Conservation of California's Great Valley Vernal Pool Landscapes:

User's Guide and Reference Manual

Presented by John Vollmar | Vollmar Natural Lands Consulting | March 1, 2023

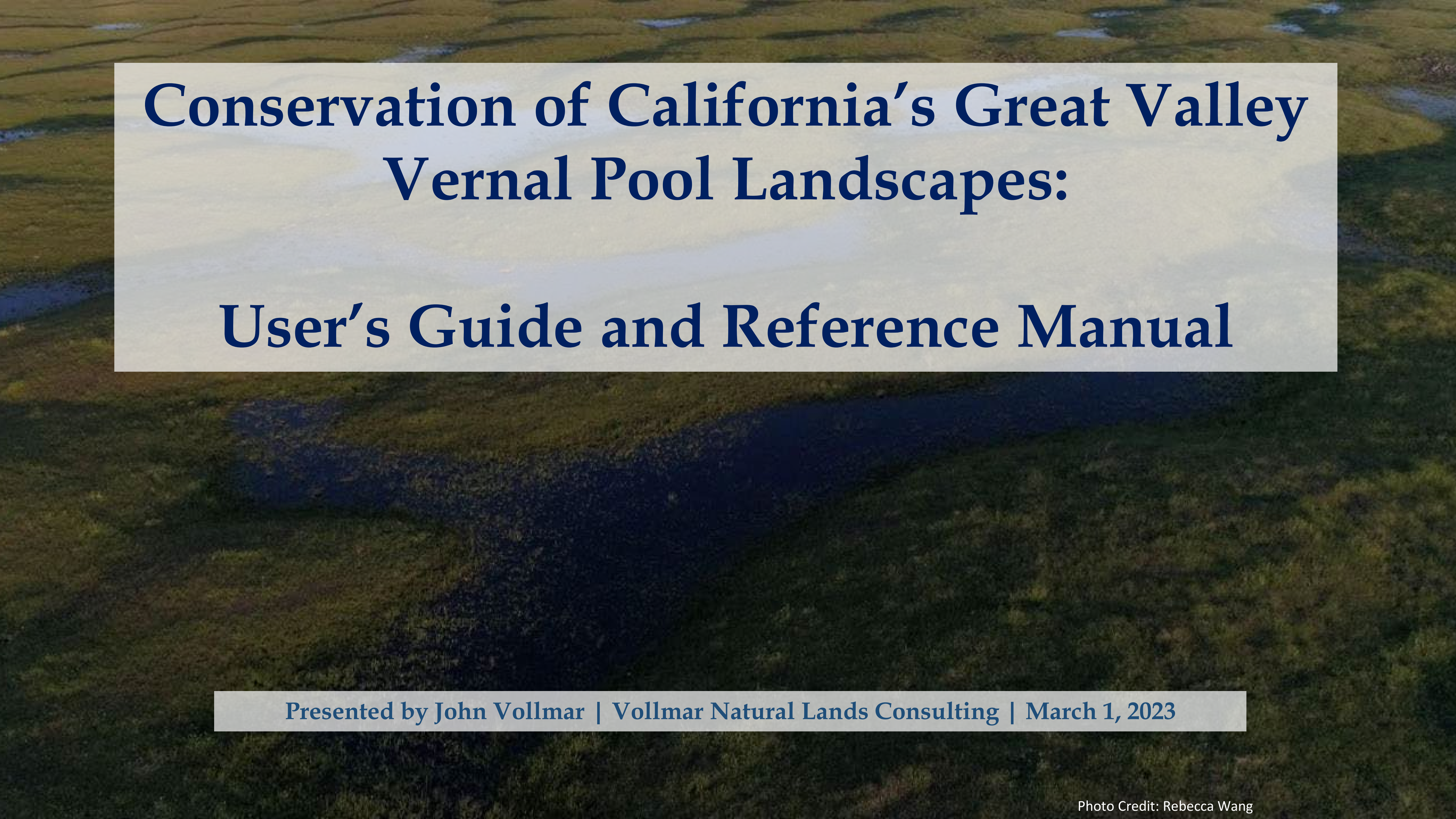

Photo Credit: Rebecca Wang

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Project Team

East Merced Resource Conservation District in partnership with Vollmar Natural Lands Consulting

- 20-year history of collaboration on vernal pool education and conservation projects
- Achieved 60K+ acres of habitat conservation, good relationships with ranch partners, numerous publications
- Highlights the value of public-private partnership
- EMRCD Team: Jean Okuye and Ursula Stock/EMRCD Board
- VNLC Team: John Vollmar, Kristen Chinn, Eric Smith, Anton Bokisch
- USEPA/WCB Project Managers: Joseph Morgan and Alexa Dunn

Project Funders

Total Budget: $380K

Primary Funding:
USEPA WPDG: $240K

Match Funding:
California State Wildlife Conservation Board (WCB): $140K

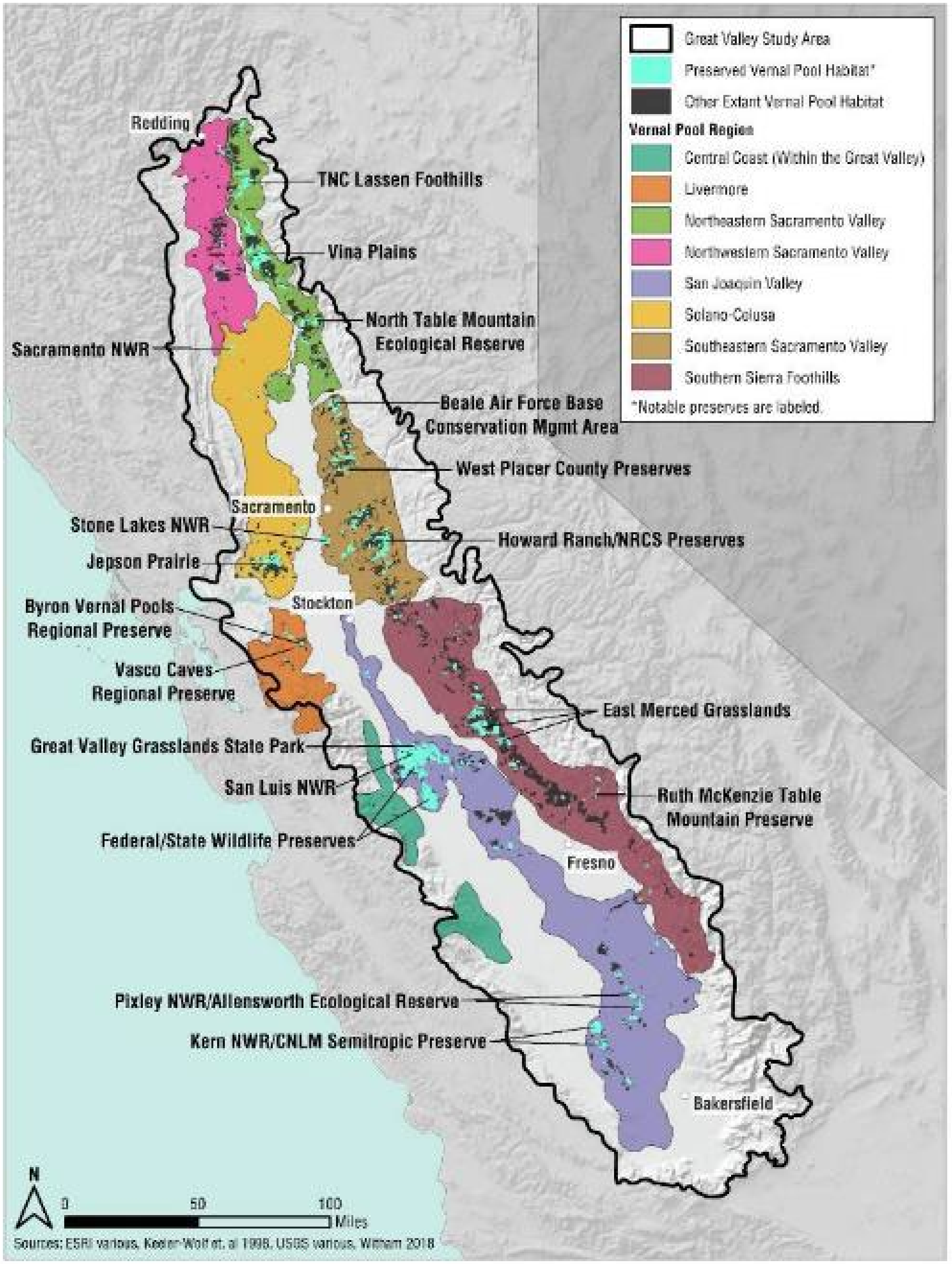
Additional Funding
In-kind Contributions from Project Technical Advisors

Combined Federal/State Funding Partners Ensure Broad Awareness and Use of Project Outputs

Project Description & Purpose

- Identify/characterize 5-10 large vernal pool habitat blocks in each of the eight defined Vernal Pool Regions in California's Great Valley as focal point of conservation
- Prepare an easy-to-use book-like 'guide' that highlights the beauty and conservation value of vernal pool habitats and species, and describes the Vernal Pool Regions and target habitat blocks
- Provide the book and GIS data to public agencies, non-profit conservation groups, mitigation companies, and others to develop a common focus on the target blocks for ongoing vernal pool habitat conservation, and avoid more scattershot conservation of smaller, isolated blocks
- Eventual conservation of all target blocks will ensure robust conservation of the essential biodiversity of Great Valley vernal pools

Mapped Vernal Pool Habitats by Great Valley Region



Study Background/Genesis

- Vernal pools are unique ephemeral wetlands with a high diversity of rare species – restricted to areas with Mediterranean climates, appropriate soils
- California arguably supports the most extensive and diverse vernal pool habitats in the world
- >90% of California's original vernal pool habitats have been lost since European arrival
- Remaining habitat is highly fragmented though some large, contiguous habitat blocks remain

Study Background/Genesis

Previous USEPA WPDG-funded Study:

MULTI-SCALE ASSESSMENT OF
PAST ACHIEVEMENTS AND FUTURE
DIRECTIONS FOR VERNAL POOL HABITAT
CONSERVATION AND MANAGEMENT
GREAT VALLEY, CALIFORNIA

Prepared For:

U.S. Environmental Protection Agency
75 Hawthorne Street, WTR-8
San Francisco, CA 94105
Wetland Program Development Grant
No. 99T06001

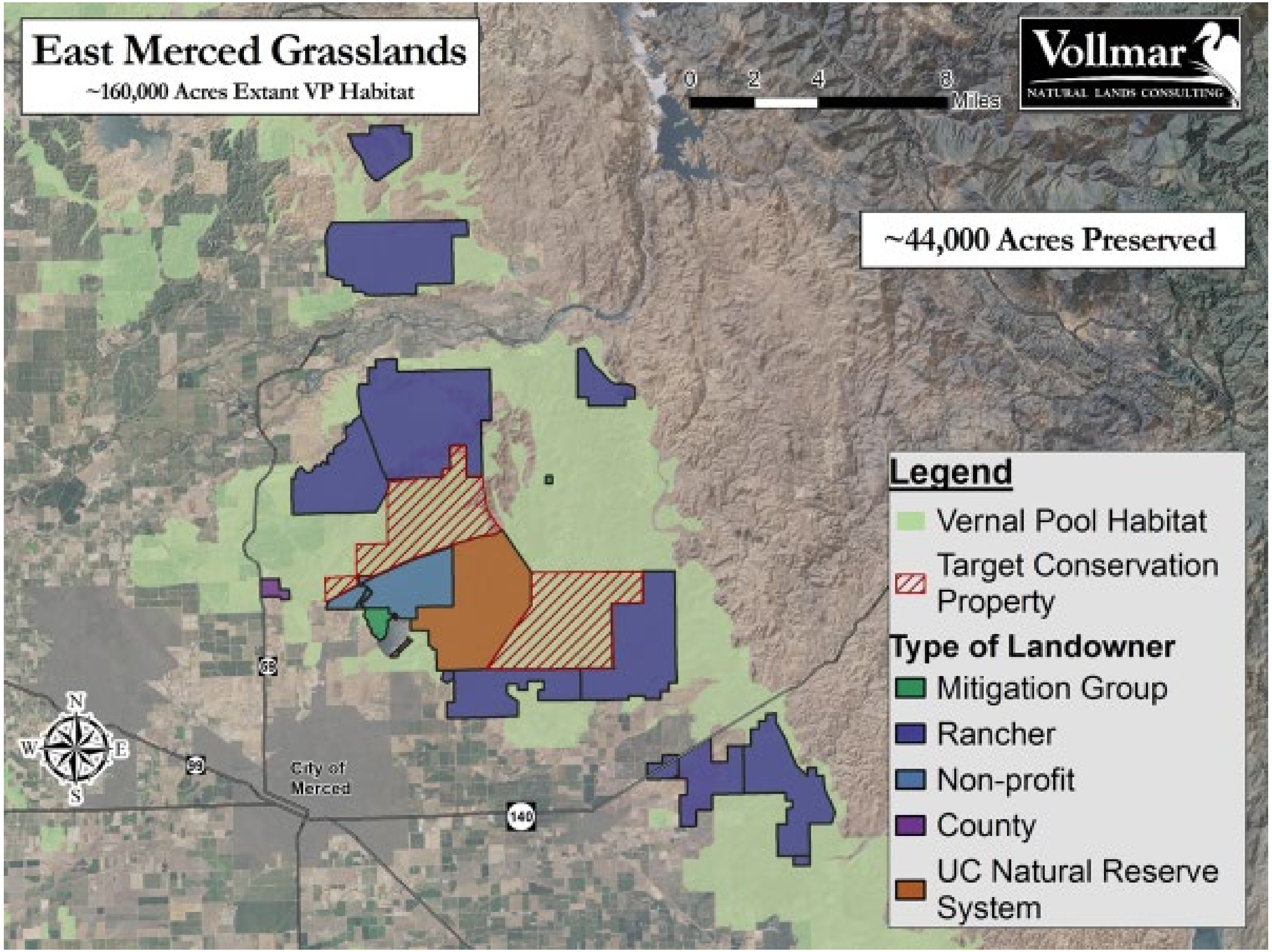
Study Background/Genesis

Key Findings of Previous Study:

VP habitat conservation has been achieved by:

- A focused awareness of specific areas of conservation interest
- A dedicated core of individuals working over decades in through an ad hoc process to conserve these specific areas

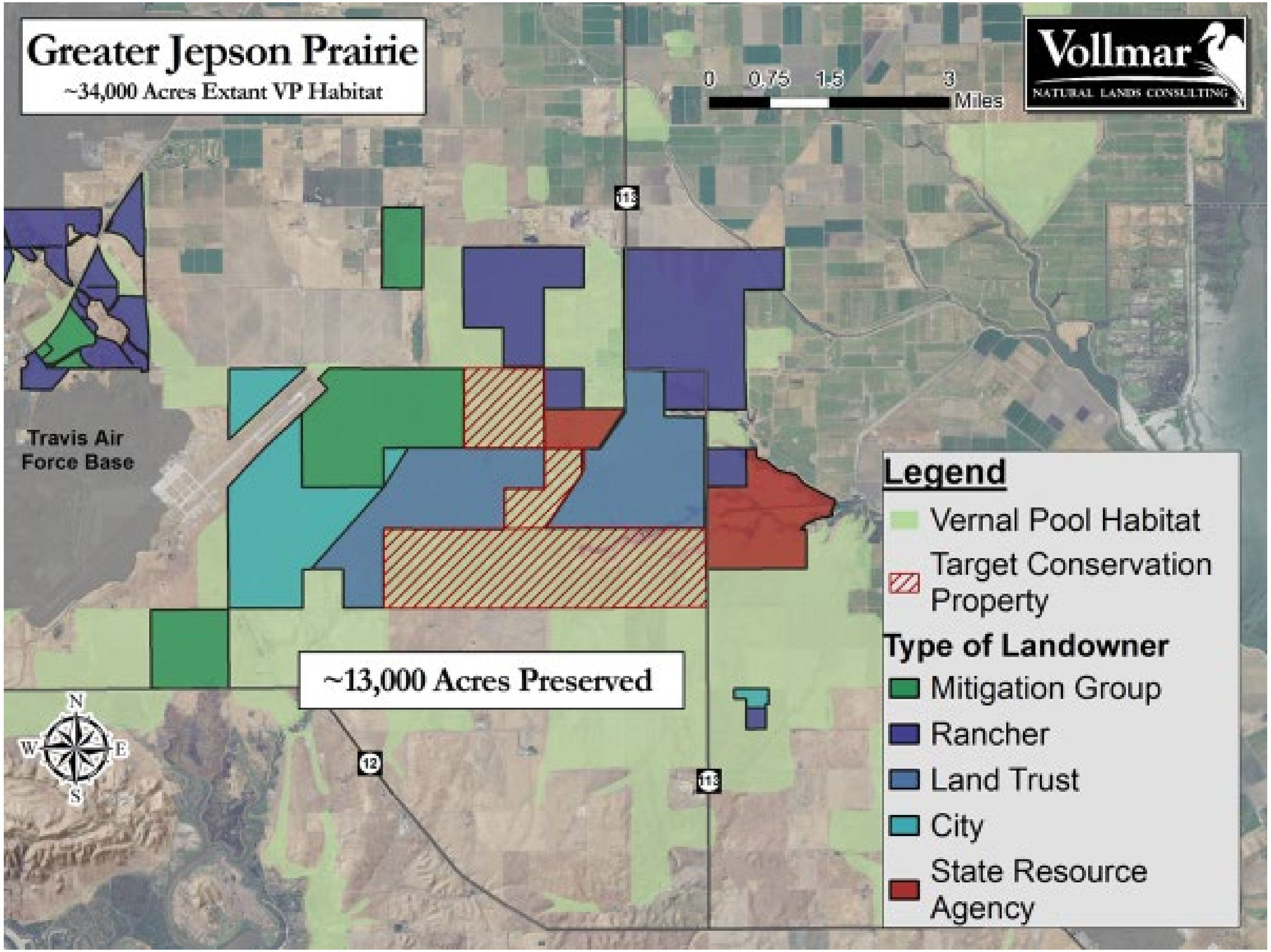
Most conservation has occurred outside of formal government conservation plans (HCP/NCCP)



East Merced Grasslands

Analysis of Preserved Vernal Pool Habitats

(Landowner Type)



Greater Jepson Prairie

Analysis of Preserved Vernal Pool Habitats

(Landowner Type)

Study Background/Genesis

Current Study Builds of Key Findings of Past Study:

- Focus on conservation of remaining large, contiguous blocks
- Select a set of blocks for each VP Region that together conserves the geologic formations and rare species populations unique to the region
- Promote selected blocks to become focal points for on-going conservation efforts through ‘organic’ ad hoc process identified in previous study

Study Tasks

Task 1 Convene and Communicate with Technical Advisors

Task 2 Identify Habitat Blocks by Vernal Pool Ecoregion

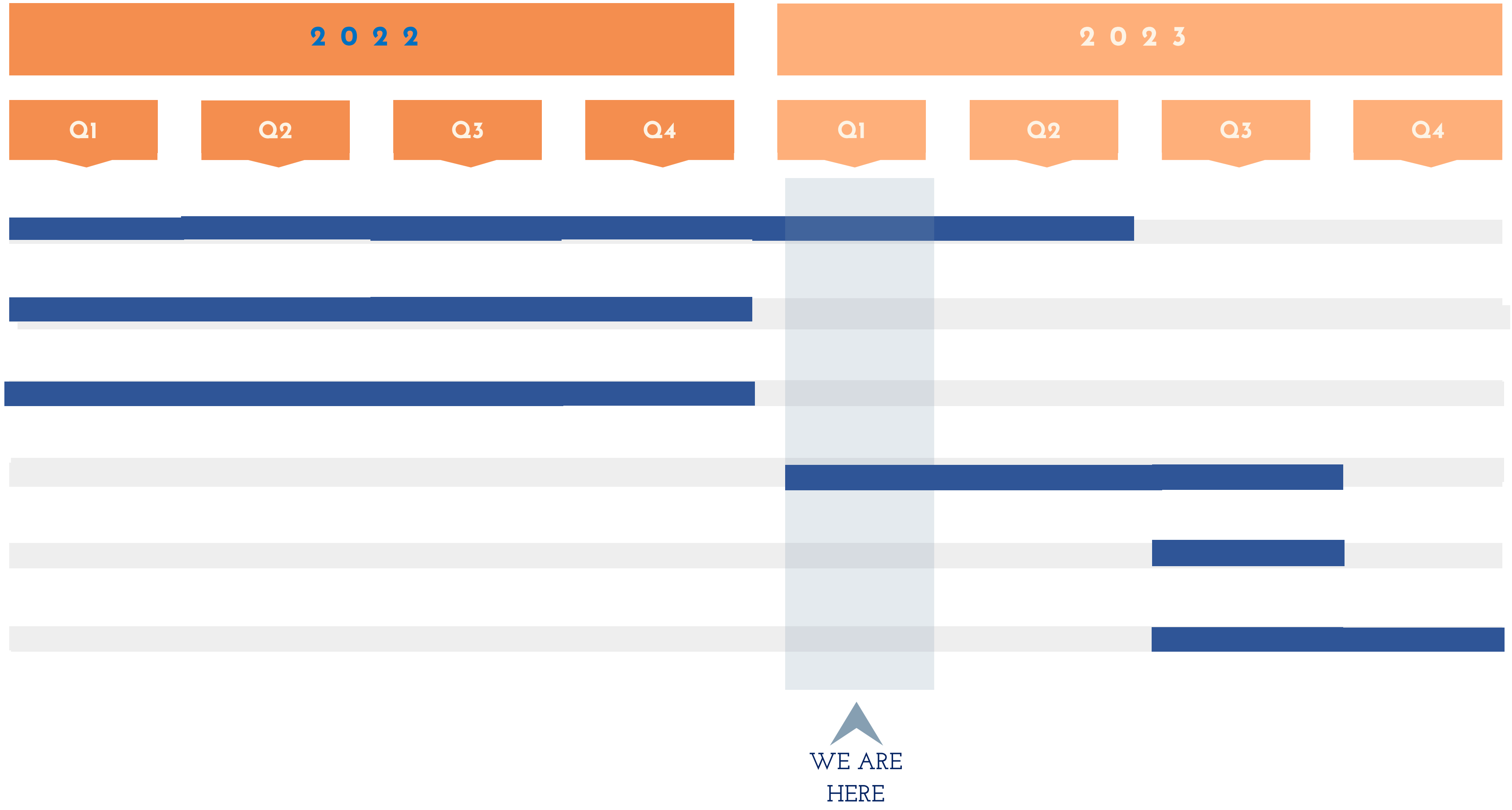
Task 3 Develop Profiles/Conservation Strategy Frameworks for Habitat Blocks

Task 4 Prepare Project Report and Geodatabase

Task 5 Disseminate Project Information and Data

Task 6 Track Ongoing Habitat Conservation in Study Area

Progress



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Summary of Conservation Guide

CONSERVATION OF CALIFORNIA'S GREAT VALLEY VERNAL POOL LANDSCAPES

USER'S GUIDE AND REFERENCE MANUAL

BY
John Vollmar, Kristen Chinn, Eric Smith, Henry Hwang, and Anton Bokisch
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IN PARTNERSHIP WITH
East Merced Resource Conservation District
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AERIAL IMAGERY BY
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ILLUSTRATIONS BY
Maria M. Vollmar

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The lead author engaged in one of his favorite activities, dip-netting for vernal pool shrimp in a flowery vernal pool on a gorgeous spring day, in eastern Merced County.

The artistry of vernal pools
Their strange and sinuous shapes
Their colorful and unexpected life forms
The feeling of immense time and landscape
Their quiet meditations in the winter
and joyful raptures in the spring
Are what draws us to them
Again and again

Foreward

In the winter of 1997, I was tasked, along with my colleagues at California Department of Fish and Wildlife (CDFW), to write a report that would present a unified understanding of California vernal pool ecosystems. Our report, developed over the following year (Keeler-Wolf et al. 1998), was intended to help guide the conservation of rare species to be addressed in a Recovery Plan of Vernal Pool Ecosystems of California and Southern Oregon being developed by the U.S. Fish and Wildlife Service (USFWS) (2005) with the support of CDFW and other federal and state agencies. In developing our report, we reviewed information on all California vernal pool environments, addressing their range of variability and their rare inhabitants across the State's extensive and diverse ecoregions. We believed delineating biogeographic boundaries for each grouping of species, which we called 'Vernal Pool Regions', would naturally target species recovery actions to specific areas. These 'Regions' would form the framework for conservation of all the listed and other rare vernal pool species.

Prior to 1998, there had been no attempt to summarize the enormous variation in California vernal pool species composition and environments. We identified 17 individual Vernal Pool Regions by circumscribing a combination of known rare species' ranges along with their underlying climatic, geomorphic, and geologic features. We relied heavily on known occurrences of rare species tracked within CDFW's California Natural Diversity Database (CNDDB) supported by collections from museums and herbaria. We defined the regions by extrapolating the physical attributes common to each of the subset of vernal pool species distributions. Our work found that the largest number of state- and federally-listed vernal pool species fall within eight vernal pool regions delineated within the Great Valley Ecoregion of California.

Now, 25 years and many studies and projects later, John Vollmar and his colleagues at Vollmar Natural Lands Consulting (VNLC) have developed an extensively updated and detailed summary of the eight Great Valley Vernal Pool Regions. Each region forms a specific chapter, with each artfully displaying the region's unique suite of attributes through excellent use of text, tables, maps, and photographs. For each region, the authors summarize information on landform and geology, rare species biology and distribution, extent of remaining and conserved vernal pool habitat, and prioritization of ongoing conservation opportunities. Most important to users of this document, the report provides clear definition and evaluation of the largest remaining individual blocks of vernal pool landscapes within each region with their relative importance to conservation priorities.

Whereas our intent of the 1998 effort was to provide a biogeographic basis for understanding the natural distribution of vernal pools and their species, the VNLC guide reviews each of the regions and delivers a well-supported, clear guide to conservation activities. Such a set of 'recipes' for conservation is what is sorely needed in all areas where complex patterns of human and natural landscapes must be teased out to arrive at an agreed upon solution to sustainable and effective conservation planning. It is wonderful to bear witness to such an evolution of thought.

Todd Keeler-Wolf
November 2022

Previous Drawings by Maria Vollmar
VII: ______
VIII: ______
IX: ________

VI

VII

CHAPTER 1

INTRODUCTION

Vernal pools are magical habitats. Bone-dry and brown through late summer and fall, these ephemeral wetlands awaken with winter rains and subsequent ponding, sparking a transitory season of life. Look into the water in winter and you'll see a frenetic swarm of strange creatures striving to reproduce before the pool dries. Depending on your location and luck, you may see California tiger salamander larvae with feathery external gills, plump, translucent western spadefoot tadpoles, prehistoric-looking tadpole shrimp, fairy shrimp gliding upside down, and various plants in an early underwater aquatic phase. Look again in mid-spring and you'll see a drying pool, the aquatic animals now encysted in the pool bottom or dispersed to the surrounding uplands, replaced by a dazzling array of flower colors and forms arranged in intricate patterns - a complete contrast to the more muted upland grasslands just a step away.

While exploring a vernal pool is an immediate, present-day experience, the abundance and variety of life encountered—as well as the pools themselves—are the result of a long evolutionary process involving an intricate interplay of changing climate, geology, and landform founded in deep Earth history. Perched on the soil surface, rain filled, and remaining ponded for only a few weeks to months each rainy season followed by months of desiccation, vernal pools harbor a myriad of unusual and rare species specifically adapted to these difficult hydrological conditions. These species, and the intricate beauty of vernal pool landscapes, have inspired an active interest in their conservation.

Conservation Context

California's Great Valley (also called the Central Valley) supports the most diverse and widespread set of vernal pool habitats in the world, due to its particular climate, geology, landforms, and size (Keeley and Zedler 1998). Easily visible from space, it is roughly 400 miles long by 50 miles wide, bounded by mountain ranges all around, a 'structural basin' of epic proportions. Formed by tectonic and other forces over the past 240 million years, it became suitable for vernal pools only within the past few million years, following the rise of the Sierra Nevada and the development of climate, landscape, and soil conditions favorable to their formation.

Unfortunately for vernal pools, the Great Valley also provides an excellent setting for humans, with its expansive areas of gentle terrain and rich soils. With a current population over 6 million people and as one of the major agriculture centers in the world, the vernal pool habitats of the region have been heavily decimated and fragmented over the past 200 years, with less than 10% of the original habitat remaining. Still, there remain large, contiguous habitat blocks distributed across the region that together offer an opportunity to conserve the essential landscapes and biodiversity of the original habitat in perpetuity. Since the 1970s, a total of roughly 270,000 acres of vernal pool habitat has been conserved in the Great Valley, much of it concentrated in areas with recognized high value vernal pool landscapes. Through ongoing, strategic efforts, we can continue to build upon and conserve remaining large habitat blocks in target areas throughout the Great Valley.

Conserving vernal pool habitat is a difficult and complex process that requires available funding, willing sellers of fee title or conservation easements on unprotected lands (typically private ranchers), engaged land trusts, and, especially, dedicated individuals willing and able to initiate and shepherd the process through to completion. Conserving whole landscapes also requires long-term, committed effort and patience, with individual properties conserved sequentially over years and even decades as funding and land or easement acquisition opportunities become available (Vollmar 2019).

Without a strategic conservation framework, the long-term outcome of these landscape-scale efforts can be scattershot, with some conserved properties isolated or in suboptimal locations and the overall set of conserved properties perhaps lacking a meaningful cohesion or not capturing all the key biodiversity. Developing some type of conservation planning framework is important to avoid this outcome. This framework, however, does not need to be a formal, centralized government program, such as a Habitat Conservation Plan (developed under a provision of the Federal Endangered Species Act). In fact, most landscape-scale vernal pool habitat conservation accomplished in the Great Valley—in such places as the Greater Jepson Prairie, East Merced Grasslands, and Lower Foothills (see **Figure 3.5** below)—has been achieved through a somewhat ad hoc process, mostly outside any formal, centralized government program. Fundamental to this process has been a core of individuals, either acting independently or representing various groups, agencies, or companies, with a passion for a particular area and long-term dedication and involvement in seeing it conserved—the very audience targeted by this publication. This overall process has been described by Vollmar (2019), a copy of which is provided in **Appendix C**.

Vernal pool tadpole shrimp (*Lepidurus packardi*) during pool aquatic phase. (Photo Credit: Doug Wirtz)

Vernal pool flowers during pool drying phase. (Photo Credit: Doug Wirtz)

Purpose of this Guide

This publication is an active user's guide and reference manual for those working to conserve key remaining vernal pool landscapes in the Great Valley. It provides succinct background information on vernal pool landscape ecology and conservation concepts, and a summary of the Great Valley setting related to geology, evolution, and current distribution and diversity of vernal pool habitats and species. It then provides an analysis and strategic framework by individual vernal pool region to help guide ongoing conservation throughout the Valley. The target audience is broad and includes land trusts, environmental groups, government agencies, private consultants and vernal pool enthusiasts, conservation-minded ranchers and other landowners, developers needing mitigation, and mitigation banking companies—essentially all individuals or groups involved in some manner in vernal pool conservation in the Great Valley. The information and mapping are presented by vernal pool region and by habitat blocks within each region to provide inspiration and guidance to those working on either a regional or local level.

This guide identifies and characterizes a set of up to 12 large, contiguous habitat blocks within each of the eight vernal pool regions in the Great Valley as targets for conservation. The target habitat blocks were selected based on three primary conservation goals:

1. Preserve the full range of habitat and species diversity of Great Valley vernal pools, including multiple, robust population centers of rare species where possible;
2. Preserve individual habitat blocks of sufficient size to sustain the full suite of species and ecological processes associated with intact vernal pool landscapes; and
3. Incorporate previous conservation planning work by using defined vernal pool regions and focusing on habitat blocks within vernal pool core recovery areas and designated critical habitat for federally listed species.

Together, the target blocks are intended to capture the essential vernal pool habitat landscapes, ecological functions, and biodiversity within each region. For each block, existing conserved lands are also described as the initial foundation for ongoing strategic conservation efforts. While it would be ideal to conserve all remaining habitat, the reality is that habitat loss continues, and available funding and opportunities for conservation are limited. Recognizing this reality, this guide aims to concentrate ongoing conservation within a carefully selected set of large remaining habitat blocks for maximum conservation benefit. As these blocks are conserved, this guide can be revised to target additional remaining habitat blocks.

The target blocks are built upon previous conservation planning work. However, since the focus of this guide is to conserve large blocks, small core recovery polygons may not be included. Still, some endangered species have important occurrences in small outlier blocks, and these are highlighted by region. The final set of target blocks and overall guide was reviewed by a technical advisory group composed of experts (see Acknowledgments), many of whom helped prepare the Vernal Pool Recovery Plan (USFWS 2005).

The target blocks are intended to serve as ongoing focal areas for engaged individuals and groups, following the ad hoc conservation process similar to that described in the paper in Appendix C. By focusing on these blocks, we can, over time, achieve meaningful conservation of large, durable landscape units that support the suite of vernal pool habitats and species that occur in the Great Valley. We will also provide future generations with large, permanently conserved areas where they can experience and enjoy a meaningful semblance of the vast and varied vernal pool landscapes that originally occurred across the region.

Vernal pool in full spring bloom on hardpan terrace, eastern Sacramento County, Southeastern Sacramento Valley Vernal Pool Region. (Photo Credit: Jeb Bjerke)

CHAPTER 2

METHODS

The Core Recovery Areas identified in the Recovery Plan for Vernal Pool Ecosystems of California and Southern Oregon (Vernal Pool Recovery Plan) (USFWS 2005) were developed through an in-depth conservation planning process involving numerous experts. Designated Critical Habitat areas for federally listed species were developed following a similar process (USFWS 2021). On a broader scale, California has been divided into 17 distinct vernal pool regions, based on differences in biogeography and associated rare species (Keeler-Wolf 1998). Eight of these regions are entirely or partially within the Great Valley. This guide builds upon this previous planning work. The vernal pool regions served as the foundation for dividing the Great Valley into conservation units, and the target habitat blocks are nearly all within USFWS Core Recovery Areas and Designated Critical Habitat polygons.

Within these areas, habitat blocks were selected through a process that involved compilation, integration, and analysis of multiple data sets, field surveys to ground-truth preliminary blocks, and review by experts who were part of the project's technical advisory group. The methods used to select and analyze the blocks are briefly summarized below. Appendix B provides a more detailed description of methods.

Base Layer Compilation and Analysis. We developed a project geodatabase in ArcGIS (ESRI 2020) with multiple data layers covering the Great Valley. We then used the layers to perform GIS analyses to identify and assess the study area and target habitat blocks. These layers included current and historical aerial imagery, current mapping of existing vernal pool habitat (Witham et al. 2014; Witham 2021), occurrence records of target rare species from the California Natural Diversity Database (CNDDB 2021) and additional unpublished records, environmental data layers on climate, topography, geology, existing preserved land, landowner parcels, and vernal pool region boundaries (see full source references in Appendix B).

Habitat Mapping and Block Delineation. We made minor adjustments to the original boundaries of the vernal pool regions to more accurately delineate them by landform and geologic formation, and to incorporate mapped vernal pool habitat that was outside of the original boundaries. These revisions were made in consultation with Dr. Keeler-Wolf (pers. comm. 2020), who led the original delineation of these boundaries. We analyzed the vernal pool habitat mapping within the revised regions to identify the 20 largest habitat blocks in each region. Mapped habitat polygons were considered part of a single block if they were within 400 meters of each other and the intervening area was natural habitat. Also, polygons separated by minor development features such as smaller roads, railroad tracks, and canals were considered part of a single block. We assumed that these features did not significantly isolate the polygons from each other ecologically. Polygons separated by larger or more developed features such as major four-lane highways, intensive agricultural development, commercial or residential development, and rural residential development (<20-acre parcels) were considered non-contiguous, separate blocks.

Rare Species Occurrences and Predicted Habitat Mapping. The rare species that we included in our analyses were a subset of those considered 'vernal pool indicator species' (SFEI 2020, Holland and Hollander 2007). Of these species, we included all species listed under the Federal or State Endangered Species Act, State Species of Special Concern, State Rank S1-S3 (critically imperiled to vulnerable) except for a few poorly studied insect species, and California Rare Plant Rank (CRPR) List 1B plant species (rare, threatened, or endangered throughout their range) (CNPS 2021). We did not include CRPR List 2-4 species except for one List 2 species, dwarf calicoflower, which primarily occurs in California vernal pools.

For each species, we obtained all California Natural Diversity Database (CNDDB 2021) occurrence records, and some additional consultant records, and then vetted them to develop a set of records that only occurred in natural vernal pools (excluding records in created stock ponds and roadside pools). We used the set of vetted records to develop predicted habitat mapping for each species. We assessed two different techniques - MaxEnt analysis (Phillips et al. 2006, Phillips and Dudík 2008; Phillips 2017) and a technique developed by Holland and Hollander (2007) and refined by Vollmar et al. (2016). Both techniques analyze a set of layered habitat parameters related to temperature, precipitation, geology, and topography to determine the suitable habitat for each species based on locations of occurrence records, and then identify all areas throughout the Great Valley where suitable (predicted) habitat exists within the same range of the combined set of parameters. After comparison of a subset of results between the two techniques, we used the Vollmar et al. (2016) technique for our analyses since it more accurately reflected the distribution of predicted habitat for the target species. **Appendix B** provides a detailed description of both techniques.

Preliminary Habitat Block Selection. Using the results of our analyses, we identified up to 12 final target blocks from the 20 largest blocks in each region that best met the project goals. The number selected by region depended on size, geologic diversity, and extent of vernal pool habitat. We prioritized the largest blocks, good representation of primary geological formations with vernal pool habitat, population centers of rare species, and unique vernal pool habitat types and settings. We separated the documented species in each region into three categories: core, sparse, and generalist. Core species included those that are endemic, highly concentrated, or otherwise have a significant population center in the region. Sparse species are those with only a few occurrences in the region (typically <5) and which are better represented in other regions. Generalist species are those that, while still rare, are widespread throughout the Great Valley or region being analyzed and will be conserved regardless of which blocks are selected. In the target blocks, we aimed to capture at least 50% of predicted habitat for each core species by region, at least 70% of documented occurrences of very rare species (<50 documented occurrences), and at least 50% of documented occurrences of all other rare species. We also aimed to select blocks with some existing conserved land and with large parcels (preferably >320 acres) that could be feasibly conserved. For some species, we did not meet our 50% conservation target because it would require targeting small habitat blocks, which is not the aim of this guide. However, these outlier occurrences are described in a section in each region chapter.

Analysis of Conservation Opportunities. We developed a set of maps for each target habitat block that showed geology, rare species occurrences, aerial imagery and land use, existing conserved lands, priority conservation lands within the block (such as lands that would link existing conserved lands into a single, larger conserved block), and vernal pool habitat restoration opportunities.

Review and Final Block Selection. We circulated the set of preliminary habitat blocks to the project technical advisors for review and comment. We also conducted field surveys during winter-spring 2022 to visit target blocks and field-check site conditions and take aerial and ground photography. We then selected the final target blocks for each region.

Development of Strategic Conservation Framework. For each region, we prepared a narrative and figures to summarize the setting and data used to select specific blocks as conservation targets. We also prepared a profile and map of each selected block to guide ongoing conservation efforts. The chapter for each region was circulated to individuals and groups involved in vernal pool habitat conservation work in the region for review and comment. The chapters were then finalized incorporating comments received.

Landscape view of Tuscan volcanic mudflow formation, unique to the northeastern Sacramento Valley, with its unusual vernal pool habitat etched into the surface overtime (Photo Credit: Evan Keeler-Wolf, January 2022)

CHAPTER 3

ECOLOGY AND EVOLUTION OF GREAT VALLEY VERNAL POOL HABITATS

This section presents background information on the ecology, evolution, and other aspects of vernal pool habitats and species, and on the origins and current setting of the Great Valley as they relate to vernal pools. These concepts underlie the analyses that we used to identify the target habitat blocks. While an enthusiasm for vernal pool habitats often begins with field visits, a deeper appreciation can be gained by learning about their deep evolutionary and earth history and the forces that create and maintain them. This understanding also improves an individual's ability to make decisions regarding which lands to target for conservation and why. This section provides a good primer on these concepts. Numerous references are included for those interested in delving deeper into specific topics.

VERNAL POOL HABITAT CHARACTERISTICS AND CONCEPTS

Definition and Characteristics of Vernal Pool Habitat

As a basic definition, vernal pools are ephemeral wetlands filled primarily by direct rainfall that pond continuously or intermittently for a few weeks to months during the rainy season in an average rain year. These pools dry down during late winter and spring and remain desiccated until the onset of the next rainy season (Jain 1976, Holland and Jain 1988; Keeley and Zedler 1998). The period of inundation for an individual pool varies annually, depending on pool size, depth, and the amount and timing of rainfall. Vernal pools occur along a spectrum of seasonal wetland types, ponding longer than more transient rain pools (Preston 2010), but shorter than seasonal marshes. This brief wet period, followed by months of desiccation, creates a unique habitat that is home to a suite of endemic plants and animals adapted to these difficult hydrological conditions. Maximum ponding depth typically ranges from 2-15 inches,

Vernal pool-swale complex with surrounding annual grasslands in winter. (Photo Credit: Evan Keeler-Wolf, January 2022)

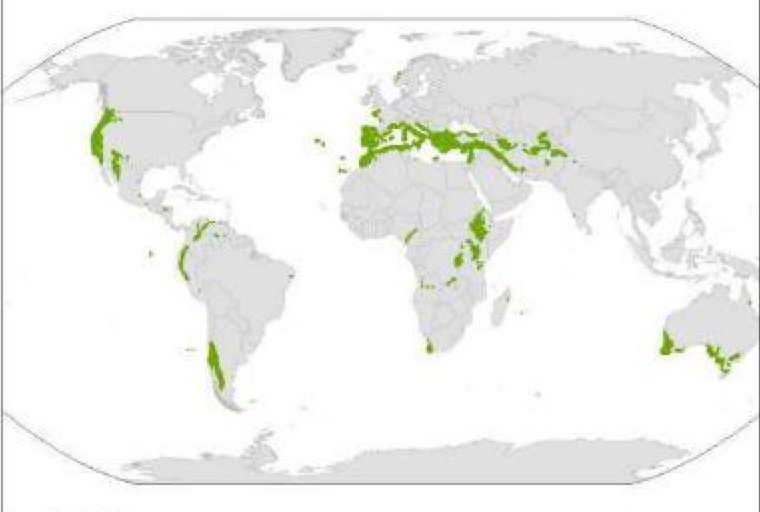
though there are occasional deeper pools up to 24 inches (Barbour et al. 2007, Vollmar 2002). Beyond this depth, the habitat typically functions as a seasonal marsh, due to more prolonged ponding, with a different, less unique, suite of associated plants and animals.

Vernal pools exist within a matrix of upland habitat, typically grasslands but sometimes scrub or savanna. Individual pools also generally occur in a network with interconnecting swales. For the purposes of this guide, 'vernal pool habitat' is defined as the complex of pool basins and swales along with the surrounding upland habitat that form local pool watersheds, and together supports the overall ecology of vernal pools (Witham et al. 2014). Wetland density within vernal pool habitat typically varies from 2-15% cover, with higher densities in some unique settings. Below 2% density, individual pools may occur, but the overall habitat does not generally appear or function as vernal pool habitat.

Several playa pools on Vina Plains Preserve in eastern Tehama County, Northeastern Sacramento Valley Vernal Pool Region. (Photo Credit Evan Keeler-Wolf, January 2022)

Exceptionally large vernal pools (typically greater than one acre in size) are often called playa pools. These pools are rare across the landscape and have unique soil, vegetation, and hydrology characteristics. They often harbor multiple rare species including many listed as threatened or endangered under the Federal or State Endangered Species Acts and as such are a high priority for conservation (USFWS 2005).

Vernal pool habitats occur in a very limited number of regions in the world, where the right combination of climate, soils, and slope support their formation. They are concentrated in regions with a Mediterranean climate (Keeley and Zedler 1998) (Figure 3.1). These areas have cool, wet winters and hot, dry summers that produce the rainfall cycle and hydrologic regime required for vernal pools. These climate areas are quite restricted on a global level and include California, the Mediterranean Basin, the southern tip of Africa and central east Africa, the southern edge of Australia, and central western Chile. California, especially the Great Valley, supports the most diverse and extensive vernal pool habitats in the world due to its unique combination of size and geologic diversity (Keeley and Zedler 1998).



Source: Beck et al. 2018

Figure 3.1. Mediterranean Climates of the World.

Within suitable climate areas, vernal pool habitats occur only on soils with some type of underlying, near-surface restrictive layer that limits downward percolation of rainwater and thus support a perched water table that allows formation of surface pools (Holland and Jain 1988). The restrictive layer may be a hardpan, claypan, or bedrock depending on geographic region and local geology. In areas with suitable climate and soils, vernal pools are concentrated in areas with fairly level terrain (slopes are typically <3%), where pool basins can form and hold water (Vollmar 2002).

In California, vernal pool habitats occur in diverse settings with these suitable conditions, including alluvial terrace, basin rim, basin, and volcanic landforms in the Great Valley, the Santa Rosa Plain in Sonoma County, volcanic plateaus in the Modoc Plateau and other localized areas, and mesa tops in San Diego County (USFWS 2005). These habitats are often classified by the type of restrictive soil layer (Holland and Jain 1988). Hardpan vernal pools form primarily on alluvial soils that develop a cemented hardpan a few feet below the surface. The hardpan typically requires thousands of years to form, through the slow downward movement, accumulation, and bonding of certain minerals (aluminum, silica, and others). As a result, vernal pools are generally absent on young alluvial surfaces such as active or recent floodplains. The oldest hardpan soils in California, located in the northeastern San Joaquin Valley, have been continuously exposed for more than four million years, with a dense, well-developed hardpan that can be several feet thick (Harden 1987). Claypan vernal pools form primarily on older floodplain soils with a high clay content or certain alluvial materials, such as volcanic sediments, that weather into clay. These soils expand and become sealed when wetted during the rainy season, preventing the downward percolation of water. Bedrock vernal pools form on volcanic flows, sedimentary rocks, and other bedrock types that are at or near the surface. All three types occur in the Great Valley with hardpan and claypan types the most prevalent.

The annual cycle of short-term, sometimes intermittent flooding followed by months of desiccation is a difficult environment for life to survive. The difficulty is amplified by inconsistent rainfall patterns from year to year and across longer time spans. The plants and animals that inhabit vernal pools need to withstand regular two- to three-year and occasional longer droughts. These conditions have led to the evolution, over the past few million years since these habitats first began forming in California, of a unique suite of species specifically adapted to vernal pools. This includes numerous regionally or locally endemic species, many of which are considered rare, threatened, or endangered. The Vernal Pool Recovery Plan (USFWS 2005) was developed in recognition of the rarity and endangered status of many of these endemic species. It includes 33 listed or other rare species that occur exclusively or primarily within California vernal pools.

Contra Costa goldfields (*Lasthenia conjugens*), an endangered species, on a vernal pool margin in southern Solano County, Solano-Colusa Vernal Pool Region. (Photo Credit: John Vollmar)

led to the designation of genetically based Distinct Population Segments (DPS) across the state and differentiated recovery units within the Great Valley for both CTS (USFWS 2017) and western spadefoot (USFWS in prep).

Effects of Preserve Size on Conservation Value

Preserve size is an important consideration for maintaining species diversity (Hanski and Gilpin 1997), especially as preserves become isolated due to development of surrounding lands. While there have been no definitive studies on required minimum preserve size for maintaining species diversity within vernal pool habitats, it is clear that certain species, such as California tiger salamander, vernal pool plant pollinator bees, and California ground squirrel (which provides important upland sheltering habitat for amphibians and other species within its burrows), require substantial upland habitat surrounding pools to maintain populations (Searcy et al. 2013). In addition, some aquatic species, such as vernal pool tadpole shrimp and succulent owl's-clover (*Castilleja campestris* ssp. *succulenta*), appear to require or prefer larger, high-density pool networks to maintain populations (Helm and Vollmar 2002; Ditter and Guardino 2002; Vollmar et al. 2016). Finally, preserve size is important for capturing the different wetland and upland habitat elements across a landscape, some of which may be widely and sporadically distributed, such as larger playa pools that often support rare or endangered species (Witham et al. 2014; Vollmar 2002; Ditter and Guardino 2002).

Definition and Basis of California Vernal Pool Regions

In 1998 the California Department of Fish and Wildlife (CDFW) published a report that divided California's vernal pool habitats into 17 distinct regions (Keeler-Wolf et al. 1998) (Figure 3.2). Preliminary boundaries were delineated according to distribution patterns of locally endemic rare vernal pool species, as determined through analysis of more than 2,600 individual occurrence records from the California Natural Diversity Database (CNDDB 1996). The boundaries were then refined through analysis of the extent of mapped vernal pool habitat and soil types associated with the occurrence records (Keeler-Wolf pers. comm. 2020). For example, if a group of endemic species in a region was associated with a unique vernal pool type, the boundaries were expanded to include all local areas with this pool type. If vernal pool habitat mapping was incomplete for a region and a group of endemic species was associated with a limited set of soil types, the boundaries were expanded to include all local areas with these soil types. A few regions were defined based on unique land use or management considerations although they were otherwise ecologically similar to adjacent regions (such as the Santa Rosa Plain) (Ibid).

Based on a review of the original report and more recent studies on vernal pool biodiversity (Barbour et al. 2007) and discussions with Dr. Keeler-Wolf (pers. comm. 2021), we concluded that the originally defined vernal pool regions provide a sound basis for dividing Great Valley vernal pool habitats into meaningful biodiversity units for conservation planning. The approach inherently defined the regions based on biodiversity since groups of locally endemic species were used as a primary basis for defining them. As discussed in the Methods section, we made minor refinements to the original boundaries to align more accurately with mapped landform, geology, and soil boundaries and to incorporate mapped vernal pool habitat that was just outside of any region. While the amphibian and invertebrate species are fairly wide-ranging across climate and geology boundaries, some of these species or genetically distinct populations of some species show clear affinities to certain regions based on climate and/or geology (Eriksen and Belk 1999; Shaffer et al. 2013). Barbour's study (Barbour et al. 2007) also confirmed the restriction of many locally rare and endemic plant species and some plant community assemblages to specific vernal pool regions.

Figure 3.2: California Vernal Pool Regions

GREAT VALLEY SETTING

The Great Valley is a massive 'structural basin', one of the most notable in the world, surrounded by several prominent mountain ranges: Coast Ranges on the west, Klamath Mountains and Cascade Range on the north, Sierra Nevada on the east, and Tehachapi Mountains and southern Coast Ranges on the south (Figures 3.3 and 3.4). The Great Valley basin consists of two main subregions, the Sacramento Valley in the north and the San Joaquin Valley in the south. This setting has caused the formation of two major drainage systems. The Sacramento River and its tributaries drain the Sacramento Valley and the San Joaquin River and its tributaries drain the San Joaquin Valley. These rivers meet near the Valley center forming the extensive Sacramento-San Joaquin Delta (Delta), and then together flow west through Suisun Bay into the San Francisco Bay and out through the Golden Gate to the Pacific Ocean. The southern end of the San Joaquin Valley is called the Tulare Basin (Figure 3.4). It is a closed basin, and the terminus of the Kings, Kaweah, Kern, and some smaller rivers, that historically contained Tulare Lake, along with a few other smaller lakes. Tulare Lake was historically the largest lake west of the Mississippi River, nearly 700 square miles (15 miles in diameter) when full. During heavy rain years, it overflowed to the north and drained into the San Joaquin River. Beginning in the late 1800s, the lake was drained through damming of tributary rivers and irrigation diversions and its basin subsequently converted to farmlands (Harden 2004). Remnants of the historic lake still form during heavy rain years.

The geography of the Great Valley developed over a very long period, roughly 240 million years, through a combination of tectonic plate movements, volcanic activity, uplift of the Coast Ranges and Sierra Nevada, sea level and climate fluctuations, and erosion (Harden 2004). These forces brought much of the California terrain into existence. They also shaped the Great Valley with its current variations in climate, landform, and geology that together have a primary influence on the location, characteristics, and diversity of vernal pool habitats.

Figure 3.3: Great Valley Continental Setting

Satellite image of Great Valley and surrounding continental setting (Photo Credit: NASA 2021)

About 60 million years ago, the eastern edge of the Great Valley seaway consisted of a mix of beaches and lagoons, much like some areas of the present California coast. These sediments were also buried over time, compressed, and re-exposed through uplift and erosion as the Ione Formation. This formation, which consists of a mix of quartzite (from metamorphosed beach sands) and shale or consolidated clay (from metamorphosed lagoon muds) is exposed as a narrow band along the eastern edge of vernal pool habitat in the Great Valley. Most vernal pool habitats on the Ione Formation occur on quartzite bedrock in areas of flat to gentle terrain. Pincushion navarretia (*Navarretia myersii* ssp. *myersii*), a rare plant species locally endemic to the central-eastern SSFH Region, is associated with pools on or near Ione Formation.

Beginning 29 million years ago, the trailing edge of the Farallon Plate was subducted under the North American Plate, starting first in present-day southern California and moving north up the California coast as a 'triple junction' of the Farallon, Pacific, and North American plates. This junction is currently located off the Oregon Coast and continues moving northward. As the Farallon Plate was subducted, it was replaced by the northward-moving Pacific Plate, with the juncture between the North American and Pacific plates being the famous San Andreas Fault.

The subduction and melting of the Farallon Plate (that began more than 240 million years ago) eventually resulted in extensive volcanism (erupting from the subterranean plutons) along the ancestral Sierra Nevada, from about 25 to 5 million years ago. These eruptions covered much of the region first with ash-fall, followed by volcanic mudflow, with deposits greater than a thousand feet thick in some areas. Erosion carried some of these sediments as alluvium into the eastern edge of the ancestral Great Valley. As with the earlier beach sediments, these materials were buried, compressed, and re-exposed through the Sierran uplift as the older Valley Springs Formation composed of volcanic ash, and the younger Mehrten Formation composed of andesitic bedrock and alluvium. Both formations support vernal pool habitats along the eastern edge of the Valley. Pincushion navarretia and Hartweg's golden sunburst (*Pseudobahia bahiifolia*) are both closely associated with Valley Springs Formation while Colusa grass (*Neostapfia colusana*) and most Hoover's spurge (*Euphorbia hooveri*) occurrences in the SSFH Region are restricted to playa pools on the Mehrten Formation. During this period there were also some basalt eruptions in the ancestral Cascade Ranges and Sierra Nevada that flowed west into the Great Valley. Remnants of these flows form table mountains east of Oroville and Fresno that support distinctive vernal pool habitats. Butte County meadowfoam (*Limnanthes floccosa* ssp. *californica*) and Jim's clover (*Trifolium jokerstii*), both of which are endemic to the NESV Region, occur on the table mountains near Oroville (as well as other volcanic formations in the region).

The next phase of the Great Valley development began about five million years ago. By this time, through a combination of continued Coast Range uplift, erosional filling, and sea level changes, the Great Valley was transitioning into a non-marine environment. Initially, drainage to the Pacific Ocean was further south, likely into present-day Monterey Bay. Ongoing


Ione Formation vernal pool habitat on ancient marine quartzite, southeastern Sacramento County, Southeastern Sacramento Valley Vernal Pool Region. High Terrace Landform. (Photo Credit Evan Keeler-Wolf, January 2022)


Valley Springs Formation vernal pool habitat with characteristic white volcanic ash soils and small, closely-spaced Mima. (Photo Credit: Evan Keeler-Wolf, January 2022)


Mehrten Formation vernal pool habitat on volcanic andesitic alluvium with diffuse mounds presumably due to the high clay content of the soils, southeastern Sacramento County, Southeastern Sacramento Valley Vernal Pool Region. High Terrace Landform. (Photo Credit: Evan Keeler-Wolf, January 2022)

movement of the San Andreas Fault blocked this drainage, sometime between about 1 million and 600,000 years ago. This caused the Great Valley to become a closed basin that became inundated, especially in the San Joaquin Valley, as a vast inland lake that persisted for a couple hundred thousand years. This lake eventually drained about 600,000 years ago when a new drainage was cut, forming the present-day Golden Gate.

The Sierra Nevada uplift began about five million years ago. Over the past four million years, there have been climate fluctuations resulting in at least four alternating glacial and interglacial periods. During the glacial periods, enormous amounts of sediments were eroded and washed down from both the Sierra Nevada and Coast Ranges, deposited as broad alluvial fans extending from the base of the mountains. The deposits from each period developed into distinct geologic formations. At the base of the Sierra Nevada, from oldest to youngest, these include the Laguna, Turlock Lake, Riverbank, and Modesto formations. At the base of the North Coast Ranges, these include the Tehama, Riverbank, and Modesto formations. The younger formations were cut into and deposited on top of the older formations in a nested arrangement. All these formations except Tehama developed soils with a well-developed subsurface hardpan and support vernal pools and Mima mound topography. Pool density and Mima mound height generally increases with age of the formation as shown in the photographs below. Certain rare species are closely associated with some of these formations. Sacramento Orcutt grass (*Orcuttia viscida*), endemic to the central SESV Region, primarily occurs in pools on Laguna Formation. Succulent owl's-clover, nearly restricted to the central SSFH Region, is concentrated on older, high terrace landforms with acidic soils composed of Laguna and North Merced Gravel formations. In the SESV and SSFH regions, midvalley fairy shrimp (*Branchinecta mesovallensis*) is concentrated on younger, low terrace formations composed of Riverbank and Modesto formations. In the southern NESV Region, Ahart's dwarf rush (*Juncus leiospermus* var. *ahartii*) is concentrated on Turlock Lake Formation.

In contrast to these alluvial formations, the Tuscan Formation in the northeast Sacramento Valley was deposited as numerous mudflows composed of volcanic ash-water slurries (lahars) that flowed down from ancestral and long-since eroded away volcanoes (Mt. Yana and Mt. Maidu) in the vicinity of present-day Mt. Lassen. This formation, roughly the same age as the Laguna and Tehama formations, also supports extensive vernal pool habitat though the pools and swales appear etched into the volcanic bedrock rather than being part of a formed Mima mound topography. Also, the subsurface restrictive layer is volcanic bedrock rather than a hardpan. Numerous vernal pool rare species within the NESV Region are restricted to or concentrated on Tuscan Formation (or Red Bluff Formation eroded on top of this formation as discussed below). These species include Butte County meadowfoam, Jim's clover, Ahart's nailwort (*Paronychia ahartii*), Hoover's spurge, Boggs Lake hedge hyssop (*Gratiola heterosepala*), hairy Orcutt grass (*Orcuttia pilosa*), slender Orcutt grass (*Orcuttia tenuis*), Greene's tuctoria (*Tuctoria greenei*), Conservancy fairy shrimp (*Branchinecta conservatio*), and vernal pool tadpole shrimp.


Lovejoy Basalt vernal pool habitat on North Table Mountain Preserve underlain by volcanic bedrock, southeastern Butte County, Northeastern Sacramento Valley Vernal Pool Region. Volcanic Flow Landform. (Photo Credit: Evan Keeler-Wolf, January 2022)


Laguna Formation vernal pool habitat on very old granitic-metamorphic alluvium with extreme Mima mound development due to age (3 to 4 million years old), eastern Merced County, Southern Sierra Foothills Region Vernal Pool Region. High Terrace Landform. (Photo Credit: Evan Keeler-Wolf, June 2022)


Riverbank Formation vernal pool habitat on moderately old North Coast Range alluvium, western Tehama County, Northwestern Sacramento Valley Vernal Pool Region. Low Terrace Landform. (Photo Credit: Evan Keeler-Wolf, January 2022)

Modesto Formation/Quaternary Basin Deposits vernal pool habitat with numerous playa pools, Jepson Prairie, southeastern Solano County, Solano-Colusa Vernal Pool Region. Low Terrace Landform. (Photo Credit: Evan Keeler-Wolf, January 2022)

Basin deposits with alkaline vernal pool habitat including playa pools, Tulare Basin, southern San Joaquin Valley Vernal Pool Region. Basin Landform. (Photo Credit: Evan Keeler-Wolf, January 2022)

Table 3.4. Primary Vernal Pool-bearing Geologic Formations of the Great Valley - Presence by Vernal Pool Region.

	Presence in Vernal Pool Region[1]							
Geologic Formation	NWSV	NESV	SESV	SSFH	SOCO	SJQV	LVMR	CCGV
Recent (Quaternary) Basin Deposits	X	X	X		X	X		
Recent Marsh Deposits					X			
Recent Bay Mud Deposits					X			
Recent Basalt Flows	X	X						
Recent Alluvial Deposits	X	X	X	X	X	X	X	X
Dos Palos Alluvium						X		
Patterson Alluvium						X		X
San Luis Ranch Alluvium						X		X
Los Banos Alluvium						X		X
Modesto	X	X	X	X	X	X	X	
Riverbank	X	X	X	X				
Turlock Lake		X	X	X				X
Red Bluff	X	X						
North Merced Gravel			X	X				
Montezuma					X			
Tehama	X				X		X	
Laguna		X	X	X				
Tuscan		X						
Lovejoy Basalt		X						
Other Miocene Volcanic Rocks				X				
Mehrten (alluvium)			X	X				
Mehrten (mudflow)			X					
Valley Springs			X	X				
Ione		X	X	X				
Panoche								X
Tertiary Sedimentary Rocks							X	
Cretaceous Sedimentary Rocks							X	
Jurassic-Cretaceous Rocks	X	X	X	X				

1. Vernal Pool Regions: NWSV = Northwestern Sacramento Valley; NESV = Northeastern Sacramento Valley; SESV = Southeastern Sacramento Valley; SSFH = Southern Sierra Foothills; SOCO = Solano-Colusa; SJQV = San Joaquin Valley; LVMR = Livermore; CCGV = Central Coast (Great Valley portion).

Vernal Pool Rare Species

There are more than 80 rare plants and animals documented in Great Valley vernal pools. Many of these are endemic or largely restricted to the Great Valley. We selected 44 of these species for the habitat block analysis and conservation planning in this guide. Table 3.6 is an annotated list of these species with the presence and number of documented occurrences by vernal pool region. Appendix A provides a range map for each species with documented occurrences in California.

Female Conservancy fairy shrimp (*Branchinecta conservatio*) with trailing egg sacs, an endangered Great Valley endemic that primarily inhabits large, turbid playa pools on low terrace and high terrace landforms; it was named in honor of The Nature Conservancy for its leading work in vernal pool conservation. (Photo Credit: Doug Wirtz)

There is a high level of endemism among the selected species. Of the 44 species, 28 (64%) are endemic to the Great Valley, or nearly with only a few outlier occurrences elsewhere. These are shown by beige rows in Table 3.6. There is also a high level of regional endemism within the Valley. Twenty species (45%) are documented in only one or two regions, or nearly so with only one or two occurrences in other regions (though a few have additional occurrences outside the Great Valley). Thirteen of these species are documented in only one region (or nearly so) including the Delta green ground beetle, three of the seven Orcutt tribe grass species, and nine other plant species. As discussed in the geology section above, many of these rare species are also restricted or concentrated on particular geologic formations both within and across regions. The relationships of core species to specific geologic formations are discussed in more detail in the regional chapters below. Those species restricted to particular regions or geologic formations include multiple life forms—vernal pool shrimp, insects, and plants—demonstrating the general evolutionary tendency toward local isolation and speciation within vernal pools in unique climate, landform, and geologic settings.

The progenitors of most of the Great Valley vernal pool endemics were terrestrial species present in the region prior to the formation of vernal pool habitats (Axelrod 1973). As these habitats formed following the rise of the Sierra Nevada, and as climate conditions fluctuated across glacial and interglacial periods and new alluvial and volcanic landforms developed over the past three million years or so, these terrestrial species colonized and then evolved into new, locally endemic species adapted to vernal pools in different and unique settings (Raven and Axelrod 1978). The result is numerous assemblages of closely related species with many regional endemics, some of which are considered rare, such as the goldfields (*Lasthenia* spp.), meadowfoams (*Limnanthes* spp.), calicoflowers (*Downingia* spp.), navarretias (*Navarretia* spp.), popcorn flowers (*Plagiobothrys* spp.), and annual saltbushes (*Atriplex* spp.). A similar process occurred with the vernal pool shrimp, with several closely-related fairy shrimp species (*Branchinecta* spp.) endemic or highly restricted to the Great Valley. Many of these species are considered rare, such as Conservancy fairy shrimp, midvalley fairy shrimp, and longhorn fairy shrimp. The Orcutt tribe grasses are an important and unique group within the Great Valley. There are seven species within three genera that are endemic to the region, all of which have very distinct and localized distribution patterns. Unlike other rare vernal pool plants, it is likely that these species evolved from an ancient aquatic grass species that existed prior to the formation of vernal pools and inhabited the edge of the Great Valley seaway (Keeley 1998). As the Great Valley transitioned from an aquatic to a terrestrial environment, these species adapted to and evolved first within large inland lakes and then the playa pools where they are commonly found today. Some other species formed from the splitting of a formerly widespread species into two related species on either side of the new Sierra Nevada divide, such as the California tiger salamander. The Selected Rare Species Profiles section below describes examples of these three modes of speciation within Great Valley vernal pools in more detail.

Delta green ground beetle (*Elaphrus viridis*), a threatened species endemic to the Greater Jepson Prairie in the southern Solano-Colusa Vernal Pool Region, where it occurs around the margins of playa pools. (Photo Credit: Doug Wirtz)

Baker's navarretia (*Navarretia leucocephala* ssp. *bakeri*), a rare vernal pool species, in a claypan pool on basin rim landform, southern Solano-Colusa Vernal Pool Region. (Photo Credit: © Aaron Arthur 2013)

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California tiger salamander (*Ambystoma californiense*) larva with its prominent feathery gills; this California endemic species is listed as threatened within the Great Valley where it breeds in deeper vernal pools and other ponds and survives the dry season in rodent burrows and other underground refugia. (Photo Credit: Doug Wirtz)

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Species[1]	Status[2]	Total	Number of Occurrences[3] By Vernal Pool Region[4]: NWSV	NESV	SESV	SSFH	SOCO	SJQV	LVMR	CCGV	Not in a Region	Notes on Great Valley Distribution[5]
Amphibians												
California tiger salamander (*Ambystoma californiense*)	FT/CT	**1,803**	-	-	115	395	121	46	564	19	392	Part of Central California Distinct Population Segment (DPS) within Great Valley
western spadefoot (*Spea hammondii*)	CSSC	**1,808**	21	13	86	513	7	133	26	7	1,070	Occurs widely in Great Valley except Delta area due to moist conditions
Vernal Pool Shrimp												
Conservancy fairy shrimp (*Branchinecta conservatio*)	FE/S2	**154**	-	31	2	6	73	41	-	-	1	Restricted to large clay soil pools; named in honor of The Nature Conservancy
longhorn fairy shrimp (*Branchinecta longiantenna*)	FE/S1S2	**123**	-	-	-	-	-	18	87	-	18	Restricted to two local areas in Great Valley – rock pools in LVMR and clay pools in SJQV
vernal pool fairy shrimp (*Branchinecta lynchi*)	FT/S3	**1,828**	44	118	478	656	96	90	35	2	108	Widespread in a diversity of pool types, occurs in all regions
midvalley fairy shrimp (*Branchinecta mesovallensis*)	S2S3	**337**	-	1	58	223	31	21	3	-	-	Concentrated in two areas, centered in Sacramento-Solano and Merced counties
vernal pool tadpole shrimp (*Lepidurus packardi*)	FE/S3S4	**1,821**	59	202	760	328	245	215	2	4	1	Widespread, except in far southern Great Valley
California fairy shrimp (*Linderiella occidentalis*)	S2S3	**586**	28	19	222	184	56	10	17	1	27	Widespread in a diversity of pool types, occurs in all regions
Insects												
Delta green ground beetle (*Elaphrus viridis*)	FT/S1	**7**	-	-	-	-	7	-	-	-	-	Endemic to the Jepson Prairie, found around large playa pools
Plants												
Orcutt Tribe Grasses[6]												
Colusa grass (*Neostapfia colusana*)	FT/CE/1B.1	**102**	-	-	-	74	11	17	-	-	-	Restricted to northern San Joaquin Valley (SJQV and SSFH) and SOCO regions
San Joaquin Valley Orcutt grass (*Orcuttia inaequalis*)	FT/CE/1B.1	**68**	-	-	-	67	1	-	-	-	-	Essentially restricted to northern SSFH Region
hairy Orcutt grass (*Orcuttia pilosa*)	FE/CE/1B.1	**59**	-	15	-	37	7	-	-	-	-	Restricted to four local disjunct areas in north Sac Valley, north SSFH Region
slender Orcutt grass (*Orcuttia tenuis*)	FT/CE/1B.1	**178**	18	55	3	-	-	-	-	-	4	Concentrated in far northern Sacramento Valley
Sacramento Orcutt grass (*Orcuttia viscida*)	FE/CE/1B.1	**23**	-	-	23	-	-	-	-	-	-	Restricted to the SESV Region
Greene's tuctoria (*Tuctoria greenei*)	FE/CR/1B.1	**56**	-	22	-	27	4	-	-	-	-	Concentrated in NESV and SSFH regions
Solano grass (*Tuctoria mucronata*)	FE/CE/1B.1	**7**	-	-	-	-	7	-	-	-	-	Restricted to two local areas in the southern SOCO Region

TALES OF EVOLUTION IN GREAT VALLEY VERNAL POOLS

Vernal pools are renowned for their abundance of species. Within the Great Valley, a single, medium-sized pool measuring 30 to 40 feet across can support more than 30 to 40 plant species, a few different amphibian and shrimp species, and numerous other aquatic invertebrates. In total, Great Valley vernal pools support more than 100 native plant species, ten fairy and tadpole shrimp species, and four amphibian species (Holland 1976; Eriksen and Belk 1999; California Herps 2021). Most of the plant and shrimp species are vernal pool endemics that occur exclusively or primarily in the Great Valley. Many of these species, especially rare ones, are further restricted as local or regional endemics, occurring in only limited areas within the Valley (**Table 3.6; Appendix A**). But, as discussed above, vernal pool habitats are relatively new to California, having developed only in the past few million years, with most landscapes less than two million years old. Vernal pools are also difficult for life to inhabit with their annual fluctuations between short-term inundation and long-term desiccation and periodic years-long droughts. So where did all these new species come from? And why are there so many?

As it turns out, evolution found several different pathways to populate these new and difficult habitats. In fact, the combination of newness and difficulty were fundamental drivers of new species development as life struggled and adapted to occupy vernal pools (Hoover 1937; Raven and Axelrod 1978). The high species diversity was further encouraged by the high landform and geologic diversity within the Great Valley as well as the dramatic climate fluctuations that have occurred over the past four million years with several alternating glacial and inter-glacial periods (Raven and Axelrod 1978, Axelrod 1973, Howard 1979, Harden 2004). Individual pools also vary significantly in ponding depth and duration, both within and across pools, creating distinct niches. All of these conditions provided the foundation for rapid and abundant new species development since vernal pools first began to form in the Great Valley. The tales of evolution below exemplify different evolutionary pathways exploited by life across these variable conditions to yield the high species diversity and regional distribution patterns that we see in the Great Valley today.

Adaptive Radiation: Calicoflowers

Adaptive radiation is a common term in evolutionary biology that describes the proliferation of a single ancestral species into numerous new species in response to the development of a set of new, closely-related habitats or microhabitats. The formation of vernal pools in the Great Valley, with distinct local variations in substrate, climate, and inter- and intra-pool hydrology conditions, presents a classic setting for adaptive radiation to occur. Many of the plant genera within Great Valley pools have multiple, closely related species with different regional distribution patterns. Some of the more noteworthy genera include calicoflowers (*Downingia*), goldfields (*Lasthenia*), popcorn flowers (*Plagiobothrys*), meadowfoams (*Limnanthes*), navarretias (*Navarretia*), clovers (*Trifolium*), and annual saltbushes (*Atriplex*). All of these genera have rare species, some of which are local endemics such as Butte County meadowfoam (*Limnanthes floccosa* ssp. *californica*), Jim's clover (*Trifolium jokerstii*), and Earlimart orache (*Atriplex cordulata* var. *erecticaulis*). Many others are mostly restricted to only one or two vernal pool regions (**Table 3.6**).

An interesting aspect of the evolution of these species is that they generally derived from terrestrial ancestors (Crampton 1954; Ornduff 1966; Spencer and Rieseberg 1997). Indeed, many of the genera listed above still have terrestrial species in proximity to vernal pools such as common goldfields (*Lasthenia californica*) and numerous terrestrial clover and saltbush species.

The calicoflowers offer a good representative example of the adaptive radiation that has occurred in vernal pool plants. This genus has a total of 13 annual species, many with named varieties (Jepson Online 2021). The flowers are striking and vary by species in terms of shape, color, and size (**see photos below**).

Caption: Representative floral variation in calicoflowers found in Great Valley vernal pools (from left to right), harlequin calicoflower (*Downingia insignis*), maroon-spotted calicoflower (*D. concolor*), and dwarf calicoflower (*D. pusilla*). (Photo Credits: Vernon Smith, Doug Wirtz, and Doug Wirtz, respectively)

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All of these species are associated with ephemeral to seasonal wetlands, including many that are strictly associated with vernal pools. All but two of these species occur in Great Valley vernal pools, with six species occurring entirely or primarily within the region (CalFlora 2021). These six species are:

- Hoover's calicoflower (*Downingia bella*)
- double-horned calicoflower (*D. bicornuta* var. *picta*)
- harlequin calicoflower (*D. insignis*)
- ornate calicoflower (*D. ornatissima*)
- valley calicoflower (*D. pulchella*)
- dwarf calicoflower (*D. pusilla*)

Each of these species has a distinct regional distribution pattern within the Great Valley (CalFlora 2021). For example, Hoover's calicoflower is concentrated around the rim of the Valley while harlequin calicoflower is concentrated in the northwest portion. Some species can co-occur within individual pools though only one species tends to dominate. There can also be two or even three species within a local area occupying different pools, indicating that the different species inhabit different pool types or microhabitats based on differences in geology, soils, ponding duration, and other characteristics. Dwarf calicoflower, a rare species, is unusual in that it occurs in vernal pools in both California and western Chile, having presumably dispersed across this great distance as seeds nestled within migrating birds.

Adaptive Radiation: Fairy Shrimp

Fairy shrimp are a type of crustacean within the large branchiopod group. Most crustaceans are marine dwelling, such as crabs and lobsters. However, there are some freshwater crustaceans such as crayfish which inhabit lakes and sloughs, California freshwater shrimp (*Syncaris pacifica*) which inhabits clearwater streams, and various types of large branchiopods which mostly inhabit shallow, rainfed pools including desert playas, rock pools, and vernal pools.

Fairy shrimp include several genera and multiple species distributed around the globe, mostly in Mediterranean or desert regions where they inhabit rainfed pools (some species also occur in marine and alkaline lake settings) (Eriksen and Belk 1999). These shrimp are highly adapted to arid or desert environments. They hatch from cysts when the pools first inundate at the start of the rainy season, grow rapidly, and typically reach breeding maturity within 3-6 weeks depending on the species (Eriksen and Belk 1999). Their lifecycle is completed when the adults breed and the embryos hatch and begin developing within the female where they are covered in a shell to produce cysts. These cysts, which are typically not visible to the naked eye, are then expelled and settle in the mud of the pool basin where they remain through the long, hot dry season until the onset of the next rainy season. Fairy shrimp and other large branchiopod cysts are among the hardiest life forms known. Experiments have shown they can survive for more than 100 years in completely dry soils (in a lab container) and then hatch once returned to an aquatic environment (Eriksen and Belk 1999). They can also survive for more than 30 years in an oxygen-free environment. These characteristics enable the species to survive in areas prone to multi-year droughts.

Representative males of three fairy shrimp species that occur in Great Valley vernal pools (from top to bottom): Conservancy fairy shrimp (*Branchinecta conservatio*), distinguished by its stout antennae with contoured bent tips; longhorn fairy shrimp (*B. longiantenna*), distinguished by its long, delicate antennae (hence the name) with curved pointed tips; and vernal pool fairy shrimp (*B. lynchi*), distinguished by its medium antennae with curved rounded tips. (Photo Credits: Doug Wirtz, Trent Pearce, and Vic Smith ©2012 California Academy of Sciences, respectively)

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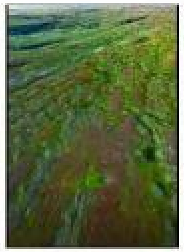
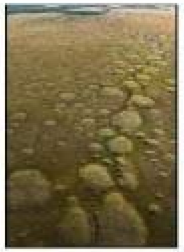
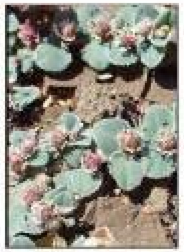
NORTHEASTERN SACRAMENTO VALLEY VERNAL POOL REGION







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Setting

The Northeastern Sacramento Valley (NESV) Vernal Pool Region encompasses volcanic and alluvial terrace landforms of the northeast Sacramento Valley, sloping west from the base of the Cascade Range in the north and the Sierra Nevada in the south, down to the eastern edge of the Sacramento River corridor (**Figure B-1**). It also includes the well-known table mountains near Oroville in the southeast with their unique and showy vernal pools, and encompasses the Sutter Buttes in the southwest. In addition to the table mountains, other prominent vernal pool landscapes in the region include the Vina Plains near the center of the region and extensive volcanic lahar mudflow areas in the north. Long and narrow, the region is about 110 miles long and varies from about 7 to 15 miles wide. It is among the smaller regions in the Great Valley, with a total area of 791,546 acres (1,237 square miles) (**Table 3.1, Chapter 3**). Elevation of mapped vernal pool habitat ranges from 71 to 1,584 feet above sea level.

The region's climate is influenced by its location at the northeast end of the Sacramento Valley, away from the moderating influence of marine air coming in through the Delta, and away from the rain shadow effects of the Coast Ranges. This gives it the distinction of being the wettest and among the hottest regions in the Valley, especially at its northern end (**Figure 3.6 and Table 3.2, Chapter 3**). Mean annual rainfall is 29 inches, which is about 5 inches higher than the NWSV region to the west and 2-3 times higher than regions to the south. There is a significant north-south rainfall and temperature gradient due to the length of the region. These local climate gradients may influence the distribution of some rare and other native species within the region.

This region has the most varied set of landforms of all the Great Valley regions. This is due to it being composed of rocks from three different and distinct sources: Cascade Range volcanics in the north, Sierra Nevada mixed granitic/metamorphic alluvium in the south, and Sutter Buttes volcanics in the southwest. The Cascade Range volcanics include three distinct geologic events. Roughly 15 million years ago, there was a large eruption in the vicinity of present-day Susanville that poured basalt lava down an ancient river valley southwest and across the northern Sacramento Valley. Remnants of this flow, named Lovejoy Basalt, form the elevated table mountains north of Oroville. Roughly 2-3.4 million years ago, a series of volcanic lahars (volcanic ash-water slurries) came rushing down from volcanoes in the present-day Mount Lassen region (ancient Mt. Yana and Mt. Maidu, long since eroded away) depositing layers of volcanic mudflow across the northern and central portions of the region. These deposits are named the Tuscan Formation. The western portion of this formation was subsequently upfolded along a nearly straight fault line. This feature, named the Chico Monocline, is clearly visible on aerial imagery and is an important boundary marker for mapped vernal pool habitat (**Figure B-1; Figure 3.8, Chapter 3**). Lastly, a series of recent basalt flows were deposited in the northern portion of the region roughly 10,000 years ago. All of these formations are part of the volcanic flow landform. Much older Ione Formation is exposed in a few areas in the south where it is overlain by Lovejoy Basalt or Tuscan Formation.

Simultaneous to these Cascade Range events, other landforms were being formed in the southern end of the region as a result of uplift and erosion of the Sierra Nevada over the past 5 million years. This area has the typical series of nested granitic/metamorphic alluvial formations situated along the base of the Sierra Nevada (both here and continuing south down through the eastern San Joaquin Valley) – Laguna, Turlock Lake, Riverbank, Modesto, Recent Alluvial Deposits. This area lacks the volcanic formations associated with the ancestral Sierra Nevada (Valley Springs and Mehrten formations) which occur prominently in both the SESV and SSFH regions to the south. The Sutter Buttes in the southeast are the remnants of local volcanic eruptions that came up through the floor of the eastern Sacramento Valley roughly 1.35-1.6 million years ago.

As described in **Chapter 3**, drainage from the entire northern Sacramento Valley was impeded for an extended period (lasting 100,000 years or more [?]) roughly 680,000 years ago which caused the establishment of a shallow inland lake. Through a poorly understood process, lateral planing by water resulted in the eroding/cutting of relatively flat terrain across the geologic formations present at the time (Tuscan and Laguna in the NESV; Tehama in the NWSV) leaving a surface termed a 'pediment veneer' by geologists. This surface, called the Red Bluff Formation, consists of a layer of gravels or cobbles with thin soils over a well-developed hardpan that, it turns out, is exceptional for the development of Mima mound to-

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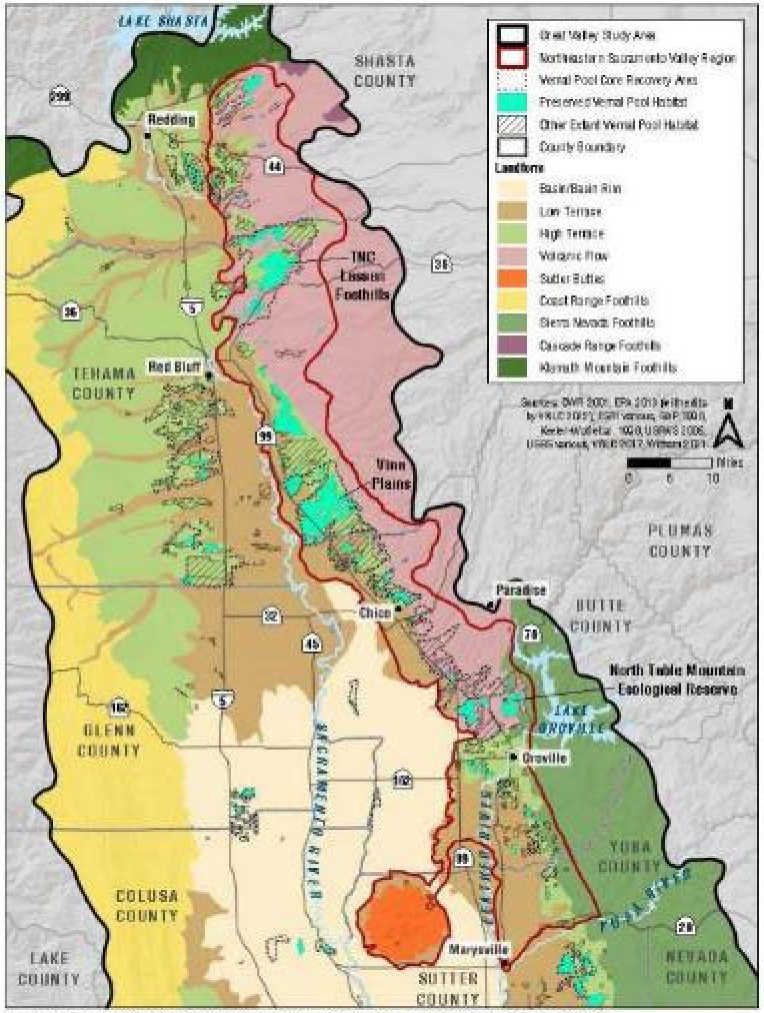

Figure B-1. Geographic Setting of the Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California

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Panorama of the Vina Plains on volcanic Red Bluff Formation in the central NESV Region, with numerous playa pools supporting an exceptional diversity and abundance of rare vernal pool species including Conservancy fairy shrimp, hairy Orcutt grass, Greene's tuctoria, and Hoover's spurge, primarily inhabiting the playa pools. (Photo Credit: Evan Keeler-Wolf, January 2022)

Panorama view of the Tuscan Formation with interspersed Modesto Formation bordering creek channels, west of the table mountains in the NESV Region, supporting key populations of the rare local endemics Butte County meadowfoam and Jim's clover. (Photo Credit: Evan Keeler-Wolf, January 2022)

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pography and vernal pools. Red Bluff Formation occurs widely in the NESV Region, formed across Tuscan Formation west of the Chico Monocline and across remnants of Laguna Formation in the southwest. It does not occur around the base of the Sierra Buttes. This surface is the most prominent for supporting mapped vernal pool habitat in the region, including the iconic Vina Plains.

Ongoing erosion subsequent to the time of the Red Bluff Formation resulted in the deposition of younger, nested formations of Riverbank, Modesto, and Recent Alluvial Deposits. All of these formations are part of the low terrace formations in the region. While all three formations occur throughout the region, they are composed of sediments from very different rock sources depending on location (Cascade volcanics, Sierran granitic/metamorphic rocks, and Sutter Buttes volcanics) and as a consequence have distinct soil and pool biodiversity characteristics in the three different areas.

Vernal pool habitat is concentrated on areas of flat to gentle terrain across the region (**Figure B-1**). The pools are primarily bedrock and claypan type in the volcanic areas and hardpan type on the southern Sierran alluvial terraces and around the Sutter Buttes. There is extensive habitat mapped across the central portion in and around the Vina Plains north of Chico. Other areas with extensive vernal pool habitats include the volcanic landforms in the north, and the table mountains and Tuscan Formation to the south in the area just north of Oroville. There is limited mapped habitat on the Sierran terraces and just a few scattered pockets mapped around the base of the Sutter Buttes. A large amount (43%) of the mapped vernal pool habitat is on Red Bluff Formation, with nearly all in the northern and central areas on volcanic surfaces. A significant amount (20%) is on Tuscan Formation. Much of the remainder is on low terrace landforms of Riverbank, Modesto, or Recent Alluvial Deposit formations. There is a small but important amount of habitat mapped on Lovejoy Basalt on the table mountains (3.9%) and on Laguna Formation (4.3%) in the south. There is also a small but important amount mapped on Quaternary Basin Deposits on volcanic surfaces (2.1%).

There are approximately 131,280 acres of vernal pool habitat remaining in the region (in 2022), representing a 17% land-cover (**Table 3.1, Chapter 3**). This is the highest cover by far among the Great Valley regions. The Vernal Pool Recovery Plan (USFWS 2005) identifies nine core areas within the region (one of which also extends into the NWSV Region) (**Figure B-1**). Of the remaining habitat, 33% is conserved and includes a mix of public, non-profit, and conserved private lands. The conserved areas are concentrated in the central and northern portions of the region where there are several large, contiguous preserved habitat blocks (**Figure B-1**). There is only limited habitat conserved in the southern portion, with the largest preserves on the table mountains, including CDFW's North Table Mountain Ecological Reserve, and in an area of Tuscan formation to the west. There are currently no conserved lands around the base of the Sutter Buttes. The Vina Plains Preserve, owned by The Nature Conservancy, is one of the most well-known vernal pool preserves in the state due to the large number of playa pools and the high diversity and abundance of rare and endangered species.

Twenty of the target rare vernal pool species are documented in the region, eleven of which are categorized as core species with key population centers in the region (**Table B-2, Figure B-2, Appendix A**). These are moderate numbers of total and core rare species compared to the other Great Valley regions which is a bit surprising given the high geologic diversity. Two of these species, Butte County meadowfoam and Jim's clover, are endemic to the region. The former is restricted to volcanic formations, or on Red Bluff Formation formed on Tuscan, in the central portion of the region including the table mountains near Oroville. The latter is restricted to the table mountains and areas of Tuscan Formation, or Quaternary Basin Deposits on Tuscan, to the west. Two other species, Ahart's dwarf rush and Ahart's paludwort, have the bulk of known occurrences in the region. Several species are concentrated in and around the Vina Plains including Conservancy fairy shrimp, hairy Orcutt grass, Greene's tuctoria, and Hoover's spurge. Others are concentrated on volcanic formations to the north including slender Orcutt grass, Boggs Lake hedge hyssop and Ahart's paludwort. Ahart's dwarf rush is unique in that it is the only species restricted to the Sierra-derived alluvial terraces in the south. Jim's clover is named after Jim Jokerst, an expert California botanist with a particular fondness for the local table mountains who unfortunately passed away at a young age in the 1990s. Ahart's paludwort and Ahart's dwarf rush are both named after Lowell Ahart, a well-regarded local botanist and rancher, who discovered the species and who co-authored a flora of Butte County (Oswald and Ahart 1994). Conservancy fairy shrimp is named after The Nature Conservancy for its leading work conserving Great Valley vernal pool habitats.

The region is within portions of Shasta, Tehama, and Butte counties and extends into the northern tip of Yuba County (**Figure B-1**). Highway 99 crosses the region north to south. The main towns, mostly located along the Highway 99 corridor, include eastern Red Bluff, Chico, and Oroville. There has been extensive agricultural conversion, especially west of Highway 99 and on both sides of the highway southeast of Red Bluff (**Figure B-4**, below). As with the NWSV Region, loss of vernal pool habitat has likely been concentrated on Riverbank and Modesto formations since they are fairly level with good agricultural soils once deep-ripped to break up the subsurface hardpan. The heavy accumulation of gravels and rough, underlying volcanic bedrock or hardpan make the Red Bluff Formation less suited for agricultural conversion. Similarly, the near-surface volcanic bedrock makes the Tuscan Formation and Recent Basalt Flows difficult for agricultural conversion.

Ahart's dwarf rush (*Juncus leiospermus* var. *ahartii*), highly restricted to the Sierran-derived terraces in the south of the NESV Region, with most documented occurrences on Turlock Lake Formation. (Photo Credit: Carol Witham)

Jim's clover (*Trifolium jokerstii*), endemic to volcanic formations in the southern NESV Region with nearly half of known occurrences on the table mountains formed of Lovejoy Basalt. (Photo Credit: George Hartwell)

Hoover's spurge (*Euphorbia hooveri*), a Great Valley endemic with key populations on the Vina Plains in the NESV Region, where it inhabits playa pools with turbid waters. (Photo Credit: Neal Kramer)

Butte County meadowfoam (*Limnanthes floccosa* ssp. *californica*), endemic to volcanic formations in the central-southern NESV Region. (Photo Credit: Jeb Bjerke)

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Geologic Formations and Mapped Vernal Pool Habitat

Table B-1 shows the acreage and percent of mapped vernal pool habitat in the region by rock source and geologic formation. The bulk of vernal pool habitat is in areas with volcanic rock sources (88.1%). Roughly half of this habitat is on Red Bluff, a quarter on Tuscan, a tenth on Riverbank, and the remainder on Lovejoy Basalt, Recent Basalt Flow, and other formations in these areas. A total of 11.2% of mapped vernal pool habitat is in areas with Sierran rock sources, the bulk of which occurs on Laguna, Turlock Lake, and Riverbank formations. Less than 1% of mapped habitat occurs around the Sutter Buttes. There is also a small amount (0.2%) on Ione Formation which is exposed in some limited areas north of Oroville, overlain by Lovejoy Basalt or Tuscan Formation.

Vernal Pool Habitat Diversity and Unique Types

The region supports a high diversity of vernal pool habitat types, based on the high geologic diversity, including some unique volcanic types that occur only in this region (or nearly so). Representative conservation of habitat on the range of geologic formations was considered in the selection of target habitat blocks to ensure the full suite of vernal pool habitat types and rare associated species are conserved.

Lovejoy Basalt, Tuscan Formation, and Recent Volcanic Flows only occur in this region (the latter has one small finger that extends across the Sacramento River as discussed in the NWSV Region chapter). Red Bluff Formation formed on Tuscan Formation is also unique to the region. The uniqueness of vernal pools on these formations is demonstrated by the numerous rare species that are entirely or primarily restricted to these formations. Butte County meadowfoam and Jim's clover are both endemic to volcanic formations in the region. Other rare species are more widespread but largely restricted to pools on volcanic formations in this region. The Riverbank and Modesto formations formed from volcanic alluvium are also unique from the formations with the same name elsewhere in the Valley, where they are composed of alluvium from other rock sources. The Riverbank and Modesto formations around the base of the Sutter Buttes support unique vernal pool habitats since they are composed of volcanic alluvium from a different source than the Cascades.

It would seem that vernal pools on the Sierra Nevada-derived formations in the region are not especially unique since the same formations with similar rock sources occur south all along the base of the Sierra Nevada. However, more than 85% (34 of the 39) of documented occurrences of Ahart's dwarf rush occur in this area, indicating some unique characteristics of these vernal pool habitats.

Vernal pool habitat atop the North Table Mountain on Lovejoy Basalt in the southern NESV Region, supporting populations of Butte County meadowfoam, Jim's clover, and Red Bluff dwarf rush. (Photo Credit: Evan Keeler-Wolf, January 2022)

Vernal pool habitat on a Recent Basalt Flow in the northern NESV Region, supporting key populations of slender Orcutt grass, Ahart's paleworl, and Boggs Lake hedge hyssop. (Photo Credit: Evan Keeler-Wolf, January 2022)

Table B-1. Mapped Vernal Pool Habitat by Geologic Formation, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California.

Geologic Formation	Landform	Age[1]	Mapped Vernal Pool Habitat[2] Acres	Mapped Vernal Pool Habitat[2] % of Region
Cascade Volcanic Rock Sources				
Lovejoy Basalt	Volcanic Flow	15 my	5,158	3.9%
Tuscan	Volcanic Flow	2-3.4 my	26,582	20.2%
Red Bluff	High Terrace	680-800 ky	56,783	43.3%
Riverbank	Low Terrace	130-450 ky	10,927	8.3%
Modesto	Low Terrace	12-90 ky	6,496	4.9%
Quaternary Basin Deposits	Basin	<12 ky	2,693	2.1%
Recent Basalt Flow	Volcanic Flow	10 ky	6,272	4.8%
Other Formations	N/A	N/A	785	0.6%
Sierran Mixed Granitic/Metamorphic Rock Sources				
Laguna	High Terrace	3-4 my	5,691	4.3%
Red Bluff	High Terrace	680-800 ky	813	0.6%
Turlock Lake	High Terrace	620-800 ky	1,923	1.5%
Riverbank	Low Terrace	130-450 ky	3,471	2.6%
Modesto	Low Terrace	12-90 ky	521	0.4%
Other Formations	N/A	N/A	2,391	1.8%
Sutter Buttes Volcanic Rock Sources				
Volcanic Rocks	Volcanic Flow	1.4 my	98	0.1%
Riverbank	Low Terrace	130-450 ky	311	0.2%
Modesto	Low Terrace	12-90 ky	43	<0.1%
Other Formations	N/A	N/A	32	<0.1%
Other				
Ione	High Terrace	40-50 my	289	0.2%
TOTAL			**131,280**	**100%**

1. Age: my = million years, ky = thousand years.
2. Extant mapped vernal pool habitat only.

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Rare Species Analysis

Of the 20 target rare species documented in the region (Table B-2), eleven are categorized as core, six as sparse, and three as generalist for the purposes of the habitat block conservation analysis. Table B-3 describes the distribution and habitat preferences of each core species. Tables B-4a and B-4b show the acreage of predicted habitat and documented occurrences, respectively, of the core species by geologic formation. Figure B-2 includes submaps of each core species showing documented occurrences and predicted habitat within the region. Figure B-3, below, is a 'hotspot' map that layers the predicted habitat of all eleven core species, highlighting areas with likely concentrations of these species. Appendix A includes California-wide distribution maps of all species.

As described above, there are some interesting localized distribution patterns of the core species within the region. Some species are restricted or concentrated on and around the Vina Plains area, others on the volcanic formations in the north, and one (Ahart's dwarf rush) on the Sierra-derived terraces in the south. Both endemic species, Butte County meadowfoam and Jim's clover, are absent from Vina Plains and areas to the north, concentrated on the table mountains and volcanic formations to the south. These data support including habitat blocks in the north, central, and southern areas of the region to ensure that the full suite of biodiversity is preserved.

Table B-2. Target Rare Vernal Pool Species Documented in the Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California. Highlighted row indicates species is endemic or highly restricted to the region. (See **Appendix A** for range-wide maps)

Species				NESV Region Occurrences	
Common Name	Scientific Name	Status[1]	Total No. of Occurrences[2]	No.	% of Total
Core Species					
Conservancy fairy shrimp	*Branchinecta conservatio*	FE/S2	154	31	20.1%
hairy Orcutt grass	*Orcuttia pilosa*	FE/CE/1B.1	59	15	25.4%
slender Orcutt grass	*Orcuttia tenuis*	FT/CE/1B.1	178	55	30.9%
Greene's tuctoria	*Tuctoria greenei*	FE/CR/1B.1	56	22	39.3%
Hoover's spurge	*Euphorbia hooveri*	FT/1B.2	65	27	41.5%
Boggs Lake hedge hyssop	*Gratiola heterosepala*	CE/1B.2	126	22	17.5%
Ahart's dwarf rush	*Juncus leiospermus var. ahartii*	1B.2	39	34	87.2%
Red Bluff dwarf rush	*Juncus leiospermus var. leiospermus*	1B.1	112	45	40.2%
Butte County meadowfoam	*Limnanthes floccosa ssp. californica*	FE/1B.1	143	143	100.0%
Ahart's paronychia	*Paronychia ahartii*	1B.1	102	85	83.3%
Jim's clover	*Trifolium jokerstii*	1B.2	57	57	100.0%
Sparse Species					
western spadefoot	*Spea hammondii*	CSSC	1,898	13	0.7%
midvalley fairy shrimp	*Branchinecta mesovallensis*	S2S3	337	1	0.3%
dwarf calicoflower	*Downingia pusilla*	2B.2	204	3	1.5%
legenere	*Legenere limosa*	1B.1	127	5	3.9%
Baker's navarretia	*Navarretia leucocephala ssp. bakeri*	1B.1	78	3	3.8%
Hartweg's golden sunburst	*Pseudobahia bahiifolia*	FE/CE/1B.1	69	1	1.4%
Generalist Species					
vernal pool fairy shrimp	*Branchinecta lynchi*	FT/S3	1,628	116	7.2%
vernal pool tadpole shrimp	*Lepidurus packardi*	FE/S3S4	1,821	202	11.1%
California fairy shrimp	*Linderiella occidentalis*	S2S3	586	19	3.2%

1. Status: FE = federally listed endangered; FT = federally listed threatened; CE = CA state listed threatened; CT = CA state listed threatened; CR = CA state listed rare; CSSC = California Species of Special Concern California State Rank: S1 = critically imperiled, S2 = imperiled; S3 = vulnerable; S4 = apparently secure (combined ranks indicate intermediate condition between stated ranks); California Native Plant Society (CNPS) California Rare Plant Rank (CRPR): List 1B = rare, threatened, or endangered in California and elsewhere; List 2B = rare, threatened, or endangered in California but more common elsewhere. 1 = seriously threatened in CA, 2 = moderately threatened in CA.

2. Occurrences from California Natural Diversity Database (CNDDB 2021) and some additional occurrences from Vollmar Natural Lands Consulting and Helm Consulting as described in the Appendix B.

Table B-3. Distribution and Habitat Preferences of Core Rare Species, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California. (See **Appendix A** for range-wide maps)

Species	Distribution and Habitat Preferences
Conservancy fairy shrimp (*Branchinecta conservatio*)	Endemic to the Great Valley, where it primarily inhabits turbid playa pools. There are three main clusters, around the Vina Plains (NESV region), Jepson Prairie (SOCO Region), and central San Joaquin Valley (SJV Region). The 31 documented occurrences in the NESV Region are concentrated on the Vina Plains, primarily on volcanic Red Bluff and Riverbank formations.
hairy Orcutt grass (*Orcuttia pilosa*)	Endemic to the Great Valley, this species occurs in four widely disjunct populations, on the Vina Plains (NESV Region), Sacramento Wildlife Refuge (SOCO Region), and near the upper Stanislaus River and central Madera County (both SSFH Region). The 15 documented occurrences in the NESV Region are narrowly concentrated on the Vina Plains in playa pools on volcanic Red Bluff formation.
slender Orcutt grass (*Orcuttia tenuis*)	Occurrences in the Great Valley are mostly restricted to the northern Sacramento Valley, with many occurrences also on the Modoc Plateau and a few in the northern Coast Ranges. Primarily inhabits larger pools. North end of the NESV Region supports a key population cluster with about 50 occupied pools on volcanic Red Bluff, Riverbank, and Recent Basalt Flow formations.
Greene's tuctoria (*Tuctoria greenei*)	Endemic to the Great Valley, primarily inhabiting larger pools. It occurs in two disjunct areas in the northern Sacramento Valley (NESV and north SOCO regions) and eastern San Joaquin Valley (SSFH Region). The 22 occurrences in the NESV region are clustered on the Vina Plains on volcanic Red Bluff Formation, with a few occurrences farther south to about Oroville on Red Bluff and Tuscan formations.
Hoover's spurge (*Euphorbia hooveri*)	Endemic to the Great Valley, primarily inhabiting playa pools. It is restricted to four widely dispersed clusters (and two outlying occurrences) on the Vina Plains (NESV Region), Sacramento NWR (north SOCO Region), Hickman vernal pools (north SSFH Region), and adjacent to St. John's River in Tulare County (south SSFH Region). The 27 occurrences in the NESV Region are concentrated on volcanic Red Bluff Formation overlying Tuscan Formation on the Vina Plains.
Boggs Lake hedge hyssop (*Gratiola heterosepala*)	Occurrences in the Great Valley are mostly in the Sacramento Valley with additional occurrences in the Modoc Plateau and North Coast Ranges. The 22 documented occurrences in the NESV region are concentrated in the north on volcanic Red Bluff and Recent Basalt Flow formations.
Ahart's dwarf rush (*Juncus leiospermus var. ahartii*)	Endemic to the Sacramento Valley with 34 of 39 documented occurrences (87%) in the NESV Region, and the remainder in the SESV (4) and NWSV (1) regions. This species has a unique distribution in the NESV Region as the only rare plant in the region restricted to the Sierra-derived alluvial formations in the south, with the bulk of occurrences on Turlock Lake Formation.

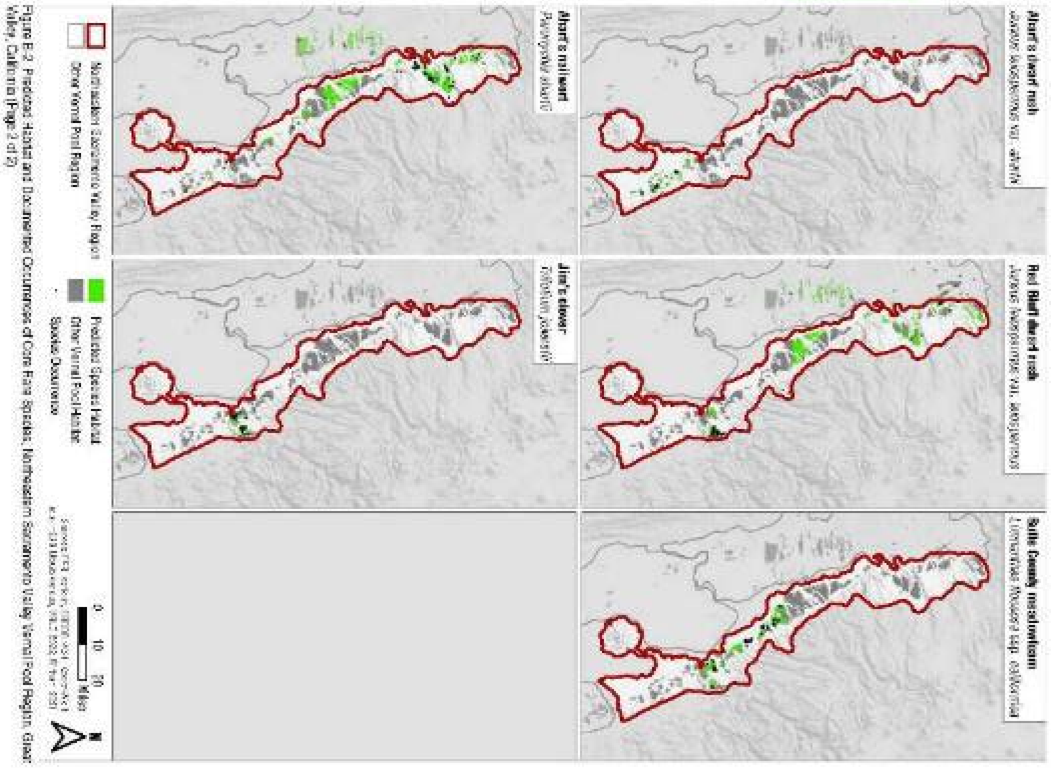

Figure B-2. Predicted Habitat and Documented Occurrences of Core Rare Species, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California (Page 2 of 2)

Table B-4a. Predicted Habitat of Core Rare Species by Geologic Formation, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California.

Species	Predicted Habitat by Geologic Formation (ac.)[1]															
	Cascade Volcanic Rock Sources								Sierran Mixed Granitic/Metamorphic Rock Sources						Other	
	Lovejoy Basalt	Tuscan	Red Bluff	Riverbank	Modesto	Quaternary Basin Deposits	Recent Basalt Flow	Other Formations	Laguna	Red Bluff	Turlock Lake	Riverbank	Modesto	Other Formations	Ione	Total
Mapped Vernal Pool Habitat	3,150	26,142	50,703	10,967	6,496	6,272	7,660	775	3,691	813	1,923	3,421	571	7,391	259	131,289[2]
Vernal Pool Shrimp																
Conservancy fairy shrimp (*Branchinecta conservatio*)	0	2	8,182	4,160	370	0	354	7	0	0	1	126	0	125	0	13,235
Orcutt Tribe Grasses																
Hairy Orcutt grass (*Orcuttia pilosa*)	0	0	16,029	717	388	0	606	18	0	0	0	0	0	0	0	17,765
Slender Orcutt grass (*Orcuttia tenuis*)	0	3,505	24,517	1,061	432	4,376	31	213	3,054	495	853	104	107	358	17	39,731
Greene's tuctoria (*Tuctoria greenei*)	0	2,156	6,880	417	1,408	0	330	7	341	0	8	238	90	455	0	14,795
Other Plants																
Hoover's spurge (*Euphorbia hooveri*)	0	740	22,681	2,518	1,140	0	745	178	0	0	0	0	0	0	0	27,013
Boggs Lake hedge-hyssop (*Gratiola heterosepala*)	0	2,066	20,665	1,249	547	3,219	620	256	514	4	13	3	0	385	0	38,533
Ahart's dwarf rush (*Juncus leiospermus var. ahartii*)	0	0	7	0	1	0	0	0	1,016	260	1,177	1,880	152	788	7	6,663
Red Bluff dwarf rush (*Juncus leiospermus var. leiospermus*)	4,411	7,035	22,162	2,068	458	2,710	18	176	65	5	0	2	1	43	1	41,039
Butte County meadowfoam (*Limnanthes floccosa ssp. californica*)	1,736	8,234	4,681	2,633	2,166	0	126	1	6	0	0	2	0	0	41	20,632
Ahart's nailwort (*Paronychia ahartii*)	0	6,295	37,127	1,627	1,096	5,105	12	404	151	369	51	3	62	671	1	53,037
Jim's clover (*Trifolium jokerstii*)	2,590	3,016	0	0	56	0	57	0	1	0	0	0	0	0	55	6,088

1. Predicted habitat calculated using revised Holland and Hollander method (Vollmar et al. 2016); extant mapped vernal pool habitat only. Geology types derived from Sutter Buttes Volcanic Rock Sources are excluded from this table (see Table B-1), as they do not support any predicted habitat for the core rare species.

2. Total mapped vernal pool habitat includes rock sources/geology types which have been excluded from this table (see Table B-1).

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Table B-4b. Documented Occurrences of Core Rare Species by Geologic Formation, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California.

Species	Documented Occurrences by Geologic Formation (no.)[1]															
	Cascade Volcanic Rock Sources								Sierran Mixed Granitic/Metamorphic Rock Sources						Total[1]	Total in Region[2]
	Lovejoy Basalt	Tuscan	Red Bluff	Riverbank	Modesto	Quaternary Basin Deposits	Recent Basalt Flow	Other Formations	Laguna	Red Bluff	Turlock Lake	Riverbank	Modesto	Other Formations		
Vernal Pool Shrimp																
Conservancy fairy shrimp (*Branchinecta conservatio*)	0	0	14	5	1	0	0	0	0	0	0	0	0	0	20	31
Orcutt Tribe Grasses																
Hairy Orcutt grass (*Orcuttia pilosa*)	0	0	12	1	0	0	2	0	0	0	0	0	0	0	15	15
Slender Orcutt grass (*Orcuttia tenuis*)	0	2	16	3	1	12	0	0	0	0	2	0	0	0	36	56
Greene's tuctoria (*Tuctoria greenei*)	0	2	12	1	0	0	4	0	0	0	0	1	0	0	20	20
Other Plants																
Hoover's spurge (*Euphorbia hooveri*)	0	1	18	2	0	0	4	0	0	0	0	0	0	0	25	27
Boggs Lake hedge-hyssop (*Gratiola heterosepala*)	0	1	17	1	0	0	1	0	0	0	0	0	0	0	21	22
Ahart's dwarf rush (*Juncus leiospermus var. ahartii*)	0	0	0	0	0	0	0	0	2	1	22	4	0	2	31	34
Red Bluff dwarf rush (*Juncus leiospermus var. leiospermus*)	25	0	0	10	1	1	0	0	0	0	0	0	0	0	37	46
Butte County meadowfoam (*Limnanthes floccosa ssp. californica*)	4	63	38	0	8	0	0	0	0	0	0	1	0	0	115	140
Ahart's paronychia (*Paronychia ahartii*)	0	10	29	0	0	22	0	0	1	1	0	0	0	0	63	65
Jim's clover (*Trifolium jokerstii*)	26	27	0	0	0	0	3	0	0	0	0	0	0	0	56	57

1. Documented occurrences with sufficient positional accuracy to be included in our predicted habitat analysis by geologic formation. Ione Formation and geology types derived from Sutter Buttes Volcanic Rock Sources are excluded from this table (see Table B-1), as they do not support any documented occurrences of the core rare species.

2. All occurrences in region including those outside of mapped vernal pool habitat and those without sufficient positional accuracy to be included in our predicted habitat analysis.

Outlier Habitat and Rare Species Occurrences

The target habitat blocks identified below capture a large percentage of the documented occurrences and predicted habitat of the core rare species in the region. However, there are some outlier occurrences that should be considered from a conservation perspective. There are numerous occurrences of Butte County meadowfoam outside of large habitat blocks. Given the local endemism and endangered status of this species, efforts should be made to conserve all known occurrences. There are also some occurrences of Ahart's dwarf rush and Ahart's nailwort that are outside of large blocks. These are important to conserve since both species are largely restricted to this region. In particular, there is a large cluster of Ahart's dwarf rush occurrences on a small block near the north end of the Sierran terraces that should be a target for conservation. Lastly, Habitat Block 2 was not included as a target habitat block even though it is the second largest, for reasons discussed below. Still, the western portion of this block has predicted habitat for a high number of core rare species. Conservation of this portion of the block should be considered if opportunities arise with willing landowners and available funding.

Past and Ongoing Conservation Efforts

There have been significant, sustained efforts over the past 40 years or so by several groups and agencies to conserve key vernal pool habitat areas and other surrounding lands in the region. These groups include non-profit land trusts and other conservation organizations, federal and state environmental agencies, local agencies, and mitigation providers.

The Nature Conservancy (TNC) has played a major role (Jake Jacobson, pers. comm. 2022). In the 1980s, TNC initiated the Lassen Foothills Project, focused on conserving an unfragmented landscape covering many hundreds of thousands of acres extending from the northeastern Great Valley floor up into the Mount Lassen foothills. The Vina Plains Preserve, totaling about 4,600 acres, was a key acquisition which is now owned and managed by TNC. Additional surrounding lands have been placed under conservation easement in cooperation with private ranch owners. Thousands of additional acres of lands with vernal pool habitats have been acquired or conserved by TNC on the 37,540-acre Dye Creek Preserve, the 36,000-acre Denny Ranch conservation easement, the 26,000-acre Inks Creek conservation easement, and other lands. Funding for these acquisitions have come from several sources including the Packard Foundation, federal and state grant funds, and TNC donors.

Other land trusts have also made important contributions. Shasta Land Trust and California Rangeland Trust hold some sizeable conservation easements in the region. Northern California Regional Land Trust and Butte County Environmental Council have spearheaded efforts to conserve occurrences of Butte County meadowfoam, and Aqua Alliance has worked on the legal front to protect and defend waters and wetlands in the region, including vernal pool habitats.

CDFW has also played an important role in the region, acquiring and establishing the 3,315-acre North Table Mountain Ecological Reserve (NTMER) in 1993 (with a small addition in 1997). CDFW's Lands Program has a goal of identifying and acquiring significant natural areas in the state with about 749 Ecological Reserves and Wildlife Areas established to date covering more than 1.1 million acres of land. Public funding for the NTMER acquisition was provided by the California Wildlife Conservation Board (WCB) using Proposition 70 funds that were voter-approved in 1988. There are some other smaller CDFW preserve lands and easements in the region.

Federal environmental agencies have contributed to conservation in the region including U.S. Bureau of Land Management (BLM) through public land ownership and NRCS with easement funding through its Wetlands Reserve Program. Cities and counties have also contributed with some conservation lands owned by the City of Chico and Butte County.

Mitigation has contributed to conservation in the region. There are at least two mitigation banks. The 2,600-acre Dove Ridge Conservation Bank is located about six miles northwest of Oroville and encompasses Tuscan Formation with occurrences of the endemic Butte County meadowfoam and Jim's clover. The 530-acre Meridian Ranch Mitigation Bank is located just southeast of the Vina Plains Preserve. There are some other project-specific 'turn-key' mitigation lands established to offset impacts from development projects. One example is CDFW's 387-acre Dales Lake Ecological Reserve located northeast of Red Bluff that was established with mitigation funds from the PG&E-PGT gas pipeline project that was constructed through the region in the early 1990s.

All of the groups mentioned above continue to be active in the region pursuing additional conservation of vernal pool habitats and other lands. There seems to be less motivation over the past decade to pursue large (5,000+ acre) acquisitions and easements such as those established by TNC between 1980 and the early 2000s. Still, additional lands continue to be conserved as opportunities and efforts merge. This guide helps provide a roadmap for key target areas moving forward.

Habitat Block Analysis

Ten of the 20 largest habitat blocks in the region are selected as targets for conservation. All figures and tables below highlight the target blocks. Three of the target blocks – 4, 6, and 17 – are already largely conserved (83%, 89%, and 98%, respectively). While conserving the remaining unprotected habitat in these blocks is important, it is more of a priority to focus on the other seven target blocks which range from 0% to 60% conserved. **Table B-5** summarizes acreage of mapped vernal pool habitat by rock source and geologic formation for all 20 habitat blocks. It also shows the acreage and percent of conserved habitat within each block. **Tables B-6a** and **B-6b** summarize core rare species predicted habitat and documented occurrences, respectively, by habitat block. **Figure B-3** is a 'hotspot' map that shows the number of core species with predicted habitat in the 20 blocks and other mapped vernal pool habitat. **Figure B-4** shows the 20 blocks in relation to aerial imagery. **Figure B-5** shows the 20 blocks in relation to land-

Vernal Pool Habitat Block	Mapped Vernal Pool Habitat by Geologic Formation (ac.)[1]															Total Size (ac.)	Conserved Habitat (ac.)	Conserved Habitat (%)
	Cascade Volcanic Rock Sources								Sierran Mixed Granitic/Metamorphic Rock Sources						Other			
	Lovejoy Basalt	Tuscan	Red Bluff	Riverbank	Modesto	Recent Basalt Flow	Quaternary Basin Deposits	Other Formations	Laguna	Red Bluff	Turlock Lake	Riverbank	Modesto	Other Formations	Ione			
1	0	1,377	19,571	8,398	1,627	0	507	0	0	0	0	0	0	0	0	**31,781**	14,074	44%
2	0	0	10,476	490	322	0	268	161	0	0	0	0	0	0	0	**11,718**	1,989	17%
3	110	7,550	2	0	304	0	257	0	1,099	22	0	3	0	0	284	**9,632**	2,620	27%
4	0	99	6,559	0	565	1,019	0	0	0	0	0	0	0	0	0	**8,292**	6,900	83%
5	0	6,879	0	0	1,199	0	0	0	0	0	0	0	0	0	0	**8,078**	184	2%
6	0	1	4,557	144	311	0	1,331	0	0	0	0	0	0	0	0	**6,343**	5,689	89%
7	0	256	3,632	0	0	2,028	0	354	0	0	0	0	0	0	0	**6,270**	1,019	16%
8	0	2,564	2,259	0	0	0	0	0	0	0	0	0	0	0	0	**4,823**	1,556	32%
9	4,679	0	0	0	0	0	0	8	0	0	0	0	0	0	0	**4,687**	2,216	47%
10	0	136	3,563	496	27	136	0	10	0	0	0	0	0	0	0	**4,367**	0	0%
11	0	0	0	0	0	0	0	0	477	226	592	1,011	116	475	0	**2,897**	0	0%
12	0	690	71	106	1	1,713	0	0	0	0	0	0	0	0	0	**2,581**	101	4%
13	0	1,102	552	0	324	0	0	0	0	0	0	0	0	0	0	**1,979**	1,195	60%
14	0	634	0	0	1,195	0	27	0	0	0	0	0	0	0	0	**1,857**	0	0%
15	0	294	448	1,011	0	0	0	0	0	0	0	0	0	0	0	**1,753**	154	9%
16	0	1,337	0	0	0	286	0	0	0	0	0	0	0	0	0	**1,622**	207	13%
17	0	737	0	0	0	673	0	0	0	0	0	0	0	0	0	**1,411**	1,386	98%
18	0	0	0	0	0	0	0	0	1,354	0	0	0	0	0	0	**1,364**	437	32%
19	0	0	899	37	244	0	0	37	0	0	0	0	0	0	0	**1,213**	0	0%
20	0	3	1,104	0	0	0	0	0	0	0	0	0	0	0	0	**1,107**	16	1%
Total All Selected Blocks	**4,789**	**11,415**	**35,352**	**9,564**	**3,150**	**3,720**	**2,396**	**362**	**1,576**	**250**	**592**	**1,014**	**116**	**475**	**285**	**75,045**	**35,234**	**47%**
% of Region Total	**93%**	**43%**	**62%**	**87%**	**48%**	**59%**	**89%**	**46%**	**28%**	**31%**	**31%**	**29%**	**22%**	**20%**	**98%**	**57%**	**81%**	**-**
Region Total[1]	**5,158**	**26,582**	**56,783**	**10,927**	**6,495**	**6,272**	**2,693**	**785**	**5,691**	**813**	**1,923**	**3,471**	**521**	**2,391**	**289**	**131,286[2]**	**43,319**	**33%**

Vernal Pool Habitat Block	Total Size (ac.)	Core Rare Species Predicted Habitat (ac.)[1]										
		BRACON	ORCPIL	ORCTEN	TUCGRE	EUPHOO	GRAHET	JUNLEIA	JUNLEIL	LIMFLOC	PARAHA	TRIJOK
1	31,782	11,385	13,086	8,609	8,590	18,130	14,948	0	11,199	7,073	12,880	0
2	11,718	1,565	4,668	4,812	1,631	7,836	5,102	7	4,787	0	8,069	0
3	9,632	0	0	854	528	0	0	222	2,082	4,784	240	3,187
4	8,292	0	0	4,384	0	0	5,361	0	2,589	0	7,966	0
5	8,078	0	0	0	1,381	35	0	0	0	3,822	1,175	112
6	6,343	0	0	0	0	164	0	0	0	0	169	0
7	6,270	0	0	4,082	0	0	3,221	0	4,385	0	6,014	0
8	4,823	0	0	820	0	0	295	0	2,205	0	126	0
9	4,687	0	0	0	0	0	0	0	4,126	1,579	0	2,482
10	4,387	0	0	2,916	0	0	416	0	1,154	0	3,365	0
11	2,897	0	0	0	31	0	0	1,197	0	0	288	0
12	2,581	0	0	2,000	0	0	257	0	465	0	2,278	0
13	1,979	0	0	0	0	0	0	0	0	1,522	320	0
14	1,857	0	0	0	1,359	773	0	0	0	227	0	0
15	1,753	0	0	961	0	0	610	0	1,513	0	1,086	0
16	1,622	0	0	1,152	0	0	895	0	1,472	0	600	0
17	1,411	0	0	1,182	0	0	1,362	0	1,300	0	1,409	0
18	1,354	0	0	1,261	0	0	0	820	0	0	23	0
19	1,213	0	0	851	0	171	860	0	880	0	892	0
20	1,107	0	0	735	0	0	644	0	489	0	1,090	0
Total All Selected Blocks	**75,045**	**11,385**	**13,086**	**20,073**	**9,149**	**18,294**	**25,502**	**1,419**	**27,194**	**14,958**	**30,070**	**5,669**
% of Region Total	**57%**	**86%**	**74%**	**51%**	**62%**	**66%**	**70%**	**24%**	**66%**	**73%**	**56%**	**93%**
Region Total[2]	**131,280**	**13,255**	**17,796**	**39,741**	**14,767**	**27,914**	**36,683**	**5,863**	**41,039**	**20,632**	**53,487**	**6,088**

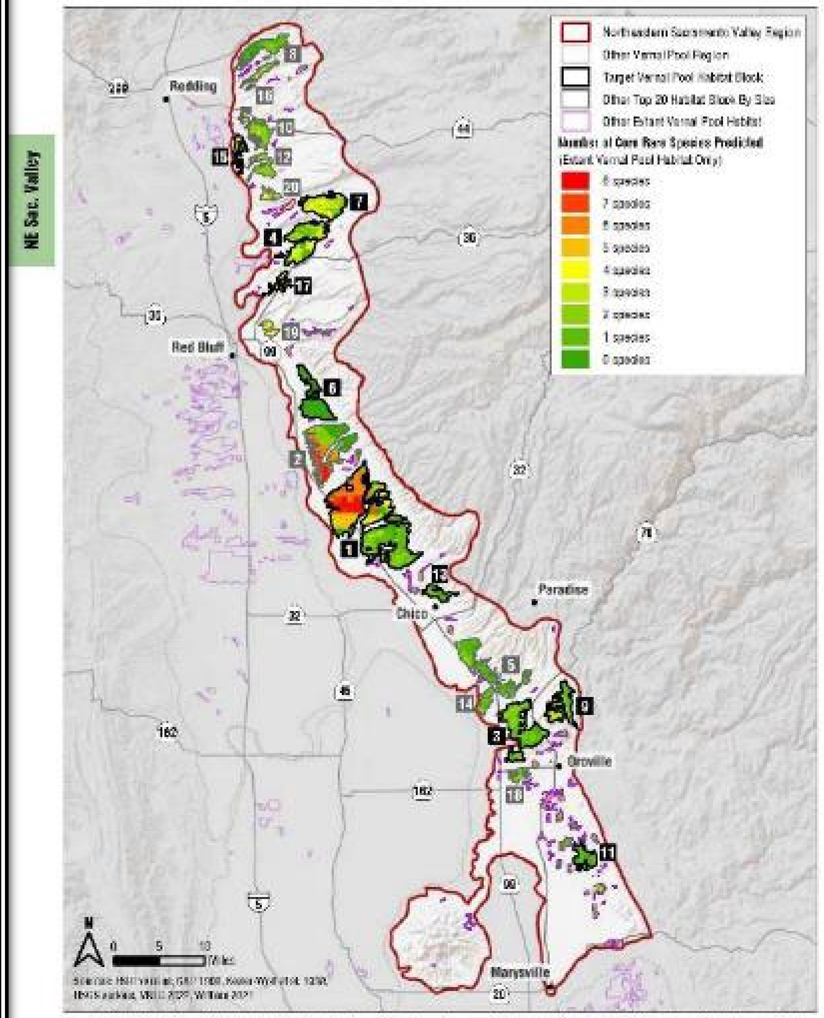

Figure B-3. Hot Spot Map of Predicted Habitat for Combined Core Rare Species, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California

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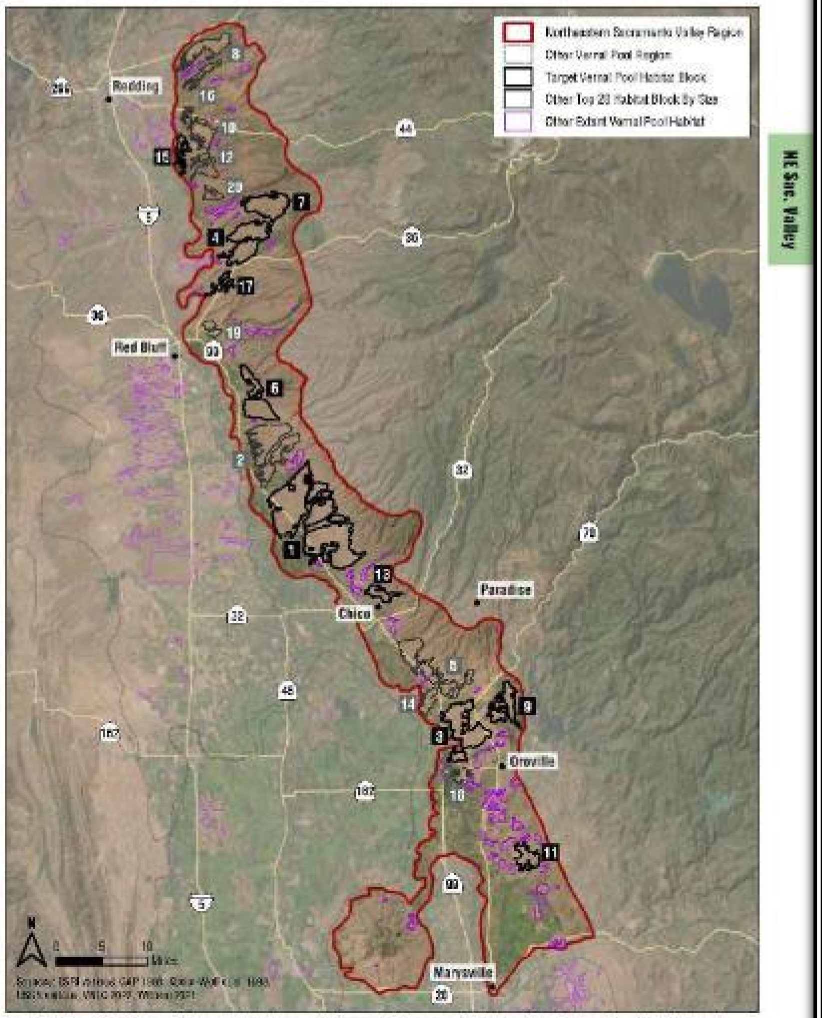

Figure B-4. Vernal Pool Habitat Blocks with Aerial Imagery, Northeastern Sacramento Valley Vernal Pool Region, Great Valley, California

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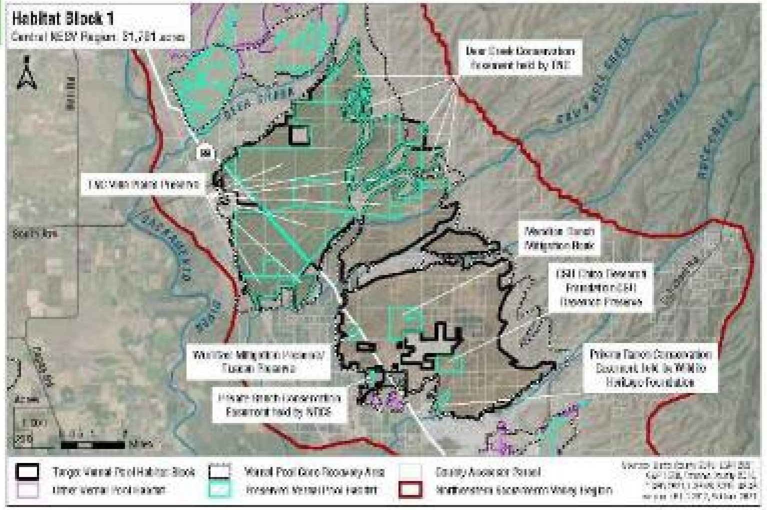
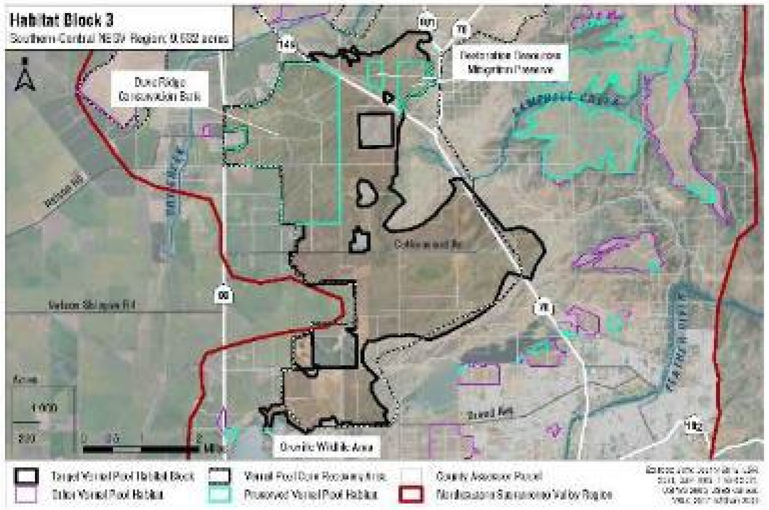
NE Sac. Valley

Habitat Block 1. This is by far the largest contiguous block of vernal pool habitat remaining in the region. At more than 31,000 acres, it is about three times larger than the next largest block. This block encompasses the Vina Plains and surrounding lands. This area has multiple playa pools and a high diversity and abundance of numerous rare species including key populations of Conservancy fairy shrimp, vernal pool tadpole shrimp, hairy Orcutt grass, Greene's tuctoria, and Hoover's spurge. It primarily encompasses volcanic Red Bluff and Riverbank formations. It also has predicted habitat for numerous core rare species. Nearly half (14,074 acres) of this block is conserved, due in large part to efforts by The Nature Conservancy over the past several decades. Most conserved habitat is in the northern half of the block which is also where many of the documented rare species occur. The southern half includes many smaller parcels and so may be more difficult to conserve. Also, this area is primarily on Riverbank Formation and may not have the same high diversity and abundance of rare species. One roughly 500-acre parcel near the center of the southern half with a number of Conservancy fairy shrimp occurrences is conserved as well as several smaller blocks to the south and west. The Nature Conservancy can probably provide the best insight into the feasibility and value of conserving additional lands in this southern area.



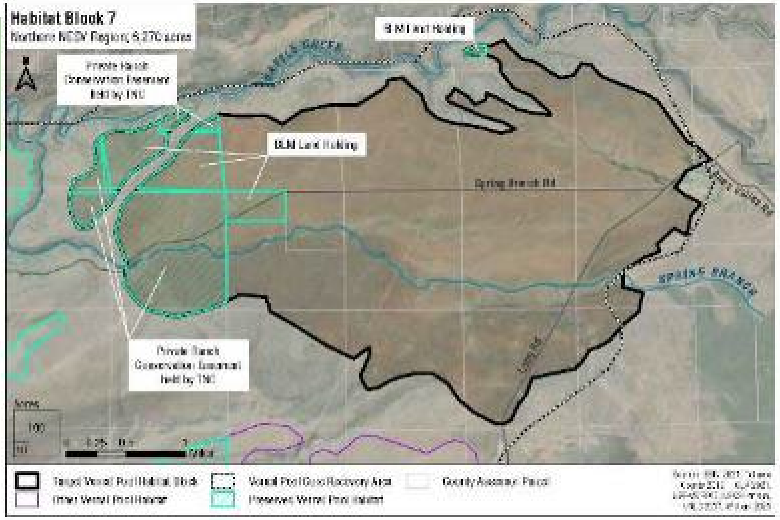
Habitat Block 3. This block, totaling 9,632 acres and located west of the table mountains, encompasses a large, contiguous expanse of Tuscan Formation. It also includes nearly 1,100 acres of Laguna Formation, the only Ione Formation mapped in the region, and a small amount of Lovejoy Basalt. It supports numerous occurrences of Butte County meadowfoam and Jim's clover, the two local endemics in the region. About a quarter of this block is already conserved, with most of this land in the northwest portion within the Dove Ridge Conservation Bank. Parcel size is relatively large (200-600 acres) throughout much of the unconserved areas, making conservation feasible depending on landowner interest. Efforts should first focus on areas with documented occurrences of Butte County meadow foam and Jim's clover given their endangered and local endemic status.



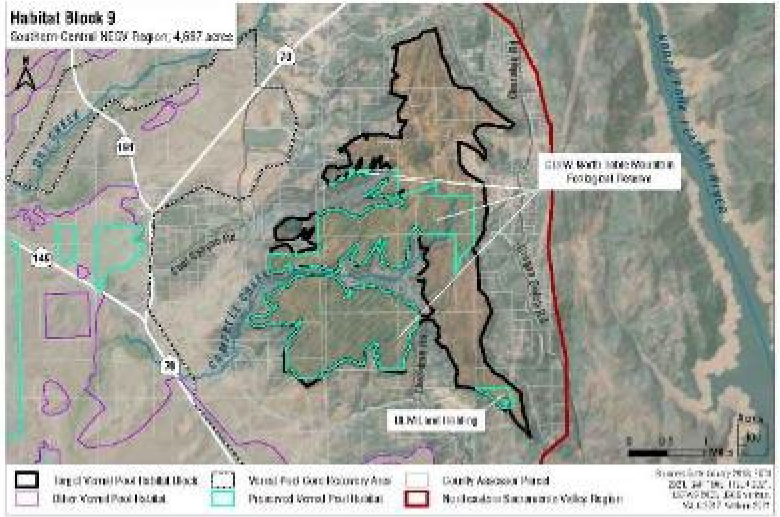
NE Sac. Valley

NE Sac. Valley

<u>Habitat Block 7.</u> This block, totaling 6,270 acres, is situated just to the northeast of Block 4 in the north of the region. Like Block 4, it consists primarily of volcanic Red Bluff Formation and Recent Basalt Flows but lacks Modesto Formation. It supports several occurrences each of slender Orcutt grass, Ahart's nailwort, and Boggs Lake hedge hyssop. Only a limited area of this block is currently conserved (16%), concentrated in the western tip within TNC's Battle Creek conservation easement. Parcel size is large, typically 640 acres, making conservation feasible depending on landowner interest.



<u>Habitat Block 9.</u> This block, totaling 4,687 acres, encompasses the table mountains north of Oroville. It consists almost entirely of Lovejoy Basalt and is the only large block with a significant acreage of this formation. It supports nearly half of documented occurrences of Jim's clover, several occurrences of Butte County meadowfoam, and the bulk of documented occurrences of Red Bluff dwarf rush in the region. About half of this block is already conserved, most of which is within CDFW's North Table Mountain Ecological Reserve. Parcel size in unconserved areas is fairly large, typically 200-640 acres, making conservation feasible depending on landowner interest.



NE Sac. Valley

Next Steps

- Complete Draft Guide (2 weeks)
- Outside Technical Review (2-3 months; 15-20 reviewers)
- Presentations to Agencies, Non-profits, Mitigation Companies, etc.
- Revise, Publish, Distribute Final Guide/GIS Data (August 2023)
- Ensure Incorporation of Target Habitat Blocks in Public Resource Conservation Databases
- Develop University Courses?
- Task 6: Track New Preserve Establishment for 3 Years

Questions?

Thank You USEPA & WCB for Project Support and Funding!