential linkages to groundwater, such as indications of standing water, water emerging from the ground, or flowing into or off of the site from a contributing area.

1.1.2.6 Refine vegetation and aquifer association for potential GDEs

We updated our geodatabase with field refinements in mapped vegetation types and extents, as well as location and extent of newly observed potential GDEs identified within the subbasin during the site survey. We then assigned the potential GDE units to aquifers based on DTW data and field observations.

1.1.2.7 Document changes to iGDE map and create final GDE map

We consolidated the remaining GDE polygons by type (e.g., vegetated, riparian) and proximity to one another, giving each grouping a descriptive name. Changes made to the original iGDE map were recorded as they were made, based on desktop or field observation of changes in vegetation type or land use, indications of no hydrologic linkage to groundwater, or areas where the hydrologic regime is dominated by human intervention, including canals. The final GDE map (Figure A2.B-2) shows these consolidated GDEs, grouped into GDE units, each with a unique color and name. A single unit, the San Joaquin River Riparian GDE Unit, occurs in the Chowchilla Subbasin. Figure A2.B-3 shows the GDE unit in greater detail.

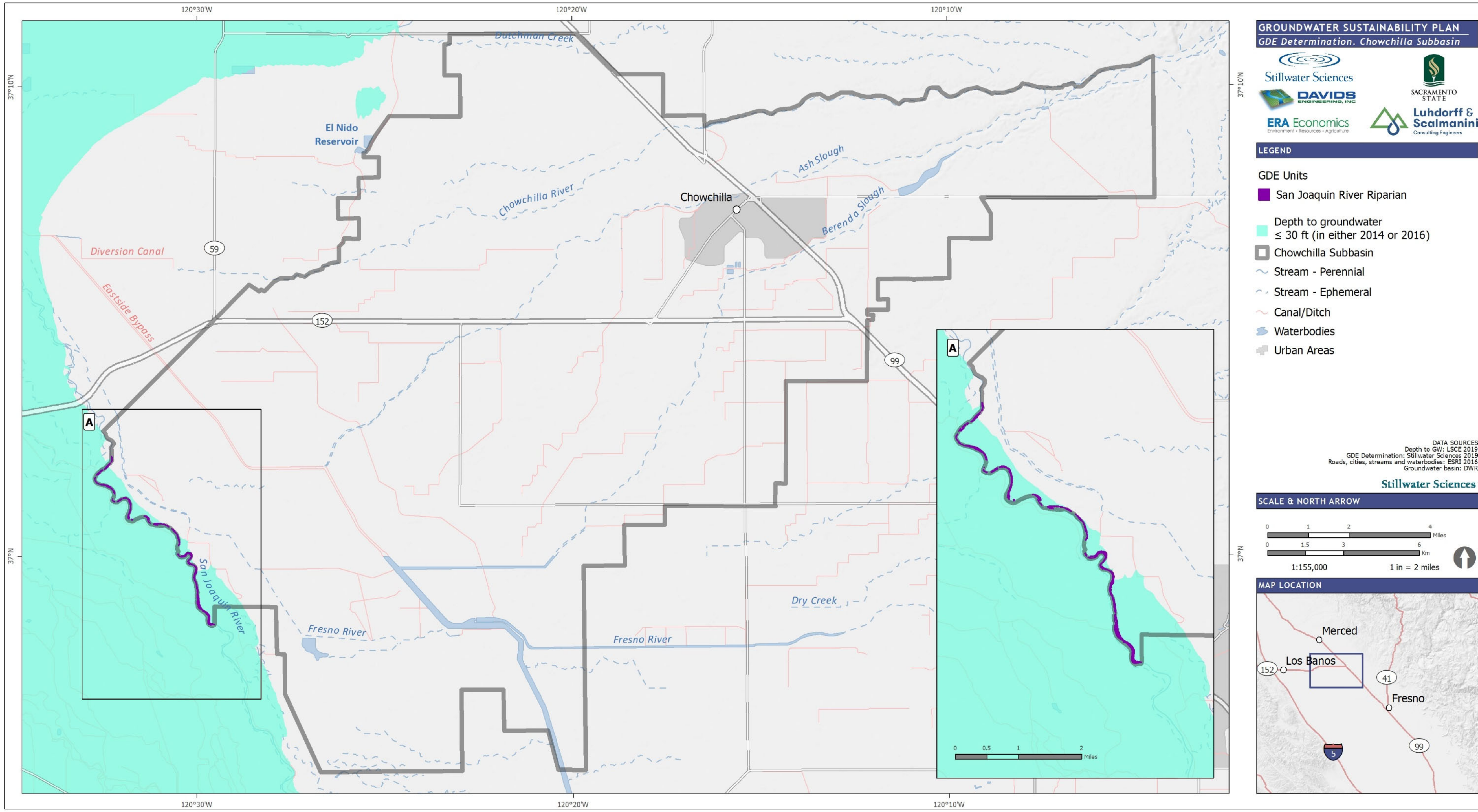

Figure A2.B-2. GDE units and depth to groundwater in the Chowchilla Subbasin.

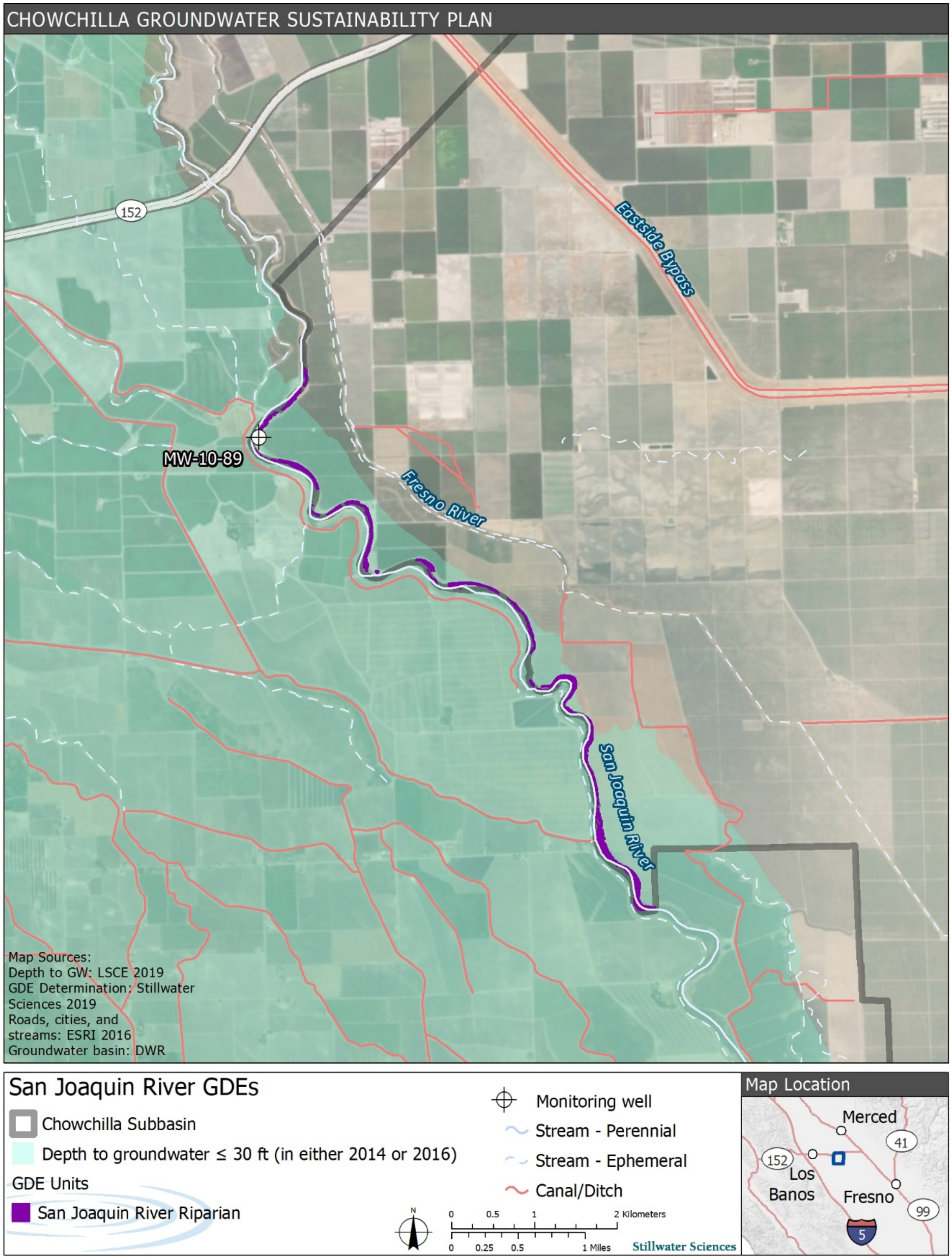

Figure A2.B-3. San Joaquin River Riparian GDE Unit, and the location of the San Joaquin River Restoration Program (SJRRP) monitoring well MW-10-89.

2 GDE CONDITION

In this section we characterize the San Joaquin River Riparian GDE Unit based on its hydrologic and ecological conditions and assign a relative ecological value to the unit by evaluating its ecological assets and their vulnerability to changes in groundwater (Rohde et al. 2018).

2.1 Hydrologic Conditions

The San Joaquin River Riparian GDE Unit is located along the western boundary of the Chowchilla Subbasin. Flows in this reach of the San Joaquin River are largely controlled by releases from Friant Dam and Mendota Pool. The unit is underlain by interbedded sands and silt/clays and the Corcoran Clay is over 200 feet below the ground surface (see Chapter 2.2.1 of this GSP).

Groundwater was less than 30 feet deep in 2014 and 2016 under the GDE unit (Figure A2.B-3). This is too deep for the surface flow of the San Joaquin River to be continuously connected to groundwater, but within the maximum rooting depth of riparian plants. The groundwater may connect to the river during sustained high flows in the San Joaquin River. Groundwater perched/mounded atop the upper clay likely originates from infiltration of surface water, agricultural runoff and infiltration, and potentially leakage from the canals in close proximity to the channel. Underneath the San Joaquin River, the groundwater is perched or mounded atop the shallow clay but there is no unsaturated zone below the perched/mounded aquifer. It is therefore possible that changes to the regional aquifer could affect the shallower perched/mounded aquifer that maintains the GDE, but this connection is unknown. Simulations using C2VSIM, a groundwater-surface water modeling system designed by DWR for the entire Central Valley, suggest the San Joaquin River in this reach was a gaining stream, on average from the 1920s through 2000 (TNC 2014). The average element size for the C2VSIM modeling was 0.64 mi^2, a much coarser grid than used for the modeling conducted as part of this GSP, and hence the C2VSIM model has a much larger uncertainty in its results.

Flows in the San Joaquin River changed following the San Joaquin River Restoration Settlement Agreement in 2006. Prior to the settlement minimum releases from Friant Dam were required to deliver 5 cfs to Gravelly Ford, located upstream in the Madera Subbasin. Interim flow releases from Friant Dam began in October 2009, and restoration flows began January 1, 2014, but were curtailed during critically dry conditions from March 2014–February 2016. Restoration flows in the San Joaquin River were reinitiated in 2016.

To determine hydrologic conditions, groundwater depth was modeled at San Joaquin River Restoration Program (SJRRP) monitoring well SJRRP_MW-10-89. The historical condition (1988–2015) is illustrated in Figure A2.B-4. This well is located adjacent to the river within 50 feet of the GDE unit (Figure A2.B-3). Two other shallow SJRRP wells, SJRRP_MW-11-161 and SJRRP_MW-11-163, which are located approximately 1,800 feet upstream of Sack Dam (and approximately 5 miles upstream of SJRRP MW-10-89), are ¼ mile east of the San Joaquin River Riparian GDE. These more distal wells can be used to assess groundwater changes near the upstream end of the GDE.

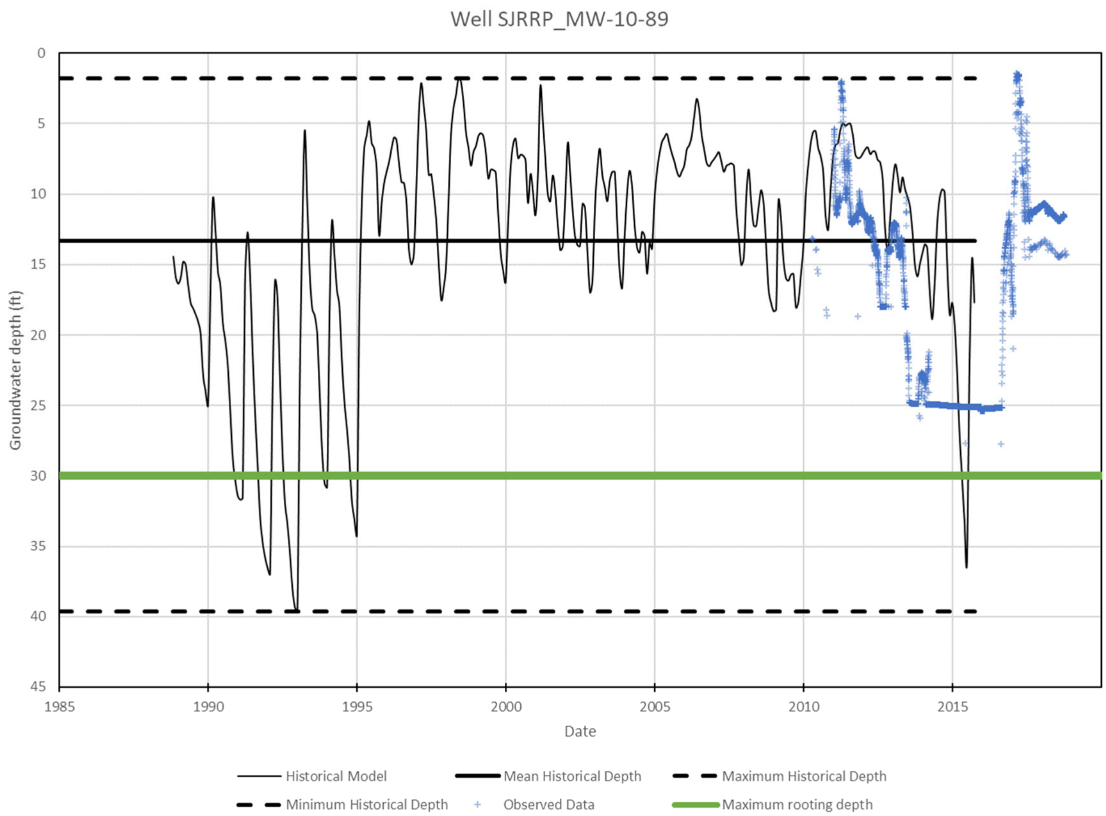

Figure A2.B-4. Modeled and observed groundwater elevations from well SJRRP_MW-10-89 located at the northwest section of the San Joaquin River Riparian GDE Unit.

Figure A2.B-4 shows the modeled depth for the finer-scale modeling results for 1988–2015 conducted as part of this GSP (black lines), groundwater depth measurements (blue plus symbols), the mean groundwater depth for 1988–2015 (horizontal solid line), and the minimum and maximum modeled depths for 1988–2015 (dashed horizontal lines) for SJRRP_MW-10-89. The model results are linked to known hydrologic inputs from 1988–2015 and observed data recorded from April 2010–October 2018 for the SJRRP_MW-10-89 well. Because the well is screened from 10 to 25 feet below the ground surface, the persistent water depths near 25 feet from 2013–2016 (Figure A2.B-4) indicate that water depth was at least 25 feet deep, but the actual depth is unknown. The SJRRP restoration flows in the San Joaquin River are likely critical to maintaining shallow groundwater elevations associated with the GDE unit. With the exception of the dry period from 2013–2016 (when the observations do not reflect changes in groundwater level because the groundwater depth exceeded 25 feet), the model does a reasonable job capturing the timing of changes in groundwater level. The magnitudes of change differ by generally about 5 feet but the model results were at least 15 feet higher than the observations in 2014. The model does a much better job representing the 2012–2016 period in wells SJRRP_MW-11-161 and SJRRP_MW-11-163. From October 1988–December 1994 the shallow groundwater was very deep and highly variable. To some degree this is due to the drought during this period in combination with the lack of interim or restoration flow releases from Friant Dam prior to 2009.

The minimum modeled groundwater depth was 36.2 feet during the drought in November 1992. The deep groundwater depths prior to 1995 were due to a combination of drought conditions in the subbasin and very low flow releases to the San Joaquin River. The mean modeled groundwater depth form 1989–2015 was 7.9 feet and the groundwater depth ranged from 1.8–39.6 feet. Over this period, the groundwater depth exceeded 30 feet (the maximum depth at which GDE connection to groundwater is likely) for 22 months (6.8% of the monthly data). The shallowest well depths indicate that the surface water may be temporarily connected with the perched/mounded groundwater beneath the well. Because the groundwater inputs are dependent on inflow from the San Joaquin River, groundwater elevations decline during low flow periods and increase during high flows.

2.2 Ecological Conditions

The San Joaquin River Riparian GDE Unit is located along the San Joaquin River on the western margin of the Chowchilla Subbasin (Figures A2.B-2 and A2.B-3) and is composed of a mix of riparian forest, shrub, and herbaceous habitat types totaling approximately 70 acres. Analysis of existing vegetation mapping data (Klausmeyer et al. 2018), color aerial imagery (ESRI 2017), and May 2019 field reconnaissance conducted in representative portions of the unit determined the quality of riparian habitat in this unit to be generally good but with habitat patches ranging from somewhat degraded to excellent quality. The width, complexity, and relative percentage of native vegetation in the riparian corridor varied along the length of the San Joaquin River in this unit, as observed during the May 2019 field survey and past surveys of the area by Stillwater Sciences' ecologists, as well as review of aerial imagery. The riverine, aquatic habitat of the San Joaquin River is not contained within the GDE unit because, although surface flows in the San Joaquin River likely contribute to shallow groundwater in the unit via infiltration (see Section 2.2.2.5 of this GSP), available hydrologic data indicates no substantial groundwater contribution to the surface flow in the river (i.e., this reach of the San Joaquin River does not gain but rather loses water to the groundwater system). However, the riparian vegetation community of the San Joaquin River Riparian GDE Unit fulfills several essential ecosystem functions or provides important habitat elements, such as large wood and riparian shade, on which both semi-aquatic species of the GDE unit and aquatic species of the San Joaquin River depend for completing essential life behaviors. The Water Quality Control Plan (Basin Plan) for the San Joaquin River Basin (CRWQCB 2018) identifies the San Joaquin River adjacent to the GDE unit as having the following beneficial uses for fish and wildlife:

- Warm freshwater habitat (WARM);
- Warm and cold migration habitat (MIGR);
- Warmwater spawning habitat (SPWN); and
- Wildlife habitat (WILD).

Designated fish and wildlife beneficial uses of other surface water bodies in the Chowchilla Subbasin, including the Fresno River and Chowchilla River, are limited to warm freshwater habitat (WARM) and wildlife habitat (WILD). The Basin Plan also lists coldwater spawning habitat (SPWN) for salmon and trout as a potential beneficial use for this portion of the San Joaquin River. Because certain special-status aquatic species and habitat elements present in the San Joaquin River may rely in part on inputs and functions provided by vegetation in the GDE unit, these contributions are considered beneficial uses warranting consideration under SGMA. Accordingly, certain special-status species and their habitat in the San Joaquin River are included in the analyses of potential effects on the San Joaquin River Riparian GDE Unit presented below.

The reconnaissance-level biological assessment of representative portions of the San Joaquin River Riparian GDE Unit conducted in May 2019 identified areas of mature riparian forest with a stratified canopy and moderately open understory, overhanging vegetation along the riverbank, and downed wood (Figure A2.B-5). Vegetation at the site provided over 90% native cover in the shrub and tree layer and 15–25% native cover in the herbaceous ground cover, with the balance occupied by non-native species. Dominant vegetation included Fremont cottonwood (*Populus fremontii*) and Goodding's willow (*Salix gooddingii*) in the overstory and narrow-leaved willow (*Salix exigua*) in the shrub layer, interspersed with herbaceous ground cover dominated by European grasses and emergent vegetation (tules, cattails) lining the channel edge. Wildlife observed within the San Joaquin River Riparian GDE Unit included white-faced ibis, barn swallow, ash-throated flycatcher, Canada goose, spotted towhee, and house wren.

Figure A2.B-5. High-quality riparian habitat in the San Joaquin River Riparian GDE Unit. Photo taken May 1, 2019 by Stillwater Sciences.

The potential for special-status species and their habitat to occur in the San Joaquin River Riparian GDE Unit was determined by querying databases on regional and local occurrences and spatial distributions of special-status species, including CNDDB (2019), CNPS (2019), and eBird (2019). Spatial database queries were centered on the potential GDE plus a 5-mi buffer. Database query results of local and regional occurrences were combined with known habitat requirements of identified special-status species to develop a list of special-status species that satisfy one or more of the following criteria: (1) known to occur in the region and suitable habitat present in the GDE unit, (2) documented occurrence within the GDE Unit, and (3) directly observed during the May 1, 2019 reconnaissance survey (Table A2.B-1).

This GDE unit does not contain or overlap any critical habitat for federally listed species (USFWS 2019, NMFS 2016) but the adjacent San Joaquin River contains Essential Fish Habitat (EFH) for Chinook salmon which is partially dependent on riparian inputs to provide important salmon habitat elements including shade, overhead cover, nutrients, and woody material for instream cover and habitat complexity (PFMC 2014). The PG&E San Joaquin Valley Operations and Maintenance Habitat Conservation Plan (Jones & Stokes 2006) includes covered lands within the San Joaquin River Riparian GDE Unit and covers some of the same species identified in our queries as potentially occurring within the unit. However, the queries and field reconnaissance we conducted for this analysis provide more recent and site-specific data on the presence or potential for special status species to occur in the GDE unit, as well as the overall ecological value, ecological condition trend, and vulnerability to future groundwater changes. Therefore, the information contained in the PG&E Habitat Conservation Plan was not incorporated into our analysis. The unit does not include any known protected lands (CPAD 2019).

2.3 Ecological Value

The San Joaquin River Riparian GDE Unit was determined to have **high ecological value** because of: (1) the known occurrence and presence of suitable habitat for several special-status species (Table A2.B-1); and (2) the vulnerability of these species and their habitat to changes in groundwater levels (Rohde et al. 2018). The unit's high ecological value is also related to its contributions to the ecological function of adjacent riverine habitat that supports special-status salmonids and other species.

Table A2.B-1. Special-status species with known occurrence, or presence of suitable habitat in the San Joaquin River Riparian GDE Unit.

Common name *Scientific name*	Status[1]	Association with GDE Unit	Source	Habitat and occurrence
Birds				
Bald eagle *Haliaeetus leucocephalus*	FD, SFP	Likely	regional occurrence (CNDDB, eBird)	moderately suitable perching and limited nesting habitat; many documented occurrences in region; suitable foraging habitat in adjacent San Joaquin River
Swainson's hawk *Buteo swainsoni*	ST	Likely	regional occurrence (CNDDB, eBird)	highly suitable nest trees and nearby foraging habitat; many documented occurrences in Madera County
Western yellow-billed cuckoo *Coccyzus americanus occidentalis*	FT, SE	Unlikely	regional occurrence (CNDDB, eBird)	although rare, species is known or believed to occur in Madera County (USFWS 2019); moderately suitable nesting and foraging habitat present
Mammals				
Pallid bat *Antrozous pallidas*	SSC	Likely	regional occurrence (CNDDB, eBird)	suitable foraging habitat and numerous large trees for roosting; small structures moderately suitable for roosting in the vicinity
Western red bat *Lasiurus blossevillii*	SSC	Likely	regional occurrence (CNDDB, eBird)	suitable foraging habitat and numerous large trees for roosting
Amphibians and reptiles				
Western pond turtle *Emys marmorata*	SSC	Nesting stage likely; foraging may occur in adjacent San Joaquin River)	regional occurrence (CNDDB)	suitable nesting habitat
Fish				
Central Valley Spring-Run Chinook Salmon *Oncorhynchus tshawytscha*	FT	Not in GDE Unit but occupies adjacent San Joaquin River	known occurrence in San Joaquin River[2]	Suitable habitat present (migration, rearing); species known to occur in San Joaquin River and is sustained by San Joaquin River Restoration Program
Central Valley Steelhead *Oncorhynchus mykiss*	FT	Not in GDE Unit but likely in adjacent San Joaquin River	local/regional occurrence in San Joaquin River (CNDDB, NMFS)	Suitable habitat present (migration, rearing); species known to occur in San Joaquin River
Hardhead *Mylopharodon conocephalus*	SSC	Not in GDE Unit but likely in adjacent San Joaquin River	local/regional occurrence in San Joaquin River (CNDDB)	Suitable habitat present; species known to occur in San Joaquin River
Plants				
Sanford's arrowhead *Sagittaria sanfordii*	1B.2, S3, G3, not state or federally listed	Likely	regional occurrence (CNDDB)	Emergent vegetation along backwater areas of channel edge could support this species.
California satintail *Imperata brevifolia*	2B.1, S3, G4, not state or federally listed	Likely	regional occurrence (CNDDB)	Occurs on stream banks and floodplains and therefore could be supported along these banks of the San Joaquin.
Brittlescale *Atriplex depressa*	1B.2, S2, G2, not state or federally listed	Likely	local occurrence (CNDDB)	Meadows, seeps, playas, vernal pools, alkaline soil, perennial grasslands, and backwater/oxbow depressions with saline soil could support this species; all CNDDB observations within buffer area are in grasslands and/or vernal pool areas; none in riparian corridor
Heartscale *Atriplex cordulata var. cordulata*	1B.2, S2, G3, not state or federally listed	Likely	local occurrence (CNDDB)	Found on saline or alkaline soils; occurs in annual grasslands, seeps, and backwater/oxbow depressions with saline soil; all CNDDB observations within buffer area are in grasslands and/or vernal pool areas; none in riparian corridor
Munz's tidy-tips *Layia munzii*	1B.2	Unlikely	local occurrence (CNDDB)	Chenopod scrub, grasslands, found on alkaline clay soils; last reported in area in 1941
Palmate-bracted bird's-beak *Chloropyron palmatum*	1B.1, FE, SE,	Likely	local occurrence (CNDDB)	Chenopod Scrub, alkaline soils, found in alkaline flats but multiple semi-recent sightings in the vicinity

Common name ***Scientific name***	**Status[1]**	**Association with GDE Unit**	**Source**	**Habitat and occurrence**
Spiny-sepaled button-celery *Eryngium spinosepalum*	1B.2, S2, G2, not state or federally listed	Likely	local occurrence (CNDDB)	Valley grassland, freshwater wetlands, wetland-riparian, vernal pools. Many CNDDB observations within buffer area are in grasslands such as those along San Joaquin riparian corridor
California alkali grass *Puccinellia simplex*	1B.2, S2, G3, not state or federally listed	Likely	local occurrence (CNDDB)	Valley grassland, wetland-riparian, Meadows, seeps, vernal pools, vernally mesic, sinks, lake margins however most CNDDB sightings are on alkali soils and/or vernal pools
Valley Sacaton Grassland	S1.1, G1	Likely	local occurrence (CNDDB)	Alkali-saline soil, and wetland found along riparian zones in California and southwest
Sycamore Alluvial Woodland	S1.1, G1	Likely	Regional occurrence (CNDDB)	Riparian, floodplain, and wetland

[1] Status codes:

G = Global

Federal

FT = Listed as threatened under the federal Endangered Species Act

FD = Federally delisted

State

S = Sensitive

SE = Listed as Endangered under the California Endangered Species Act

ST = Listed as Threatened under the California Endangered Species Act

SSC = CDFW species of special concern

SFP = CDFW fully protected species

Global Rank

1 Critically Imperiled—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.

2 Imperiled—At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.

3 Vulnerable — At moderate risk of extinction or elimination due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.

4 Apparently Secure — Uncommon but not rare; some cause for long-term concern due to declines or other factors.

California Rare Plant Rank

1B Plants rare, threatened, or endangered in California and elsewhere

2B Plants rare, threatened, or endangered in California, but more common elsewhere

3 More information needed about this plant, a review list

4 Plants of limited distribution, a watch list

CBR Considered but rejected

CRPR Threat Ranks:

0.1 Seriously threatened in California (high degree/immediacy of threat)

0.2 Fairly threatened in California (moderate degree/immediacy of threat)

0.3 Not very threatened in California (low degree/immediacy of threats or no current threats known)

[2] San Joaquin River Restoration Program. 2017. Fisheries Framework: Spring-run and Fall-run Chinook Salmon. June 2017. http://www.restoresjr.net/?wpfb_dl=1055

3 POTENTIAL EFFECTS ON GDEs

This section presents the methods and results of our analysis to identify how groundwater management could affect GDEs in the Chowchilla Subbasin. Adverse effects (impacts) on GDEs are considered undesirable results under SGMA (State of California 2014). The analysis is based on the hydrologic conditions affecting GDEs and their susceptibility to changing groundwater conditions, trends in biological condition of the GDEs, and anticipated conditions or management actions likely to affect GDEs in the future.

3.1 Summary

This section provides a summary of potential effects for the San Joaquin River Riparian GDE Unit. The methods used to determine the GDE unit's current ecological condition and its susceptibility to changing groundwater conditions are described in Section 3.2 below. The analyses and rationale for these assessments are described in Sections 3.3, 3.4, and 3.5.

The San Joaquin River Riparian GDE Unit is characterized as having high ecological value with moderate susceptibility to changing groundwater conditions. The perched/mounded shallow groundwater associated with this unit has a potential connection with the regional aquifer and could be affected by groundwater pumping. Reconnaissance level biological assessment, aerial photograph analysis, and NDVI/NDMI data indicate the ecosystem structure and functions of the San Joaquin River Riparian GDE Unit are relatively intact and within the range of natural variability (Biological Condition Gradient Level 2 – Minimal Changes) and adverse impacts are not likely occurring in the unit as a result of current groundwater management (Table A2.B-2).

Projected future trends in depth to water indicate a modest decline in the average groundwater depth in the unit and an increase in the frequency and duration with which groundwater depth is expected to exceed historical lows. Adverse impacts related to future groundwater management are therefore possible.

Table A2.B-2. Summary of ecological value, susceptibility, and condition gradient in the San Joaquin River Riparian GDE Unit.

Ecological value	Rationale
High	1. Presence of special-status species 2. Vulnerability of special-status species and their habitat to changes in groundwater
Susceptibility to changing groundwater conditions	**Rationale**
Moderate	Current groundwater conditions (since 2015) are within the baseline range (1988–2015) but future changes in groundwater conditions may cause it to fall outside the baseline range.
Biological condition gradient	**Rationale**
Level 2—Minimal Changes	1. No change observed in NDVI/NDMI trends over the period 1985–2018 2. Relatively intact biotic structure and function as deduced from reconnaissance level assessment of riparian vegetation community condition 3. Suitable habitat present for those special-status species with likelihood to occur

3.2 Methods

SGMA describes six groundwater conditions that could cause undesirable results, including adverse impacts on GDEs. These are (1) chronic lowering of groundwater levels, (2) reduction of groundwater storage, (3) seawater intrusion, (4) degraded water quality, (5) land subsidence, and (6) depletions of interconnected surface water. Rohde et al. (2018) identify chronic lowering of groundwater levels, degraded water quality, and depletions of interconnected surface water as the most likely conditions to have direct effects on GDEs, potentially leading to an undesirable result. Following this guidance and based on available information for the Chowchilla Subbasin, we have eliminated reduction of groundwater storage, seawater intrusion (the subbasin is not located near or hydrologically connected to the ocean), and land subsidence from consideration. Current evidence indicates that groundwater pumping from the regional aquifer is unlikely to affect surface water flows in the subbasin, thus depletion of interconnected surface water is considered unlikely. The San Joaquin River is adjacent to, but not a part of, the San Joaquin River Riparian GDE Unit and is in a net-losing condition, with surface flow likely contributing directly to the shallow groundwater system that supports the vegetation in the unit. However, the shallow groundwater system adjacent to and disconnected from the San Joaquin River, which supports the GDE unit, does have at least the potential (albeit quite muted) to be affected by regional groundwater pumping.

This section evaluates the potential for chronic lowering of groundwater levels and degraded groundwater quality to cause direct effects on GDEs compared to baseline conditions), with a focus on effects related to groundwater levels. First, we identified baseline hydrologic conditions for the GDE unit using available information (see Section 2.2.2 of this GSP). The primary baseline hydrological condition metric used for our analysis was depth to groundwater. Next, we determined each GDE unit's susceptibility to changing groundwater conditions using available hydrologic data and the GDE susceptibility classifications (Rohde et al. 2018) summarized in Table A2.B-3.

Table A2.B-3. Susceptibility classifications developed for evaluation of a GDE's susceptibility to changing groundwater conditions (Rohde et al. 2018).

Susceptibility classifications	
High Susceptibility	Current groundwater conditions for the selected hydrologic data fall outside the baseline range.
Moderate Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range but future changes in groundwater conditions are likely to cause it to fall outside the baseline range. The future conditions could be due to planned or anticipated activities that increase or shift groundwater production, causing a potential effect on a GDE.
Low Susceptibility	Current groundwater conditions for the selected hydrologic data fall within the baseline range and no future changes in groundwater conditions are likely to cause the hydrologic data to fall outside the baseline range.

We used these susceptibility classifications to trigger further evaluation of potential effects on GDEs by integrating existing biological data, field reconnaissance assessments, and aerial photography analysis. If we determined a GDE unit to have moderate or high susceptibility to changing groundwater conditions, we used biological information to assess whether evidence exists of a biological response to changing groundwater levels or degraded water quality. The biological response analysis consisted of a combined approach of reconnaissance-level biological assessments in representative areas of each GDE unit, and quantitative trend analysis of Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) data for individual vegetation polygons within the GDE unit (Klausmeyer et al. 2019). The polygons correspond to different GDE mapping units (i.e., different species compositions) and the size of the GDE polygons varied.

NDVI, which estimates vegetation greenness, and NDMI, which estimates vegetation moisture, were generated from surface reflectance corrected multispectral Landsat imagery corresponding to the period July 9 to September 7 of each year, which represents the period when GDE species are most likely to use groundwater (see Klausmeyer et al. 2019 for further description of methods). Vegetation with higher NDVI values indicate increased density of chlorophyll and photosynthetic capacity in the canopy, an indicator of vigorous, growing vegetation. Similarly, high NDMI values indicate that the vegetation canopy has high water content and is therefore not drought stressed. These indices are both commonly used proxies for vegetation health in analyses of temporal trends in health of groundwater dependent vegetation (Rouse et al. 1974, Jiang et al. 2006; as cited in Klausmeyer et al. 2019). NDVI and NDMI trend analysis included compilation of NDVI and NDMI trend data from 1985 to 2018 for all delineated GDE polygons from the GDE Pulse Interactive Map (TNC 2019) that are within the GDE unit boundary. These data were used to calculate mean NDVI and NDMI, and 95% confidence intervals, by year for the GDE unit as a whole, and then change in mean NDVI/NDMI was visually inspected to identify increasing, decreasing, or no change in temporal trends over the period 1985 to 2018. Negligible changes were identified as those that failed to exceed the level of uncertainty in mean values as indicated by 95% confidence intervals.

To examine the effect of variable precipitation on NDVI/NDMI, annual precipitation data for each GDE was downloaded from the GDE Pulse Interactive Map (TNC 2019), and multiple linear regression analysis was used to evaluate potential relationships between precipitation and vegetation health. A weak correlation was interpreted as a weak coupling between precipitation and NDVI/NDMI, suggesting a comparatively stronger influence of groundwater conditions on NDVI/NDMI. We also evaluated the effect of surface water flows on NDVI/NDMI using the San Joaquin Valley Index (SJVI), which is calculated by DWR and is a function of San Joaquin flow into Millerton Reservoir, Merced River flow into Lake McClure, Tuolumne River flow to New Don Pedro Reservoir, and Stanislaus River flow into New Melones Reservoir (CDEC 2019). The index is used to determine water year type and flow releases in the San Joaquin River and its major tributaries. Because the SJVI is used to determine flow releases into the San Joaquin Valley and includes the previous year's hydrologic condition, it is a good proxy for hydrologic conditions experienced by GDEs located along San Joaquin Valley rivers.

Reconnaissance level biological assessments were used to determine the overall condition of riparian vegetation within the GDE unit, assess evidence of recent riparian tree recruitment, and detect biological indications of degraded water quality. Field observations were augmented with analysis of recent (2017 and 2018) aerial photographs to assess the degree to which field observations were consistent with trends detected in aerial photographs as well as spatial variability across the GDE unit.

These field-based, and remotely sensed biological data sources were used to determine any apparent trends in biological condition of the vegetation composing the GDE unit. These trends were evaluated over the period 1985–2018 (NDVI/NDMI) and 2017–2019 (using field-based and aerial photograph analyses) within the Biological Condition Gradient classification scheme (USEPA 2016) (Table A2.B-4). To assess impacts to GDEs, minimal or evident changes (Levels 2 and 3) were considered to indicate the potential for impacts due to changing groundwater conditions, with further data collection and analysis (i.e., monitoring) needed to evaluate the connection between impacts and groundwater management, if any. Moderate to severe changes (Levels 4–6), if detected, were considered to indicate adverse impacts to GDEs and therefore undesirable results in the subbasin.

Table A2.B-4. Classifications of the Biological Condition Gradient, a conceptual framework developed for interpretation of biological responses to effects of water quality stressors (USEPA 2016).

Biological condition gradient classifications	
Level 1—Natural or Native Condition	Native structural, functional, and taxonomic integrity is preserved. Ecosystem function is preserved within the range of natural variability. Functions are processes required for the normal performance of a biological system and may be applied to any level of biological organization.
Level 2—Minimal Changes	Minimal changes in the structure of the biotic community and minimal changes in ecosystem function. Most native taxa are maintained with some changes in biomass and/or abundance. Ecosystem functions are fully maintained within the range of natural variability.
Level 3—Evident Changes	Evident changes in the structure of the biotic community and minimal changes in ecosystem function. Evident changes in the structure due to loss of some highly sensitive native taxa; shifts in relative abundance of taxa, but sensitive ubiquitous taxa are common and relatively abundant. Ecosystem functions are fully maintained through redundant attributes of the system.
Level 4—Moderate Changes	Moderate changes in the structure of the biotic community with minimal changes in ecosystem function. Moderate changes in the structure due to the replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups. Ecosystem functions largely maintained through redundant attributes.
Level 5—Major Changes	Major changes in the structure of the biotic community and moderate changes in ecosystem function. Sensitive taxa are markedly diminished or missing; organism condition shows signs of physiological stress. Ecosystem function shows reduced complexity and redundancy.
Level 6—Severe Changes	Severe changes in the structure of the biotic community and major loss of ecosystem function. Extreme changes in structure, wholesale changes in taxonomic composition, extreme alterations from normal densities and distributions, and organism condition is often poor. Ecosystem functions are severely altered.

3.3 Hydrologic Data

3.3.1 Baseline conditions

The baseline hydrologic conditions for the San Joaquin River Riparian GDE were assessed using the modeled period from October 1988 to September 2015 (water years 1989–2015). Because the shallow groundwater elevations are tied to flows in the San Joaquin River, changes to the operations of Friant Dam have the potential to alter shallow groundwater levels. In particular, SJRRP interim flow releases beginning in 2009 and restoration flow releases beginning in 2014, and from 2017 to present, will likely help to maintain shallower groundwater elevations in the GDE compared with the scant flow releases in the San Joaquin River prior to 2009. Nevertheless, we use the entire 1988–2015 period as the baseline condition because it incorporates two droughts, which are most likely to impact the health of the GDE. Moreover, releases from Friant Dam generally aid the GDE, but have been curtailed during critically dry years typical of droughts.

The minimum modeled groundwater depth for 1988–2015 is an inverse function of the SJVI (Figure A2.B-6), which is integrates runoff in the San Joaquin Basin for a given water year and hydrologic conditions the previous year. Low values of the SJVI are correlated with drier conditions and higher values reflect wetter conditions. Groundwater is deepest for San SJVI values less than 2.1, which correspond to critically dry water years. Modeled groundwater depths were more variable.

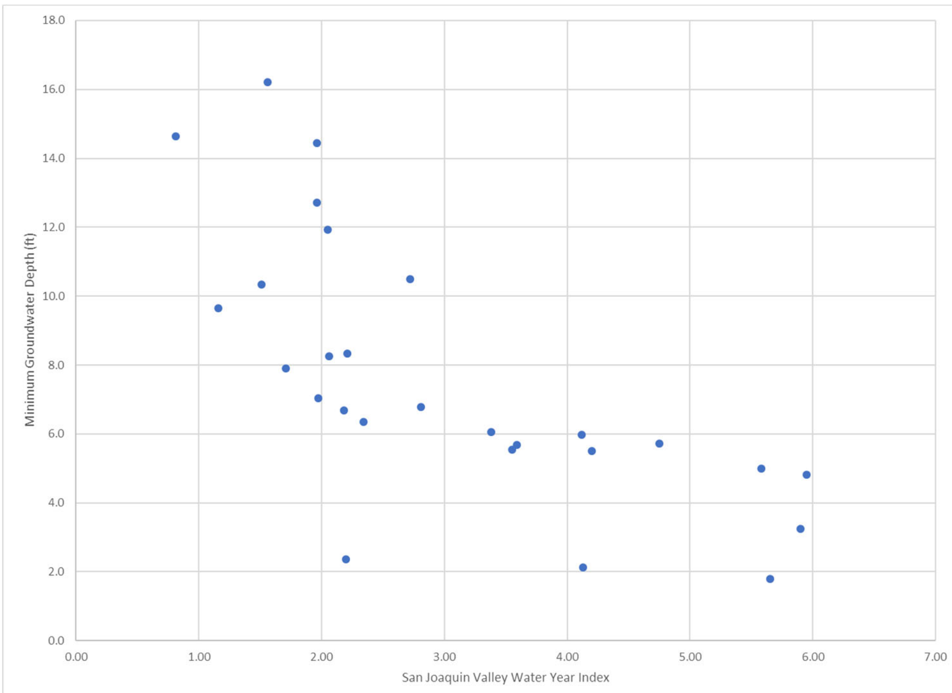

Figure A2.B-6. Minimum modeled groundwater depth for well SJRRP_MW-10-89 relative to San Joaquin Valley water year index, 1988-2015.

Groundwater quality data is available for multiple wells and constituents near the San Joaquin River Riparian GDE Unit (see Chapter 2.2.2.3 of this GSP). Maximum total dissolved solids (TDS) concentrations in the shallow groundwater of the GDE unit is elevated (>1,000 mg/L) at some locations, but other nearby wells indicate much lower values from 251–500 mg/L. High TDS conditions may be a result of naturally-occurring salinity in the groundwater system, especially in Coast Range-sourced sediments, which have marine origin. Other constituents, including nitrate, fall below applicable thresholds for environmental protection and human health at wells near the GDE unit.

The hydrologic baseline for the San Joaquin River Riparian GDE Unit is represented by the period from 1988–2015. This period experienced two droughts during which shallow groundwater depths likely were below the maximum rooting depth of riparian plants, but groundwater levels recovered once flows increased. There was no trend in shallow groundwater levels near the San Joaquin River Riparian GDE during the hydrologic baseline, rather the groundwater responded to surface hydrologic conditions, with monitoring and modeling results showing the groundwater very close to the ground surface during wet periods. While the San Joaquin River may be hydrologically connected to the groundwater during high flow events, this connection is likely very short-lived and likely reflects high runoff in the San Joaquin Basin. Since its construction in 1942, Friant Dam has diverted San Joaquin River water for agriculture. Operations were altered starting in 2009 to increase surface water flows for restoration and may help to maintain shallow groundwater elevations.

3.3.2 Susceptibility to potential effects

Future groundwater conditions were simulated by others for purposes of this GSP using MCSim, the same groundwater model used to assess the historical period shown in Figure A2.B-4. The future modeling was developed for use in GSP analyses assuming that the GSA will implement groundwater recharge projects, decrease groundwater demand, and to a lesser extent replace groundwater use with surface water use. As discussed in Chapter 3 of this GSP, the climate data used to model the first 20 years after implementation included a series of wet, average, and dry years that reflected the long-term historical average hydrologic conditions for the subbasin, but does not include a continuous series of dry or wet years. Following the implementation period (i.e., 2020–2040), historical hydrology from 1965–2015 is used for 2041–2090 and includes groupings of wet years and dry years (i.e., short- and longer-term droughts). Climate change was incorporated into the model following DWR guidelines (e.g., DWR 2018). In addition, model projections include a 10-year drought from 2060–2070 that is longer than the droughts experienced in the Chowchilla Subbasin during the historical modeling period, to explore the effects of a severe drought on groundwater sustainability.

Figure A2.B-7 shows the simulated and observed groundwater elevations for well SJRRP MW-10-89 from 1988–2090. The observed and simulated groundwater elevations for the historical (baseline) period (1988–2015) are identical to Figure A2.B-4, but Figure A2.B-7 includes the future simulation described above. Relative to the modeled baseline (1988–2015), the mean simulated shallow groundwater depth from 2020–2090 declines by 1.6 feet, from 13.3 in the baseline period to 14.9 ft in the implementation and sustainability periods (Figure A2.B-7 and Table A2.B-5). For the implementation period (2020–2040), which does not include the simulated 2060–2070 drought, the mean modeled groundwater elevation was 14.2 feet, between the 1988–2015 mean depth and the 2020–2090 mean depth. The range of simulated groundwater depth also increased as the minimum depth was closer to the surface (from 1.8 to 0.7 feet) and the maximum depth increases from 39.6 to 47.1 feet. As a consequence, the standard deviation of depth increases from 7.9 to 8.3 feet for the baseline and future conditions, respectively (Table A2.B-5). The fraction of months with groundwater depth greater than 30 feet increased from 6.8% for the baseline period to 9.2% for the implementation and sustainability periods (2020–2090).

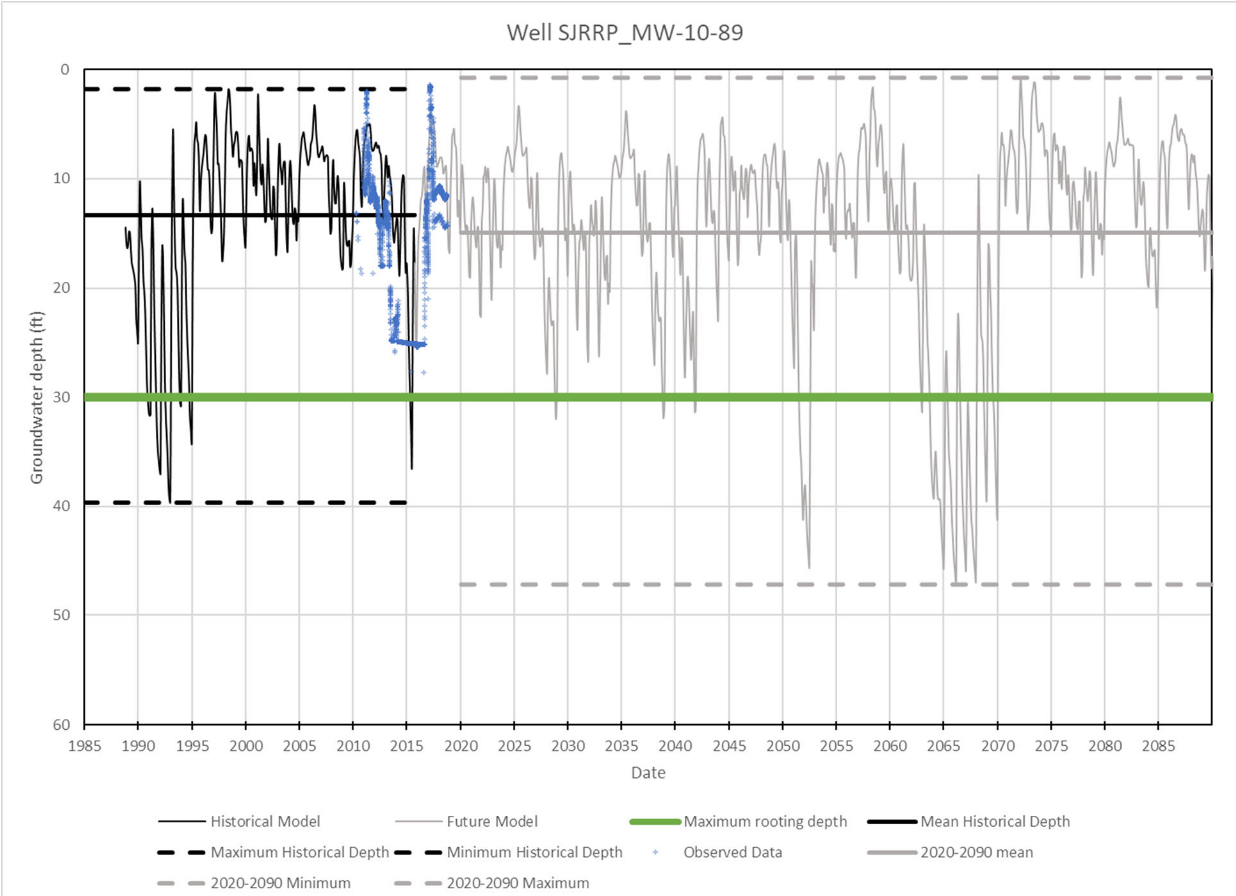

Figure A2.B-7. Simulated historical (black line 1988–2015) and modeled projected (grey line 2016–2090) monthly groundwater depth for well SJRRP_MW-10-89. Observed data (blue plus signs) were recorded hourly. The solid horizontal lines represent the mean modeled groundwater depth for the historical (black) and projected post-implementation (2020-2090) (grey) periods, while the horizontal dashed lines represent the maximum and minimum groundwater depth for the historical (black) and projected (grey) periods. The horizontal green line represents the maximum depth (30 feet) at which phreatophytic plants can access groundwater.

Table A2.B-5. Statistics of monthly modeled well depth for the SJRRP_MW-10-89 well.

Date range	Number of months	Mean depth (ft)	Standard deviation (ft)	Maximum depth (ft)	Minimum depth (ft)	Days depth>30 ft	% of days where depth>30 ft
1988–2015	324	13.3	7.9	39.6	1.8	22	6.8
2020–2090	849	14.9	9.3	47.1	0.7	78	9.2

During the implementation and sustainability periods, groundwater elevations are projected to show significant seasonal variation. On average, the groundwater depth varies by 12.0 feet within a water year from 1988–2015 and 12.2 feet from 2020–2090 (Figure A2.B-7). The simulated maximum groundwater elevation change was 34.1 feet in 1988–2015 and 37.2 feet from 2020–2090, while the minimum variation in monthly water elevations within a year was 4.0 feet for both the historical and future periods. Seasonal variation in groundwater depth is typically highest during the wettest or driest years. During the wettest years, the minimum groundwater depths are very shallow, while during the driest years, the maximum depths are very deep. Both the observed and model data show that shallow groundwater at well SJRRP_MW-10-89 can decline significantly during droughts but responds very quickly once San Joaquin River discharge increases. This response pattern is illustrated in Figures A2.B-6 and A2.B-7.

Combined, annual trends in depth to water during the observed and projected time periods indicate relatively stable groundwater conditions in the San Joaquin River Riparian GDE Unit. The small drop in mean groundwater depth is unlikely to have an adverse effect on the GDE, but the potential for more severe and longer-lived droughts may cause a decline in the health and extent of the San Joaquin River Riparian GDE. Groundwater modeling, however, provides evidence for an increase in the portion of months where depth to water exceeds the 30-foot rooting depth criterion (Section 1). The San Joaquin River Riparian GDE has persisted through droughts before, but the degree to which a threshold exists where the GDE is unable to recover is not known. If it exists, such a threshold effect could include replacement of native vegetation with more xeric non-native species or a reduced extent of the GDE. Either of these outcomes would have associated impacts to species relying on riparian vegetation for habitat and other ecological functions. As a result, the San Joaquin River Riparian GDE Unit was determined to be **moderately susceptible** (Table A2.B-3) to groundwater conditions falling outside the baseline range.

3.4 Biological Data

Average summer NDVI and NDMI for the period 1985–2018 indicate little to no overall change and modest fluctuations in both indices in the San Joaquin River Riparian GDE Unit (Figures A2.B-8 andA2.B-9). NDVI for individual, mapped polygons ranges from approximately 0.10 to 0.70, and mean NDVI for all polygons was lowest in 1992 (0.36) and highest in 2018 (0.54) (Figure A2.B-8). Change in NDVI between 1985 and 2018 showed a negligible increase (0.09) for mean NDVI. NDVI tends to decline during drier periods as indicated by the SJVI. For example, mean NDVI declined from 0.44 to 0.36 from 1985–1992 (Figure A2.B-8). A similar trend occurred from 2007–2010 and 2012–2016. In contrast, NDVI tends to increase during the wettest years. NDMI for individual, mapped polygons shows a similar trend to NDVI but with values ranging from approximately -0.2 to 0.45 (Figure A2.B-9). Mean NDMI for all polygons was also lowest in 1992 (-0.005), and highest in 2018 (0.17). Like NDVI, mean NDMI also showed a negligible increase (0.08) between 1985 and 2018. While there were interannual fluctuations in both NDVI and NDMI, lack of any long-term trend in either of these indicators of vegetation health suggests that the vegetation health in the San Joaquin River Riparian GDE has been stable throughout this period. Other factors may also influence NDVI and NDMI, including channel migration and erosion/deposition of sediment during floods.

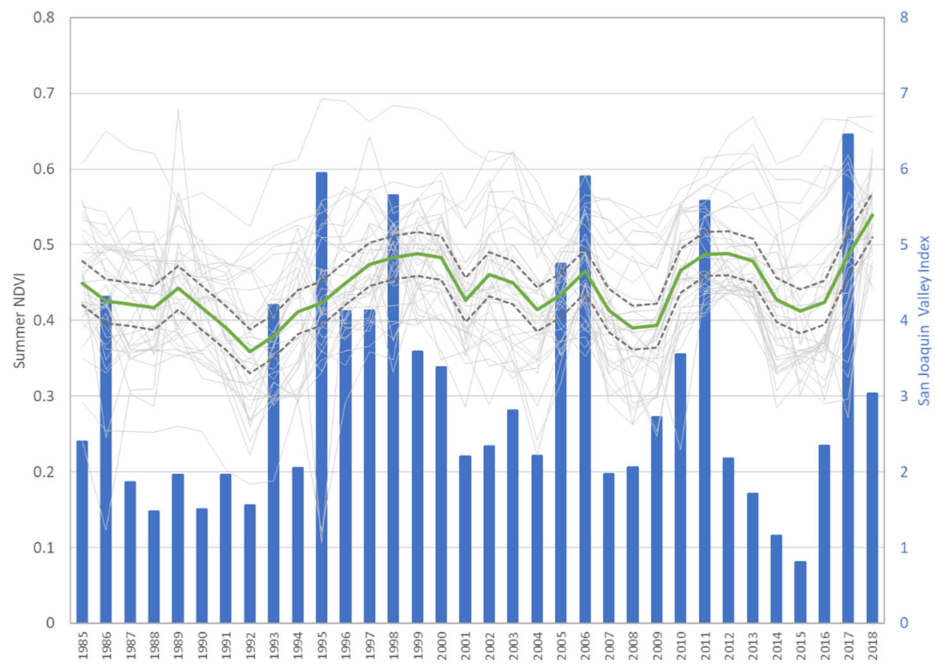

Figure A2.B-8. Summer NDVI for all GDE polygons identified in the GDE Pulse Interactive Map comprising the San Joaquin River Riparian GDE Unit from 1985–2018 (light grey lines). Mean NDVI (green line), and 95% confidence intervals of the mean NDVI (dashed black lines). The blue bars show the San Joaquin Valley Index, with low values corresponding to drier years and high values corresponding to wetter years.

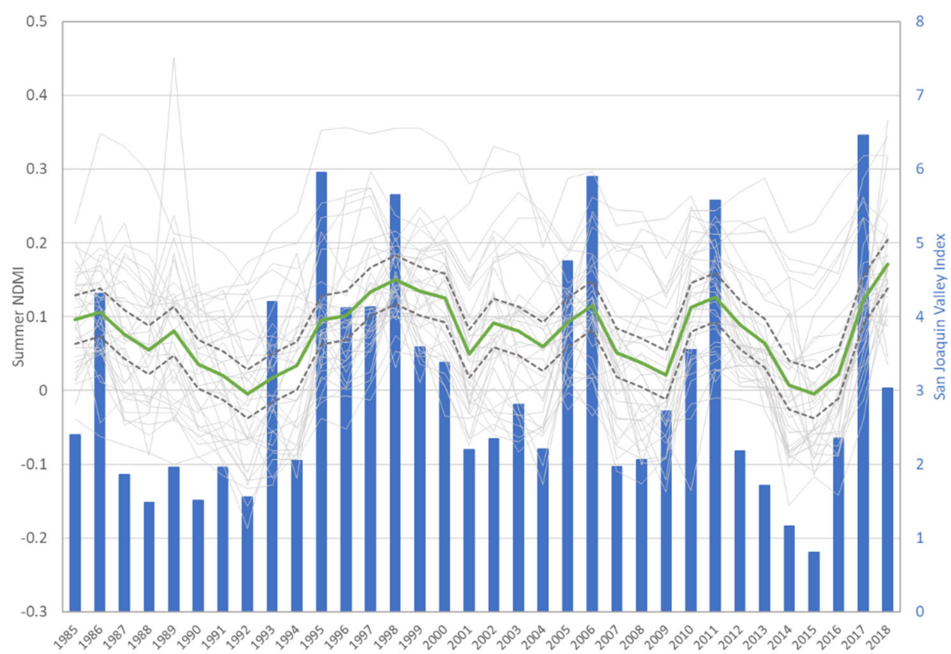

Figure A2.B-9. Summer NDMI for all GDE polygons identified in the GDE Pulse Interactive Map comprising the San Joaquin River Riparian GDE Unit from 1985–2018 (light grey lines). Mean NDMI (green line), and 95% confidence intervals of the mean NDMI (dashed black lines). The blue bars show the San Joaquin Valley Index, with low values corresponding to drier years and high values corresponding to wetter years.

Multiple linear regression was used to assess the effect of year, and annual precipitation on NDVI/NDMI. Annual precipitation was not a statistically significant predictor variable of mean NDVI ($p = 0.35$), and explained little, if any, of the variation in NDVI ($R^2 = 0.03$). Conversely, annual precipitation was a statistically significant predictor variable of mean NDMI ($p = 0.01$), but still showed little explanatory power of the variation in NDMI ($R^2 = 0.18$)

A reconnaissance field assessment of the San Joaquin River Riparian GDE Unit documented presence of recent riparian tree recruitment at representative sites in May 2019 as part of this study and also in 2013 as documented in Bureau of Reclamation (2014). The riparian vegetation observed in May 2019 appeared very healthy, with dense, green canopies at multiple layers with evidence of recent growth and saplings less than five years of age indicating recent recruitment of native riparian trees. Analysis of recent satellite imagery corroborates these field observations.

3.5 Potential Effects

Reconnaissance level biological assessments, aerial photograph analysis, and NDVI/NDMI data indicate adverse impacts are not likely occurring in the San Joaquin River Riparian GDE Unit as a result of changes in groundwater levels or degraded groundwater quality. However, detection of some types of adverse impacts may be precluded by insufficient data on the extent to which groundwater management may be influencing shallow groundwater underlying the GDE unit, and the potential for concomitant effects on riparian vegetation dynamics and habitat for special status species.

Groundwater in the San Joaquin River Riparian GDE Unit is tightly coupled with surface flow and runoff, and is generally maintained at depths within the maximum rooting depth of riparian species present in the unit (see Section 2.2.2 of this GSP). In the Chowchilla Subbasin, the San Joaquin River flows adjacent to the San Joaquin River Riparian GDE Unit and is in a net-losing condition, with surface flow likely contributing directly to the shallow groundwater system that supports the vegetation in the unit. Evidence of recent riparian tree recruitment (within 5 years) observed in the San Joaquin River Riparian GDE Unit, along with high-density, healthy vegetation at multiple layers, and the presence of these attributes throughout the unit suggests that baseline groundwater levels (i.e., those occurring since 1988 are sufficient to maintain ecosystem functions essential for the survival and reproduction of riparian plant species. In addition, trends in NDVI/NDMI show little to no change in overall vegetation health within the unit, and although past fluctuations in these indices appear correlated with periods of drought in the San Joaquin Basin (e.g., 2012–2016), both indices have rebounded following 2107 which was a wet water year. Based on these recent historical response patterns, it appears the dominant native vegetation composing the San Joaquin River Riparian GDE Unit is sufficiently resilient to maintain ecosystem integrity and function in the face of predicted fluctuations in groundwater conditions around the recent historical baseline level. The observed vegetation response following the 2012–2016 drought suggests that the ecological integrity of the GDE Unit would be maintained following periods of drought predicted to occur within the next 30–50 years, although adverse impacts ranging from short-term (e.g., water stress) to prolonged (reduced growth and recruitment, habitat loss) are possible (Rohde et al. 2018). The extent to which the late-1980s-early1990s drought impacted the GDE is not known, but we observed several cottonwood and oak trees in the GDE unit that likely pre-date that drought.

Riparian vegetation condition and NDVI/NDMI trends within the GDE unit also indicate groundwater quality is not limiting ecosystem functions essential for the survival and reproduction of riparian plant species. Rohde et al. (2018) list declining NDVI/NDMI, reduced tree canopy and understory, shifts in vegetation type, tree mortality, and habitat fragmentation as indicators of adverse impacts; however, none of these was detected within the GDE unit. Because the NDVI assessment was confined to the GDEs mostly mapped in 2014, our analysis does not account for potential reduction in the extent of riparian vegetation (and hence a reduction in the area of the polygons) prior to the vegetation mapping.

The response of perennial, resident wildlife and vegetation species, including those with protected status, and overall species composition to groundwater dynamics in the San Joaquin River Riparian GDE Unit is not well understood because population dynamics during the baseline period are not known. Many of these species survived the droughts in the early 1990s and the mid-2010s, but the effects on the species and their susceptibility to future changes are unknown. Appropriate data for evaluating these relationships is not readily available but, if obtained, could provide insight to additional interactions between groundwater conditions and biological responses, leading to a more complete evaluation of potential adverse impacts. Recommendations for monitoring to provide additional data for this purpose are included below in Section 5.

4 SUSTAINABLE MANAGEMENT CRITERIA

Sustainable management criteria for the Chowchilla Subbasin were developed using information from stakeholder and public input, correspondence with the GSAs, public meetings, hydrogeologic analysis, and meetings with GSA technical experts. The sustainable management criteria and methods used to establish them are described in Chapter 3 of this GSP.

4.1 Sustainability Goal

The sustainability goal developed for the Chowchilla GSP is expected to maintain the ecological integrity and function of the San Joaquin River Riparian GDE Unit. This includes maintenance of riparian habitat conditions for special-status species and other native species in the unit or those likely to occur, and provision of important ecosystem support functions for Central Valley spring-run Chinook salmon, Central Valley steelhead, and other special-status species and native aquatic species in the adjacent San Joaquin River. The GSP's sustainability goal would be achieved by implementing a package of projects and management actions that will, by 2040, balance long-term groundwater system inflows with outflows based on a 50-year period representative of average historical hydrologic conditions.

4.2 Minimum Thresholds for Sustainability Indicators

Minimum thresholds for the applicable sustainability indicators are described in Section 3.3 of this GSP. The minimum thresholds for chronic lowering of groundwater levels, the sustainability indicator most likely to affect GDEs in the subbasin, are based on selection of representative monitoring sites from among existing production and monitoring wells located throughout the subbasin and screened in both the Upper and Lower Aquifers. Of the representative monitoring sites for the subbasin, three are located in the Upper Aquifer and in close proximity to the San Joaquin River Riparian GDE Unit and one, SJRRP_MW-10-89, is considered to best represent shallow groundwater conditions potentially affecting the GDE unit. The proposed minimum threshold for groundwater levels in this well is 48 feet below ground surface (Section 3.3 of this GSP). Although the minimum threshold depth is greater than the 30-foot maximum rooting depth of the dominant native woody riparian plant species composing the GDE, modeled historical lows also show depths to water exceeding 30 feet. This is an indication that the dominant vegetation in the GDE unit is able to survive short-term declines in water levels, possibly due in part to the presence of a capillary fringe above the water table. The modeled future exceedances of the 30-foot rooting depth threshold (i.e., depth to water approaching each well's minimum threshold for this sustainability indicator) are projected to be of relatively short duration (1–5 years) and to occur only once or twice during the 70 years that include the 20-year implementation period and the 50-year sustainability period. If these projected reductions in groundwater levels occur, effects on GDEs could include short-term adverse impacts such as water stress and could also lead to longer-term impacts such as reduced growth and recruitment, and potential branch dieback or some tree mortality resulting in some loss of vegetation structure, ecological function, and habitat for special-status species. However, given their relatively low projected frequency and short duration, coupled with the inherent uncertainty in model projections and response of the GDE to the recent multi-year drought, longer-term impacts are unlikely. Historical model results for well SJRRP_MW-10-89 reflect shallow groundwater conditions under which the GDE vegetation currently composing the unit has persisted since 1985 with no apparent adverse effects, suggesting that similar conditions in the future (and possibly deeper water levels) would continue to support the GDEs. In addition, restoration flows in the San Joaquin River under the SJRRP are expected to provide continued hydrologic inputs contributing to long-term support of the San Joaquin River Riparian GDE unit.

Based on this information, the native vegetation communities composing the San Joaquin River Riparian GDE are expected to be maintained in good health by sustainable groundwater management in the Chowchilla Subbasin and therefore resilient to short-term adverse impacts, thus the minimum thresholds are not expected to cause substantial adverse impacts to GDEs.

4.3 Measurable Objectives and Interim Milestones

Measurable objectives and interim milestones for the applicable sustainability indicators are described in Section 3.3 of this GSP. Measurable objectives and interim milestones for groundwater levels, the sustainability indicator most likely to affect GDEs in the subbasin, are proposed for representative monitoring sites in the subbasin including well SJRRP_MW-10-89, which best represents groundwater conditions associated with the San Joaquin River Riparian GDE Unit. The proposed measurable objectives and interim milestones for groundwater levels in these three wells range from 8–14 ft below ground surface (Section 3.3 of this GSP). The groundwater level objectives and milestones are well within the range of maximum vegetation rooting depth and are expected to maintain or increase the spatial extent of the GDE unit, with no net loss of native plant species dominance. These characteristics can be assessed through monitoring to measure the areal extent of the vegetated GDE unit and the ecological condition of phreatophytic vegetation.

5 GDE MONITORING

Data on San Joaquin River riparian forest condition and extent, as well as surface water and shallow groundwater hydrology of the San Joaquin River, are among the types of information that have been collected, analyzed, and reported under the auspices of the SJRRP. The SJRRP is currently monitoring shallow groundwater in several wells along the San Joaquin River in the Chowchilla Subbasin. However, the ecological characteristics and hydrologic dependencies of the San Joaquin River Riparian GDE unit are not currently the subject of regular, systematic monitoring as part of any known program. Actions to improve the existing monitoring network may be warranted so that GDE conditions can be thoroughly documented and impacts to GDEs can be detected. Biological data should be collected with sufficient spatial and temporal coverage to adequately characterize the GDE's reliance on groundwater and, together with evaluation of associated hydrologic data, to monitor the response of GDEs to groundwater management, including projects and management actions proposed to be implemented under this GSP (Section 6).

The San Joaquin River Riparian GDE is moderately susceptible to changing groundwater conditions and has high ecological value, thus the following types of monitoring recommended by Rohde et al. (2018) should be considered:

- Annual desktop monitoring using simple biological indicators such as remote sensing indexes (NDVI/NDMI) and aerial photograph analysis to monitor changes in vegetation condition, growth, and the spatial extent of the GDE.
- Biological surveys (e.g., vegetation transects) conducted at regular intervals (minimum every 5 years or more frequently if needed based on the desktop surveys or biological surveys that indicate the GDE condition or extent has declined) to document baseline biological conditions and changes corresponding to GSP implementation and groundwater management.

Biological monitoring data should be evaluated as part of an adaptive management framework to facilitate improvements in the monitoring program and refinement of projects and management actions or implementation of new actions to avoid adverse impacts to GDEs.

6 PROJECTS AND MANAGEMENT ACTIONS

Implementation of the GSP will require the Chowchilla Subbasin to be operated within its sustainable yield by 2040. To ensure the subbasin meets its sustainability goal by 2040, the GSAs have proposed projects and management actions to address undesirable results (see Chapters 3 and 4 of this GSP). To achieve this, GSAs may implement projects to increase groundwater recharge, reduce groundwater pumping, or both.

Because no undesirable results were identified for the San Joaquin River Riparian GDE Unit under baseline, existing, or projected future with-project conditions, no GDE-specific projects or management actions were developed for this GSP. Effects on GDEs resulting from increased groundwater recharge and reduced groundwater pumping are expected to be beneficial, as groundwater levels accessed by vegetation in the San Joaquin River Riparian GDE Unit are expected to remain relatively similar to historical and recent baseline conditions, thus maintaining an accessible and reliable water source.

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