RESTORATION **PLAN**
for the Laguna de Santa Rosa



SFEI San Francisco Estuary Institute

This restoration plan is dedicated to the memory of ERIC LARSON.

His humor, intellect, partnership, and commitment to improving the health of the Laguna greatly benefited this effort.

Eric Larson (far left), in the field with the Project team.






RESTORATION **PLAN**
for the Laguna de Santa Rosa

JUNE 2023

SFEI San Francisco Estuary Institute

AUTHORS
Scott Dusterhoff
Alison Whipple
Sean Baumgarten
April Robinson
Samuel Shaw
Kyle Stark

DESIGN AND PRODUCTION
Ruth Askevold
Micaela Bazo
Kyle Stark

PREPARED BY San Francisco Estuary Institute

IN COOPERATION WITH and FUNDED BY
California Department of Fish and Wildlife
Sonoma Water

IN PARTNERSHIP WITH
Sonoma Water
Laguna de Santa Rosa Foundation

SAN FRANCISCO ESTUARY INSTITUTE PUBLICATION #1123

SUGGESTED CITATION

San Francisco Estuary Institute-Aquatic Science Center. 2023. *Restoration Plan for the Laguna de Santa Rosa.* An SFEI Resilient Landscapes Program report developed in cooperation with Sonoma Water, the Laguna de Santa Rosa Foundation, a Technical Advisory Committee, and a Management Advisory Committee. Publication #1123. San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

Version 1.4 (August 2023)

REPORT AVAILABILITY

Report is available at sfei.org

COVER CREDITS

Left to right: photo, SFEI; imagery courtesy of Google Earth.

THE TRIBES OF SONOMA COUNTY

Sonoma County is traditionally home to several federally recognized tribes, including the Cloverdale Rancheria of Pomo Indians of California, Kashia Band of Pomo Indians of the Stewarts Point Rancheria, Lytton Band of Pomo Indians, Dry Creek Rancheria Band of Pomo Indians, and the Federated Indians of Graton Rancheria. The Federated Indians of Graton Rancheria, whose enrollment includes Citizens of both Southern Pomo and Coast Miwok ancestry, recognize the Laguna de Santa Rosa watershed as their traditional territory. Both Southern Pomo and Coast Miwok people have lived in the area now known as the Laguna de Santa Rosa since time immemorial. The Coast Miwok and Southern Pomo survived genocide and a legacy of colonialism. As a living tribe they promote and support positive changes for native and non-native communities through their mission of social justice and cultural and environmental stewardship.

Contents

Acknowledgments

This project was co-funded by the California Department of Fish and Wildlife (CDFW) Proposition 1 Grant Program, and Sonoma Water. We would like to thank our project partners Neil Lassettre and Mike Thompson of Sonoma Water, Wendy Trowbridge of the Laguna de Santa Rosa Foundation, and Eric Larson of CDFW for lending their support, guidance, and expertise throughout the development of this Restoration Plan. We also thank David Kuszmar, Clayton Creager, Kelsey Cody, and Lisa Bernard of the North Coast Regional Water Quality Control Board (NCRWQCB) for their tireless support of this effort.

We would also like to thank Buffy McQuillen (Federated Indians of Graton Rancheria) for her review of this Restoration Plan and for all of her input during this project.

Members of our Technical Advisory Committee (TAC) provided invaluable technical assistance and guidance through a series of meetings, as well as by providing helpful comments on draft materials. The TAC members were Betty Andrews (ESA), Peter Baye (Coastal and Wetlands Ecologist), Brian Cluer (NOAA), Matthew Cover (CSU Stanislaus), Brenda Grewell (USDA and UC Davis), Eric Larson (CDFW), and Mariska Obedzinski (UCSD, California Sea Grant).

We are very grateful to the Management Advisory Committee (MAC) who participated in meetings and provided helpful comments. The MAC members were Derek Acomb (CDFW), Gina Benigno (CDFW), Lisa Bernard (NCRWQCB), Lisa Bernard (NCRWQCB), Hattie Brown (Sonoma County Regional Parks), Denise Cadman (City of Santa Rosa), Sierra Cantor (Gold Ridge RCD), Kelsey Cody (NCRWQCB), Clayton Creager (NCRWQCB), Ann DuBay (Sonoma Water), Sheri Emerson (Sonoma County Agricultural Preservation and Open Space District), Mitsuko Grube (CDFW), Noelle Johnson (Gold Ridge RCD), John Mack, (Sonoma County), Alydda Mangelsdorf (NCRWQCB), Greg Martinelli (CDFW), Buffy McQuillen (Federated Indians of Graton Rancheria), Sean McNeil (City of Santa Rosa), Valerie Minton Quinto (Sonoma County RCD), Anne Morkill (Laguna Foundation), Molly Oshun (Sonoma Water), Jessica Pollitz (Sonoma County RCD), Sara Press (Sonoma Land Trust), Charles Striplen (NCRWQCB), Liane Ware (City of Rohnert Park), and Chris Watt (NCRWQCB). Additionally, we would like to thank the Aggios, Denners, LaFranchi, and many other local landowners who shared their expertise and insights, and provided access to their properties for site visits.

Numerous SFEI staff assisted with data collection and compilation, mapping, analysis, reporting, editing, and project management. Particular thanks go to Robin Grossinger, Amy Richey, Matthew Benjamin, Gloria Desanker, Lawrence Sim, Katie McKnight, Gwen Miller, Denise Walker, Helen Casendino, Meredith Lofthouse, and Patrick Walsh.

Summary

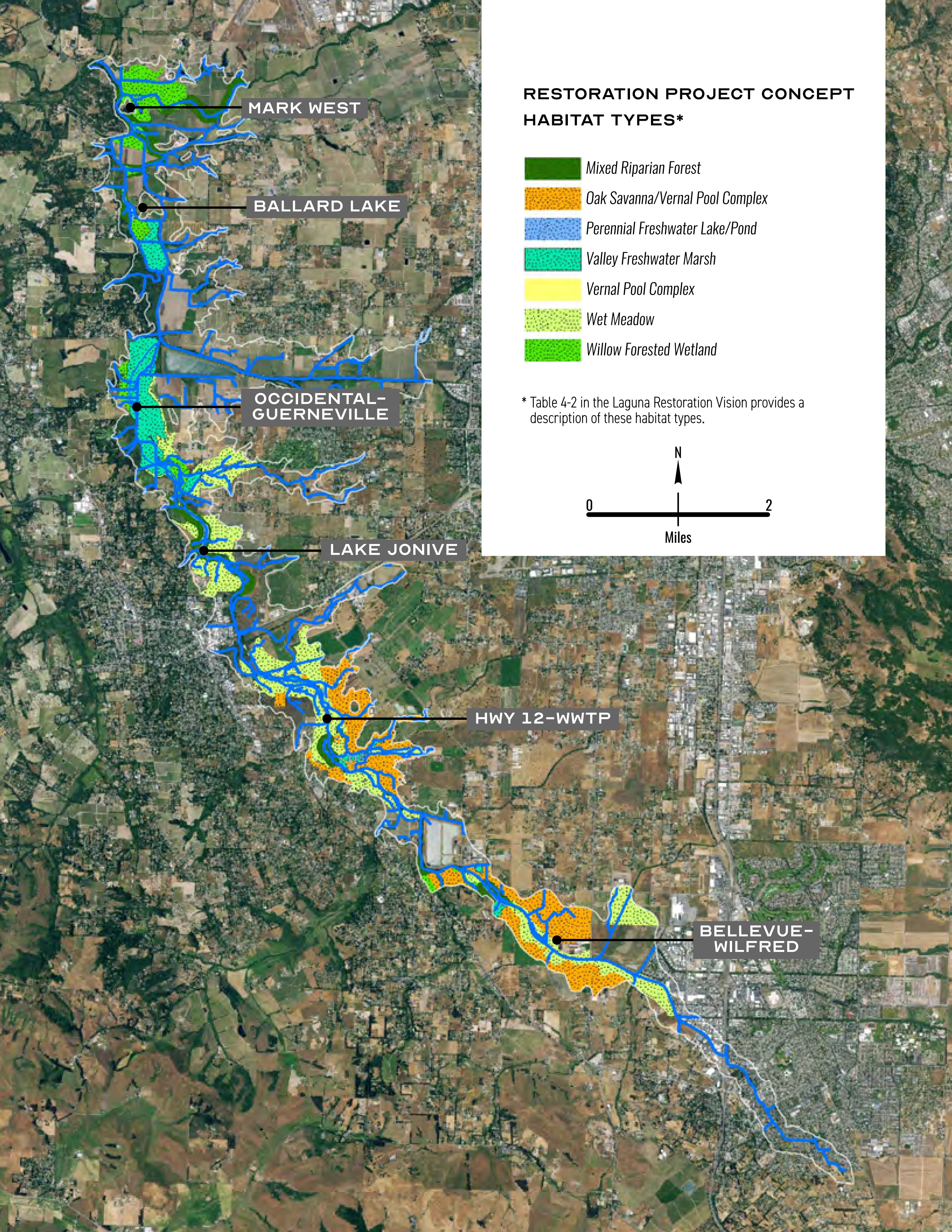
THE LAGUNA DE SANTA ROSA, located in the Russian River watershed in Sonoma County, CA, is an expansive freshwater wetland complex that hosts a rich diversity of plant and wildlife species, many of which are federally or state listed as threatened, endangered, or species of special concern.

The Laguna is home to the Southern Pomo and Coast Miwok Tribes of present day Sonoma County. It is also has a thriving agricultural community that depends on the land for its livelihood. Since the mid-19th century, development within the Laguna and its surrounding watershed have had a considerable impact on the landscape, affecting both wildlife and people. Compared to pre-development conditions, the Laguna currently experiences increased stormwater runoff and flooding, increased delivery and accumulation of fine sediment and nutrients, spread of problematic invasive species, and decreased habitat for native fish and wildlife species. Predicted changes in future precipitation patterns and summertime air temperatures, combined with expanding development pressure, could exacerbate these problems. People who manage land and regulate land management decisions in and around the Laguna, including landowners; federal, state, and local agencies; and local stakeholders, are seeking a long-term management approach for the Laguna that improves conditions for the wildlife and people that call the Laguna home. The California Department of Fish and Wildlife and Sonoma Water funded the Laguna-Mark West Creek Watershed Master Restoration Planning Project to develop such a management approach, focusing on the need to identify restoration and management actions that enhance desired ecological functions of the Laguna, while also supporting the area's agriculture and its local residents.

The Restoration Planning Project began with the development of a long-term Resilient Landscape Vision within the Laguna's 100-year floodplain that highlights opportunities for multi-benefit habitat restoration and land management. The Vision was developed through a collaborative science-based process that identified opportunities for restoring habitats and improving ecosystem functioning and resilience to benefit wildlife and people. The development process included a detailed analysis of landscape change (both past and potential future), workshops with technical advisors and stakeholders to discuss findings and desired restoration approaches, and a synthesis of technical work and advisor and stakeholder feedback into a map of restoration opportunities and their associated ecosystem benefits.

Building from the Resilient Landscape Vision, this Laguna Restoration Plan was developed through a collaborative process that focused on moving forward identified restoration opportunities into conceptual designs that can be used to establish implementable restoration projects. The Restoration Plan includes the following elements:

- **A restoration framework that offers a planning structure for landscape scale restoration that can be further developed and refined over time.** It identifies a suite of landscape metrics (i.e., parameters that can be measured to track ecosystem condition) and targets associated with enhancing the extent and configuration of habitat types within the Laguna and helping achieve established Management Goals and Objectives.
- **Restoration project concepts in the Laguna's 100-year floodplain developed from selected restoration opportunity areas shown in the Vision.** The concepts are at the 10% design level and provide general information about the location and extent of key habitat types and changes to channel alignment within an approximate project boundary. The concepts range from partial restoration of historical ecosystems, with emphasis on functions such as nutrient removal or sediment trapping, to establishment of historical habitats modified for increased resilience in a changed climate. They are evaluated using the landscape metrics and targets in the restoration framework, highlighting how each uniquely contributes to the larger Laguna landscape and the ecological benefits it provides.
- **Restoration project concept prioritization and sequencing criteria** that can be used to evaluate the degree to which restoration project concepts address established Management Objectives, and to assess the variety of reasons (e.g., physical, ecological, cultural, logistical) why certain restoration projects should be pursued sooner than others.


RESTORATION PROJECT CONCEPT HABITAT TYPES*
Mixed Riparian Forest
Oak Savanna/Vernal Pool Complex
Perennial Freshwater Lake/Pond
Valley Freshwater Marsh
Vernal Pool Complex
Wet Meadow
Willow Forested Wetland
* Table 4-2 in the Laguna Restoration Vision provides a description of these habitat types.
N
0
2
Miles
MARK WEST
BALLARD LAKE
OCCIDENTAL-GUERNEVILLE
LAKE JONIVE
HWY 12-WWTP
BELLEVUE-WILFRED

Summary, continued

A suite of restoration project concepts built from the Vision are presented in this Restoration Plan. The concepts cover a large portion of the Laguna and address most of the wetland and aquatic restoration opportunity areas identified in the Vision. Chapter 3 introduces each concept, describes the current and historical landscape, provides detailed descriptions of suggested changes and their benefits, and quantifies the potential benefits of the concept through the restoration metrics.

Mark West: Several alternatives are described in this Plan. Alternative A features a realignment of lower Mark West Creek to its historical course, expanded willow forested wetland and mixed riparian habitat, and increased in-channel storage and floodplain sediment deposition. Alternative B reroutes lower Mark West Creek to create a new confluence near River Road and expands mixed riparian forest habitat. Alternative C is similar to Alternative B but realigns the tributary to the south, creating more mixed riparian forest and willow forested wetland habitat. Alternative D reroutes lower Mark West Creek across the narrowest span of agricultural land currently separating the Laguna and the creek, creating forested wetland/mixed riparian habitat.

Ballard Lake: This restoration project concept restores a deep historical freshwater lake along the Laguna mainstem, while introducing a large upstream area of valley freshwater marsh and willow forested wetland.

Occidental-Guerneville: This restoration project concept between Occidental and Guerneville roads is the largest of the concepts, and is associated with some of the largest changes to the landscape metrics and expected ecological benefits. It entails the rerouting of the Laguna mainstem to a more natural geometry, and the conversion of a large area of invasive *Ludwigia* spp. and farmed wetland into restored freshwater marsh habitat.

Lake Jonive: Lake Jonive is the Laguna's largest and only remaining historical perennial freshwater lake. The project attempts to return the lake to a more natural state through dredging it to historical depths, expanding the forested riparian habitat around the lake, and adding new wet meadow habitat.

HWY 12-WWTP: This restoration project concept involves expanding wet meadow habitat, dredging and deepening a historical perennial lake and expanding forested riparian habitat around the lake, and restoring valley freshwater marsh habitat around the Roseland Creek confluence and along the Laguna mainstem.

Bellevue-Wilfred: This project concept involves the expansion of wet meadow habitat around the Laguna mainstem, restoration of vernal pool habitat, dredging of a historical perennial lake just south of the Santa Rosa Wastewater Treatment Plan, expanding forested riparian habitat around the restored lake, and creation of freshwater marsh adjacent to the lake.

Implementing this suite of restoration project concepts could provide considerable ecosystem benefits, from increased wildlife habitat to improved water quality. All concepts combined could result in a >100 hectare (>250 acre) increase in mixed riparian forest/willow forested wetland, a >100 hectare (>250 acre) increase in valley freshwater marsh, a >300 hectare (>750 acre) increase in wet meadow, and a 10 hectare (25 acre) increase in perennial freshwater lake/pond habitat. The increased habitat extent would greatly benefit native fish and wildlife species who utilize these habitat types for part or all of their lifecycle. The restored areas would also help improve water quality through fine sediment trapping and nutrient assimilation, and decrease conditions favorable for invasive *ludwigia* spp.

Moving from the restoration concepts provided in this Plan to restoration projects will require considerable effort and a close partnership with the Tribes of Sonoma County. Before construction can begin, several key pieces of information are still required: an improved understanding of both local and landscape-scale physical and biological processes; an understanding of the ecosystem benefits associated with the sequencing of projects; the development of detailed project designs; and the development of plans for maintaining and monitoring restoration projects over the long-term. Central to this effort is the inclusion of input from the Federated Indians of Graton Rancheria (FIGR), whose traditional ecological knowledge expands beyond what is described in this Plan. The inclusion of FIGR's knowledge and perspectives will increase the impact of restoration projects within the Laguna and emphasize the importance of tribal cultural resource protection and tribal access in restoration planning and design.

This Restoration Plan provides a toolkit for further improvements to the Laguna landscape. The utilization of these tools and the ultimate success of restoration efforts in the Laguna will first and foremost require local landowner support and adequate funding to implement the restoration and manage and sustain the benefits through long-term stewardship. It will also require coordination among all the agencies responsible for managing the land and water within the Laguna and its surrounding watershed. The path forward will be challenging, but with commitment and collaboration the Laguna community is well on its way toward a reconciled Laguna landscape that supports desired ecosystem functions for people and wildlife. §

LAGUNA DE SANTA ROSA AT THE LAGUNA WETLANDS PRESERVE. PHOTO: LAGUNA DE SANTA ROSA FOUNDATION

1. Introduction

Background

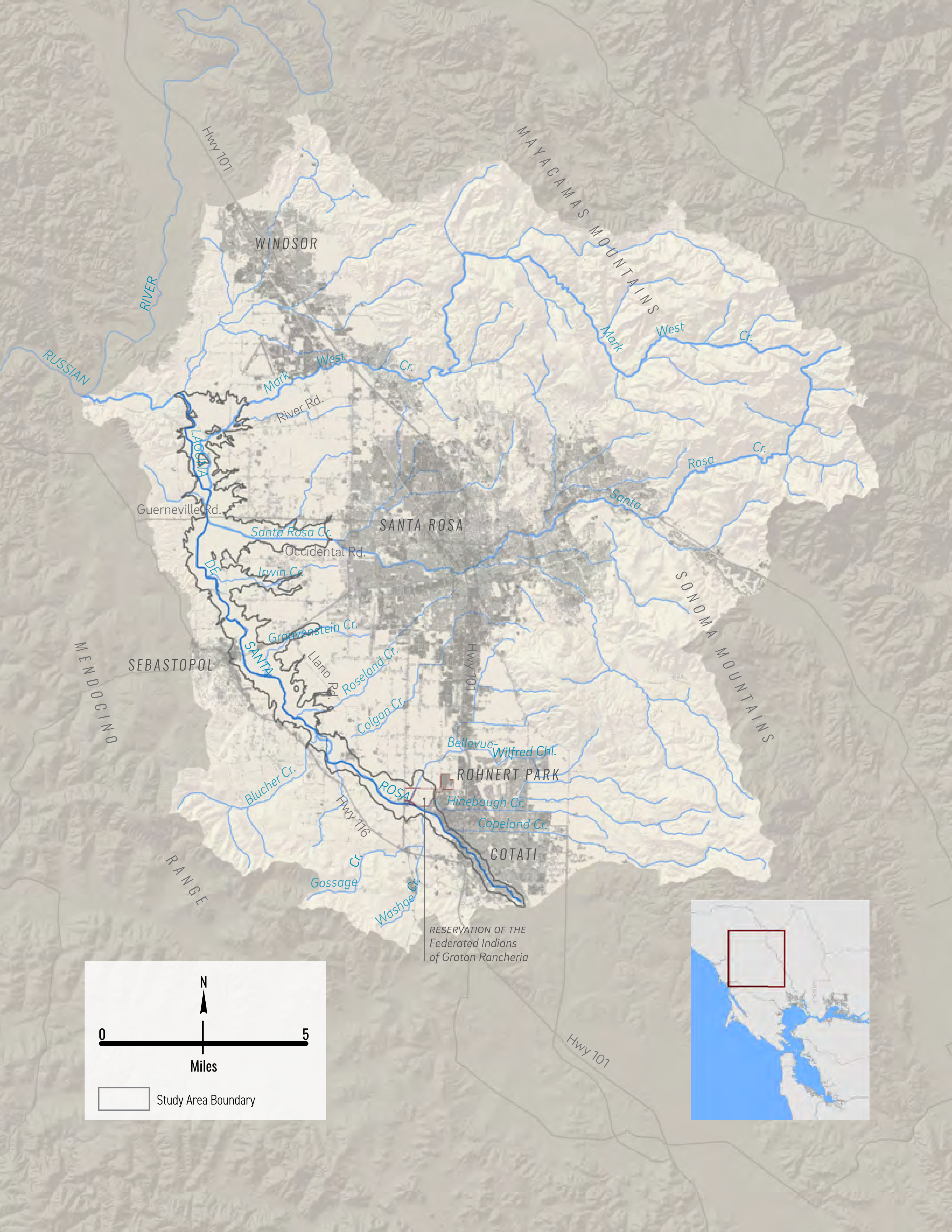
The Laguna de Santa Rosa is an expansive freshwater wetland complex in the Russian River watershed that is the most biologically diverse region of Sonoma County, and the second largest freshwater wetland complex in Northern California (PWA 2004, Laguna de Santa Rosa Foundation 2011). The diverse natural habitats of the Laguna include seasonal and perennial creeks, ponds and lakes, wet meadows, marshes, vernal pools, forested riparian areas, oak woodlands, and grasslands. These complex habitats are home to over 200 species of birds ranging from song sparrows (*Melospiza melodia*) to common yellowthroat (*Geothlypis trichas*) to bald eagles (*Haliaeetus leucocephalus*), and are a major stopover for thousands of waterfowl as they traverse the Pacific Flyway. The Laguna supports many species of mammals, from river otters (*Lontra canadensis*) to bobcats (*Lynx rufus*) to mountain lions (*Puma concolor*), as well as reptiles and amphibians such as western pond turtle (*Actinemys marmorata*), California tiger salamander (*Ambystoma californiense*), and gopher and garter snakes (*Pituophis catenifer, Thamnophis sirtalis*). In addition to many native and non-native warm water fishes that live in the Laguna year-round, its waterways also support migrating coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*), and provide vital feeding and rearing habitat for these salmonids (Honton and Sears 2006, USFWS 2016). Its plant diversity reflects a high degree of richness, hosting common species, such as valley oaks (*Quercus lobata*) and willows (*Salix* spp.), as well as unique endemic species in its vernal pools and wetlands (USFWS 2005). Because of its importance for a wide array of terrestrial and aquatic wildlife, a portion of the Laguna is recognized as a Ramsar Wetland of International Significance (Sloop 2009).

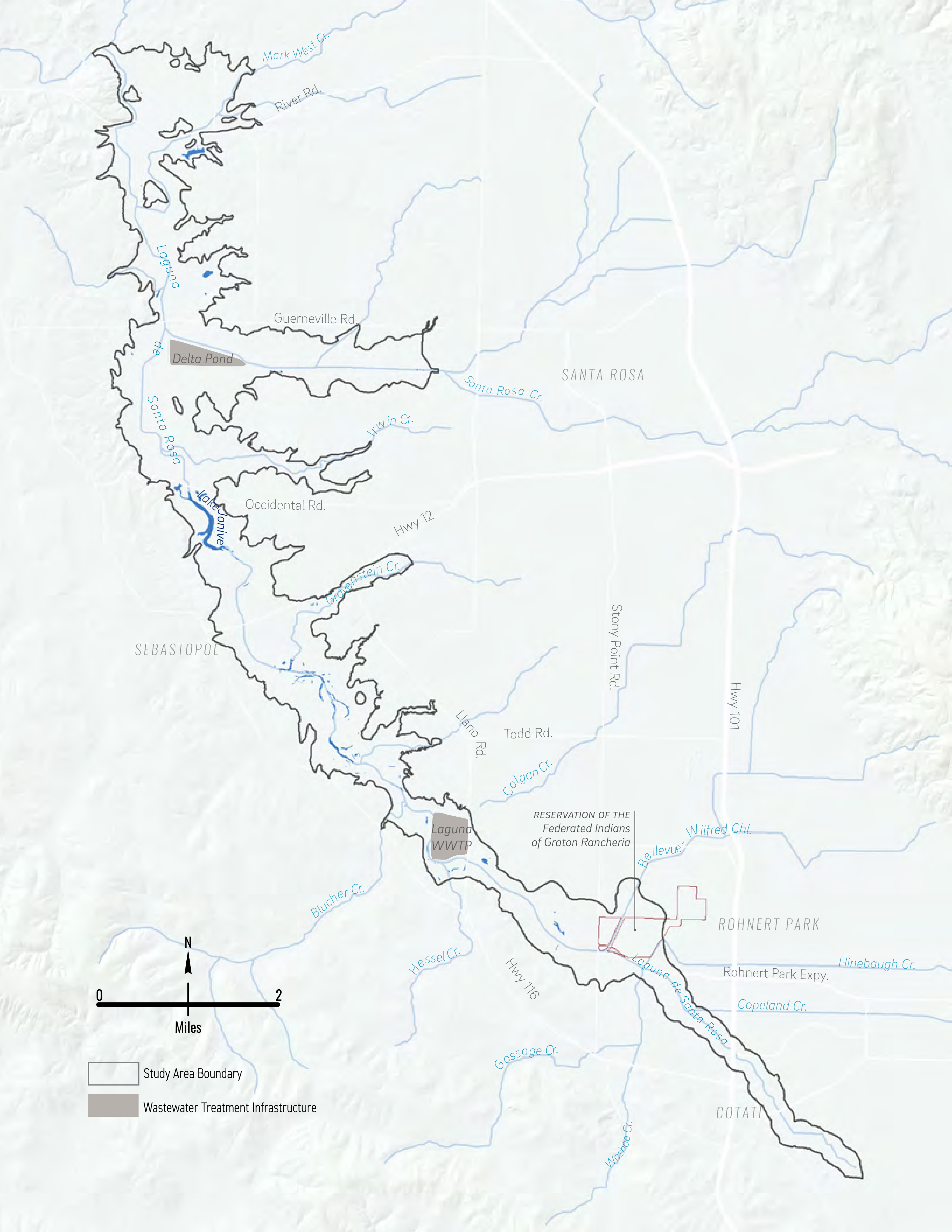
Although it remains a vital ecosystem, the Laguna has been considerably altered since the onset of intensive European-American settlement in the region and will continue to experience further pressures into the future. Over the past 200 years, development within the Laguna and its surrounding watershed have had a considerable impact on the landscape, negatively affecting both wildlife and people. Urbanization, conversion of lands to agriculture, and the rerouting and channelization of the Laguna and its tributaries have led to problems such as increased stormwater runoff and flooding, increased delivery and accumulation of fine sediment and nutrients within the Laguna, introduction of invasive species, and widespread habitat loss for native fish and wildlife species within and adjacent to the Laguna. Looking to the future, changing precipitation patterns and summertime air temperatures and extreme events of floods, droughts, and wildfire, combined with expanding development pressure, will likely exacerbate many of these problems. Addressing the issues affecting wildlife and people in the Laguna and its surrounding landscape will require a management approach that considers how the ecosystem has changed since the onset of intensive development, as well as changes that accompany continued population growth and shifting climatic conditions.

Over the past few decades, there have been many efforts focused on addressing the challenges the Laguna faces, and the appropriate management approaches for preserving and enhancing the ecosystem. Foundational work includes Enhancing and Caring for the Laguna de Santa Rosa (Honton and Sears 2006), which identifies key focus areas for improving the Laguna ecosystem, and The Altered Laguna: A Conceptual Model for Watershed Stewardship (Sloop et al. 2007), which lays out a conceptual understanding of the past and present physical and biological functioning of the Laguna and management recommendations for ecosystem improvement. Additionally, the US Environmental Protection Agency funded sediment and nutrient studies in support of Total Maximum Daily Load (TMDL) development that provide detailed information on past and present sediment and nutrient dynamics in the Laguna (Tetra Tech 2015a; 2015b). More recently, historical ecology studies have investigated historical alignments of tributaries to the Laguna, estimated historical and modern nutrient loads, and investigated land cover in the central portion of the Laguna (Butkus 2010, 2011; Dawson and Sloop 2010; Baumgarten et al. 2014, 2017). Finally, a partnership of state and local entities identified management actions within the Laguna that could improve overall ecosystem functioning (SCWA et al. 2016). What is now needed is a cohesive restoration plan that builds from these previous efforts and synthesizes the best available knowledge of past, present, and potential future ecosystem conditions and provides specifics about restoration efforts within the Laguna, including the ecosystem benefits that could be achieved by the identified efforts considering both current and projected future land use and climatic conditions.

To address this need, Sonoma Water, in partnership with the Laguna de Santa Rosa Foundation and the San Francisco Estuary Institute (SFEI), received a Proposition 1 grant from the California Department of Fish and Wildlife (CDFW) for a project titled Laguna-Mark West Creek Watershed Master Restoration Planning Project. The overall project goal was to develop a plan that supports ecosystem services in the Laguna through the restoration and enhancement of landscape processes that form and sustain habitat for native species, while considering flood management issues and the sustainability of agricultural lands. The project was focused primarily on the Laguna within the FEMA-defined 100-year floodplain but also considered management actions in the surrounding watershed that are necessary for the success of restoration efforts within the Laguna (Figures 1-1 and 1-2). The project includes the development of a long-term Laguna Restoration Vision, a Laguna Restoration Plan built from the Vision, and preliminary designs and permitting documentation for a high priority restoration project. Development of project elements included close coordination with local landowners, agency stakeholders, and tribal representatives. The development process ensured transparency and resulted in project concepts that are integrated with management goals within the Laguna and surrounding watershed.

Figure 1-1. (right) Laguna de Santa Rosa watershed.


Hwy 101
MAYACAMAS MOUNTAINS
WINDSOR
RUSSIAN
RIVER
Mark West Cr.
River Rd.
Mark West Cr.
LAGUNA DE SANTA ROSA
Guerneville Rd.
Santa Rosa Cr.
SANTA ROSA
Santa Rosa Cr.
Occidental Rd.
Irwin Cr.
Gravenstein Cr.
SONOMA MOUNTAINS
MENDOCINO RANGE
SEBASTOPOL
Llano Rd.
Roseland Cr.
Hwy 101
Colgan Cr.
Bellevue-Wilfred Chl.
ROHNERT PARK
Blucher Cr.
Hinebaugh Cr.
Hwy 116
Copeland Cr.
COTATI
Gossage Cr.
Washoe Cr.
RESERVATION OF THE
Federated Indians
of Graton Rancheria
N
0
5
Miles
Study Area Boundary
Hwy 101


Mark West Cr.
River Rd.
Laguna
de
Santa Rosa
Guerneville Rd.
Delta Pond
SANTA ROSA
Santa Rosa Cr.
Irwin Cr.
Lake Jonive
Occidental Rd.
Hwy 12
Gravenstein Cr.
SEBASTOPOL
Stony Point Rd.
Hwy 101
Llano Rd.
Todd Rd.
Colgan Cr.
RESERVATION OF THE
Federated Indians
of Graton Rancheria
Laguna
WWTP
Bellevue-Wilfred Chl.
Blucher Cr.
ROHNERT PARK
N
0
2
Miles
Hessel Cr.
Hwy 116
Laguna de Santa Rosa
Rohnert Park Expy.
Hinebaugh Cr.
Copeland Cr.
Gossage Cr.
Study Area Boundary
Wastewater Treatment Infrastructure
COTATI
Washoe Cr.

MANAGEMENT GOALS AND OBJECTIVES

Management Goals the Project Addresses

The following Management Goals are the desired ecosystem outcomes for the Laguna that the Restoration Vision and Restoration Plan aim to address:

- Improve overall Laguna ecosystem functions and services for people and wildlife.
- Establish a landscape that will be resilient under a changing climate.
- Enhance environmental, agricultural, and tribal benefits of current and future land uses within and adjacent to the Laguna. This will require meaningful input from a wide range of stakeholders including local landowners and tribal representatives. This goal includes incorporating tribal stewardship in restoration project goals and traditional ecological knowledge in restoration project design and implementation.

Management Objectives the Project Addresses

The following Management Objectives are conditions that must be attained to accomplish the Management Goals.

- Mimic a natural hydrograph in lands draining to the Laguna that can decrease stormwater velocity and discharge to the Laguna during frequently occurring storm events, and increase groundwater recharge.
- Decrease sediment and nutrient delivery to the Laguna, especially at areas of high deposition/accumulation rates. Move sediment from accumulation areas where appropriate.
- Enlarge riparian and wetland habitat patches and improve their connectedness.
- Control the extent of invasive plant species, and encourage conditions that enable native species to outcompete invasives (e.g., *Ludwigia* spp., emerging invasive species).
- Improve late spring/summer water quality through improved drainage and flow conveyance. §

Figure 1-2. (left) Laguna-Mark West Creek Watershed Master Restoration Project study area.

Laguna Restoration Vision and Plan

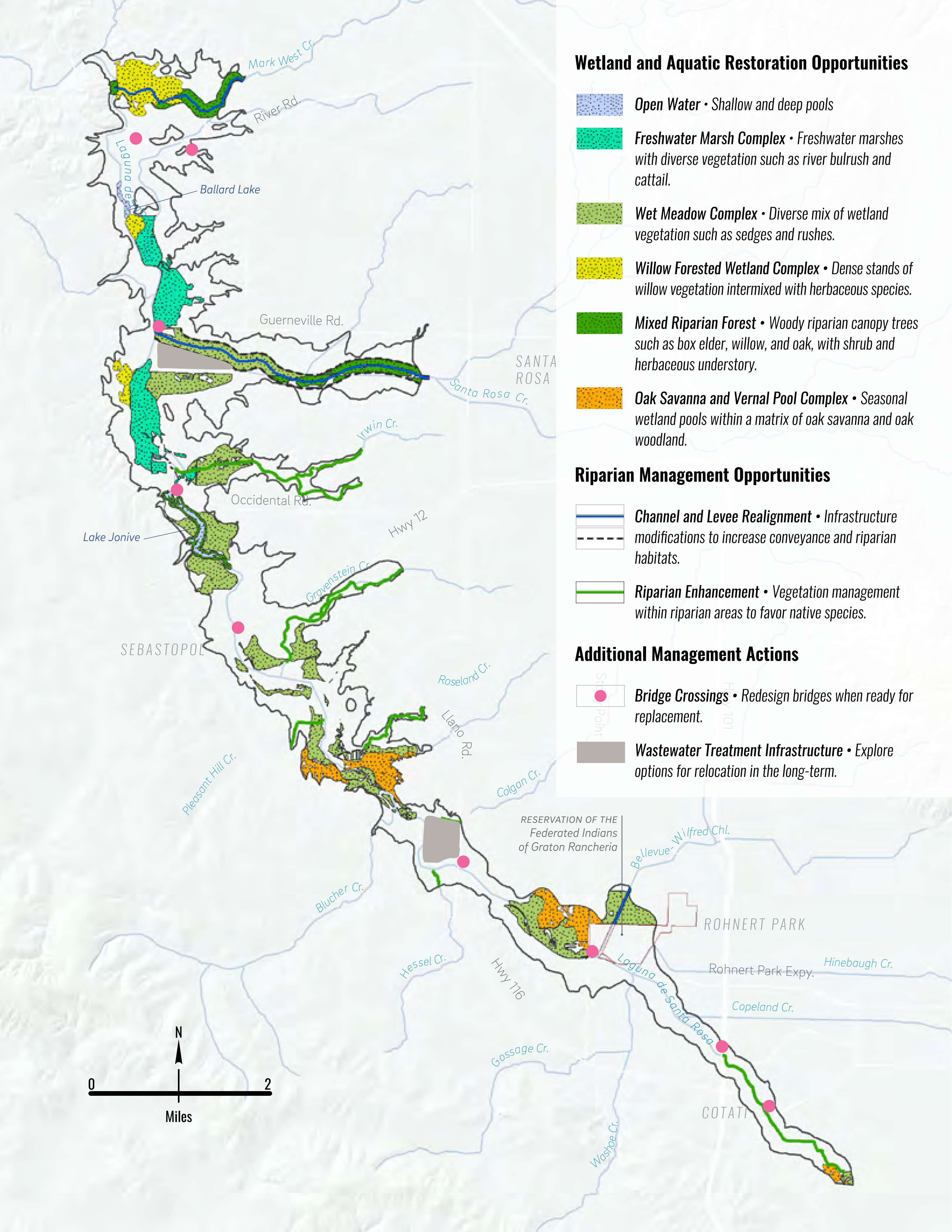
The Laguna Master Restoration Planning Project has developed resources to support a long-term management approach that improves conditions in the Laguna for both people and wildlife. The first phase of the project produced the Laguna Restoration Vision (SFEI-ASC 2020). The Vision highlights opportunities for multi-benefit habitat restoration and land management within the Laguna's 100-year floodplain (Fig. 1-3), and describes the watershed management actions needed for supporting the Vision. The Restoration Plan presented here builds on the foundation provided by the Vision to offer more detail and greater guidance for developing restoration projects that support the Management Goals and Objectives. Both the Vision and Restoration Plan identify actions that can enhance desired ecological functions of the Laguna, while also supporting the area's agriculture and its local residents.

The Vision was developed through a collaborative science-based process that identified opportunities for restoring habitats and improving ecosystem functioning and resilience to benefit wildlife and people. The development process included a detailed analysis of landscape change (both past and potential future), workshops with technical advisors and stakeholders to discuss findings and desired restoration approaches, and a synthesis of technical work and advisor and stakeholder feedback into a map of restoration opportunities and their associated ecosystem benefits.

Vision Report Highlights:

- Historically, the lands and waterway of the Laguna were protected and maintained by Tribes through generational stewardship practices since time immemorial. The Laguna was once characterized by a diverse and extensive array of wetland, riparian, and aquatic habitats that supported a wide variety of plants and animals, together providing an abundance of resources for the Southern Pomo and Coast Miwok Tribes.
- Though the Laguna still provides valuable wildlife habitat and a range of other ecosystem services, the landscape has been heavily modified over the past two centuries. These land and water use modifications have resulted in a ~60% decrease in wetland habitat and widespread habitat fragmentation, reducing the Laguna's ability to support native biodiversity and provide other ecological functions and services.
- Through a collaborative process, the project team identified a suite of short-term and long-term restoration and management opportunities that together form a Resilient Landscape Vision. The Vision identifies opportunities for Wetland and Aquatic Habitat Restoration, Riparian Management, and Infrastructure Redesign. Implementing the Vision would result in an approximate 20% increase in open water, an approximate 50% increase in mixed riparian forest, and a doubling of valley freshwater marsh and wet meadow within the Laguna. In addition, the proportion of wetlands in the Laguna surrounded by natural land cover types would increase from approximately 50% to 60%.

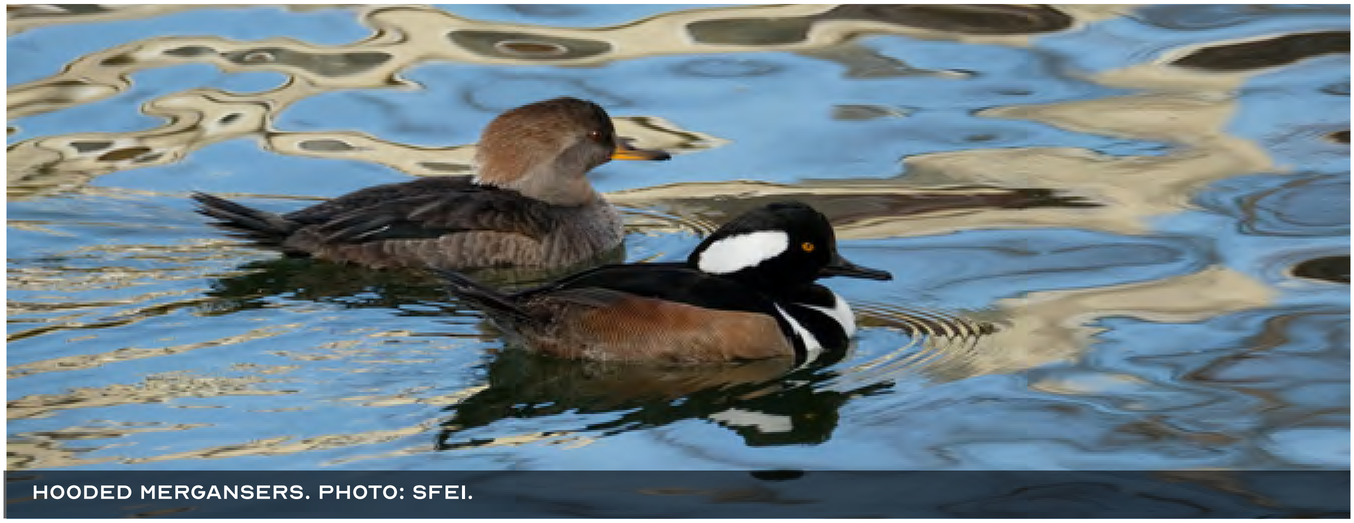
Figure 1-3. (right) Laguna de Santa Rosa Restoration Vision map.


Wetland and Aquatic Restoration Opportunities
Open Water • Shallow and deep pools
Freshwater Marsh Complex • Freshwater marshes with diverse vegetation such as river bulrush and cattail.
Wet Meadow Complex • Diverse mix of wetland vegetation such as sedges and rushes.
Willow Forested Wetland Complex • Dense stands of willow vegetation intermixed with herbaceous species.
Mixed Riparian Forest • Woody riparian canopy trees such as box elder, willow, and oak, with shrub and herbaceous understory.
Oak Savanna and Vernal Pool Complex • Seasonal wetland pools within a matrix of oak savanna and oak woodland.
Riparian Management Opportunities
Channel and Levee Realignment • Infrastructure modifications to increase conveyance and riparian habitats.
Riparian Enhancement • Vegetation management within riparian areas to favor native species.
Additional Management Actions
Bridge Crossings • Redesign bridges when ready for replacement.
Wastewater Treatment Infrastructure • Explore options for relocation in the long-term.
Mark West Cr.
River Rd.
Ballard Lake
Guerneville Rd.
SANTA ROSA
Santa Rosa Cr.
Irwin Cr.
Occidental Rd.
Hwy 12
Lake Jonive
Gravenstein Cr.
SEBASTOPOL
Roseland Cr.
Llano Rd.
Pleasant Hill Cr.
Colgan Cr.
RESERVATION OF THE
Federated Indians
of Graton Rancheria
Bellevue-Wilfred Chl.
Blucher Cr.
ROHNERT PARK
Hessel Cr.
Hwy 116
Rohnert Park Expy.
Hinebaugh Cr.
Laguna de Santa Rosa
Copeland Cr.
Gossage Cr.
N
0
2
Miles
COTATI
Washoe Cr.

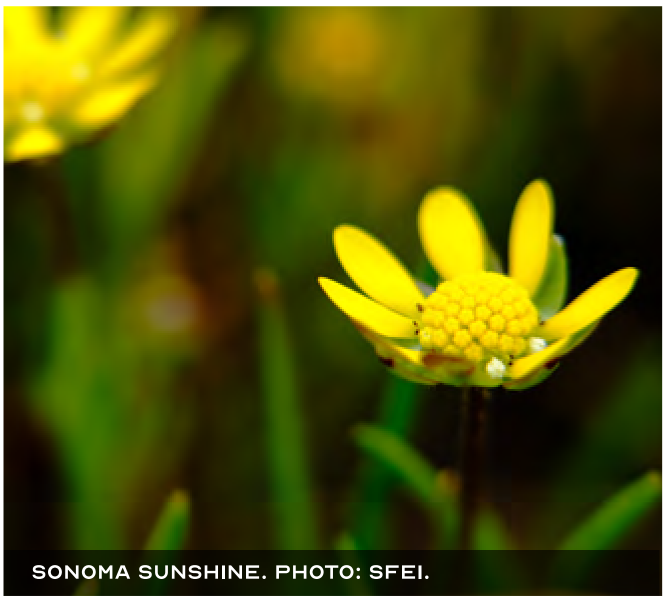
The Restoration Plan was developed in close coordination with technical advisors, stakeholders, and landowners through a process that focused on moving forward restoration opportunities highlighted in the Vision into project concepts to be used to establish implementable restoration projects. The Restoration Plan includes the following elements:

- **A restoration framework** that offers a planning structure for landscape-scale restoration that can be further developed and refined over time. It identifies a suite of landscape metrics (i.e., parameters that can be measured to track ecosystem condition) and targets associated with enhancing the extent and configuration of habitat types within the Laguna and helping achieve the established Management Goals and Objectives.
- **Restoration project concepts** in the Laguna's 100-year floodplain were developed from selected restoration opportunity areas shown in the Vision. The concepts are at the 10% design level and provide general information about the location and extent of key habitat types and changes to channel alignment within an approximate project boundary. The concepts range from partial restoration of historical ecosystems, with emphasis on functions such as nutrient removal or sediment trapping, to establishment of historical habitats modified for increased resilience in a changed climate. They are evaluated using the landscape metrics and targets in the restoration framework, highlighting how each uniquely contribute to the larger Laguna landscape and the ecological benefits it provides.
- **Restoration project concept prioritization and sequencing criteria** that can be used to evaluate the degree to which restoration project concepts address the established Management Objectives, and to assess the variety of reasons (e.g., physical, ecological, cultural, logistical) why certain restoration projects should be pursued sooner than others.

These resources provide the Laguna community with a roadmap for how to improve the overall functioning of the Laguna ecosystem, and will be essential for prioritizing and advocating for effective restoration projects. The ultimate success of the Vision and the Restoration Plan will be determined by local landowner support, adequate funding for implementation, on-going monitoring and stewardship, as well as an updated approach to landscape management within the Laguna's surrounding watershed.



HOODED MERGANSERS. PHOTO: SFEI.



SONOMA SUNSHINE. PHOTO: SFEI.

RIVER OTTER. PHOTO: USFWS.

COHO SALMON. PHOTO: OREGON FISH AND GAME

WESTERN POND TURTLE. PHOTO: USFS.

2. Restoration Planning Framework

Overview

Improving the ecological integrity and resilience of riverine and wetland ecosystems to support the needs of both people and wildlife requires restoration and management toward a sound vision of the future derived from an understanding of the problem, its root causes, and constraints (Palmer et al. 2005; Beechie et al. 2013). However, ecological restoration and management can fall short of these ultimate goals when they are undertaken in the absence of clear goals and objectives, opportunistically, without consideration of interrelated issues, lacking quantifiable links between the causes of degradation and the intended response, and/or at scales incommensurate with challenges at hand (Beechie et al. 2010; Skidmore et al. 2013). Established restoration planning frameworks provide a means for circumventing these pitfalls by connecting goals and objectives to physical and ecological characteristics that can guide restoration and management actions. Also, since no single project can be expected to achieve all objectives, evaluating projects within a common framework can demonstrate how, together, a suite of opportunities can add up to the landscape-scale vision. Such frameworks support the elements of successful restoration programs, including understanding of past and current conditions and drivers of change, realistic future visions given altered and changing conditions, tools to evaluate expected benefits, quantified evaluation of progress relative to objectives, defined ongoing management and monitoring needs for long-term stewardship, knowledge gap identification, and adaptive management processes.

As part of this restoration planning effort for the Laguna de Santa Rosa, a restoration planning framework was established to help connect the Laguna Management Goals and Objectives to restoration project concepts via metrics and associated targets. This framework is offered as a starting place for establishing a planning structure for landscape-scale restoration that can be expanded and refined to support large-scale and long-term ecosystem restoration in the Laguna. It is grounded in the idea that rehabilitating ecological integrity and resilience depends on restoring the physical and biogeochemical patterns and processes that drive native plant and wildlife communities. The framework includes physical and ecological characteristics to consider in the process of project planning, implementation, monitoring, and adaptive management. However, only categories and types of metrics are shown as possible options for evaluating implementation project designs and conducting monitoring and adaptive management. As part of this framework, the expectation is that a future Laguna restoration program will develop more detailed monitoring and adaptive management plans. A central function of the framework is to be a place to articulate connections between physical and ecological parameters that can be measured in the landscape and the baseline and restored ecological functions and services relating to the Management Goals and Objectives. The framework supports the development of a quantified evaluation process to compare and prioritize projects. It can also be used to evaluate how projects can together provide desired benefits and show how key factors of interest, measured at a local scale, can be assessed and compiled to answer questions about the landscape-level functioning of the Laguna.

SEEKING A RECONCILED LAGUNA LANDSCAPE AND ECOSYSTEM

In highly modified and urbanized watersheds, such as the Laguna and its watershed, restoration opportunities are constrained by legacy impacts and ongoing human activities (Bernhardt and Palmer 2007). The concept of reconciliation ecology offers a way to think about managing for improved ecological benefits of altered or "novel" ecosystems when traditional concepts of restoration may not be desired or feasible (Rosenzweig 2003; Hobbs et al. 2009; Moyle 2014). It has been used to support the process of rehabilitating ecosystems within highly modified and human-dominated landscapes. And, it carries increasing weight as an approach to manage ecosystems within the context of climate change. This concept conveys that, while restoring pre-disturbance conditions may not be achievable, reinstating functional elements within the landscape - supporting physical and biological processes and species' life history needs - may be possible through combinations of traditional restoration as well as creative and more managed or engineered practices or elements to meet specific objectives. This may be a useful concept to consider for the highly altered Laguna, where fully addressing root causes of degradation is not possible and adaptation to continued land use, climate change, and other human alteration will be necessary. With the Laguna Management Goals and Objectives encompassing benefits to both humans and wildlife, there is an inherent understanding that restoration and management activities will be balancing multiple, and sometimes competing, priorities. As shown in the Laguna Vision, a reconciled Laguna landscape therefore looks different from the past and present, but can improve ecological integrity and resilience while also providing enhanced ecosystem services to humans. Considering a reconciled Laguna could support setting realistic expectations where different parts of the Laguna may serve different functions and benefits and allow for a range of restoration and management approaches. A reconciliation approach also conveys a sense of moving forward toward enhanced ecosystem functions and benefits, but on an ever-evolving trajectory. §

While this planning effort addresses habitat restoration opportunities within the 100-year floodplain of the Laguna, the Laguna ecosystem is affected by watershed processes and human alteration of those processes. A central challenge in river and floodplain restoration is that root causes of degradation may occur at scales or locations different from the responses (Skidmore et al. 2013). Large-scale habitat restoration within the Laguna as well as restoration and management actions in the surrounding watershed are needed to shift the trajectory of the Laguna and address the Management Goals and Objectives (Sloop et al. 2007; SFEI-ASC 2020). The dependence upon upstream factors, including flow, sediment, habitat connectivity, and nutrients, limits the potential of current opportunities for restoration within the Laguna, and there is an understood need for further watershed-scale restoration and management planning

(SFEI-ASC 2020). The framework presented here is structured flexibly such that, as watershed planning occurs, watershed as well as within-Laguna form, processes, and functions can (and should) be included more explicitly with associated metrics and targets.

This Restoration Plan focuses on characteristics that can be evaluated at this stage of the planning process within the Laguna, namely the spatial extent and configuration of habitat types within the Laguna for the different restoration project concepts. As concepts transition to design, implementation, and monitoring phases, additional factors will need to be included and evaluated. These include conducting the data collection and research necessary to draw explicit connections between restoration and management actions, expected physical and ecological responses, and desired ecosystem function and service outcomes. At the later project stages, the restoration framework presented here should be tailored to describe the project context (including conducting necessary site-level assessments, modeling, and/or field-based studies) and refine project objectives, parameters, targets, and timeframes for expected responses (Skidmore et al. 2013). For example, monitoring and adaptive management measures, some of which are discussed in Chapter 3, will need to be considered for evaluating individual projects and assessing progress at the landscape scale.

Overall, the restoration planning framework presented here is intended to support the development of a more comprehensive and long-term Laguna Watershed restoration and management process, which can be built upon as projects are designed and implemented, with the aim to

- determine if management goals and objectives are being met,
- compare and prioritize restoration and management opportunities,
- identify what additional baseline information is needed,
- inform project design and implementation,
- enable metrics evaluated at the site-scale to link up to landscape-scale understanding,
- define on-going management and long-term stewardship needs,
- guide understanding of unexpected responses, and
- adapt to evolving management needs as projects are implemented and priorities or needs shift.

FRAMEWORK COMPONENTS

Development of successful restoration projects and enhancement of freshwater wetland and floodplain landscapes involves the definition of clear goals and objectives, ways to measure success that are tied to the desired physical and ecological functions, processes, and services, targets for those measures, and identified methods or actions to achieve the goals and objectives (Fig. 2-1). Skidmore et al. (2013) describe restoration project development as requiring quantifiable objectives linked to overarching goals with defined metrics, and associated targets and timelines for those metrics. As an example, the large-scale Kissimmee River restoration project involved an evaluation program centered on restoration expectations that were linked to overall goals and endpoints or objectives through the evaluation of metrics for historical, current, and expected conditions (Toth and Anderson 1998; Koebel and Bousquin 2014). The following sections describe each of the restoration framework components outlined in Fig. 2-1. As noted, only some aspects are of focus in this planning-level effort. Therefore, only the metrics selected to evaluate the Laguna habitat restoration project concepts are described in detail.

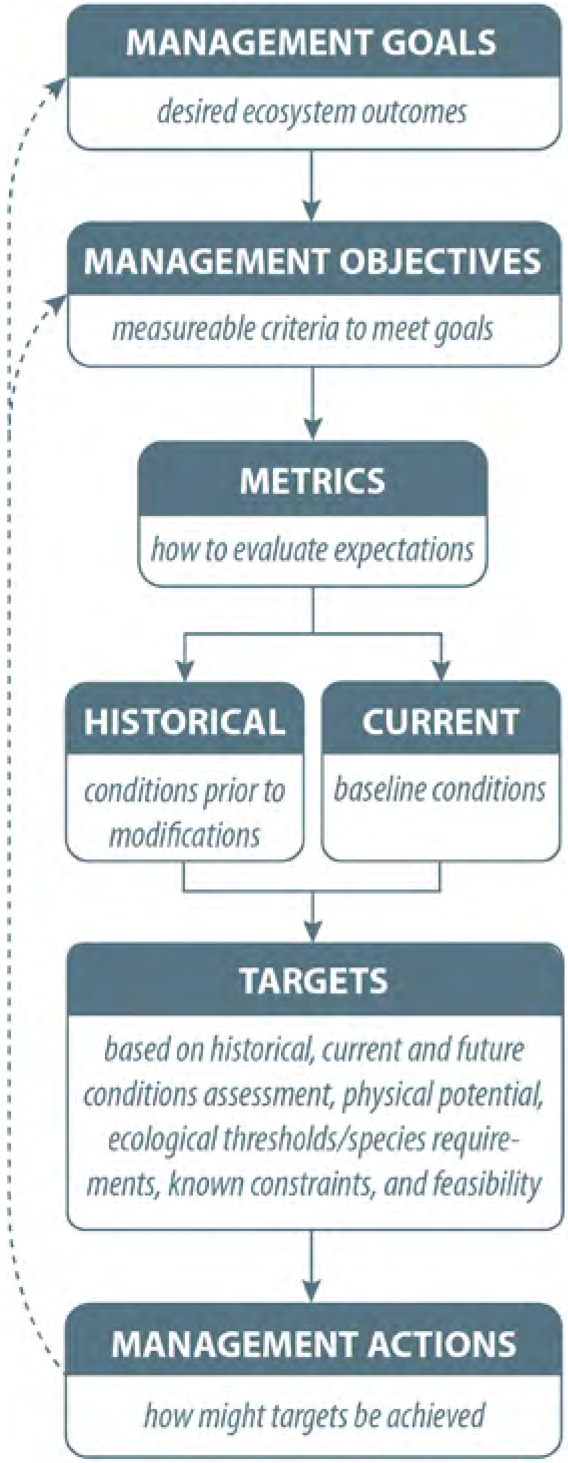


Figure 2-1. Restoration planning framework, illustrating how defined management goals and objectives are evaluated with metrics relating to ecological structure and functions. Assessing historical, current and possible future conditions supports the development of restoration targets. Management actions, including habitat restoration, are then considered for how they might achieve targets. The dotted line illustrates the adaptive management process of adjusting objectives, metrics and targets as new information becomes available, conditions change, and management actions are undertaken.

Management Goals and Objectives

A well-recognized and critical element of successful restoration planning is to establish clearly stated goals and objectives, developed from a solid understanding of the problem, its causes, and constraints. Restoration goals should broadly seek structurally and functionally sustainable ecosystems, linked to attributes of restored ecosystems (see definitions in SER 2004). Objectives should be measurable, such that hypotheses can be tested, project alternatives compared, and project success evaluated (Skidmore et al. 2013). Prior research and science synthesis efforts for the Laguna have documented historical conditions, within-Laguna and watershed factors driving change, and resulting ecological impacts, water quality degradation, and flood risk in the Laguna (Sloop et al. 2007; Baumgarten et al. 2014, 2017). Based on this understanding, key Management Goals and Objectives addressing needs for both people and wildlife were defined for the Laguna Restoration Vision and Restoration Plan (see Chapter 1). The goals and objectives relate to ecosystem form, function, and stability as well as societal benefits of the Laguna landscape.

The project concepts presented in this Restoration Plan represent several habitat restoration opportunities within the Laguna 100-yr floodplain. Project concept development focused on the potential extent and configuration of habitat types. Thus, while project concepts were developed with all Management Objectives in mind and the suite of Objectives are considered qualitatively for concept prioritization and sequencing (see Chapter 3), the metrics and targets developed and evaluated within this Restoration Plan primarily address the habitat-related objectives. While other objectives are indirectly considered, directly addressing them requires watershed management and restoration actions as well as data and analysis that is not currently available for landscape scale and planning level analysis. As Laguna restoration project design and implementation moves forward, however, they should be conducted within a more holistic watershed-based planning approach that more comprehensively addresses the Management Goals and Objectives, including further developing metrics and targets and the monitoring and modeling necessary to determine them.

Restoration Metrics

METRICS FOR EVALUATING MULTIPLE BENEFITS OF LANDSCAPE-SCALE RESTORATION

Restoration projects are often undertaken to meet specific criteria for a particular issue or species of concern. The restoration planning effort for the Laguna seeks a broader perspective for restoring and enhancing ecosystem functions and services. A range of factors need to be understood to determine how restoration actions can shift abiotic and biotic processes, and to evaluate the potential for restoration actions to address the Management Goals and Objectives. This involves establishing measures by which to quantify and infer ecosystem functions and services of the past, present and potential future Laguna landscape. To do so, metrics describing landscape, physical, chemical, and biological patterns and processes need to be identified to track changes to functions and services. Key categories of metrics proposed for the Laguna Restoration Planning Framework include landscape composition and configuration (landscape ecology), hydrology, geomorphology, water quality, habitat quality, vegetation and wildlife, and human disturbance (Table 2-1). Selected metrics should also be appropriate for evaluating landscape resilience, with components of setting, process, connectivity, diversity/complexity, redundancy, scale, and people, as described by Beller et al. (2019). These metrics should address key drivers of change, temporal dynamics, and expectations over the short- and longer-term post-restoration. Furthermore, there needs to be clearly articulated connections between what is measured and the ecological relevance. These might be in the form of questions or hypotheses, supported by observations and/or scientific literature. These linkages provide the pathway to describe what management objective(s) a metric relates to and how.

Metrics can be used for a variety of purposes over the evolution of restoration planning, design, implementation, and monitoring and adaptive management. As illustrated in Fig. 2-1, a primary step is to evaluate selected metrics under historical and current conditions. This information, along with an understanding of current constraints and future limitations, then feeds into the development of metric targets for setting expectations for what might be achieved given restoration actions to help meet management objectives (discussed further in the following section). Of focus here, metric evaluation of project concepts can be used to set expectations, compare different concepts, and demonstrate how a large-scale restoration plan such as this can be composed of multiple individual projects that together achieve landscape-scale goals and objectives.

Certain metrics may be appropriate to consider for different types or at different phases of projects. Table 2-1 includes initial classification of identified metric categories relating to scale,

Metric: For this planning effort, metrics are defined as physical, chemical, and biological parameters that can be measured to quantify and infer functions and services of the past, present and potential future ecosystems, to track changes to functions and services, and to evaluate progress toward addressing management goals and objectives. §

Table 2-1. Key categories of metrics proposed for the overall Laguna Restoration Planning Framework.

Category	Metric type	Primary scale of actions affecting metric	Applicable phase for evaluating projects	Feasibility (data availability)	Feasibility (analysis)
Landscape	Size	Site	Planning, Design & Monitoring	High	Desktop
	Connectivity/ adjacency	Site	Planning, Design & Monitoring	High	Desktop
Hydrology	Flow regime	Watershed	Design & Monitoring	Medium	Modeling/Field-based
	Floodplain inundation regime	Site + watershed	Design & Monitoring	Medium	Modeling/Field-based
	Groundwater	Watershed	Design & Monitoring	Low	Modeling/Field-based
Geomorphology	Landscape heterogeneity	Site + watershed	Monitoring	Medium	Desktop/Modeling
	Sediment regime	Watershed	Design & Monitoring	Low	Modeling/Field-based
	Channel planform and geometry	Site + watershed	Design & Monitoring	Medium	Desktop/Field-based
	Channel complexity	Site + watershed	Monitoring	Medium	Field-based
Water Quality	Assimilative capacity	Site + watershed	Design & Monitoring	Low	Modeling/Field-based
	Temperature regime	Site + watershed	Design & Monitoring	Low	Modeling/Field-based
	Turbidity	Site + watershed	Monitoring	Low	Modeling/Field-based
	Dissolved oxygen	Site + watershed	Monitoring	Low	Modeling/Field-based
Human Disturbance	Infrastructure	Site + watershed	Planning, Design & Monitoring	Medium	Desktop
	Impervious surface area/land use changes	Watershed	Planning, Design & Monitoring	High	Desktop
Habitat quality	Physical and biotic condition indices	Site + watershed	Monitoring	Low	Field-based
Vegetation & Wildlife	Productivity	Site + watershed	Monitoring	Low	Modeling/Field-based
	Diversity/Community composition	Site + watershed	Monitoring	Low	Modeling/Field-based
	Species populations	Site + watershed	Monitoring	Low	Modeling/Field-based
	Species ranges	Site + watershed	Monitoring	Low	Modeling/Field-based

applicability for evaluating potential projects, and feasibility in terms of data availability and type of analysis. For scale, each metric group is considered for the degree to which it is affected by site-scale restoration actions in the Laguna and watershed restoration and management actions. For example, watershed management actions as opposed to within-Laguna habitat restoration projects are likely to have the primary impact on the Laguna flow and sediment regime. With regard to the applicable project phase, many metrics can only be reasonably evaluated for baseline (current) conditions and then monitored over time once projects are implemented (e.g., habitat quality), as opposed to being used as planning criteria to compare project alternatives (e.g., extent of planned habitat types). Stated more directly, it is not possible to evaluate the habitat quality of a project concept presented in this document. Also, some metrics may be more or less directly related to ecosystem functions. For example, certain field-based monitoring can more directly assess particular ecosystem functions that may be only indirectly related to other types of metrics. Attributes of habitat types – including structure, dynamics, and composition – are key determinants of provided functions, and should be considered in the planning, design, and monitoring phases of projects. Some metric categories, such as flow and sediment regime, should be well-understood to develop realistic restoration designs and expectations. That is, some metrics are useful for understanding abiotic drivers and how they might interact with a restoration project to have a desired ecological response, whereas others are more useful for monitoring trends in condition post-implementation and understanding progress toward management objectives. In terms of feasibility for the current planning effort, metric categories were ranked as high, medium, or low for data availability for the Laguna and characterized in terms of the type of analysis (i.e., desktop, modeling, field-based). The selection of metrics applied at this stage of the planning process was based on metrics primarily affected by site-scale restoration actions, that could be quantitatively evaluated for project concepts, and had readily available information and desktop-based analysis. Therefore, metrics essential for monitoring and adaptively managing implemented projects are not explored beyond the general metric types introduced in Table 2-1.

LANDSCAPE METRICS FOR RESTORATION PROJECT CONCEPT EVALUATION

Metrics, common in the field of landscape ecology, that relate to habitat type composition and configuration were used to evaluate the project concepts (Table 2-2). Landscape ecology metrics, referred to as landscape metrics herein, are often applied to understand and quantify spatial patterns in the landscape at different scales, evaluate changes in ecosystem functions and services over time, and support conservation planning by clarifying priorities and enabling the comparison of alternative landscape scenarios (Leitão and Ahern 2002). Though research has pointed to the challenges of determining the ecological relevance of landscape ecology metrics, there continues to be research into how various metrics indicate or relate to ecological functions or specific species requirements (Frazier and Kedron 2017). Also, tracked over time, these metrics can reveal change in response to restoration actions (Taddeo and Dronova 2020). It is recognized, however, that these metrics alone are inadequate for evaluating progress toward achieving expected benefits, and that metrics involving field-based monitoring will be important to more directly evaluate project benefits (e.g., salmonid rearing, trophic support, sediment trapping, decreased water temperature, increased dissolved oxygen, nutrient assimilation) once project implementation has occurred. Landscape metrics evaluated here focus on the extent, patch size, core area, connectivity, and adjacency of target habitat types. Metrics were selected and in some cases parameterized based on understanding of ecological benefits and thresholds. Thus, while these landscape metrics do not directly measure ecosystem functions and services,

Table 2-2. Landscape metrics applied for the Laguna Restoration Plan evaluation of restoration project concepts, with a matrix showing connections to Management Goals and Objectives.

				Goal 1: Improve overall Laguna ecosystem functions and services for people and wildlife Goal 2: Establish a landscape that will be resilient under a changing climate Goal 3: Enhance environmental, tribal, and agricultural benefits of current and future land uses within and adjacent to the Laguna				
Category	**Metric**	**Description**	**Habitat type**	**Objective 1. Mimic a natural hydrograph** in lands draining to the Laguna that can decrease stormwater velocity and discharge to the Laguna during frequently occurring storm events, and increase groundwater recharge	**Objective 2: Decrease sediment and nutrient delivery** to the Laguna, especially at areas of high deposition/ accumulation rates. Move sediment from accumulation areas where appropriate	**Objective 3: Enlarge riparian and wetland habitat patches** and improve their connected-ness	**Objective 4: Control the extent of invasive plant species,** and encourage conditions that enable native species	**Objective 5: Improve late spring/ summer water quality** through improved drain-age and flow conveyance
Landscape	**Extent**	Total area (ha)	Perennial Freshwater Lake/Pond	x	x	x	x	x
			Valley Freshwater Marsh		x	x		x
			Forested Wetland and Mixed Riparian Forest/Scrub		x	x		x
			Wet Meadow		x	x	x	
	Patch size	Total area >10 ha patch size	Valley Freshwater Marsh	x	x	x		
			Forested Wetland and Mixed Riparian Forest/Scrub		x	x		
			Wet Meadow		x	x		
	Core area	Total core area index (total core area/total area)	Valley Freshwater Marsh			x		
	Distance to large patch	% total area within 500 m of a large >10 ha patch	Valley Freshwater Marsh			x		
			Forested Wetland and Mixed Riparian Forest/Scrub			x		
			Wet Meadow			x		
	Terrestrial adjacency	% area of terrestrial habitats types within a wetland habitat buffer (140 m)	Wetland habitat types (Farmed Wetland, Perennial Freshwater Lake/Pond, Non-native Aquatic/Emergent Vegetation, Valley Freshwater Marsh, Wet Meadow); Terrestrial habitat types (Oak Savanna or Woodland/Vernal Pool Complex/Valley Grassland, Other Upland, Forested Wetland and Mixed Ripari-an Forest/Scrub)			x		
	Channel adjacency	% of channel length with adjacent wetland habitat types	Valley Freshwater Marsh	x	x	x		x
			Forested Wetland and Mixed Riparian Forest/Scrub		x	x		x
			Wet Meadow		x	x	x	x
	Riparian width	% of channel length with riparian buffer >100 m wide	Laguna mainstem channel		x	x		x
			Tributary channel		x	x		x

the connections to them were explored and guided the metric selection and parameterization. These linkages are described briefly for the following metrics selected and evaluated as part of this effort.

Habitat type extent

Habitat type extent is a straightforward way of measuring the progress and impact of restoration actions, as restoration goals are often linked to acreage targets for different habitat types. A larger extent of a given habitat type generally means greater levels of the functions and services associated with that habitat type, including population support for species of concern, diverse native vegetation and wildlife communities, sediment trapping, and nutrient assimilation. In addition to the extent of each individual habitat type, increasing the combined extent of different habitat types at the landscape scale can support high biodiversity. A high degree of habitat diversity is linked to high species diversity (e.g., Crutsinger et al. 2008) and higher levels of ecosystem functioning (Alsterberg et al. 2017). The ecological value of the Laguna has been ascribed to the extent and diversity of freshwater wetland types represented (Sloop et al. 2007).

The extents of habitat types for the project concepts were assessed based on the habitat types from the Laguna Vision landscape change analysis. The four classes evaluated were Perennial Freshwater Lake/Pond, Valley Freshwater Marsh, Forested Wetland and Mixed Riparian Forest/Scrub, and Wet Meadow. These habitat types denote broad classifications of ecological communities determined largely by hydrologic characteristics and vegetation type and are not meant to represent habitat for particular wildlife species. As projects are implemented, the changing habitat extents can be tracked as a measure of restoration success and progress toward Management Goals and Objectives.

Patch Size

In addition to the overall extent of each habitat type, the configuration of that habitat type also affects the degree and type of functions provided. Patch size is a useful measure for describing configuration and has been linked to species diversity and abundance. Large habitat patches are assumed to be more valuable than smaller habitat patches because they support more habitat complexity, greater species diversity, and larger wildlife populations than smaller habitat patches (Ovaskainen 2002; Fletcher et al. 2018). However, small patches can provide important ecological value as well by supporting remnant populations or providing ecological connectivity between large patches (Wintle et al. 2019). For example, wetlands greater than 5 ha are associated with greater likelihood of wetland birds being present (Benoit and Askins 2002), while wetlands greater than 100 ha have been found to be more likely to support high densities of marsh birds (Spautz and Nur 2002; Spautz et al. 2005; Liu et al. 2012).

Landscape patterns and habitat fragmentation in human-dominated landscapes are often assessed in terms of patch dynamics, assessing discrete patches of desired habitat types within a matrix of lower habitat value (Forman 1995). The concept of a binary landscape (e.g., wetland habitat and non-wetland habitat) simplifies the complexities of how species interact with their surroundings, and does not account for other factors, such as habitat quality, that are important in determining the level of support provided by each patch.

To assess this metric, discrete areas were evaluated for each of three habitat types: Valley Freshwater Marsh, Forested Wetland and Mixed Riparian Forest/Scrub, and Wet Meadow. Discrete areas were considered to be within the same patch if they were within given threshold distances, based on dispersal distance research for wetland and riparian birds (SFEI-ASC 2014; SFEI-ASC 2020).

Core area

The shape of a patch can affect wetland function by determining the complexity of the interface between a patch and its surrounding landscape, and the relative amount of each patch vulnerable to edge effects. Edge effects refer to how areas of a patch close to its outer edge generally experience different conditions and interactions than areas within its "core," are more accessible to predators, and are less buffered from human disturbance in the modern landscape (Forman 1995). Core area is inversely related to the patch shape complexity and the proportion of core area generally increases with increasing area. While habitat edges can be beneficial for wildlife populations—providing transition zones and adding habitat complexity—when core to edge ratios are low as a result of habitat fragmentation they are associated with reduced population viability and greater probability of extirpation within habitat fragments (Lindenmayer and Fischer 2006).

For this analysis, the total core area index (ratio of total core area to total area), defined by McGarigal and Marks (1995), was applied to the Valley Freshwater Marsh habitat type and represents the overall landscape composition as it relates to core area. Core area was defined as the marsh patch's total area greater than 50 m from the patch's edge. This distance is based on research indicating a significant positive relationship between California black rail (Laterallus jamaicensis coturniculus) presence and marsh core area (defined as > 50 m from marsh edge; Spautz and Nur 2002; Spautz et al. 2005).

Distance to large patch

Connections between wetland patches are important for wildlife dispersal, gene flow, and overall population resilience. The likelihood that a patch will be colonized (or re-colonized after a disturbance event) is expected to increase with increased proximity to other wetland patches, particularly large patches. Large, well-functioning patches are more likely to support high densities of species, such as marsh birds (Spautz and Nur 2002; Spautz et al. 2005; Liu et al. 2012). Decreasing the average distance to a large marsh is expected to increase the demographic and genetic connectivity of wetland species in the Laguna. For this metric, we calculated the distance between large (defined as > 10 ha) marsh and wet meadow patches and smaller patches.

Terrestrial adjacency

The presence of wide terrestrial habitats adjacent to wetland and aquatic habitats is important for many species, including many reptiles and amphibians, which require both terrestrial and wetland habitats for different portions of their life history (e.g., wetlands for breeding and foraging and upland habitat for overwintering). Semlitsch and Bodie (2003) suggest a buffer of 140 m around wetlands and aquatic areas is the minimum distance recommended to provide sufficient terrestrial habitat required by semiaquatic reptiles and amphibians, and such a buffer would provides sufficient space for a variety of other important ecological processes operating across these transition zones (Robinson et al. 2017).

This metric involved evaluating the percent of area occupied by natural terrestrial habitats (e.g., oak savanna) within a 140 m buffer zone adjacent to wetland and aquatic habitats, including channels. Analysis methods were based on those of the Laguna Vision (SFEI-ASC 2020).

Channel adjacency

Floodplain habitats immediately adjacent to stream channels provide many benefits to the Laguna, including filtering stormwater runoff, buffering stream channels from external inputs of nutrients, sediment, and pollutants and helping to maintain water quality downstream (Mitsch and Gosselink 1993; Teels et al. 2006; Kaushal et al. 2008). These channel-adjacent wetland and riparian habitats also support many wildlife species, including various aquatic birds and reptiles, that use multiple habitat types along a wet-dry gradient under the right conditions across different life history stages. Riparian forests and wetlands also shade adjacent aquatic habitats, which helps to regulate water temperature, and provide inputs of leaf litter, large woody debris, and macroinvertebrates, which helps support salmonids and other native fishes (Wenger and Fowler 2000; Teels et al. 2006; Henning et al. 2006; Opperman et al. 2017).

This metric involved classifying the length of mainstem Laguna and tributary channel according to its adjacent habitat type on both banks. This was summarized as the percent of total channel length associated with each of the three main wetland and riparian types: Valley Freshwater Marsh, Forested Wetland and Mixed Riparian Forest/Scrub, and Wet Meadow. Methods followed the Laguna Vision.

Riparian width

Woody riparian areas provide structurally complex environments that support biodiversity and life history support for native wildlife. Wide riparian corridors support movement of native wildlife through the landscape better than narrow corridors (Hilty and Merenlender 2004), and provide habitat for species less likely to inhabit narrower riparian areas (Laymon and Halterman 1989; Holmes et al. 1999; Hilty and Merenlender 2004). This metric quantifies the percent length of channel with width of woody riparian habitat types greater than 100 m. Where channels occur along lakes and freshwater marsh (which were not included in the width calculation), woody riparian habitat types bordering these features were counted toward the width calculation. Methods to evaluate width were based on the analyses in the Laguna Vision (SFEI-ASC 2020). Riparian width was assessed separately for the Laguna mainstem and the primary tributaries to highlight the different opportunities presented in each location by the different project concepts. Having wide riparian corridors along both the mainstem and its tributaries helps support wildlife movement and provide habitat throughout the Laguna.

Restoration Targets

Generally, targets for metrics should reflect historical and current conditions, ecological thresholds or species requirements, and known limitations and constraints (e.g., land and water use, climate change, property ownership, and other physical and socioeconomic factors). Restoration target development for this effort was focused on setting expectations for landscape metrics assuming all project concepts achieved their intended habitat extent and distribution (see Chapter 3). That is, the Laguna landscape targets represent the metric values attained when all project concepts are considered together. As mapping potential habitat distribution for project concepts involved consideration of the past landscape as well as present-day and potential future conditions (including known limitations and constraints), the project concepts taken together were considered to be a reasonable step toward developing landscape targets. Each project concept represents just a part of the larger landscape and can only address a subset of the total habitat restoration. Showing how they each could contribute to landscape targets can therefore help set expectations for individual projects.

Different analytical approaches are needed to set targets for metrics other than the landscape metrics used here to evaluate patterns in habitat types. For example, considering needs for further study, setting targets for physical parameters such as the extent and duration of inundation would require an empirically-derived and/or numerical model-based understanding of current conditions, future conditions with land use and climate change, and how those conditions may be affected by restoration actions. Importantly, such analysis would be necessary at the scale of the Laguna rather than at the site scale. As another example, for targets based on regulatory processes, the current Laguna TMDL development being conducted by the North Coast Regional Water Quality Control Board will involve specific water quality targets centered on sediment and nutrients.

The development of longer-term targets (i.e., over the next several decades) requires further study, including data collection and modeling, to better describe the landscape potential and how to address ecological thresholds and species requirements. It should involve the consideration of temporal dynamics (e.g., expectations under drought versus wet years) and expected time lags associated with restoration responses or response times for management. Longer-term targets need to be developed with assumptions about ongoing stewardship within the Laguna and watershed management activities, as well as improved understanding of physical processes and species responses to climate change. Within the context of adaptive management, it should also be expected that long-term targets will shift over time as new information becomes available and as conditions and priorities shift. Rather than achieving some static state, restoration should be considered as a shifting ecological trajectory, where dynamics and interactions over the short and long term mean that the structure and functions of the ecosystem will shift in space and time.

Management Actions

The final component within the restoration planning framework presented here is the suite of management actions or responses employed to meet the targets and achieve management goals and objectives. A range of management actions may be necessary to meet restoration targets. While this effort documents selected wetland and aquatic habitat restoration opportunities for the Laguna floodplain, land use management and other watershed-scale actions will be necessary to more fully address the Laguna Management Goals and Objectives (SFEI-ASC 2020). Ultimately, as management actions are undertaken, ongoing maintenance and stewardship will be required, which should feed into an adaptive management process where ongoing monitoring is used to evaluate whether targets are being met. In this process, knowledge gaps are identified and addressed, and the framework is adjusted to reflect the improved understanding and new management actions are established. While it is not within the scope of this Restoration Plan to describe the maintenance, stewardship, monitoring, and adaptive management process for Laguna Restoration, it is expected that development of these elements will be required for successfully achieving Laguna Management Goals and Objectives.

NATIVE PLANT RESTORATION EFFORT AT LAGUNA UPLANDS. PHOTO: LAGUNA DE SANTA ROSA FOUNDATION

OAK TREE IN THE LAGUNA. PHOTO: SFEI

3. Restoration Project Concepts

Overview

The restoration project concepts developed for the Laguna illustrate habitat restoration actions aimed at improving the functioning of the Laguna for people and wildlife. Built from the Restoration Vision and Restoration Framework, they cover much of the Laguna floodplain and were developed in close coordination with technical advisers, agency representatives, tribal representatives, and local landowners and stakeholders who shared their knowledge and expertise. Project advisors and stakeholders also helped develop a set of restoration project prioritization criteria and sequencing considerations that can be used to assist with future decisions regarding which restoration projects should move forward first. This chapter provides detailed descriptions of the restoration project concepts, including associated ecosystem benefits, along with the prioritization criteria and sequencing considerations.

Concept Development Process

INITIAL RESTORATION PROJECT CONCEPTS

Restoration project concepts were developed within the Laguna based on the habitat information shown in the Laguna Vision. From the Bellevue-Wilfred Channel confluence in the southern Laguna downstream to the Mark West Creek confluence, a suite of restoration project concept areas was delineated within the 100-year floodplain, with upstream and downstream extents of each set by natural features (e.g., channel confluences and extents of historical habitats to be restored), bridge crossings, and property boundaries. Within each concept area, the habitat types, extents, and channel alignments from the Vision were refined based on a detailed examination of past and present site conditions (e.g., ecology, hydrology, geomorphology, and soils), opportunities for expanding the restoration extent, and local constraints. Conceptual (10%) designs were developed for each concept showing the location and extent of key habitat types and restored channel alignments within an approximate restoration project boundary.

Following the development of initial restoration project concepts, prioritization criteria and sequencing considerations were compiled to help guide future decisions on which projects to move forward first. The prioritization criteria address ways in which a concept helps meet the Management Objectives, including the quantitative landscape metrics as well as other more qualitative considerations. The sequencing considerations reflect the physical, ecological, cultural, and logistical elements that must be assessed when deciding on the implementation order of a suite of restoration projects. The initial sequencing considerations were developed from input received from the Technical Advisory Committee (TAC) and Management Advisory Committee (MAC) during the development of the Vision.

OUTREACH AND WORKSHOPS

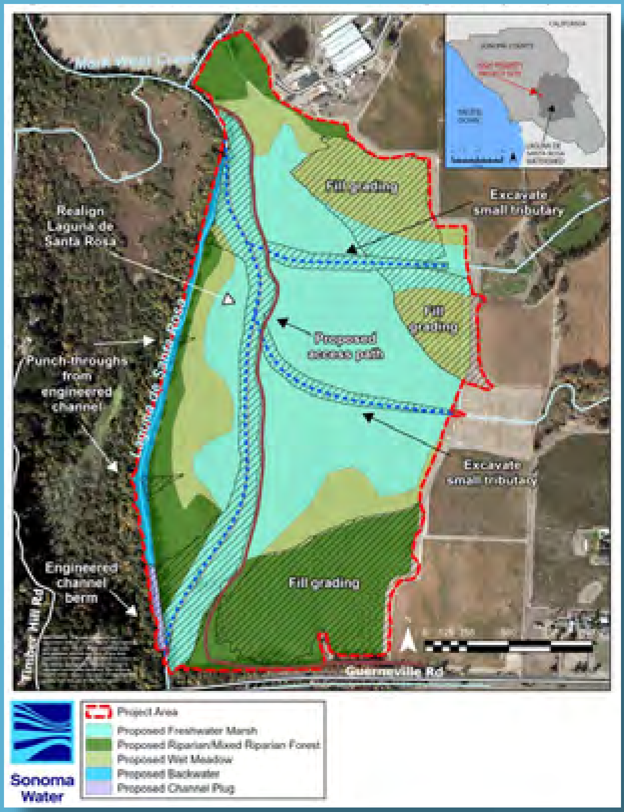
A series of meetings were held in 2020 to receive feedback on restoration project concepts and prioritization and sequencing criteria. On June 10, 2020, Sonoma Water, the Laguna de Santa Rosa Foundation, and SFEI hosted a virtual meeting with the project TAC focused on presenting the Restoration Framework and the initial restoration project concepts. TAC members included scientists and managers with expertise in hydrology, groundwater, plant ecology, fisheries, and wildlife ecology (see the Acknowledgments for full list). Based on the feedback received during this meeting and in follow-up conversations with individual TAC members, the restoration project concepts were refined and presented to the TAC, the project MAC, and local landowners, along with initial project prioritization and sequencing criteria, at a virtual meeting held on October 20, 2020. Members of the MAC included local regulatory and non-regulatory agency partners with expertise in land and water management (see the Acknowledgments for full list). Landowners included owners of farms and ranches along the Laguna and a representative from the FIGR, whose reservation is in the southeastern portion of the Laguna 100-year floodplain. During the October 2020 meeting, participants were given the opportunity to provide feedback on the restoration project concepts; however, most of the time was spent discussing the project prioritization and sequencing criteria. The TAC, MAC, and landowners had a range of perspectives and provided valuable feedback that improved the concepts and helped hone the prioritization and sequencing criteria. Updated criteria were then provided to the TAC, MAC, and local landowners in April 2021 for review and comment.

FINAL RESTORATION PROJECT CONCEPTS

The Laguna restoration project concepts were finalized by incorporating the feedback received during the October 2020 meeting and follow-up conversations with members of the TAC and MAC, and with several landowners. Similarly, the prioritization criteria and sequencing considerations were finalized by incorporating the feedback received from the TAC, MAC, and landowners on the April 2021 draft.

HIGH PRIORITY PROJECT

In addition to developing a suite of restoration project concepts, the Laguna-Mark West Creek Watershed Master Restoration Planning Project includes developing detailed project designs (65% designs) for a high priority project. Located on a 119 acre parcel just downstream of the confluence with Santa Rosa Creek, this project is focused on restoring lost riparian and wetland habitat, restoring the mainstem Laguna channel to its historical alignment, reconnecting two tributaries with the historical alignment, and creating a backwater within the existing Laguna channel. §



Elements of the High Priority Project for the Laguna-Mark West Creek Watershed Master Restoration Planning Project (source: Sonoma Water 2023).

Laguna Restoration Project Concepts

The restoration project concepts presented here together represent profound potential change in the composition and function of the Laguna, including restoring hundreds of hectares of natural wetland and riparian habitat and enhancing resiliency for the benefit of native plants and wildlife, as well as the Laguna's human community. The concepts cover a large portion of the Laguna and address most of the wetland and aquatic restoration opportunity areas shown in the Restoration Vision. The specific areas of focus for the concepts were determined by the project team on the basis of where restoration is feasible and/or would considerably improve habitat conditions. The concepts show restored habitat types, habitat extents, and channel alignments on both public and privately-owned land (Fig. 3-1). Each concept is unique, impacting the extent and configuration of habitat types differently depending on its geometry and location. Landscape metrics related to Management Goals and Objectives and ecosystem benefits presented in the Restoration Planning Framework (see Chapter 2) are used here to quantify the impact of each project concept, allowing for examination of how concepts compare to each other, as well as the contribution of an individual concept to the total benefits that could be realized if all the concepts were implemented.

It is important to note that the restoration concepts shown here do not cover all restoration opportunities within the Laguna. The intent of this Restoration Plan is to provide project concepts for those opportunity areas highlighted in the Vision. Restoration opportunities that arise outside the Vision extent and the area covered by this Plan should also be considered within the context of the Restoration Planning Framework (see Chapter 2).

Beyond project design and implementation, the success of restoration project concepts shown here in supporting ecosystem function and sustaining high-quality habitat depends on management actions within restored areas and in the surrounding watershed. Critical management actions to ensure a healthy and resilient Laguna and effective restoration project concepts include:

Surrounding Watershed

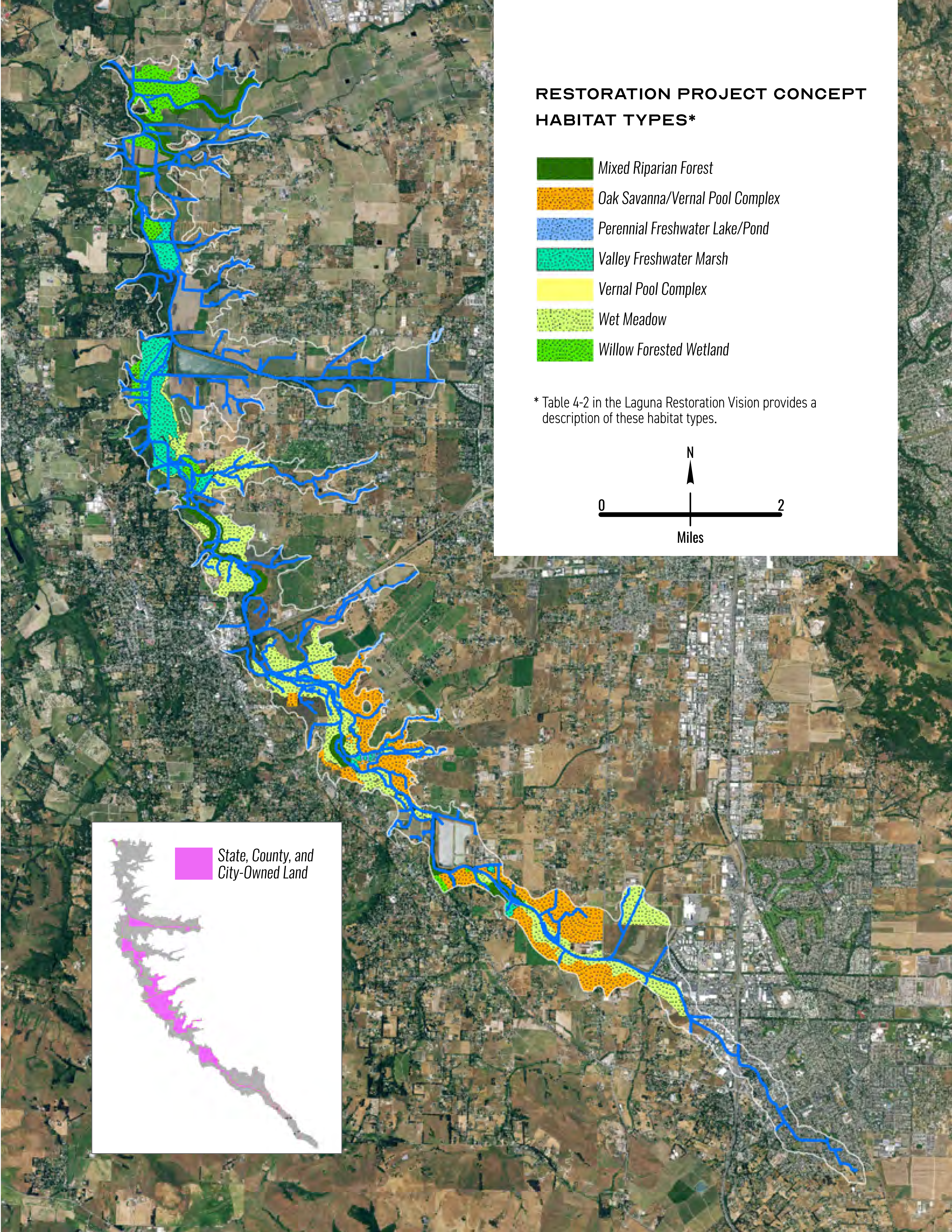
- stormwater runoff management (source control, capture and storage)
- Groundwater recharge
- Sediment source control
- Nutrient source control

Within Restored Areas

- Nutrient interception, processing and removal
- Sediment capture, storage, and removal
- Invasive vegetation management (especially invasive *Ludwigia spp.*)

Chapter 7 of the Restoration Vision report provides information on the types of management actions that will need to be implemented both within and outside the Laguna to support the concepts.

Figure 3-1 Restoration project concepts in the Laguna (right), with public lands map (inset).

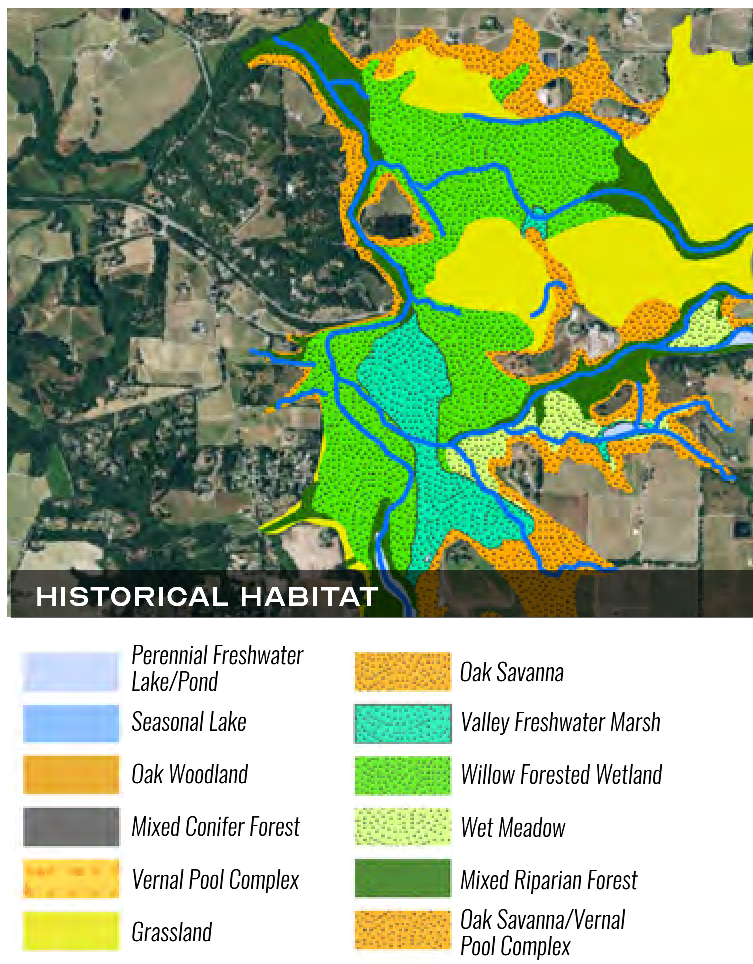

RESTORATION PROJECT CONCEPT HABITAT TYPES*
Mixed Riparian Forest
Oak Savanna/Vernal Pool Complex
Perennial Freshwater Lake/Pond
Valley Freshwater Marsh
Vernal Pool Complex
Wet Meadow
Willow Forested Wetland
* Table 4-2 in the Laguna Restoration Vision provides a description of these habitat types.
N
0
2
Miles
State, County, and City-Owned Land

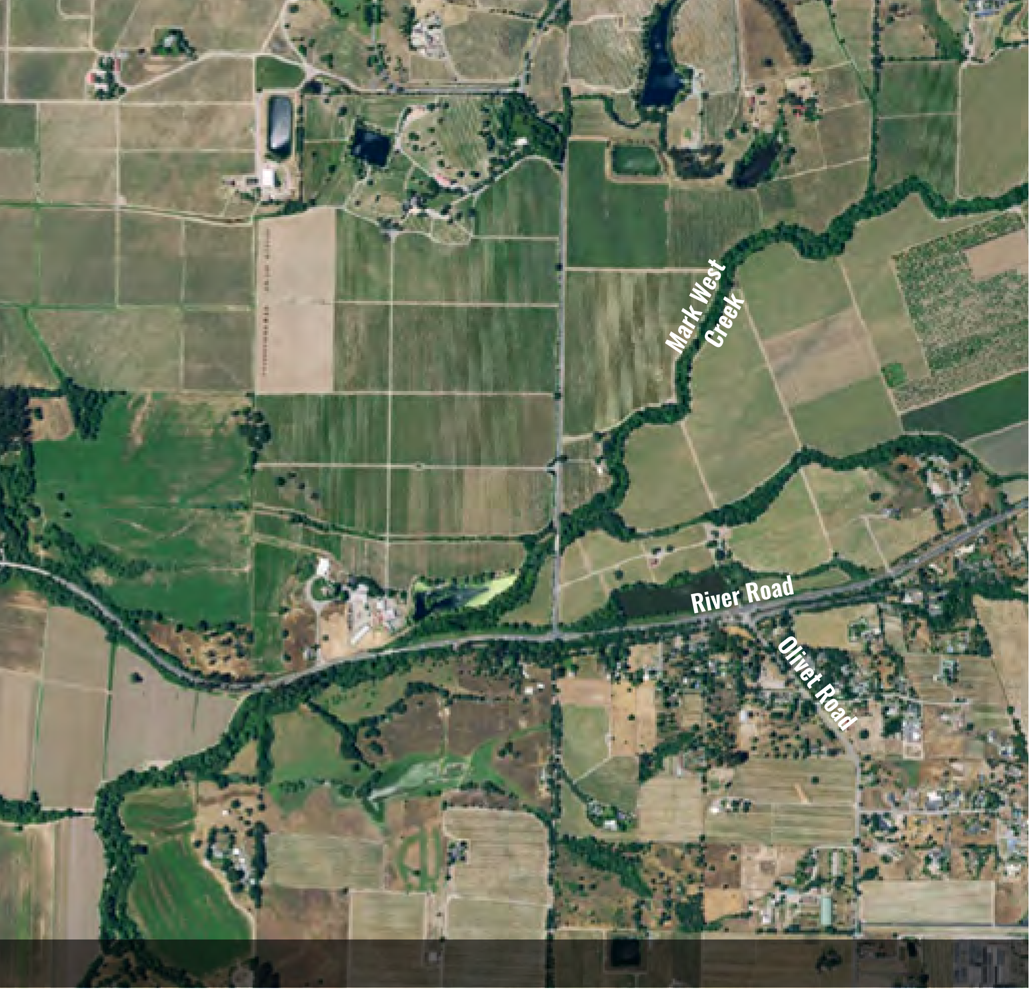
RESTORATION PROJECT CONCEPT FOR

MARK WEST (A)

INTRODUCTION

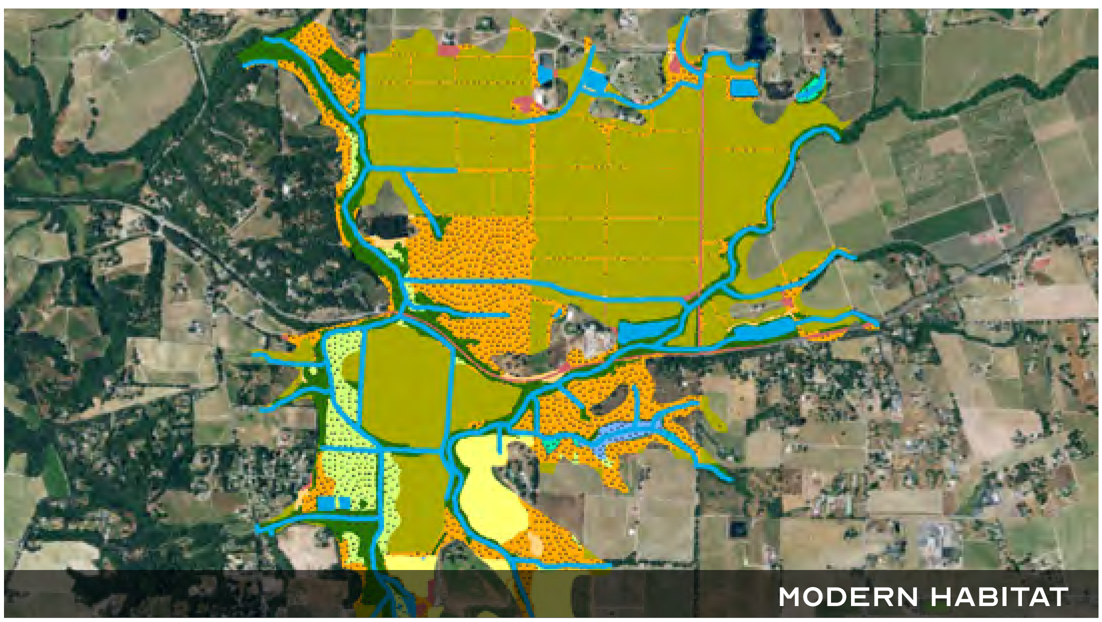
The Mark West Creek (A) restoration project concept aims to address flooding concerns resulting from the current alignment of the tributary confluence with the Laguna, while promoting sediment deposition upstream of the confluence and expanding riparian and floodplain habitats. Over time, the confluence of Mark West Creek with the Laguna has been realigned to the south to maximize farmable land and control flooding, while the tributary itself has been channelized from a complex and shifting alluvial stream to a single, confined channel. This has changed hydrological and sediment dynamics in the Laguna, concentrating sediment deposition in the main channel, which affects water quality and exacerbates upstream flooding. The current confluence creates unfavorable hydraulic conditions where Mark West Creek flows south directly into the Laguna mainstem that flows north, causing a backwater effect that can intensify upstream flooding. With several historical alignments to the creek and several possible solutions to current conditions, we developed four potential restoration project concepts for this area. This first of four concepts moves the tributary back to its ca. 1850 orientation. This restoration project concept features a realigned tributary channel with a wide (150–250 m) riparian buffer to allow for wildlife passage and habitat, cooler water through shading, and nutrient assimilation. The new tributary and its confluence with the Laguna would be unrestricted, allowing for lateral sediment deposition and natural channel migration. At the lower tributary and confluence, new willow forested wetland, would be more amenable to frequent inundation and sedimentation.





N
1,000 FEET
300 METERS
1:20,000 SCALE

The historical location of the Mark West Creek confluence with the Laguna has been entirely replaced by agriculture. Mark West Creek has been rerouted to flow into the Laguna about 2 miles (3.2 km) upstream. In addition to the conversion of willow forested wetlands and riparian forest to farmland, the remaining riparian buffers around Mark West Creek and the Laguna mainstem have been substantially reduced, affecting wildlife habitat and water quality.



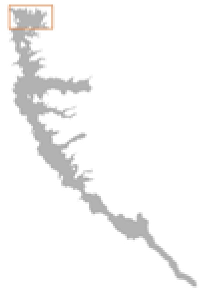
N
2,000 FEET
500 METERS
1:35,000 SCALE

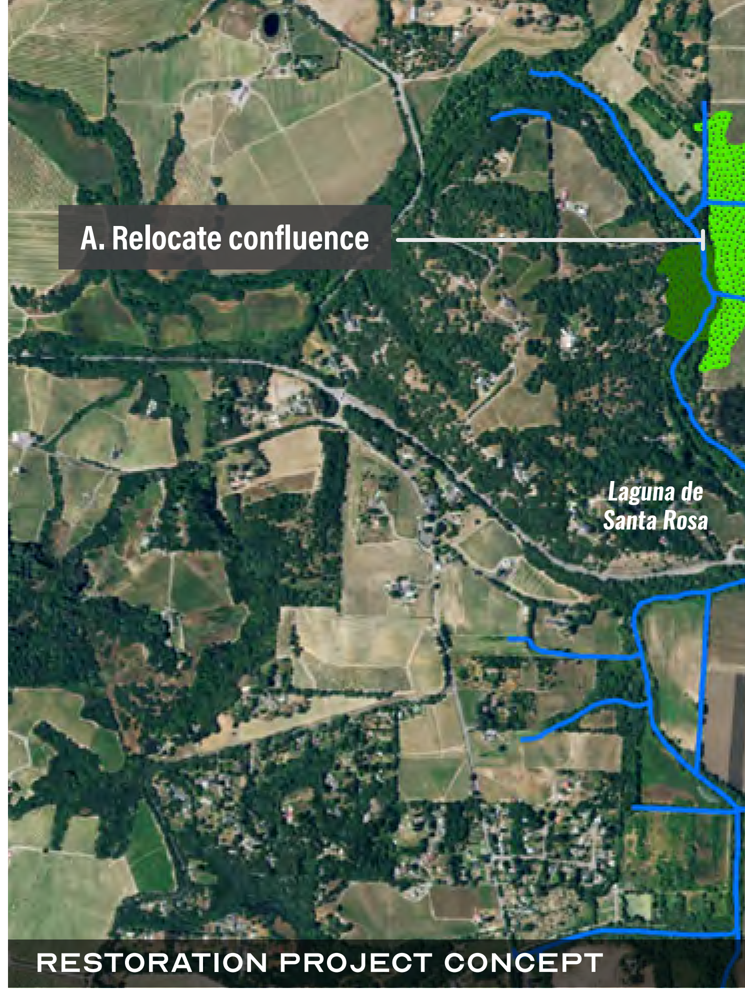
Developed/Disturbed
Forested Wetland and Mixed Riparian Forest/Scrub
Hayfield/Pasture/Vernal Pool Complex
Oak Savanna or Woodland/Vernal Pool Complex/Valley Grassland
Other Agriculture
Other Upland
Perennial Freshwater Lake/Pond
Storage Pond
Valley Freshwater Marsh
Wet Meadow

RESTORATION CONCEPT

RESTORATION PROJECT CONCEPT FOR

MARK WEST (A)

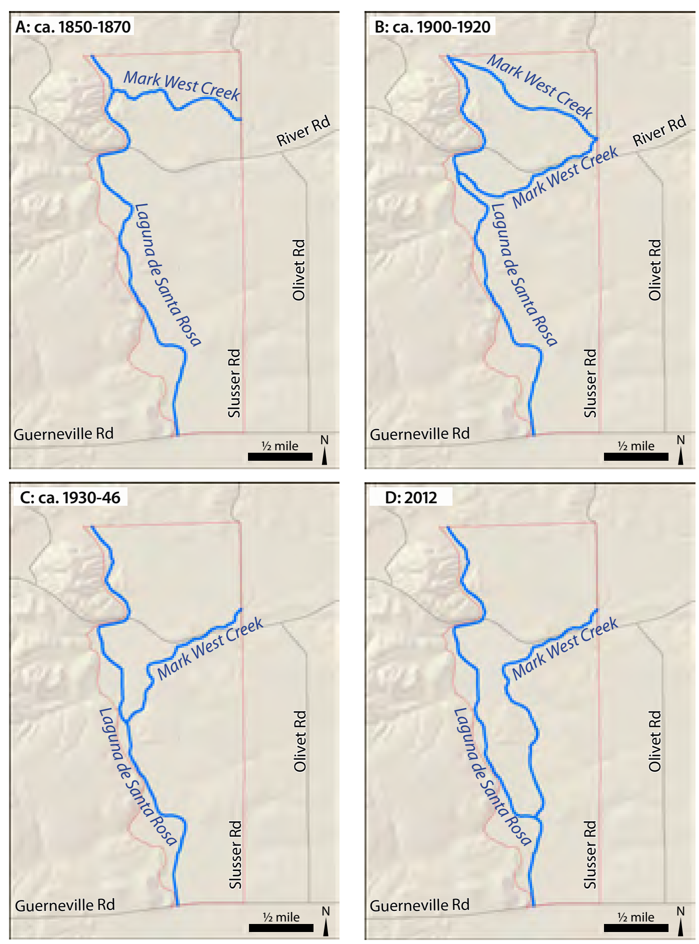


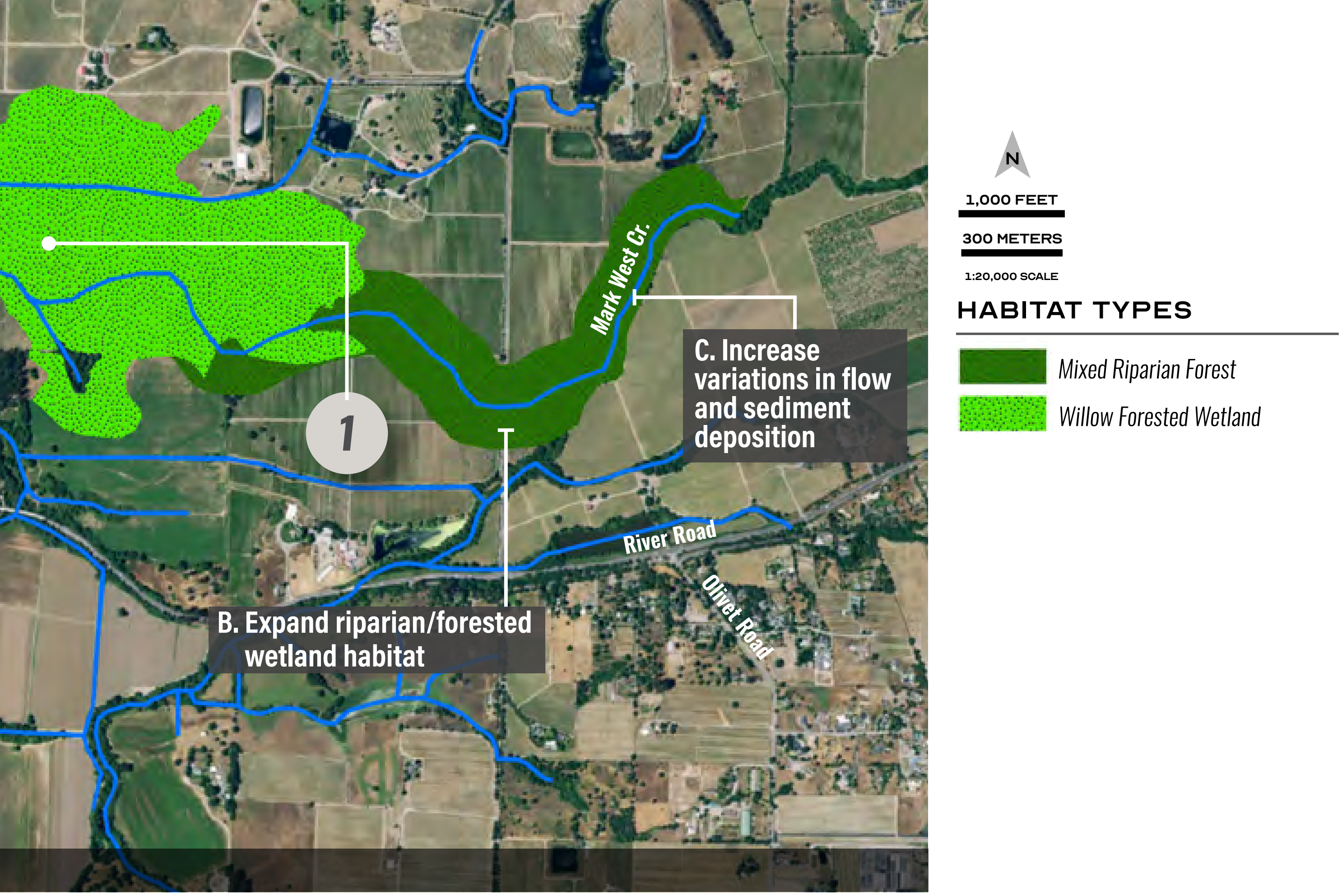


A. Relocate confluence The proposed relocated confluence between Mark West Creek and the Laguna de Santa Rosa would match the previous location prior to anthropogenic realignment. This would alleviate acute hydraulic problems and in-channel sedimentation that trouble the site of the current confluence to the south and exacerbate flooding for a considerable distance upstream.

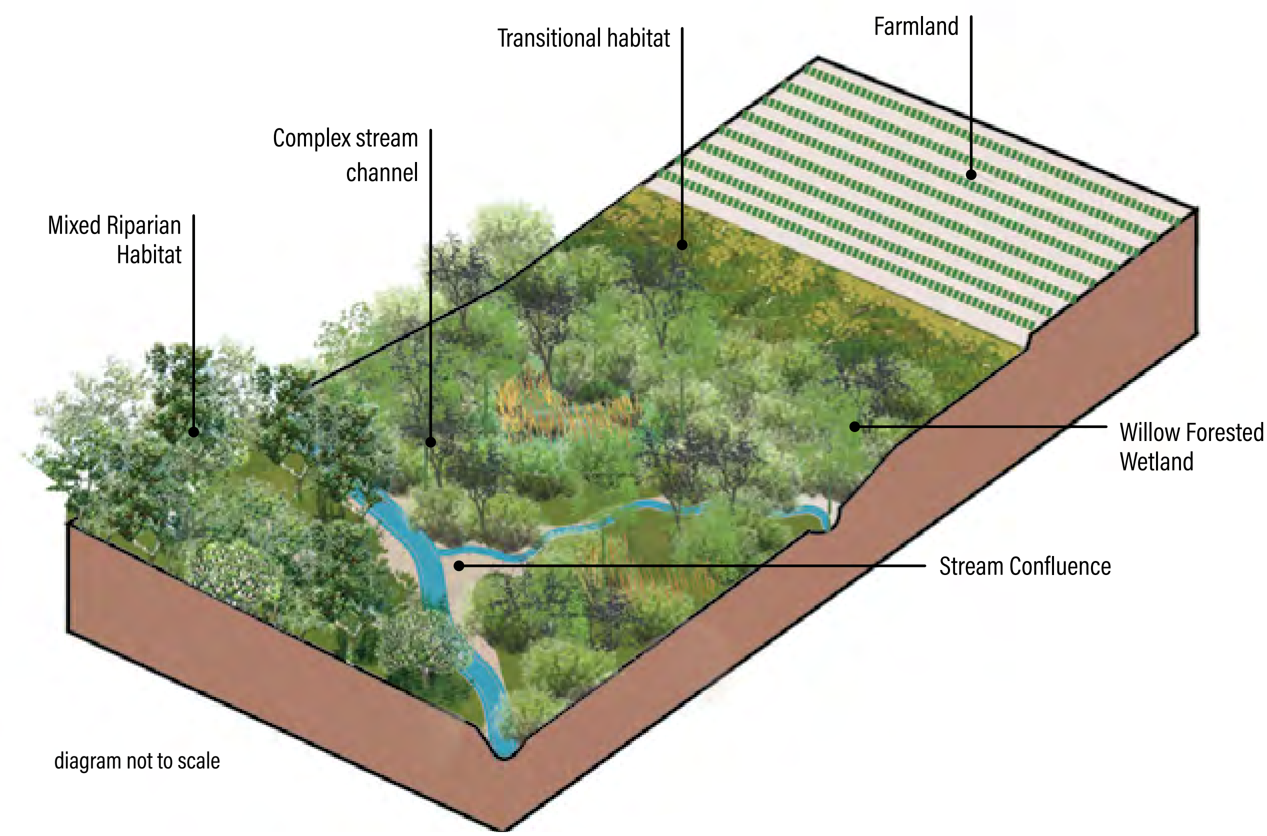
B. Expand riparian/forested wetland habitat The rerouted Mark West creek would be surrounded by a large forested riparian buffer of mixed native trees, as well as willow-dominated wetlands closer to the tributary's confluence with the Laguna, adding over 100 ha of mixed riparian/forested wetland habitat to the floodplain study area. This habitat offers critical resources and refuge for native and migratory wildlife, and also serves as a protected corridor for animals to traverse between the Laguna floodplain and upper reaches of the watershed.

C. Increase variations in flow and sediment deposition The proposed path of the restored Mark West Creek channel follows a curving, sinuous form similar to the historical alignment. This alignment will be more likely to enable spatial variations in flow and sediment deposition, which are necessary in creating habitat and life-cycle support for fish and other aquatic organisms. Variations in flow velocity along the lower Mark West Creek also allow for greater in-channel sediment storage, channel aggradation, a fine sediment deposition on the adjacent floodplain. This may help alleviate excess sedimentation in the Laguna mainstem, which is particularly acute at the current Mark West/Laguna confluence, where the straightened tributary efficiently transports sediment where it is deposited in the Laguna mainstem.





1 Example habitat gradient within the restoration project concept



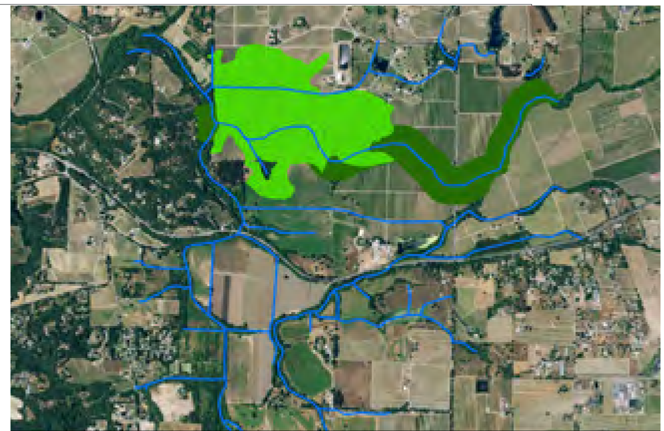
RESTORATION PROJECT CONCEPT FOR

MARK WEST (A)

1 INTRODUCTION: PAST AND PRESENT

2 ANNOTATED RESTORATION PROJECT CONCEPT

3 BENEFITS, CONSIDERATIONS, AND METRICS

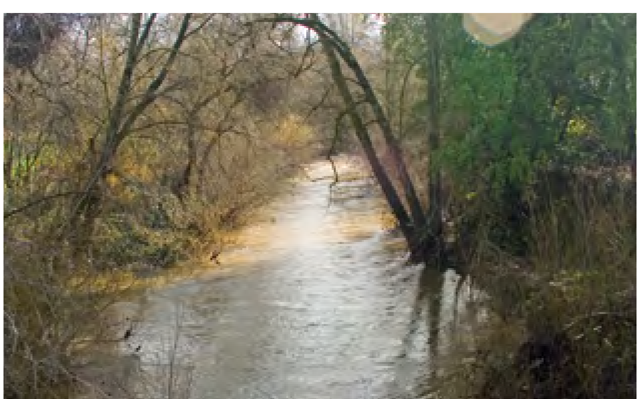


RESTORATION PROJECT CONCEPT

BENEFITS OF THE PROJECT

A realignment of Mark West Creek to its historical course has many potential physical and ecological benefits, as indicated by restoration metrics and other physical changes. It is expected to improve ecosystem functions by restoring core habitat with the expansion of willow forested wetland transitioning to mixed riparian forest moving upstream. This forested lower tributary reach would provide greater cover and movement pathways for resident and migratory fish and wildlife, notably salmonids and birds between the Laguna floodplain and upper watershed. Riparian restoration and enhancement under this concept increases riparian forest habitat types areal coverage by over 100 ha, or an increase of 32% compared to current conditions. With this project concept, the length of major tributaries in the Laguna floodplain buffered by >100 m wide riparian forest increases from 1.76 km to 4.9 km.

Aside from direct habitat enhancements, realignment of Mark West Creek provides migrating coho (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) a more direct route to spawning and rearing habitat in the Mark West Creek watershed. The realignment and reestablishment of a more natural tributary course and vegetated floodplain has great potential to improve water quality by increasing shading and lowering water temperatures, and by by decreasing sediment and nutrient loads to the Laguna. Sediment will be more readily deposited in the alluvial Mark West Creek and delta, and agricultural nitrogen and phosphorus borne in runoff and groundwater will filter through more complex channels, restored wetland habitats, and the riparian root system, improving water quality. Finally, the proposed confluence with the Laguna mainstem will improve flow conveyance upstream, as it alleviates the current conflicting hydraulic conditions.



LOWER MARK WEST CREEK AFTER A WINTER RAIN. PHOTO: STEVE SHUPE. CREATIVE COMMONS.

ADULT STEELHEAD TROUT. PHOTO: NOAA

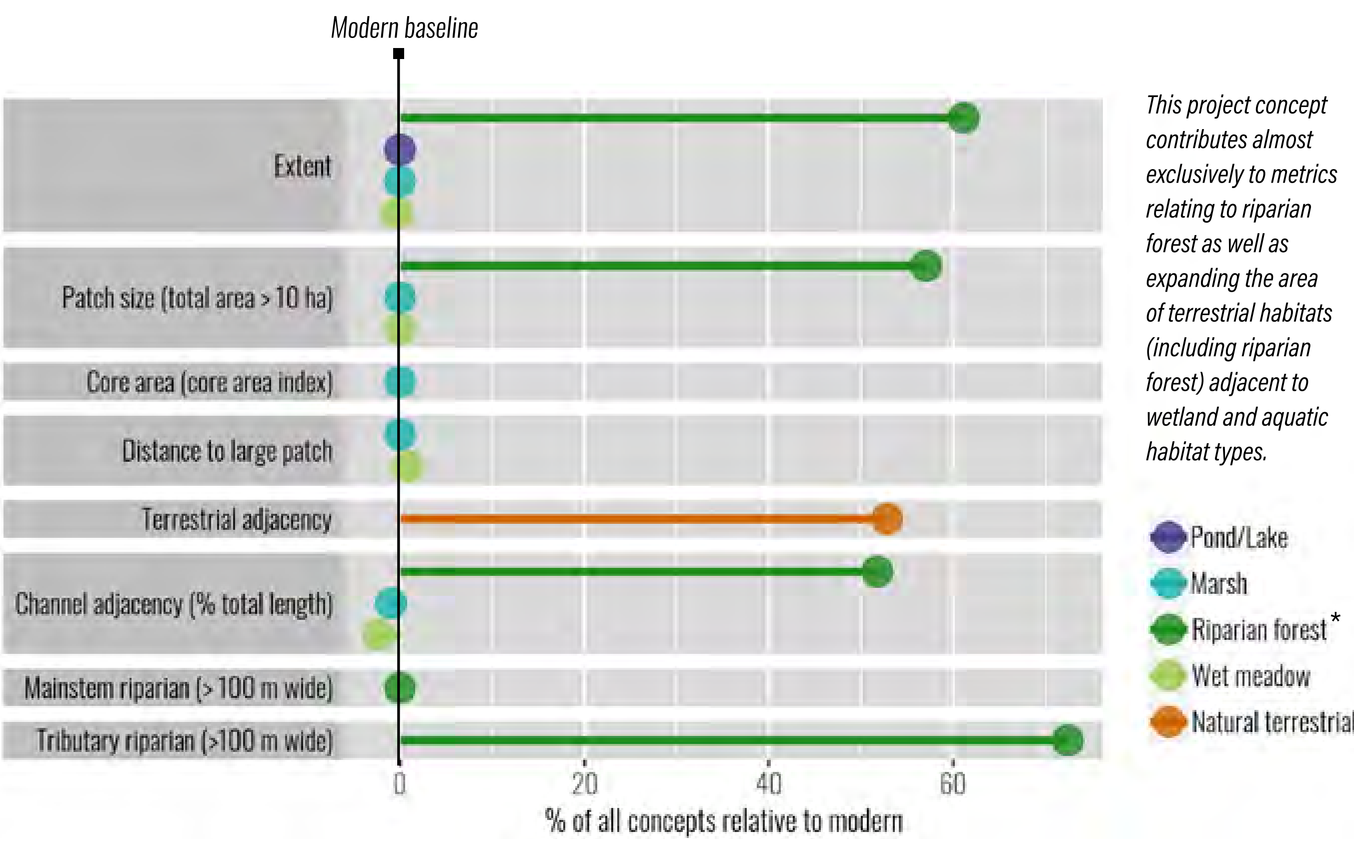
KEY CONSIDERATIONS

Though current empirical data and modeling is insufficient for quantifying the expected effects of this concept on hydrology and geomorphology, the Mark West Creek realignment should support the physical functioning of the Laguna in several ways. Widening the stream corridor will allow for lateral movement of the channel and increased in-channel storage and floodplain sediment deposition. The current channelized tributary is relatively straight upstream and downstream of a sharp bend and its morphology is highly simplified, lacking deposition bars, side channels and pools that were present in the channel historically. In addition to physical process benefits, variability in channel geometry provides important benefits for fish and benthic macroinvertebrates, as well as many other native species. Realignment of this major tributary also offers the potential benefit of easier passage for spawning adult and out-migrating juvenile salmonids. Special attention should be paid to species protection and monitoring for native fish after channel realignment.

Finally, realigning Mark West Creek will affect sediment and inundation dynamics for areas upstream along the mainstem Laguna. These effects should be considered (via monitoring and modeling) in decisions related to the sequenced implementation of restoration project concepts. Changes in sediment and hydrodynamics may particularly impact the Ballard Lake concept area (see page 43), which lies just downstream of the current Mark West/Laguna confluence. Rerouting Mark West to the historical alignment will result in sediment delivery to the Laguna mainstem downstream of Ballard Lake, which would likely lead to greater chance of success for the Ballard Lake restoration concept due to a decreased rate of lake infilling.

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept contributes almost exclusively to metrics relating to riparian forest as well as expanding the area of terrestrial habitats (including riparian forest) adjacent to wetland and aquatic habitat types.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

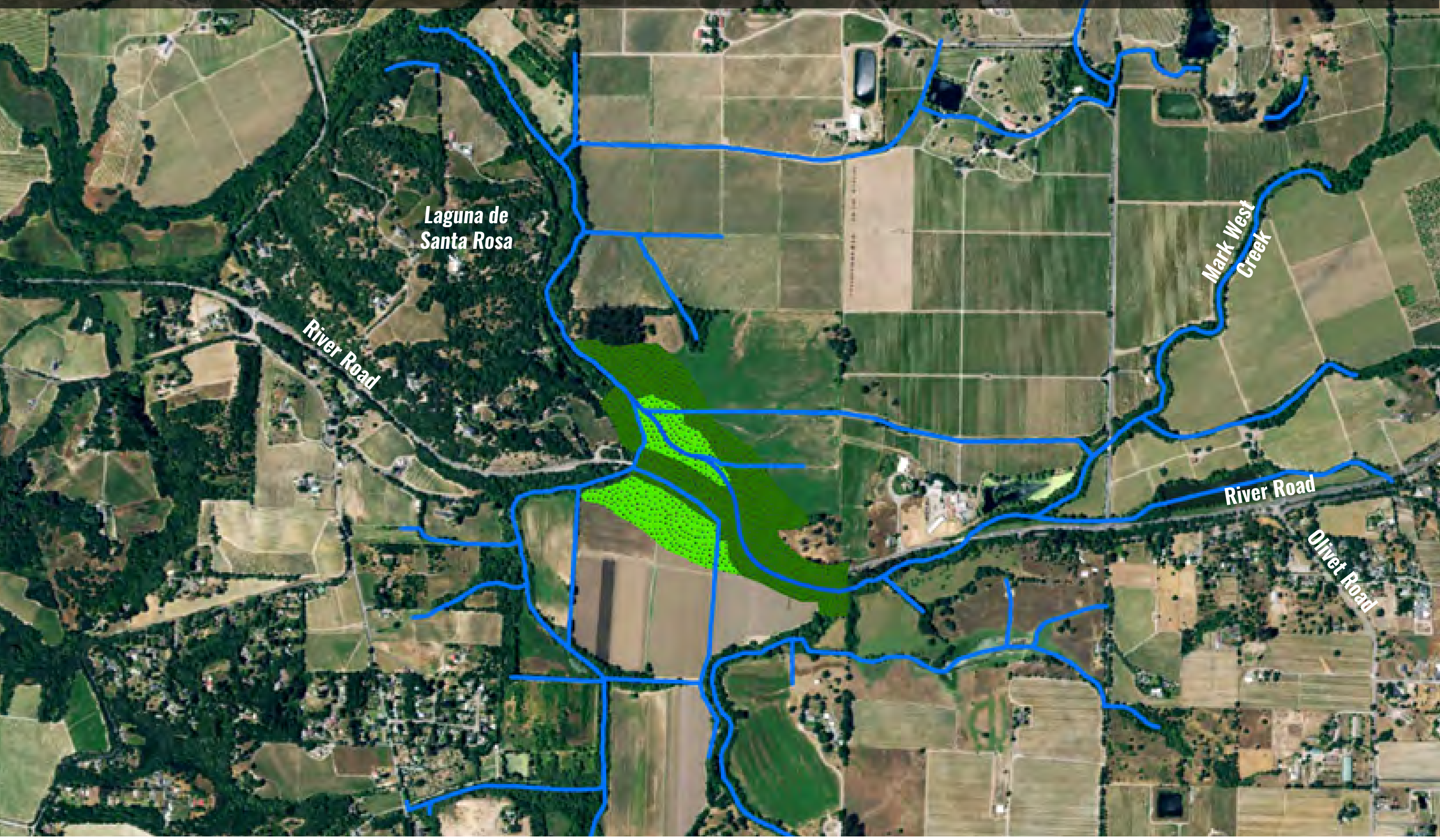
MARK WEST (B)

INTRODUCTION,
BENEFITS,
CONSIDERATIONS,
AND METRICS

INTRODUCTION: ALTERNATIVE B

This alternate restoration project concept to the Mark West A project concept creates a new confluence between Mark West Creek and the Laguna just north of where River Road crosses the mainstem Laguna. This proposed reroute of Mark West Creek could go under River Road, which currently runs along an earthen berm above the floodplain. This would require the conversion of River Road into a raised roadway to allow for passage of the rerouted tributary and connectivity of surrounding restored riparian forest and willow forested wetlands.

MARK WEST: ALTERNATIVE B RESTORATION PROJECT CONCEPT



N

1,000 FEET

300 METERS

1:20,000 SCALE

HABITAT TYPES

- *Mixed Riparian Forest*
- *Willow Forested Wetland*

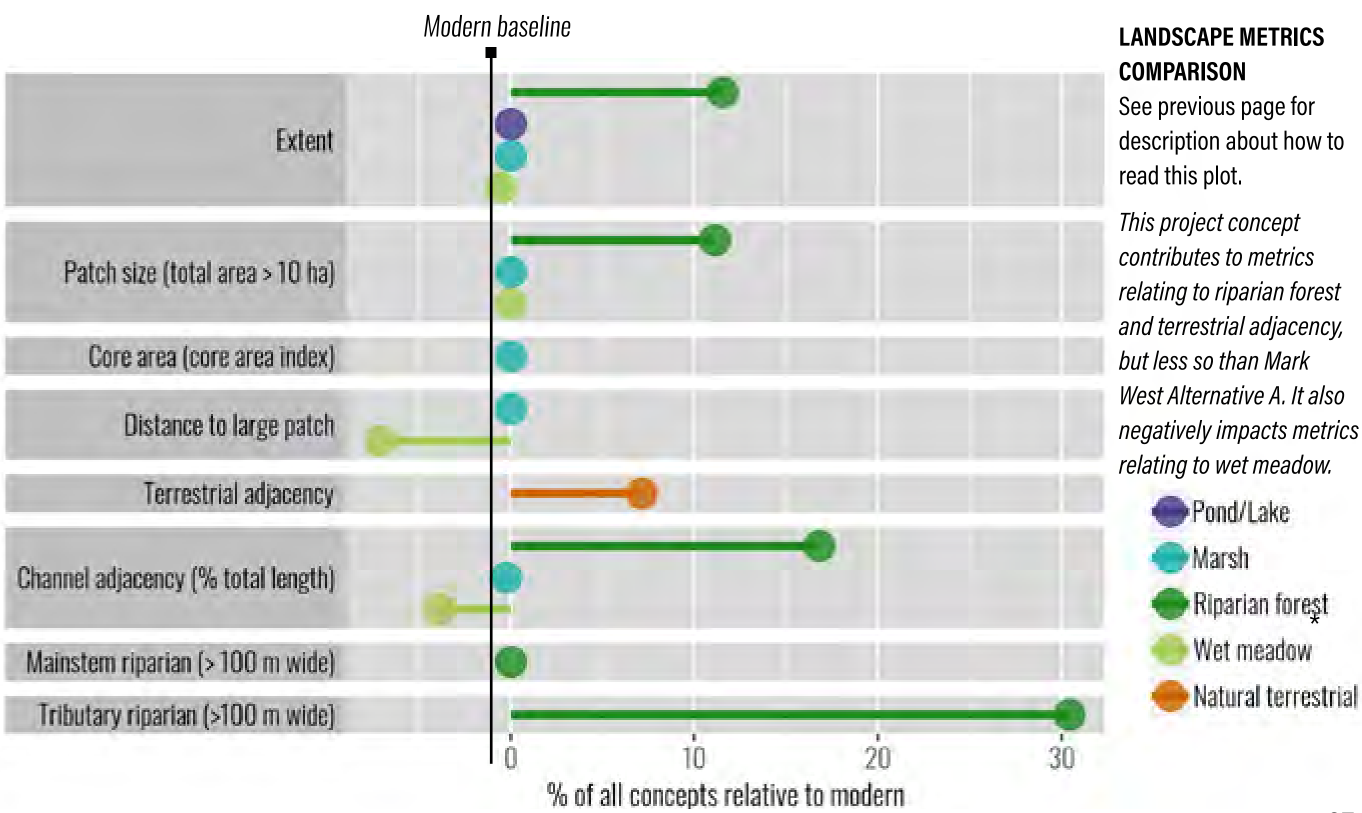
BENEFITS OF THE PROJECT

The Mark West B channel reroute concept adds 20 ha of mixed riparian forest habitat to the study area compared to modern conditions, primarily replacing low-productivity agricultural and grazing land. It also increases the length of major tributaries buffered by more than 100 m wide riparian forest from 1.8 km to 3.1 km. All of these increases hold potential benefits for movement of wildlife along riparian corridors, and increase habitat for nesting birds and other wildlife.

Some benefits of this channel reroute and riparian expansion are not captured by the quantitative landscape metrics. The realignment provides native salmonids a more direct route to critical habitat in the Mark West Creek watershed. Also, an increase of forested riparian buffer around the channel in an intensively agricultural setting has the potential to markedly increase nutrient assimilation before waterborne nitrogen and phosphorus reach creek habitats. Other improvements in water quality may come from increased shading and associated lowering of water temperatures. By requiring the conversion of River Road into an elevated causeway, this project concept has the potential to increase both flood conveyance as well as floodplain hydrological and habitat connectivity. Finally, similar to the Mark West A reroute, an unconstrained and alluvial tributary/mainstem confluence would relieve the current conflicting hydraulic conditions of the existing confluence.

KEY CONSIDERATIONS

As stated above, this tributary reroute would require structural changes to River Road to allow passage of Mark West Creek underneath, namely its conversion to an elevated causeway for a length of at least 200 meters. This would require funding and coordination between relevant agencies. Similar to the Mark West A concept, detailed plans for this creek reroute in later design stages would benefit from modeling to better anticipate effects on flooding, sediment dynamics, in-channel changes, and benefits for fish, both within the mainstem Laguna and in the rerouted creek.



LANDSCAPE METRICS COMPARISON
See previous page for description about how to read this plot.

This project concept contributes to metrics relating to riparian forest and terrestrial adjacency, but less so than Mark West Alternative A. It also negatively impacts metrics relating to wet meadow.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

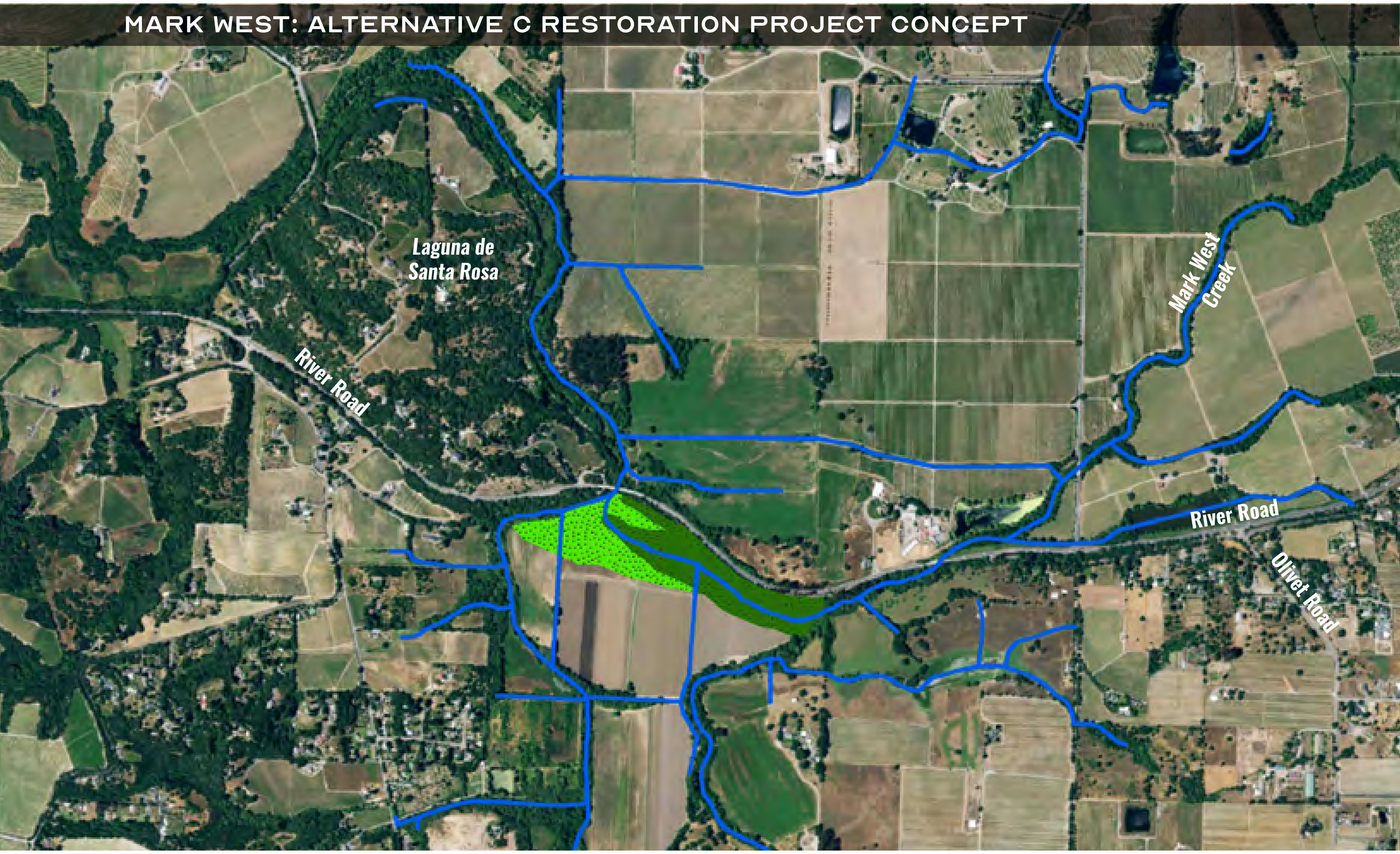
MARK WEST (C)

INTRODUCTION,
BENEFITS,
CONSIDERATIONS,
AND METRICS

INTRODUCTION: ALTERNATIVE C

The next alternative Mark West reroute, restoration project concept C, realigns the tributary to the south of River Road, creating a new confluence just upstream of where River Road crosses the Laguna. The reroute would be accompanied by an expansion of mixed riparian forest and willow forested wetland habitat types.

MARK WEST: ALTERNATIVE C RESTORATION PROJECT CONCEPT



N

1,000 FEET

300 METERS

1:20,000 SCALE

HABITAT TYPES

- *Mixed Riparian Forest*
- *Willow Forested Wetland*

BENEFITS OF THE PROJECT

The Mark West C concept would add 12 ha of forested wetland and mixed riparian forest and 800 m of major tributary channel length buffered by more than 100 m of riparian forest. As with other Mark West reroutes, this forested expansion would allow for a more direct route into the watershed for native salmonids, greater movement of wildlife along the riparian corridor, improved habitat and refuge, cooler water, and more complex and traversable channels for native fish. It could also provide improvements in water quality through increased shading and the lowering of water temperatures.

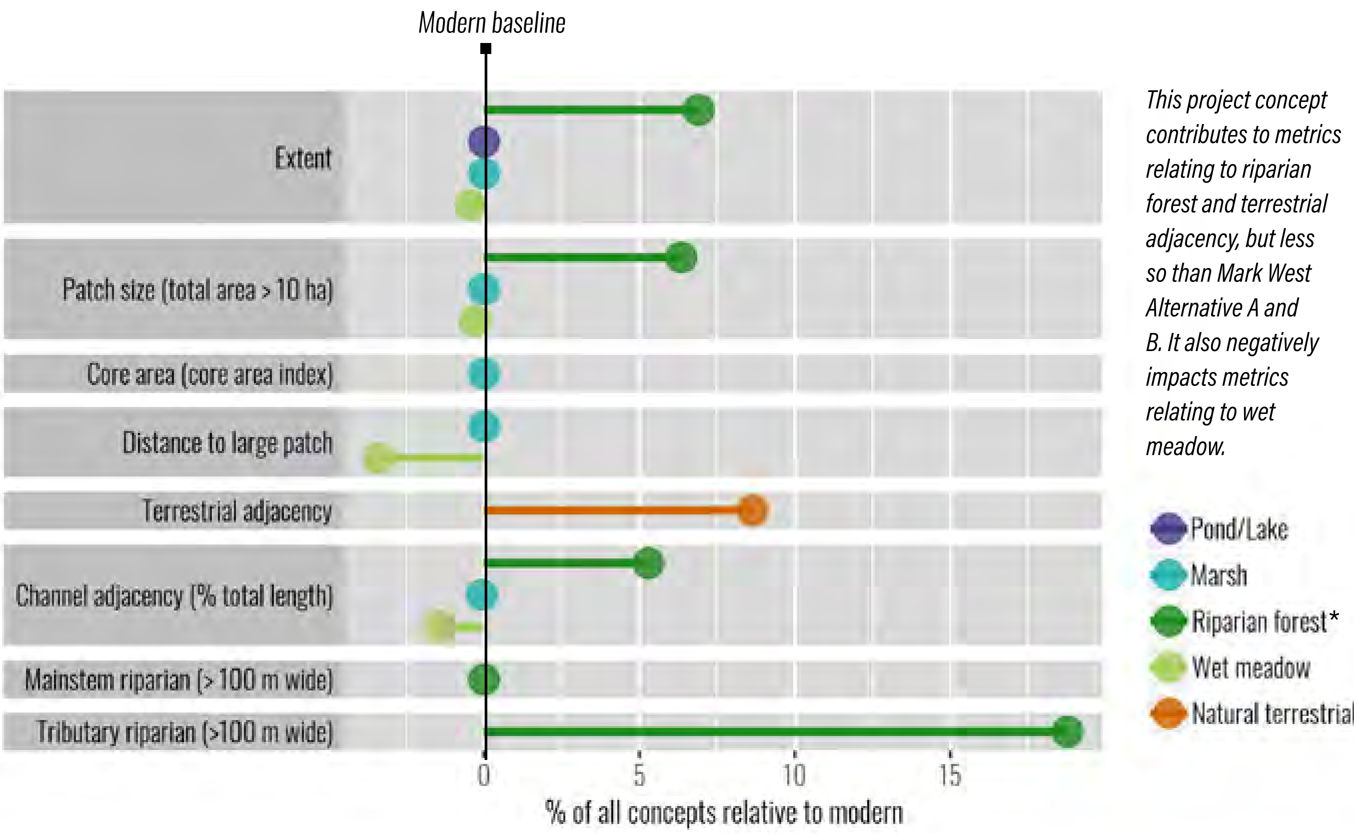
Benefits not captured by the landscape metrics include enhanced nutrient assimilation within the vegetated riparian zone, as well as improved channel complexity and deposition of coarse sediment to enhance fish and benthic macroinvertebrate habitat.

KEY CONSIDERATIONS

Unlike the Mark West B concept, this reroute of the creek would not necessitate significant changes to the nearby River Road, aside from routine assessment of and protections against flood risk. However, the introduction of a confluence just upstream of the River Road bridge may lead to some constriction on high flows and sediment. Improved hydraulic and sediment modeling is needed to assess the magnitude of this influence. It is likely, however, that this tributary realignment would still improve upon hydraulic conditions at the current Mark West/Laguna confluence.

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept contributes to metrics relating to riparian forest and terrestrial adjacency, but less so than Mark West Alternative A and B. It also negatively impacts metrics relating to wet meadow.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

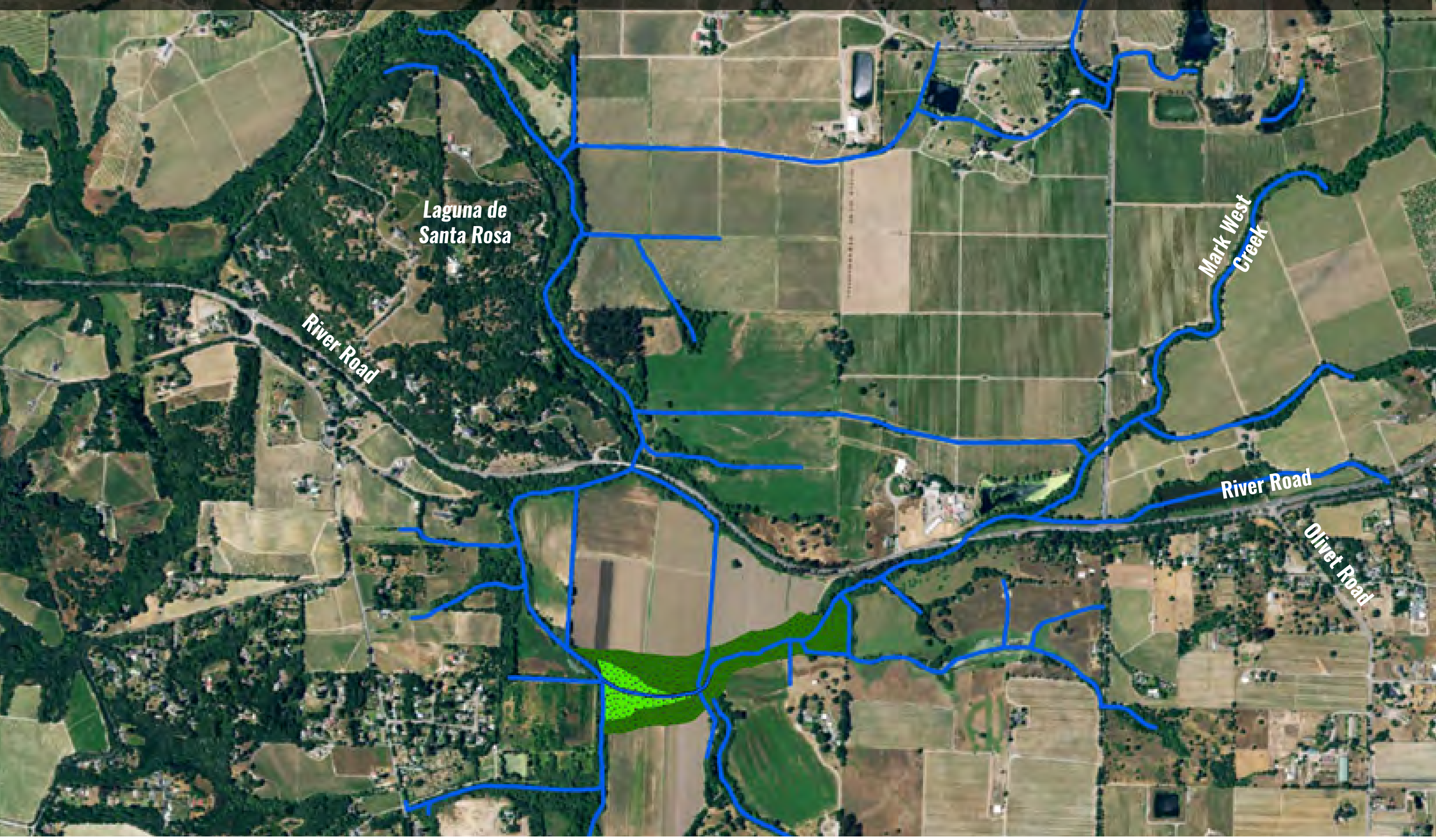
MARK WEST (D)

INTRODUCTION,
BENEFITS,
CONSIDERATIONS,
AND METRICS

INTRODUCTION: ALTERNATIVE D

The final Mark West alternative, Mark West D, reroutes the creek channel across the narrowest span of agricultural land currently separating the Laguna and the Mark West Creek tributary. This creek realignment would be accompanied by a ~200 m wide riparian buffer of mixed forest and willow forested wetland.

MARK WEST: ALTERNATIVE D RESTORATION PROJECT CONCEPT



N

1,000 FEET
300 METERS
1:20,000 SCALE

HABITAT TYPES

- *Mixed Riparian Forest*
- *Willow Forested Wetland*

BENEFITS OF THE PROJECT

This restoration project concept would add 7.5 ha of forested wetland/mixed riparian habitat to the study area, while increasing the length of channel with more the 100 m wide riparian forest from 1.8 km to 2.7 km.

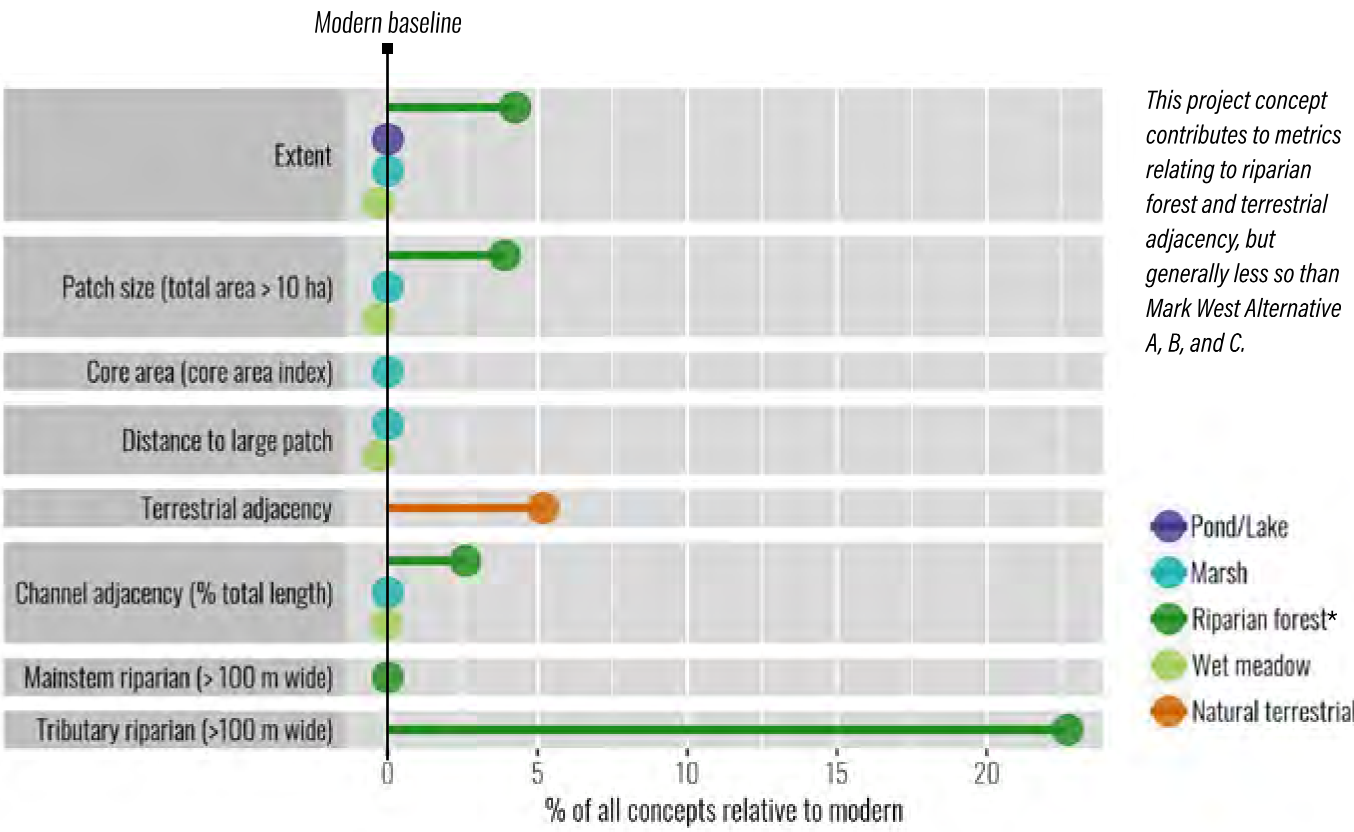
In addition to the benefits captured by the metrics, this creek realignment would shorten the migratory distance for spawning anadromous fish, relieve deleterious hydraulic conditions existing at the current confluence upstream, and create a wide, unconstrained alluvial area that would allow for sediment deposition and the creation of physically complex habitat.

KEY CONSIDERATIONS

This project concept is most likely the least expensive of the four Mark West alternatives, while simultaneously making the smallest impact on restoration landscape metrics and expected ecological benefits (see Prioritization and Sequencing criteria). Costs would include the building of a bridge to allow access to agricultural land and the rerouting of a treated wastewater pipe. Added habitat and associated ecological benefits are minimal, compared to the other alternatives, but it could result in increased flow conveyence and improved access to the watershed by native salmonids. As with other Mark West realignment concepts, hydraulic and sediment transport modeling will be important to assess the effects of different options and determine the relative value of each Mark West concept alternative.

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept contributes to metrics relating to riparian forest and terrestrial adjacency, but generally less so than Mark West Alternative A, B, and C.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

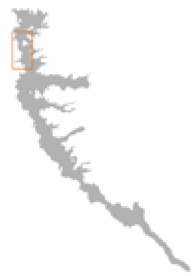
RESTORATION PROJECT CONCEPT FOR

BALLARD LAKE

1 INTRODUCTION: PAST AND PRESENT

2 ANNOTATED RESTORATION PROJECT CONCEPT

3 BENEFITS, CONSIDERATIONS, AND METRICS



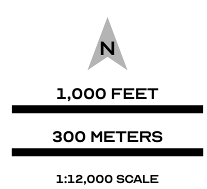
INTRODUCTION

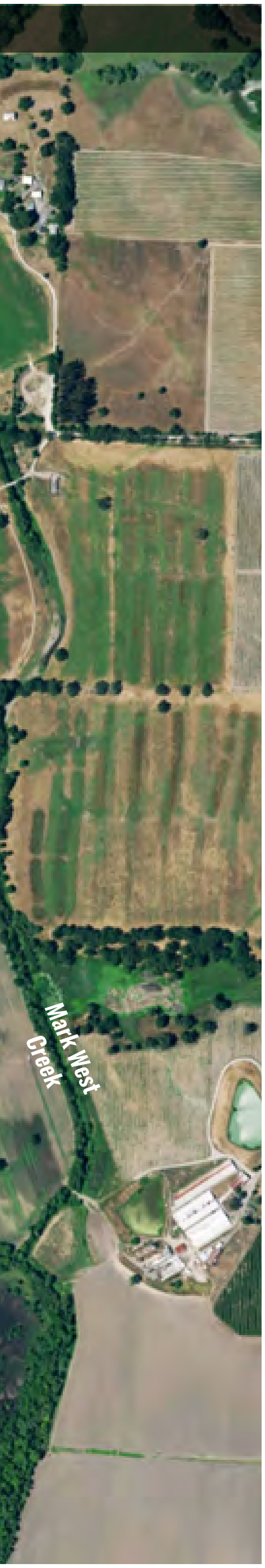
The Ballard Lake restoration project concept restores a deep historical lake along the Laguna mainstem, while introducing a large upstream area of valley freshwater marsh and willow forested wetland. The Laguna de Santa Rosa historically ran through several long, narrow, and relatively deep perennial lakes—of which Ballard Lake was the furthest north—likely formed by vertical displacement of the underlying Sebastopol fault (Nishikawa et al. 2013). Early botanical records and other historical evidence indicate that these lakes were deep, cold, oligotrophic water bodies. Aquatic plants like *Potamogeton illinoensis*, for instance, present in collections from around 1900, are relicts from the Pleistocene that only occur under these conditions. Modern channelization has caused a substantial loss of this habitat type for fish and waterfowl, with an associated increase of invasive aquatic plants such as invasive *Ludwigia* spp.

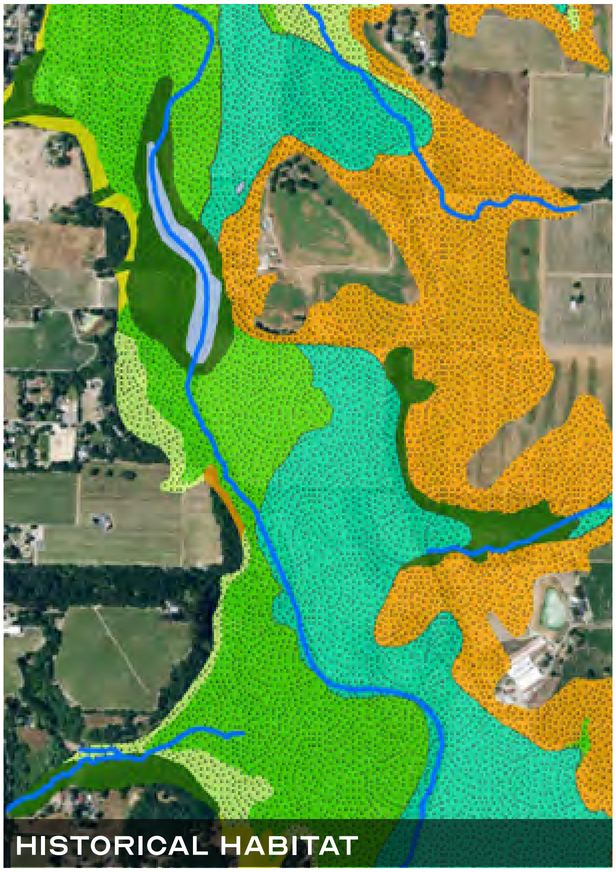
This concept would involve expanding the site of Ballard Lake to a maximum depth of over 6 m, expand the riparian buffer surrounding the lake, and introducing approximately 27 ha of freshwater marsh and 10 ha of willow forested wetland upstream of the restored lake. Given the history of intensive agriculture in the Laguna de Santa Rosa floodplain, steps must be taken during restoration to mitigate potentially harmful nutrient remobilization. These steps include chemical modification such as introduction of iron or aluminum compounds to precipitate excess phosphorus, growth and culling of aquatic plants to remove nutrients, or rapid bank stabilization or clean sediment capping to inhibit large-scale remobilization of legacy sediments.

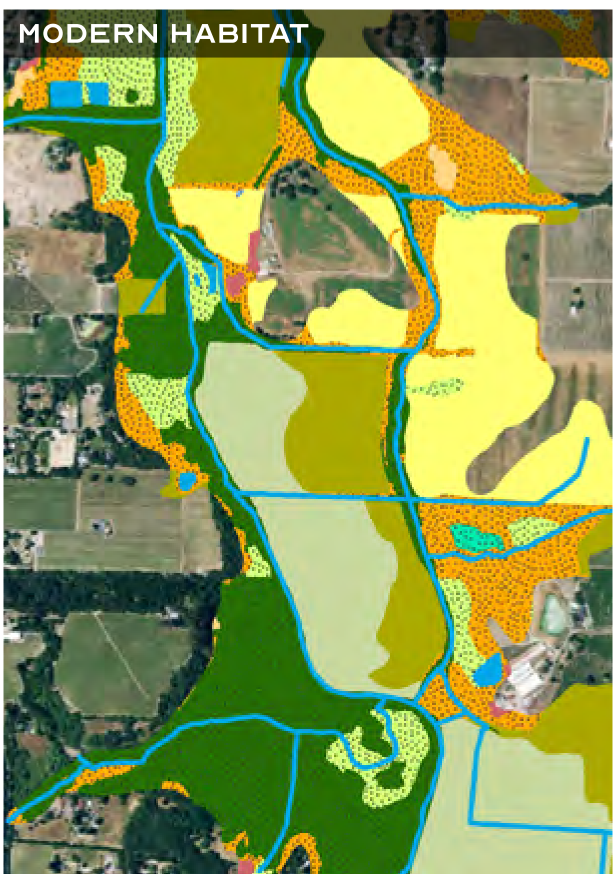
CONTEMPORARY LANDSCAPE

The area around former Ballard Lake is largely converted to agriculture, which still floods regularly due to the natural function and geography of the Laguna.









Former Ballard Lake has been drained and largely filled in. Mark West Creek, which was rerouted to flow into the lake in the early 20th century, was subsequently rerouted and its confluence with the Laguna now lies south of the former lake.

- *Perennial Freshwater Lake/Pond*
- *Seasonal Lake*
- *Oak Woodland*
- *Mixed Conifer Forest*
- *Vernal Pool Complex*
- *Grassland*
- *Oak Savanna*
- *Valley Freshwater Marsh*
- *Willow Forested Wetland*
- *Wet Meadow*
- *Mixed Riparian Forest*
- *Oak Savanna/Vernal Pool Complex*

N

1,000 FEET

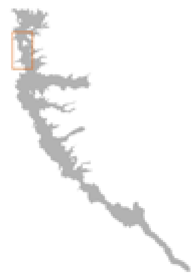
300 METERS

1:20,000 SCALE

- *Developed/Disturbed*
- *Farmed Wetland*
- *Forested Wetland and Mixed Riparian Forest/Scrub*
- *Hayfield/Pasture/Vernal Pool Complex*
- *Non-native Aquatic/Emergent Vegetation*
- *Oak Savanna or Woodland/Vernal Pool Complex/ Valley Grassland*
- *Other Agriculture*
- *Other Upland*
- *Perennial Freshwater Lake/Pond*
- *Storage Pond*
- *Valley Freshwater Marsh*
- *Wet Meadow*

Aside from the deep perennial lake, this area was characterized by extensive freshwater marshes and willow forested wetlands historically.

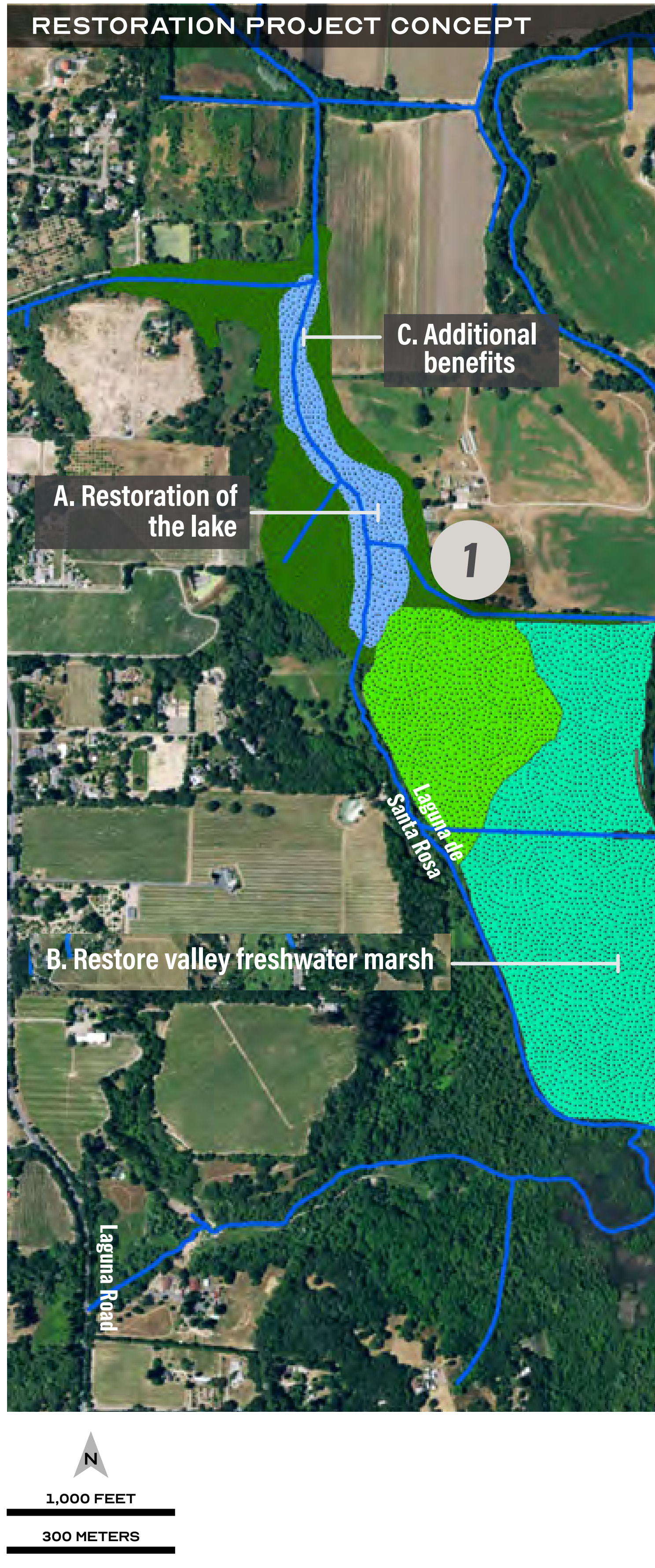
RESTORATION PROJECT CONCEPT FOR
BALLARD LAKE

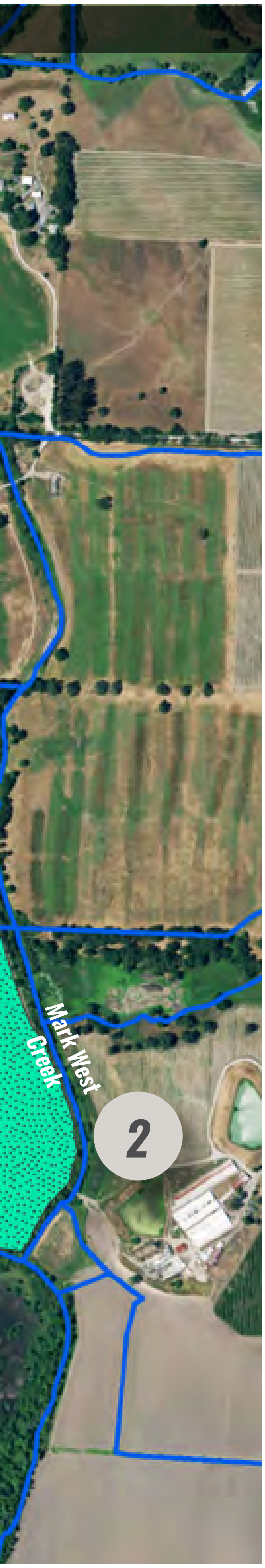


A. Restoration of the lake Restoration of the historical Ballard Lake would reintroduce valuable deep water (> 6 m) habitat at the northern end of the Laguna floodplain. Returning the lake to its historical depth would maintain colder water to support resident fish, as well as fish migrating from the Russian River, which the Laguna joins ~7 km downstream.

B. Restore valley freshwater marsh Restoring 27 ha of valley freshwater marsh would provide critical habitat and resources to a variety of native species. Freshwater marsh is the most diminished habitat in the modern landscape relative to historical conditions, and that which remains is highly degraded (SFEI-ASC 2020). A large patch of biodiverse freshwater marsh in an area of the Laguna where it has been eliminated would supply food and nesting habitat to native and migratory birds, and to various amphibians and reptiles. The high core-to-edge ratio of this proposed marsh would also ensure refuge for many species in the core of the marsh, buffered from predation and human disturbance at the marsh edge. The proximity of the marsh area to farmland also provides the possibility of substantial uptake of nutrients from agricultural runoff.

C. Additional benefits Deepening and restoring Ballard Lake holds several potential benefits beyond the addition of cold deep water habitat. Deepening the lake would inhibit growth of invasive *Ludwigia* spp., which currently dominates the shallow-water area of the former perennial lake. Additionally, periodic dredging to maintain the depth of the restored lake may be eligible for funding through the nutrient credit trading program.



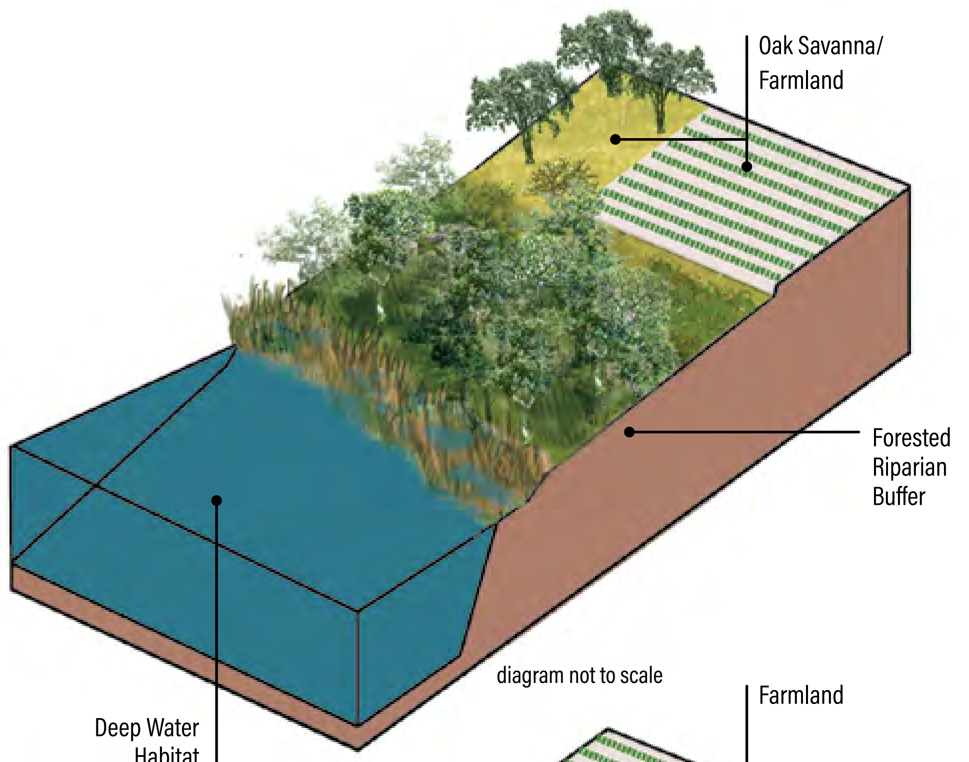


HABITAT TYPES

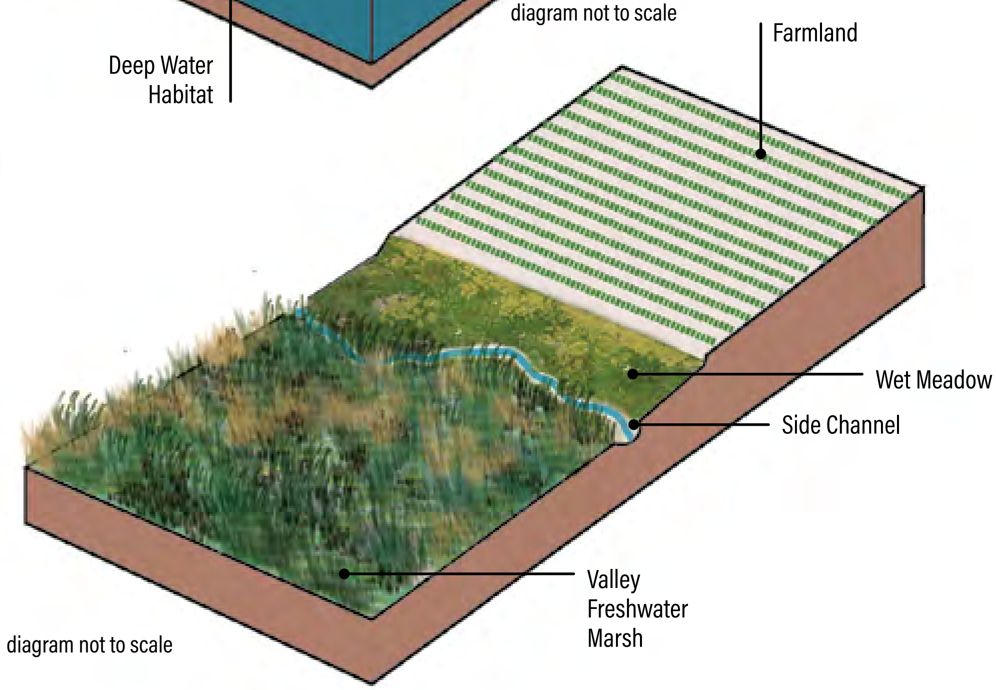
- *Freshwater Marsh*
- *Mixed Riparian Forest*
- *Perennial Freshwater Lake/Pond*
- *Willow Forested Wetland*

The proposed concept restores Ballard Lake to its previous depth of ~6-7.5 meters, and reintroduces extensive freshwater marsh and willow forested wetland upstream. Beyond providing habitat itself, the marsh has the potential to filter water flowing into the lake, enhancing water quality and its value as deep water habitat for fish.

1 Example habitat gradients within the restoration project concept



2



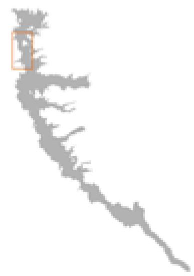
RESTORATION PROJECT CONCEPT FOR

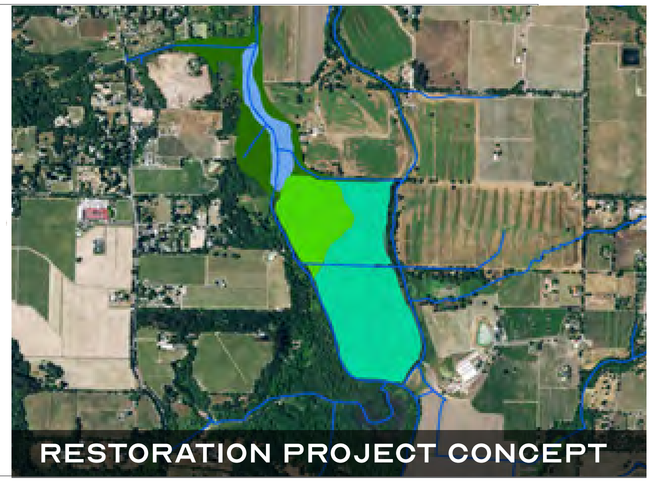
BALLARD LAKE

1 INTRODUCTION: PAST AND PRESENT

2 ANNOTATED RESTORATION PROJECT CONCEPT

3 BENEFITS, CONSIDERATIONS, AND METRICS





BENEFITS OF THE PROJECT

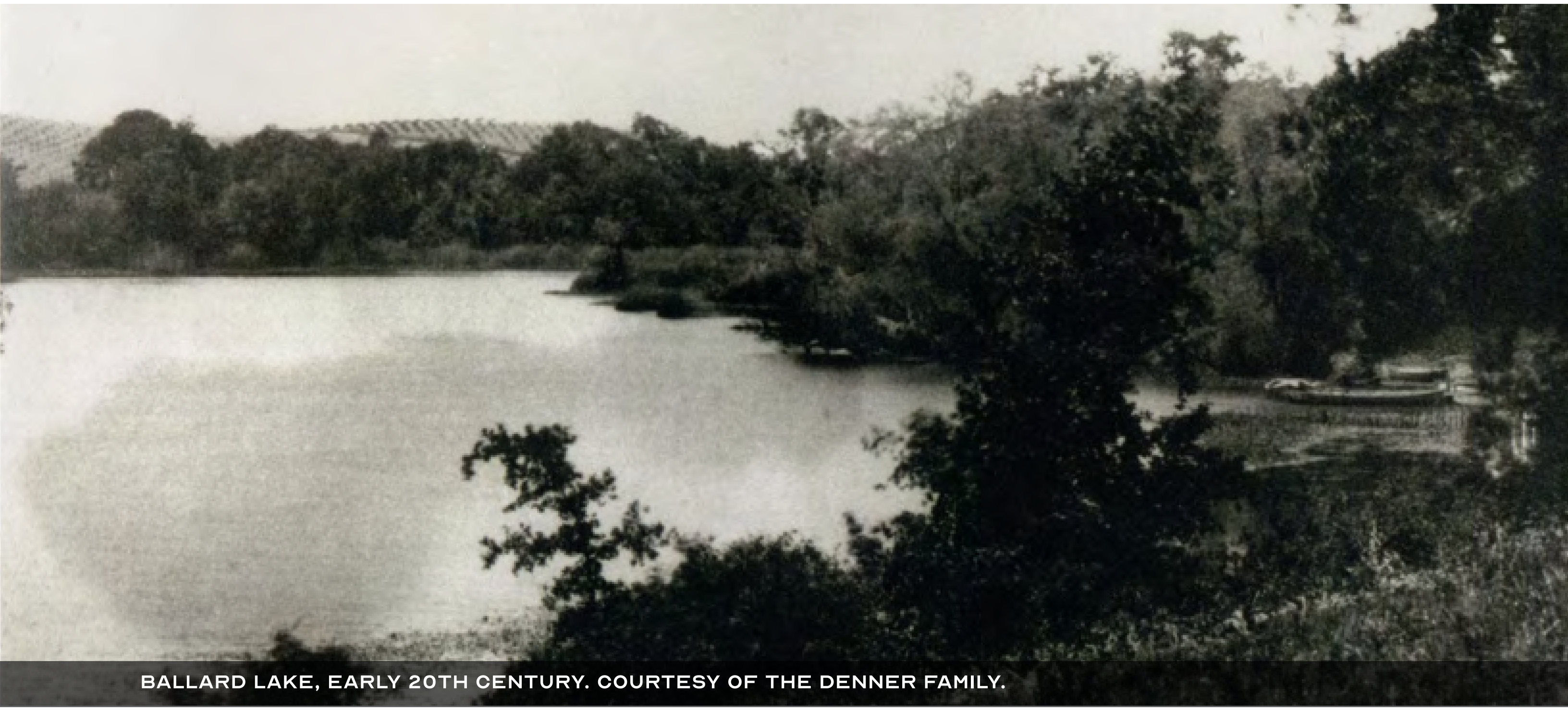
Restoration of Ballard Lake would increase perennial freshwater lake area by 5.2 ha, or a 16% increase from modern conditions, the most of any of the proposed restoration project concepts. Re-establishment of deep cool water habitat would provide benefits to native fish species, including overwintering habitat for coho.

The Ballard Lake restoration project concept leads to a marked increase in freshwater marsh habitat (~27 ha). The proposed freshwater marsh also has a high core-to-edge ratio, with a large amount of core area more than 50 m from the marsh edge, allowing for more protected habitat for species sensitive to stressors found near borders with other habitats or human activity. The size and position of the restored marsh also increases habitat connectivity, reducing the mean distance to a large marsh habitat patch (>10 ha) within the Laguna study area by ~300 m.

Restoration of Ballard Lake and the marsh upstream also have numerous potential benefits outside of the quantified landscape metrics. The size of the marsh and its proximity to nutrient sources (e.g., farmland) is expected to enhance nutrient assimilation, resulting in improved water quality, increasing dissolved oxygen in particular. Deepening the historical lake may also improve water conveyance during the late spring and early summer and make the lake less amenable to invasive *Ludwigia* sppgrowth.

KEY CONSIDERATIONS

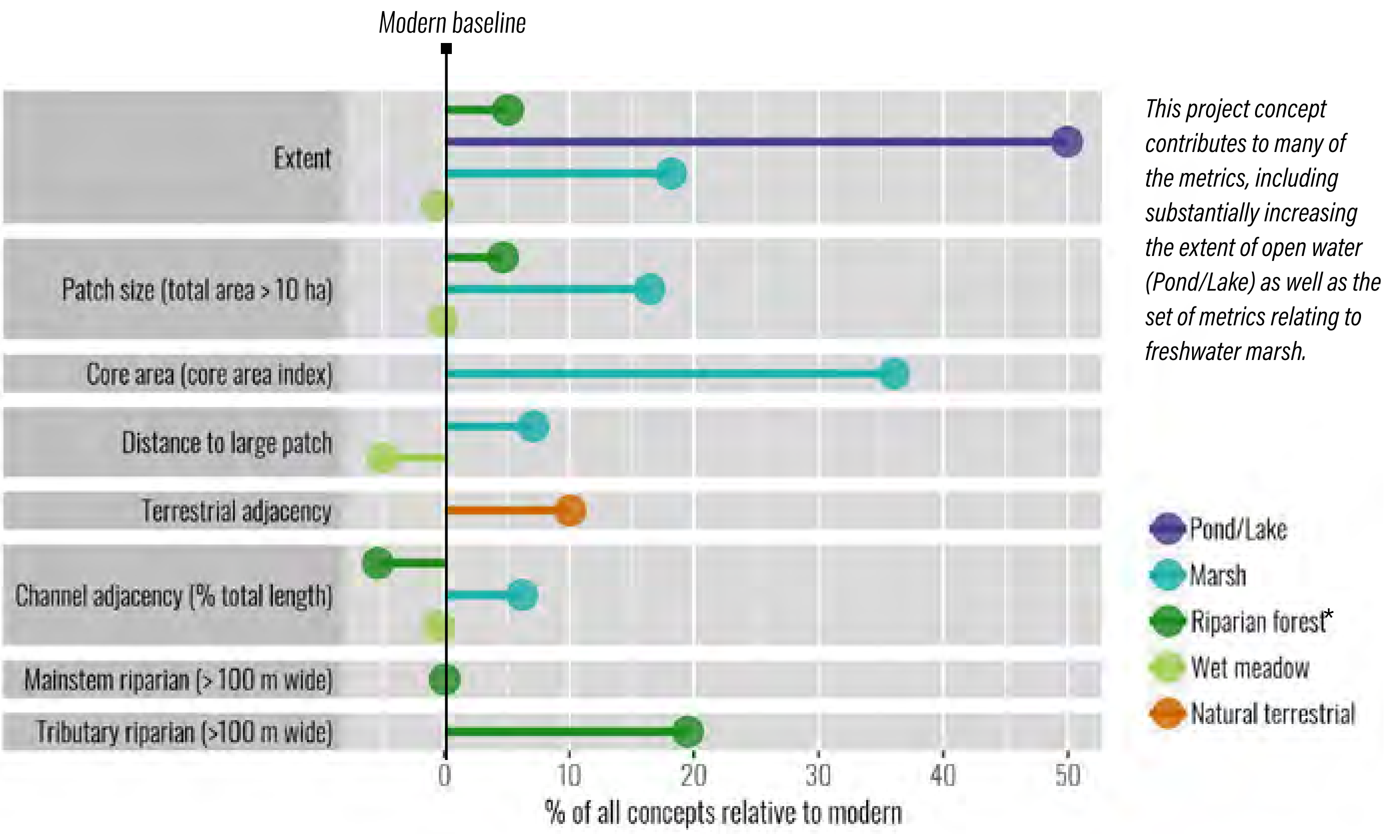
The confluence of the Laguna with Mark West Creek is currently located at the southern, upstream end of this restoration project concept. If this current configuration remains, then restoration designers must account for high levels of sedimentation in the proposed freshwater marsh, and likely within the lake as well. If Mark West Creek is realigned downstream of Ballard Lake before restoration of these habitats, then these sediment deposition concerns would be lessoned and the current Mark West channel could be repurposed as a side channel along the edge of the freshwater marsh and draining into the lake, which would increase hydrologic connectivity to the restored marsh. Dredging and removal of nutrient-laden sediments from Ballard Lake could supply phosphorus removal credits which could facilitate funding of the restoration project. Subsequent periodic maintenance dredging could help fund ongoing management and invasive species removal within the marsh and willow wetland habitats. After dredging Ballard Lake and regrading surrounding shores, restoration action must include rapid initial vegetative stabilization to prevent remobilization of fine sediment and legacy phosphorus.



BALLARD LAKE, EARLY 20TH CENTURY. COURTESY OF THE DENNER FAMILY.

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept contributes to many of the metrics, including substantially increasing the extent of open water (Pond/Lake) as well as the set of metrics relating to freshwater marsh.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

OCCIDENTAL–GUERNEVILLE

INTRODUCTION

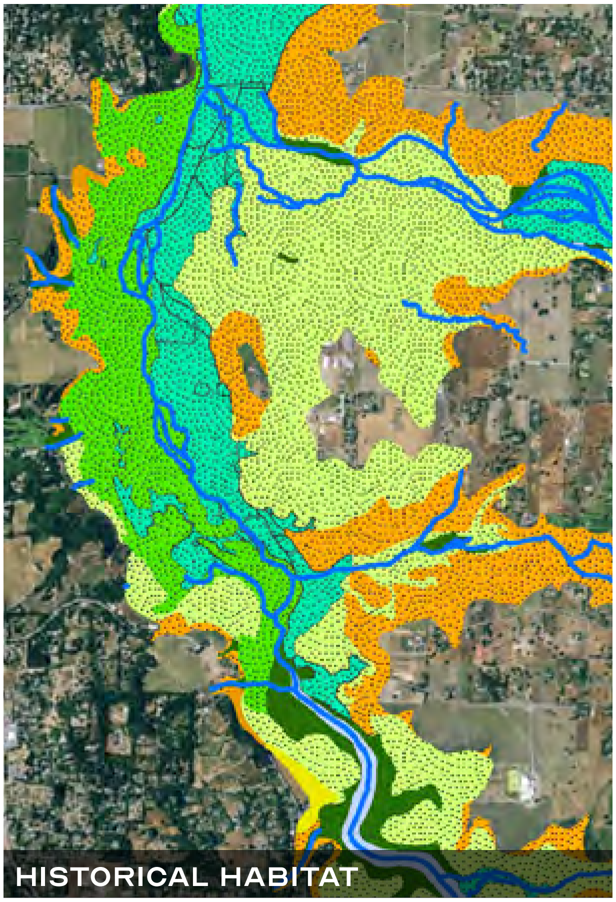
The restoration project concept between Occidental and Guerneville roads is the largest of the concepts, and consequently is associated with some of the largest changes to the landscape metrics and expected ecological benefits relative to other concepts. It entails the rerouting of the Laguna mainstem to a more natural geometry, and the conversion of a large area of invasive *Ludwigia* spp. and farmed wetland into restored freshwater marsh habitat.

Currently, the mainstem Laguna through this reach is channelized and straightened, with right angle turns navigating frequently inundated fields and sporadically farmed wetlands. Sediment from dredging and rerouting the mainstem was placed along the sides of the channel, creating artificial levees, and subsequent sediment deposition has elevated the channel bed above the surrounding floodplain. This has resulted in extensive and prolonged flooding as surrounding marsh and farmlands are unable to drain, leading to extensive invasion by aquatic *Ludwigia* spp.. The constricted and artificial geometry of the current channel also decreases flow conveyance.

This project concept would reroute and lower the mainstem channel to restore a more complex geometry and hydrologic connectivity to the floodplain and facilitate drainage. By reducing prolonged shallow inundation, it would reduce the potential of invasion by *Ludwigia* spp., supporting transformation into an expansive valley freshwater marsh. Wet meadow and willow wetland habitat surrounding the confluence of the Laguna and Irwin Creek would also be restored.

Invasive *Ludwigia* spp. (bright green vegetation) currently dominates the stagnant water held back by the dredging spoils of the rerouted Laguna mainstem.

N
1,000 FEET
300 METERS
1:22,000 SCALE



Historically, this area featured a large uninterrupted freshwater marsh, and extensive wet meadow habitats upstream of the Santa Rosa Creek confluence.

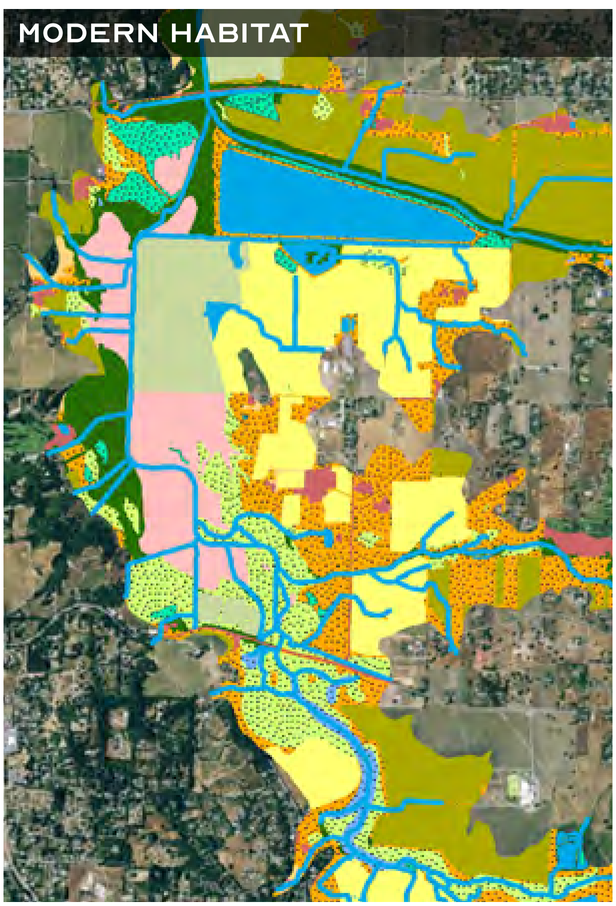
- *Perennial Freshwater Lake/Pond*
- *Seasonal Lake*
- *Oak Woodland*
- *Mixed Conifer Forest*
- *Vernal Pool Complex*
- *Grassland*
- *Oak Savanna*
- *Valley Freshwater Marsh*
- *Willow Forested Wetland*
- *Wet Meadow*
- *Mixed Riparian Forest*
- *Oak Savanna/Vernal Pool Complex*

N

2,000 FEET

500 METERS

1:40,000 SCALE



- *Developed/Disturbed*
- *Farmed Wetland*
- *Forested Wetland and Mixed Riparian Forest/Scrub*
- *Hayfield/Pasture/Vernal Pool Complex*
- *Non-native Aquatic/Emergent Vegetation*
- *Oak Savanna or Woodland/Vernal Pool Complex/ Valley Grassland*
- *Other Agriculture*
- *Other Upland*
- *Perennial Freshwater Lake/Pond*
- *Storage Pond*
- *Valley Freshwater Marsh*
- *Wet Meadow*

The stretch of the Laguna floodplain has undergone significant change, including channelization of Santa Rosa Creek and the Laguna around Delta Pond, rerouting of the Laguna mainstem, and the near-complete loss of freshwater marsh to farmland.

RESTORATION CONCEPT

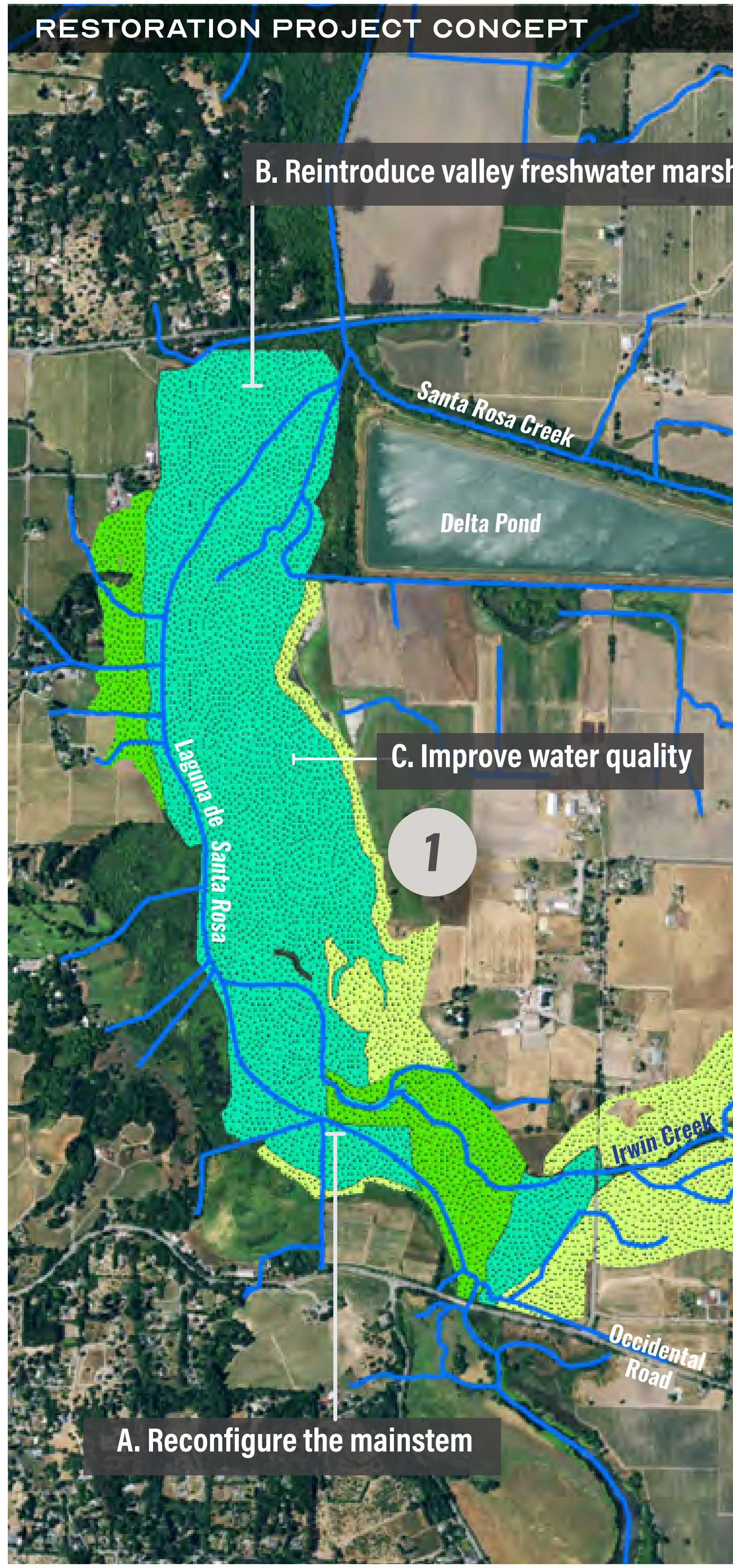
RESTORATION PROJECT CONCEPT FOR

OCCIDENTAL–GUERNEVILLE

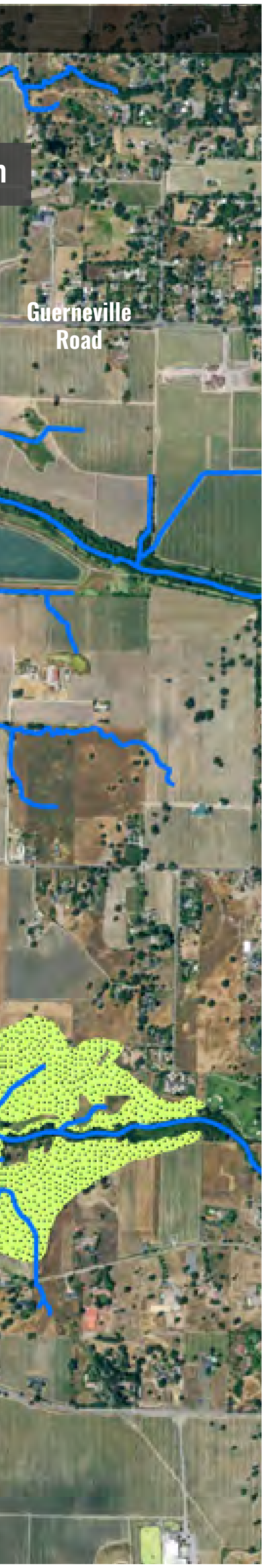
A. Reconfigure the mainstem The Laguna mainstem is currently routed through the concept area in a right-angled, "stairstep" geometry, with dredging spoils on either side of the channel, which has raised the channel above the floodplain with ongoing sedimentation. This constricts flow conveyance and prolongs flooding through the surrounding area through decreased connectivity between the floodplain and channel. A reconfiguration of the mainstem from its current state into a more complex, multi-threaded, and direct geometry would allow for greater hydrologic connectivity, and would reduce standing water on lands outside the channel, thereby enabling native vegetation to compete with invasive *Ludwigia* spp., which currently dominates the concept area.

B. Reintroduce valley freshwater marsh The center of this restoration project concept is the introduction of a very large (113 ha) valley freshwater marsh, located near the geographical center of the Laguna 100-year floodplain, and just upstream of the Laguna's largest tributary, Santa Rosa Creek. The size and location of this freshwater marsh give it substantial potential as a core habitat and a hub for native wildlife.

C. Improve water quality This area has legacy sediments that are a source of phosphorous to the Laguna. By filtering the Laguna mainstem through a large freshwater marsh via complex channels and sloughs, this restoration project concept offers the possibility of significant improvements in water quality through nutrient assimilation and fine sediment deposition, essentially converting a nutrient source into a nutrient sink.



N
1,000 FEET
300 METERS
1:22,000 SCALE



HABITAT TYPES

Freshwater Marsh

Mixed Riparian Forest

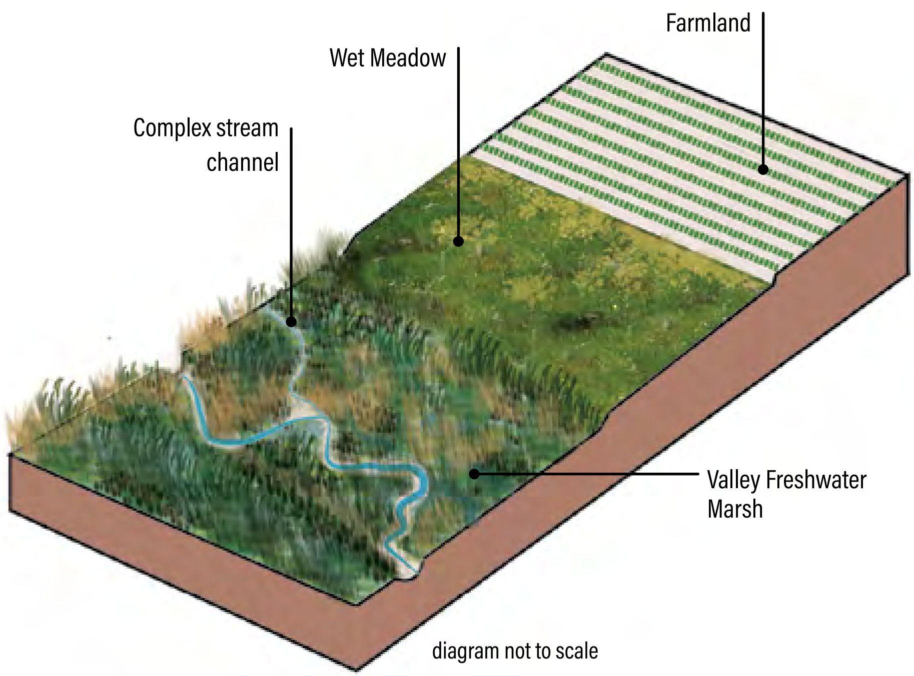
Oak Savanna/Vernal Pool Complex

Wet Meadow

Willow Forested Wetland

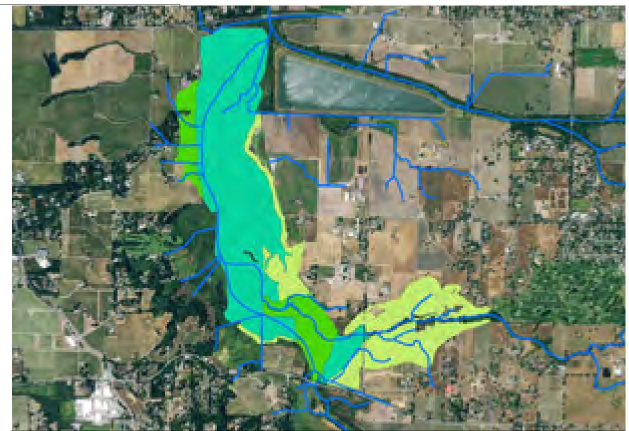
This restoration project concept restores a large area of freshwater marsh from frequently flooded and unproductive farmlands, and changes the current path of the mainstem Laguna into a more complex and connected channel network similar to historical conditions.

1 Example habitat gradient within the restoration project concept



RESTORATION PROJECT CONCEPT FOR

OCCIDENTAL–GUERNEVILLE



RESTORATION PROJECT CONCEPT

BENEFITS OF THE PROJECT

This project concept proposes a very large contiguous area of valley freshwater marsh, leading to substantial increases in landscape metrics associated with that habitat type. Overall marsh area would increase by 113 ha, providing more foraging habitat for migratory and resident birds, and floodplain food resources for rearing of juvenile salmonids and other native fish. Expanding valley freshwater marsh on the northeastern portion of the site would require levee removal, which would decrease local flow constriction and help alleviate slow drainage in this portion of the Laguna.

The marsh expansion also increases the area of large marsh patches, increasing total area of marsh patches greater than 10 ha by 106 ha, or a 187% increase from the modern study area. The restored marsh, with its large areal extent, would increase the marsh core area index from 0.04 to 0.50 for the Laguna floodplain. Additionally, the central location of the Occidental-Guerneville concept leads to a 1.3 km decrease in the average distance to a large marsh patch within the floodplain. This concept expands habitat availability for species that rely on multiple types of habitat, or travel between marsh patches.

Wet meadow expansion along the confluence with Irwin Creek and along the marsh edge leads to an overall increase of 31.3 ha of that habitat type.

There are also significant ecological and physical benefits associated with this restoration project concept not captured by the landscape metrics. Large-scale expansion of emergent freshwater marsh is expected to generate substantial uptake and assimilation of nutrients borne by runoff from surrounding agricultural uplands, improving water quality within and downstream of the concept area. Expansion of seasonally inundated wet meadow habitat will also increase nutrient uptake.

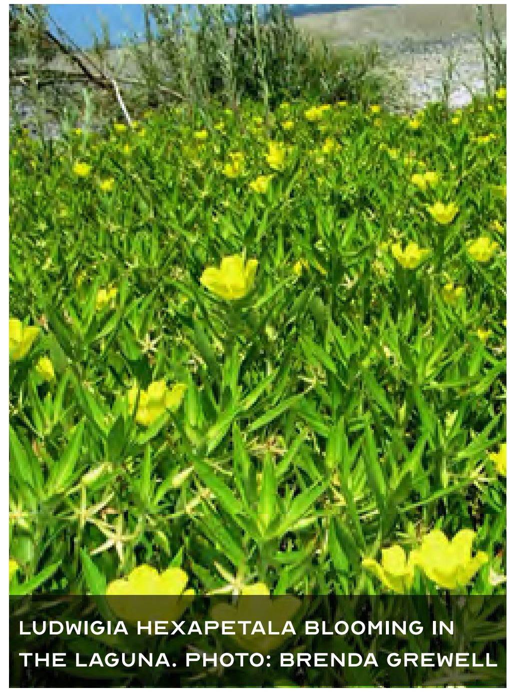
Dredging and rerouting the mainstem Laguna to a more natural course is also expected to improve drainage and facilitate fish passage. The Occidental-Guerneville concept is located just upstream of the Laguna's confluence with Santa Rosa Creek, its largest tributary. Large scale habitat restoration at this confluence could produce a habitat node at the terminus of the Santa Rosa Creek riparian corridor, enhancing connectivity for wildlife between the Laguna floodplain and upstream habitats.

Finally, replacement of invasive *Ludwigia* spp. with native marsh plant species would improve water quality and provide a native plant propagule source for freshwater marsh areas downstream.

KEY CONSIDERATIONS

The size of this concept implies significant benefits for the Laguna de Santa Rosa ecosystem, but could also mean relative difficulty in implementation compared to other restoration project concepts. This concept will likely have to be executed in multiple phases over several work seasons, beginning with the rerouting of the mainstem and grading of the surrounding area, followed by a phased habitat restoration. Initial dredging of the channel and subsequent sediment removal may be eligible for funding through the nutrient credit trading program.

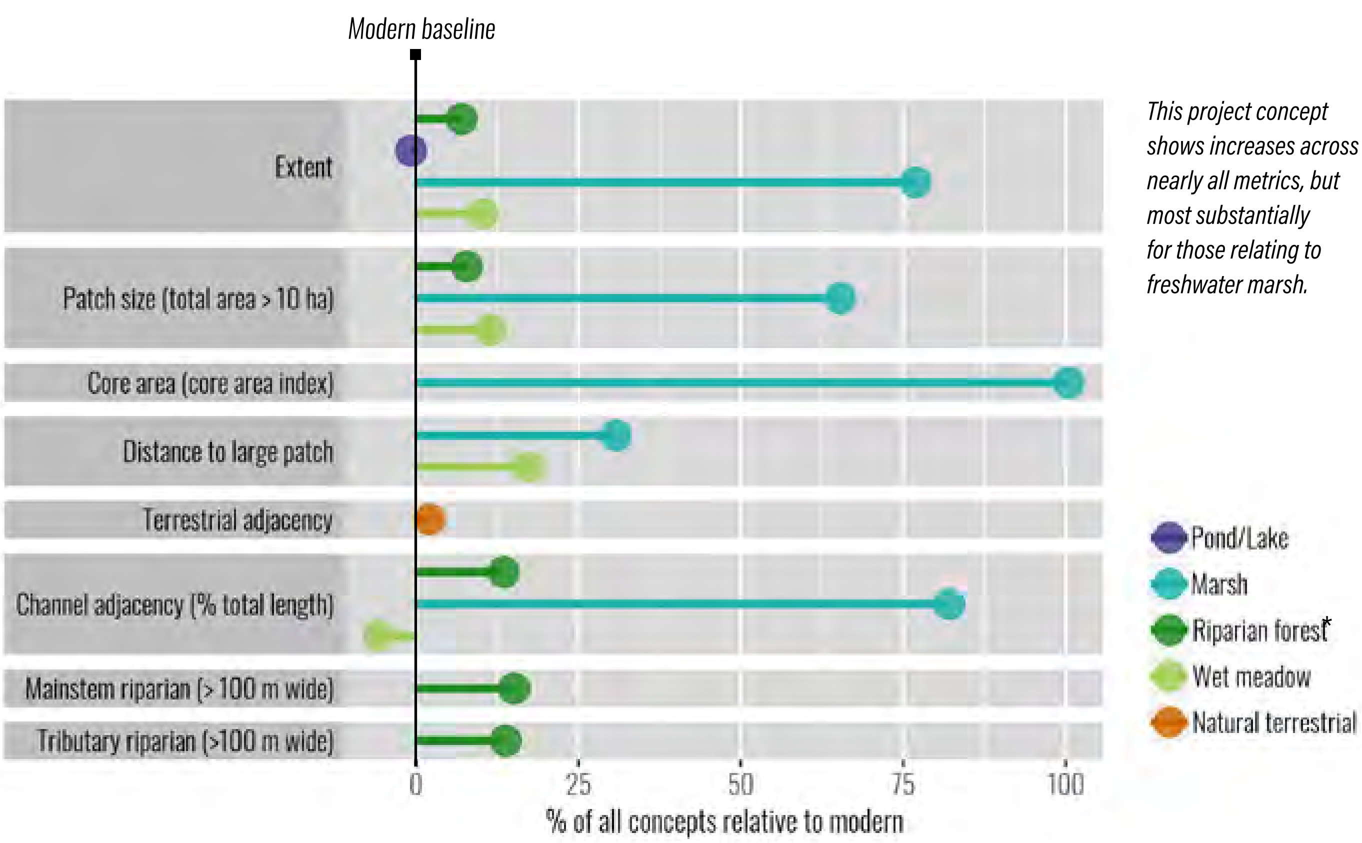
Finally, the overwhelming presence of *Ludwigia* spp. in the area will continue to be a concern. Though improved drainage should help to mitigate *Ludwigia* spp. growth by increasing competition from native plant species, execution of this concept should include an ongoing invasive *Ludwigia* spp. eradication and management plan, especially in the years immediately following restoration, when native marsh plant communities are still in the process of establishing and maturing.



LUDWIGIA HEXAPETALA BLOOMING IN THE LAGUNA. PHOTO: BRENDA GREWELL

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept shows increases across nearly all metrics, but most substantially for those relating to freshwater marsh.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

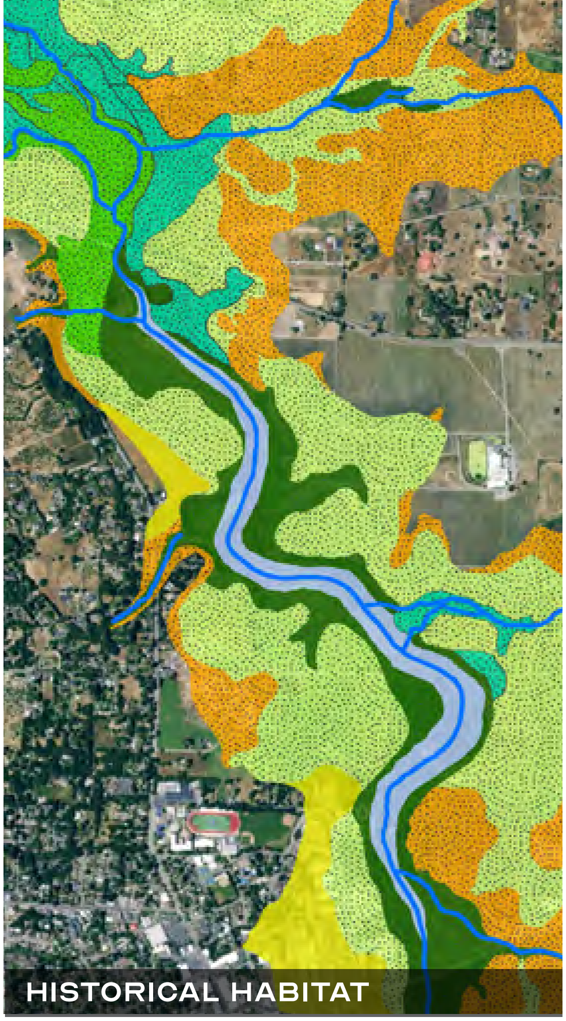
LAKE JONIVE

INTRODUCTION

Lake Jonive, located just south of Occidental Road, is the Laguna's largest and only remaining historical perennial freshwater lake. Like Ballard Lake, it likely formed by vertical displacement of the underlying Sebastopol fault. Historically, it extended 3 km from Occidental Rd. south to Hwy 12, and had a maximum depth of 7 m (SFEI-ASC 2020). Today, due to drainage efforts and high rates of sedimentation, Lake Jonive has reduced in size by approximately 50% (from ~27 ha to ~14 ha) and is shallower than it was during the mid-19th century (Butkus 2011a). The shallower lake enables the growth of invasive *Ludwigia* spp., depleting dissolved oxygen and outcompeting native wetland plants. The historical forested riparian buffer adjoining the historical lake has largely disappeared, and the majority of the surrounding wet meadow habitat has been converted to vineyards and pasture.

The Lake Jonive restoration project concept involves dredging the lake to historical depths, supporting a return of cold water habitat. It would expand a forested riparian buffer surrounding the lake and extending to the south around the inter-channel area called Dei Island, increasing forested wetland and mixed riparian habitat by 36 ha. It would also expand wet meadow habitat by 53 ha, shifting pasture and other agricultural land to seasonally-inundated habitats.

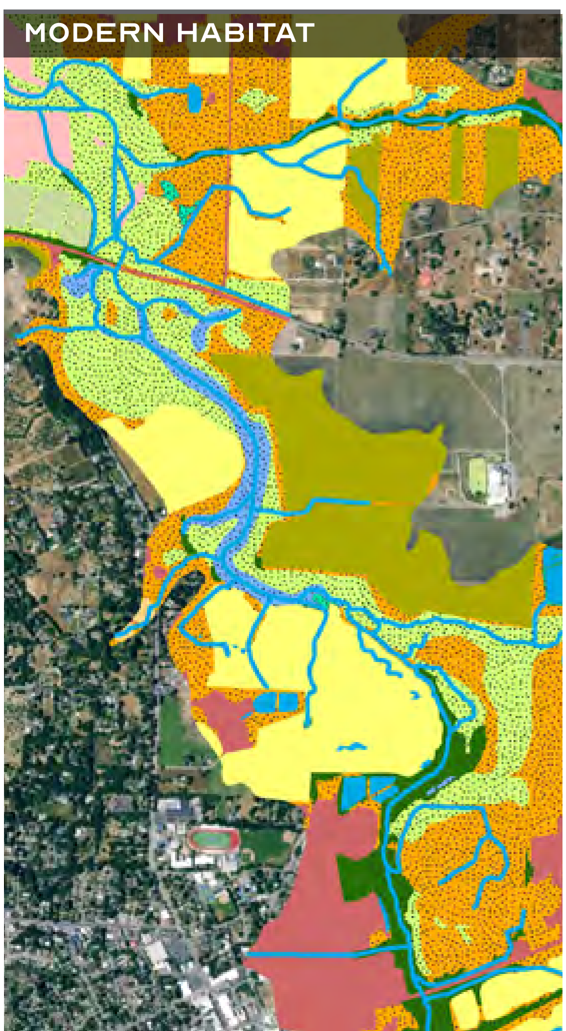
(Contemporary landscape, right) Since the 19th century, Lake Jonive has diminished in both extent and in depth. It has lost most of its surrounding riparian forest, and is dominated by invasive *Ludwigia* spp., visible in this aerial image (bright green aquatic vegetation). Surrounding wet meadow habitat has largely been converted to agriculture.



HIstorically, Lake Jonive had a much larger areal extent, and had depths of over 6 meters. It was fringed on all sides by a forested buffer, and surrounded by wet meadow habitat.

Perennial Freshwater Lake/Pond
Seasonal Lake
Oak Woodland
Mixed Conifer Forest
Vernal Pool Complex
Grassland
Oak Savanna
Valley Freshwater Marsh
Willow Forested Wetland
Wet Meadow
Mixed Riparian Forest
Oak Savanna/Vernal Pool Complex

N
1,000 FEET
300 METERS
1:24,000 SCALE



Developed/Disturbed
Farmed Wetland
Forested Wetland and Mixed Riparian Forest/Scrub
Hayfield/Pasture/Vernal Pool Complex
Non-native Aquatic/Emergent Vegetation
Oak Savanna or Woodland/Vernal Pool Complex/ Valley Grassland
Other Agriculture
Other Upland
Perennial Freshwater Lake/Pond
Storage Pond
Valley Freshwater Marsh
Wet Meadow

Today, Lake Jonive has been sedimented to shallow depths and a reduced area. Trees that shaded its waters are mostly gone, and it is surrounded by farmland.

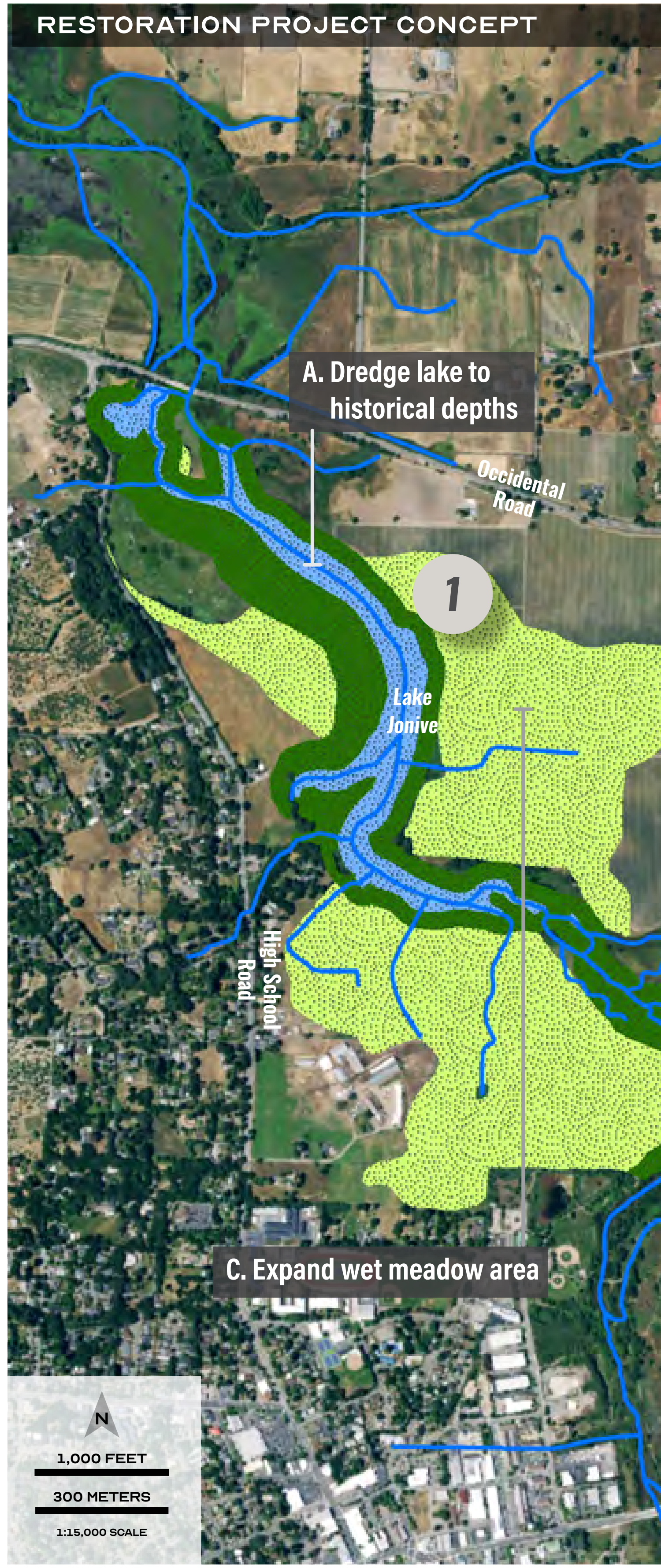
RESTORATION PROJECT CONCEPT FOR

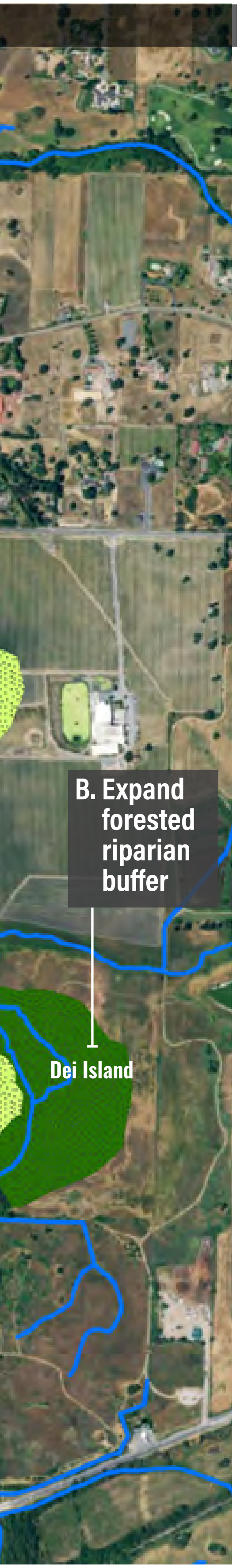
LAKE JONIVE

A. Dredge lake to historical depths Lake Jonive would maintain its current extent, but would be dredged to its historical depths (~7.5 m). This would provide cold water habitat for resident and anadromous fish. Deepening the lake would also inhibit the growth of invasive *Ludwigia* spp., which currently covers large portions of the lake's surface and diminishes water quality through annual decomposition.

B. Expand forested riparian buffer This concept includes an expanded riparian buffer along the edge of the lake and to the south at the area known as Dei Island. Shading of the Laguna and the lake from mature trees would lower water temperatures, and discourage growth of invasive *Ludwigia* spp. This habitat expansion would also serve as a valuable refuge and a corridor for movement of wildlife.

C. Expand wet meadow area A substantial expansion of wet meadow (53 ha) around the area of Lake Jonive would enhance nutrient assimilation from surrounding agricultural sources, as well as provide food and habitat for a variety of native species. Wet meadow can also trap sediment during flood events.



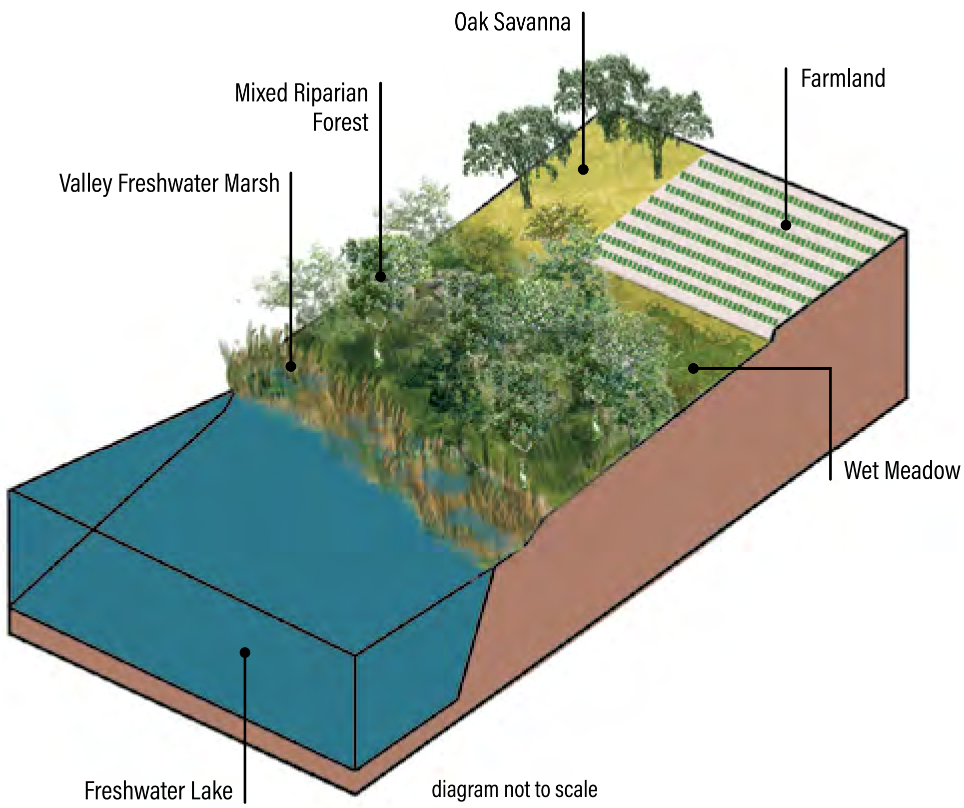


HABITAT TYPES

- *Mixed Riparian Forest*
- *Perennial Freshwater Lake/Pond*
- *Wet Meadow*

A restored Lake Jonive could be a valuable resource for wildlife and people. Deepening the lake and allowing for cooler waters, while expanding the forested riparian buffer, will enhance the the ecological functioning and habitat conditions of this unique feature in the Laguna landscape. Restoration of historical habitats and conditions will also improve recreational opportunities for people looking to enjoy the lake.

1 Example habitat gradient within the restoration project concept



RESTORATION PROJECT CONCEPT FOR

LAKE JONIVE

1 INTRODUCTION: PAST AND PRESENT

2 ANNOTATED RESTORATION PROJECT CONCEPT

3 BENEFITS, CONSIDERATIONS, AND METRICS

RESTORATION PROJECT CONCEPT

BENEFITS OF THE PROJECT

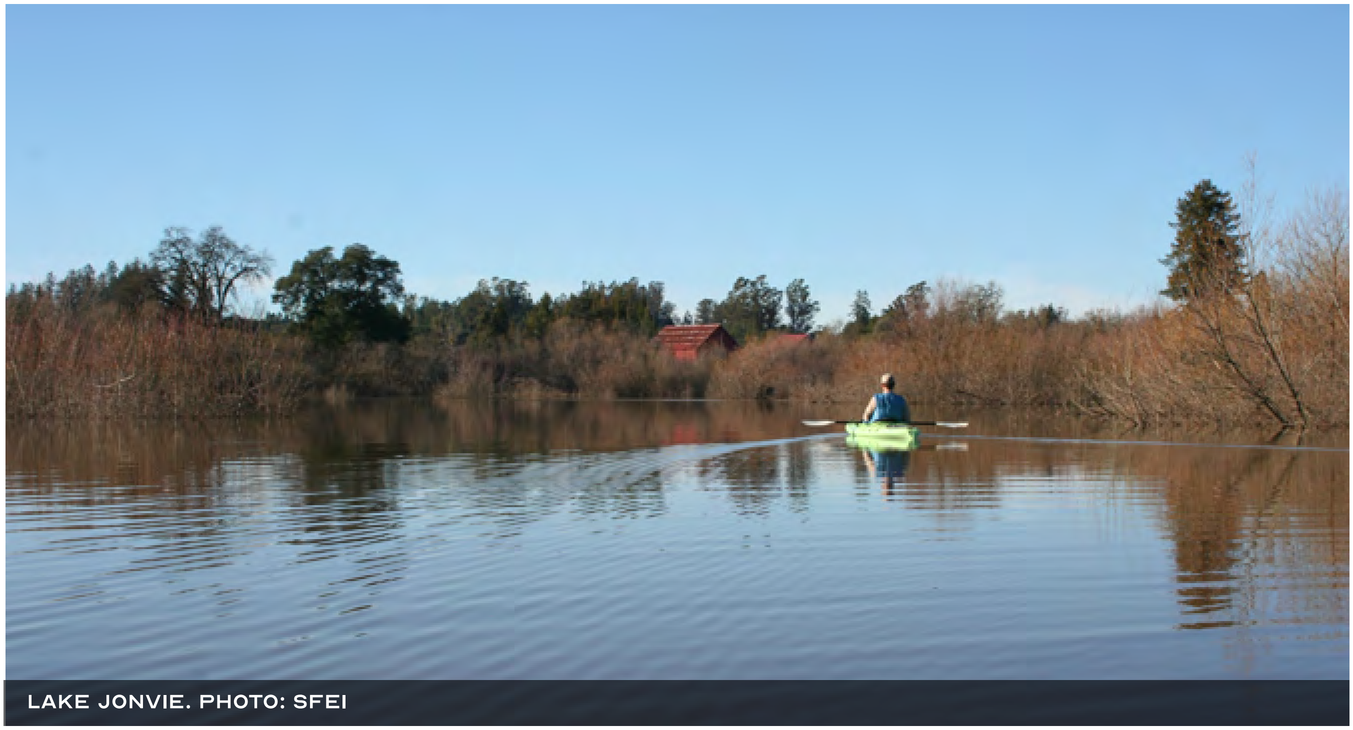
Surrounding Lake Jonive, riparian forest expansion by 36 ha would increase native biodiversity, increase channel shading and inputs of food resources for fish, and increase filtering of pollutants. The riparian expansion in this concept creates the second greatest change in the length of channel with wide (>100 m) riparian forest, from 3.1 km to 5.0 km. Also, the significant expansion of wet meadow habitat (53 ha) supports biodiversity and provides nesting and foraging habitat for native birds, reptiles, and amphibians.

There are also multiple benefits that are not captured by landscape metrics. Removal of nutrient-laden legacy sediment would have considerable benefits for the overall water quality in the Laguna. Though the extent of Lake Jonive would not change, restoring Lake Jonive to a depth of >7 m would increase deep cold water habitat for native anadromous fish and diving waterfowl. It will also decrease the viability of invasive *Ludwigia* spp. growth in the water column, as light attenuates in the deeper water. Riparian expansion along the lake bank will increase water shading, inhibiting *Ludwigia* spp. growth in shallows, while also lowering water temperature to the benefit of aquatic species. Finally, expansion of wet meadow habitat between the Laguna mainstem and upland agriculture will improve nutrient uptake and assimilation from those sources.

KEY CONSIDERATIONS

Though it is not reflected in the modern habitat assessment of the study area, some portions of this concept's proposed riparian restoration have been planted or are underway. These areas consist of a riparian buffer between Lake Jonive and vineyards to the east, as well as forested riparian expansion southeast of the lake around Dei Island.

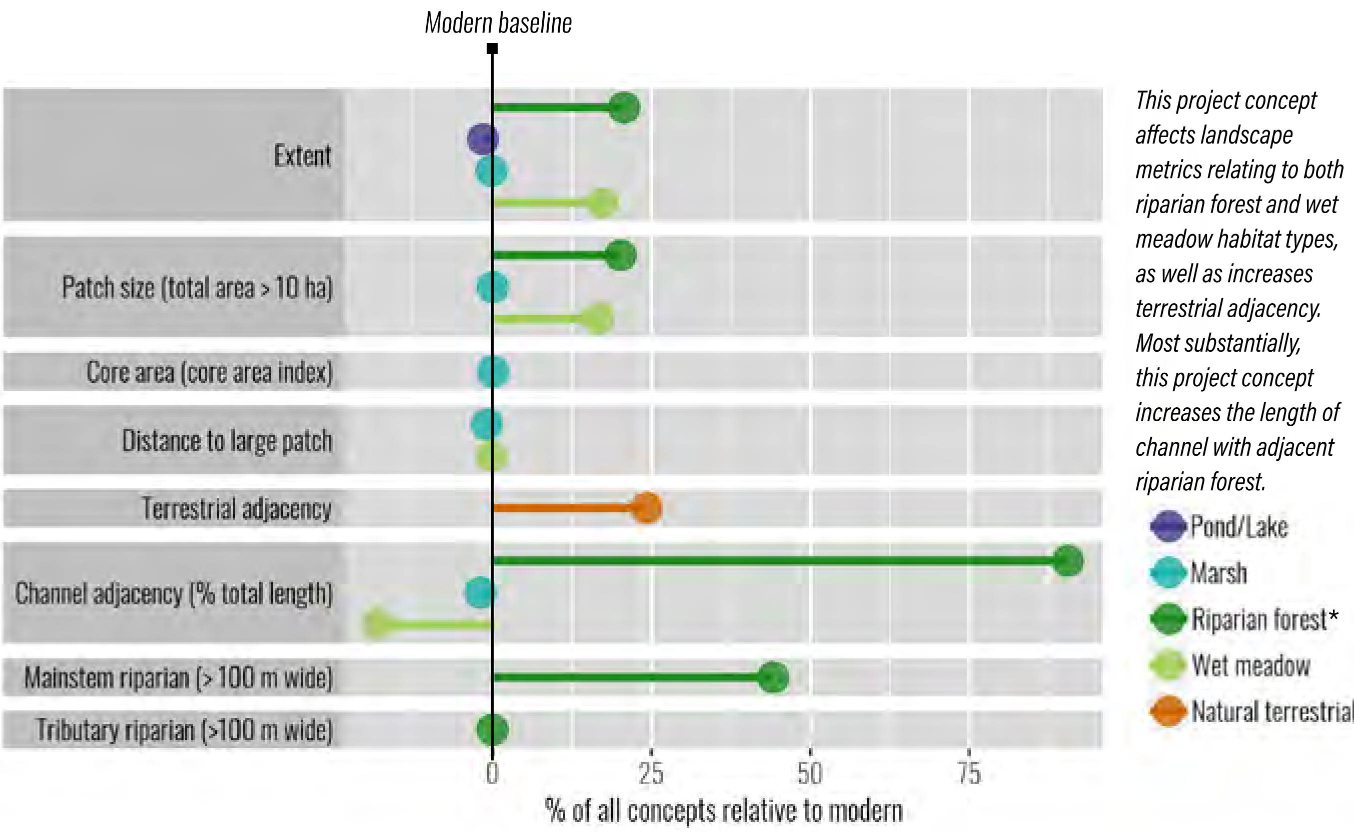
Dredging Lake Jonive of sediment accumulated over the past 150 years would remove nutrient-laden fine sediment from the system, which would help improve overall water quality and habitat conditions. A deepened and expanded Lake Jonive could trap a considerable amount of sediment, ameliorating sedimentation problems for restored areas and other habitats downstream. Due to continuing sedimentation, Lake Jonive will likely require periodic dredging to maintain depths that will support native fish and inhibit invasive *Ludwigia* spp. Steps should be taken to minimize negative impacts of remobilized nutrients during dredging (similar to the steps taken for Ballard Lake). Finally, Lake Jonive is currently overwhelmed by invasive invasive *Ludwigia* spp. growth. Lake dredging and riparian shading should be accompanied by a long-term invasive *Ludwigia* spp. eradication and management plan in order to maintain water quality and support native aquatic plants. Riparian tree plantings should also be accompanied by a dense ground layer of native plants to suppress growth of invasive *Ludwigia* spp.



LAKE JONVIE. PHOTO: SFEI

LANDSCAPE METRICS COMPARISON (below)

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.

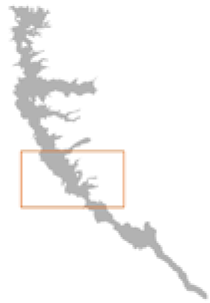


This project concept affects landscape metrics relating to both riparian forest and wet meadow habitat types, as well as increases terrestrial adjacency. Most substantially, this project concept increases the length of channel with adjacent riparian forest.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

HWY 12-WWTP



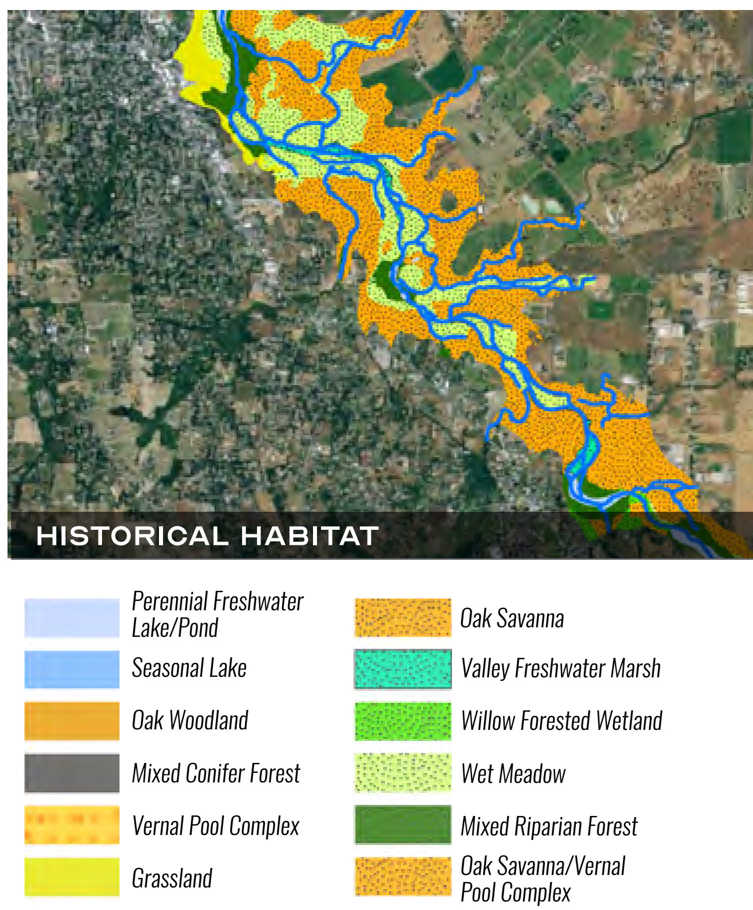
INTRODUCTION

The area of the Laguna floodplain between Highway 12 and the Santa Rosa Wastewater Treatment Plant (WWTP) is not as substantially impacted in terms of habitat loss and degradation compared to most other restoration project concept areas. The greatest physical impact on the area is the presence of the WWTP, which forces the confinement and channelization of the Laguna to the south and west, and Colgan Creek to the north, thereby bifurcating the floodplain between the two waterways. North and east of the Laguna, historical wet meadow and oak savanna/vernal pool complex have been mainly converted to hayfields and other low-intensity agriculture, while some low-density development and farming impinges to the west and south.

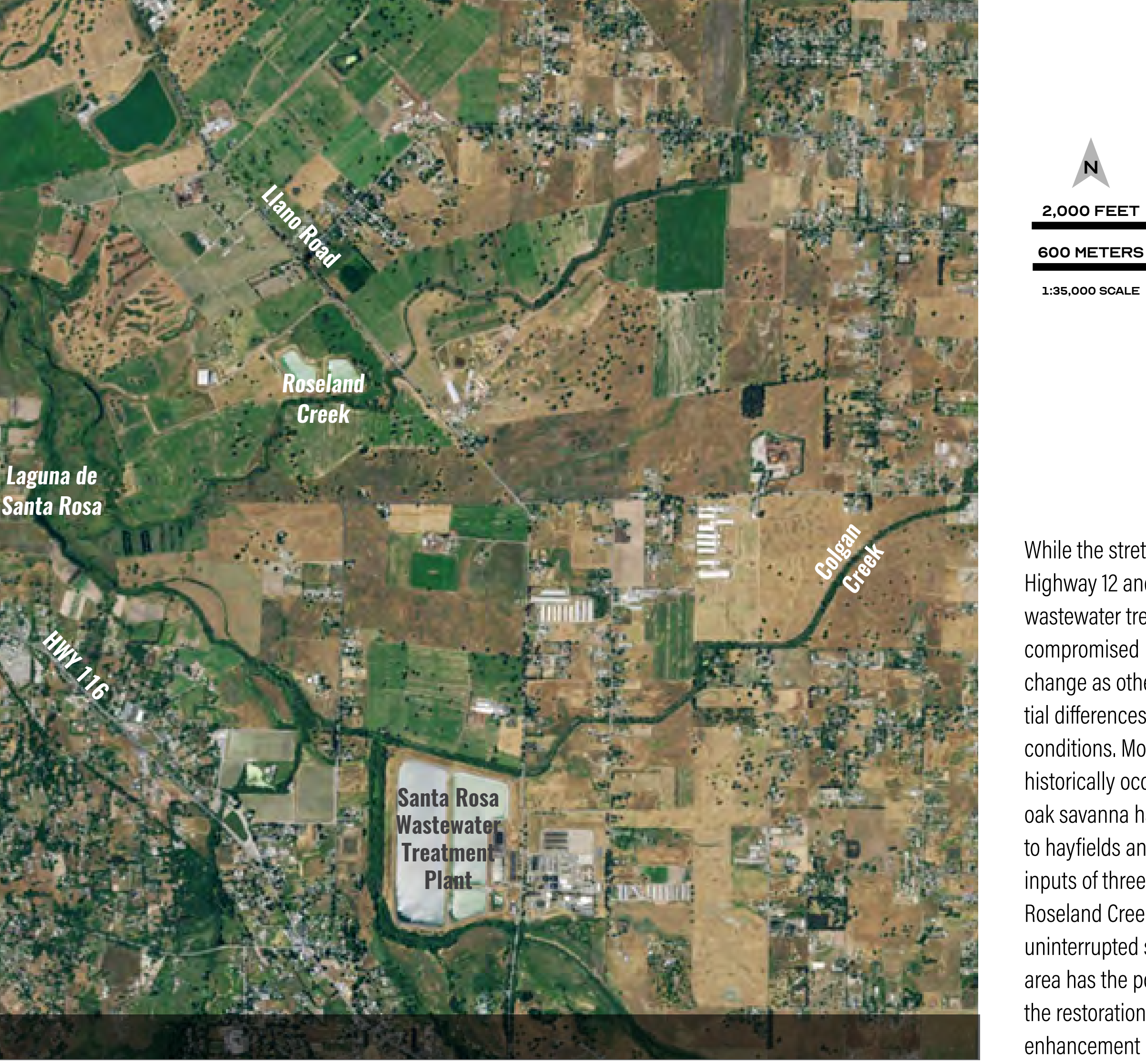
This concept involves the expansion of wet meadow surrounding the Laguna along the northern and southern stretches of the concept, ultimately adding ~105 ha. This concept also includes the dredging and deepening of a historical perennial lake, surrounding it with a 100 m forested riparian buffer. Finally, it restores and connects valley freshwater marsh habitat around the confluence of Roseland Creek and the Laguna, and along the Laguna mainstem at the northern end of the concept.

Much of the ecological potential for this concept comes from enhancement of existing habitats. Though disturbed, large areas of natural habitat types persist. Habitat enhancement for this concept includes the introduction of diverse freshwater marsh species, planting of additional oak trees, and vegetation planting to enhance seasonal vernal pools.

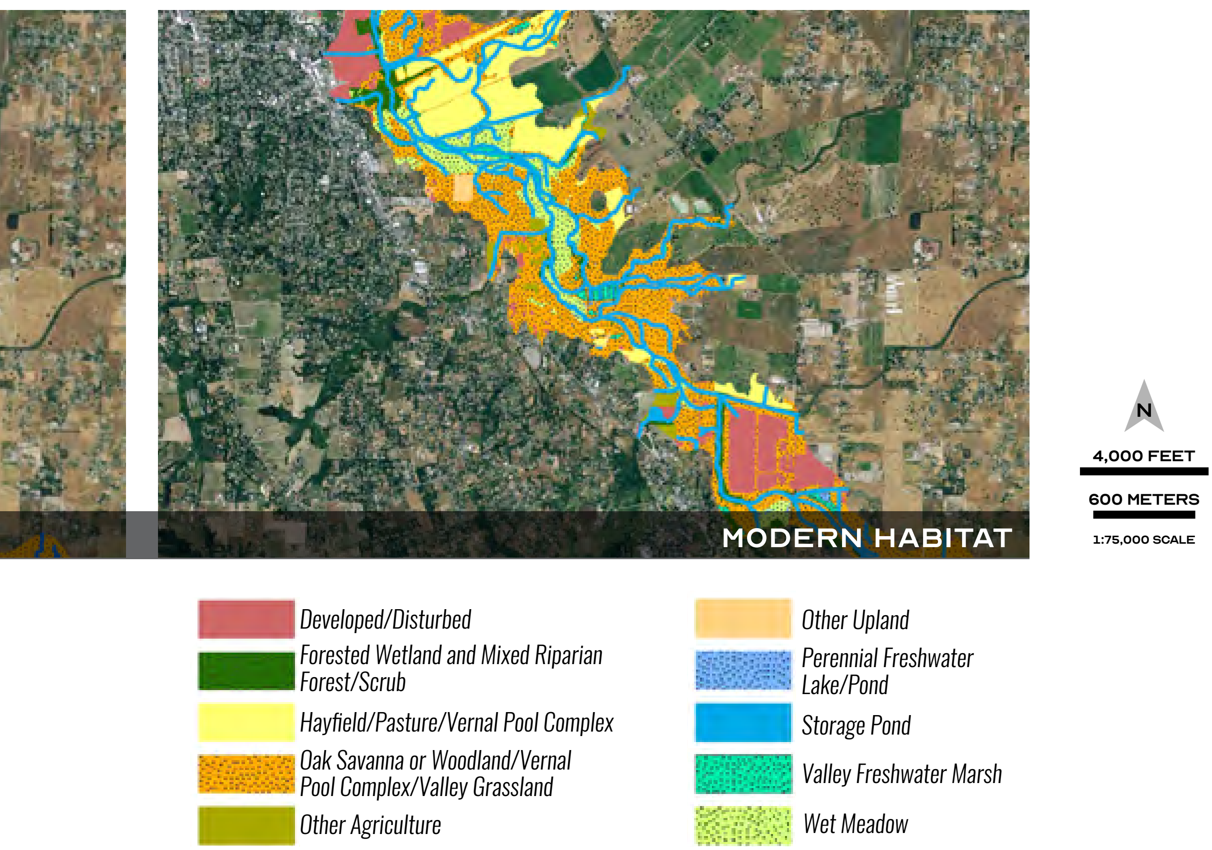
CONTEMPORARY LANDSCAPE



HISTORICAL HABITAT

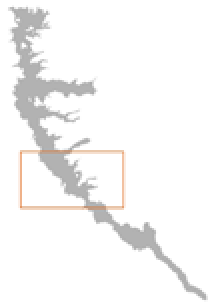


While the stretch of the Laguna between Highway 12 and the City of Santa Rosa's wastewater treatment plant (WWTP) is not as compromised by development and land use change as other areas, there are still substantial differences between historical and modern conditions. Most notably, substantial areas historically occupied by wet meadow and oak savanna habitats have been converted to hayfields and pasture. With the hydrologic inputs of three tributaries in Gravenstein Creek, Roseland Creek, and Colgan Creek, and large uninterrupted swaths of open space, this area has the potential to benefit greatly from the restoration of historical habitats and the enhancement of existing habitats.



RESTORATION PROJECT CONCEPT FOR

HWY 12-WWTP

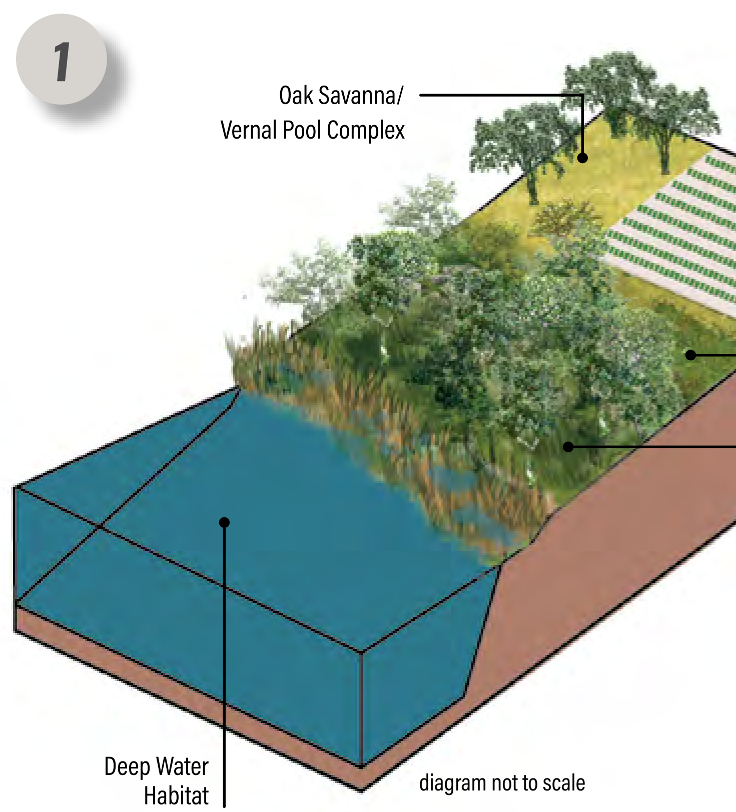


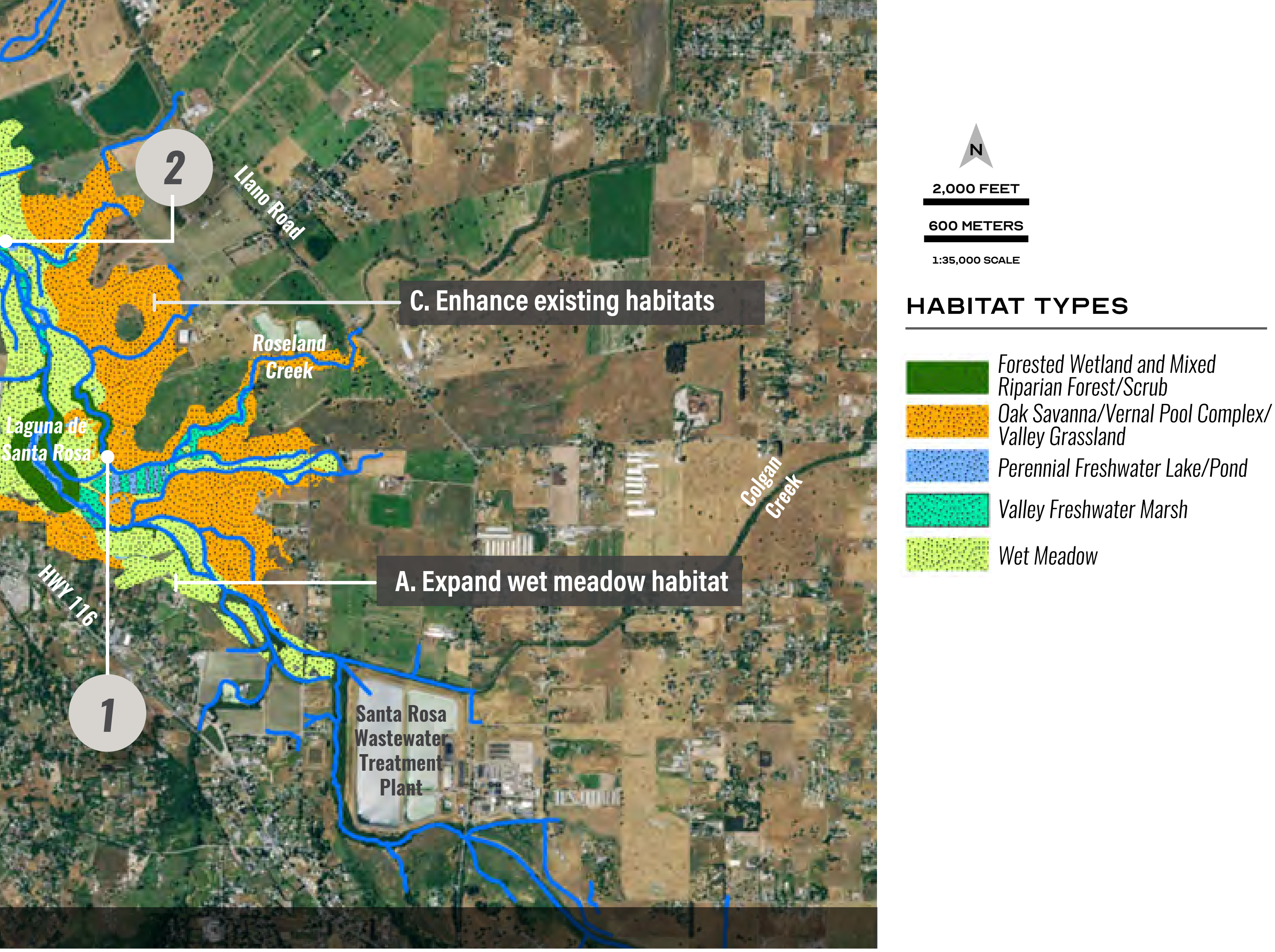
A. Expand wet meadow habitat The HWY 12-WWTP restoration project concept adds ~105 ha of wet meadow habitat to the Laguna floodplain, especially at the far northern and southern ends of the concept. These expanded wet meadows would increase nutrient assimilation and improve water quality, and provide a wide and variable assemblage of plant species to support native wildlife.

B. Build on existing restoration This concept builds upon some smaller-scale restoration efforts already underway in the area, specifically around Gravenstein Creek, where riparian buffers have been planted with native trees and shrubs. Other mitigation and restoration efforts have also been undertaken at Brown Farm, owned by the City of Santa Rosa, where additional expansion of wet meadow is proposed. This concept also proposes converting current holding ponds and grazed area around Roseland Creek into valley freshwater marsh habitat. The property on this site, Alpha Farm, is also owned by the City of Santa Rosa.

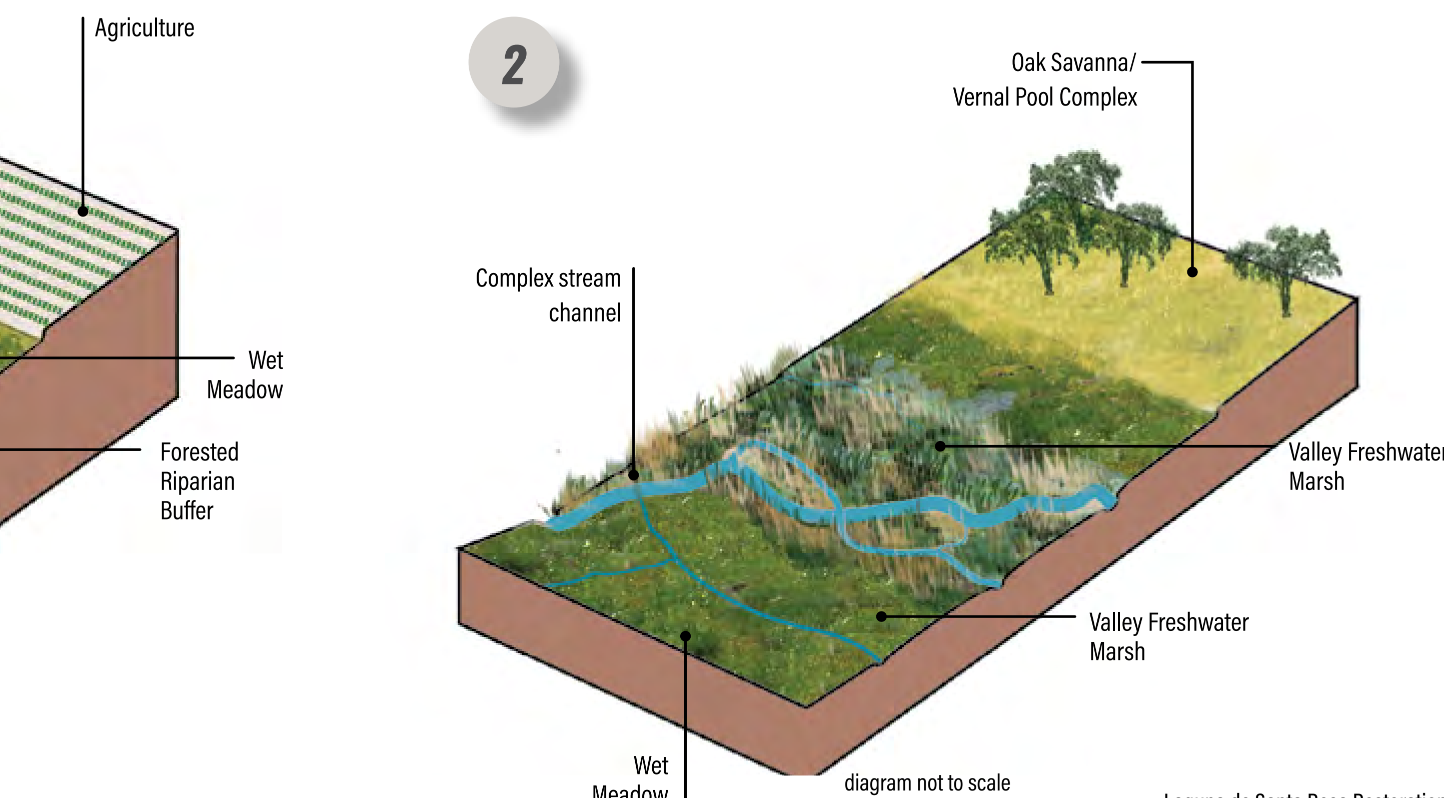
C. Enhance existing habitats Enhancement of existing habitats within this concept will offer support for endangered and threatened species native to the Laguna watershed. Most notably, upland areas within existing oak savanna would benefit from the restoration of vernal pool complexes, which were eliminated to maximize agricultural outputs. Vernal pool restoration would support a wide array of specialized flowering plants and their associated pollinators, as well as amphibians like the California Tiger Salamander (*Ambystoma californiense*).

Exa





mple habitat gradients within the restoration project concept



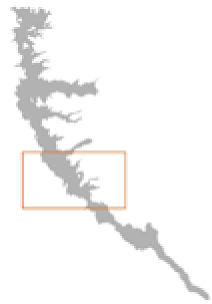
RESTORATION PROJECT CONCEPT FOR

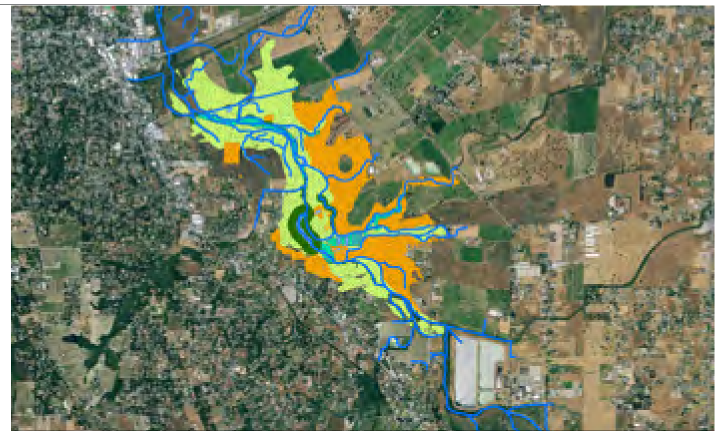
HWY 12-WWTP

1 INTRODUCTION: PAST AND PRESENT

2 ANNOTATED RESTORATION PROJECT CONCEPT

3 BENEFITS, CONSIDERATIONS, AND METRICS





RESTORATION PROJECT CONCEPT

BENEFITS OF THE PROJECT

The greatest change in habitat extent associated with this restoration project concept is the expansion of wet meadow habitat, which at ~105 ha is the second-greatest increase behind the Bellevue-Wilfred concept (p. 69). The benefits of wet meadow habitat expansion include increased foraging and nesting opportunities for a wide variety of species, increased connection to tributaries and other wildlife movement corridors, floodplain habitat for fish, improved nutrient uptake/assimilation, sediment trapping, and the increase of culturally significant habitat and species, such as basket sedge *(Carex barbarae).*

Expansion and connection of marsh around the Laguna mainstem allows for the creation of one contiguous large (>10 ha) marsh patch, which reduces the mean distance to a large valley freshwater marsh patch within the Laguna 100-year floodplain by a notable ~3.7 km.

The current absence of a large forested riparian patch in the southern area of the Laguna makes the expansion of the 100 m riparian forest buffer around the dredged lake, which would add 0.8 km to the length of aquatic habitats bordered by riparian forest, particularly significant. The dredged lake, which adds 3.4 ha of this habitat type, would be partially shaded once trees are established, enhancing its potential as cool deep water habitat for resident fish, as well as those migrating to and from the Laguna's southern tributaries.

Finally, though not reflected in the landscape metrics, the restoration and enhancement of existing habitats within this concept hold great potential benefits. Replacement of a 12-acre patch of eucalyptus with native oaks and grasses would improve local hydrology and improve resources for native species. Enhancement of vernal pools would be hugely beneficial to endemic specialist plant species, such as Sebastopol meadowfoam *(Limnanthes vinculans)*, Sonoma sunshine *(Blennosperma bakeri)* and Burke's goldfields *(Lasthenia burkei)*, as well as their associated insect pollinators.

KEY CONSIDERATIONS

Though they are not reflected in the modern habitat map, there are some ongoing restoration efforts within the concept boundary, namely a 60 m wide riparian buffer planted with native trees along Gravenstein Creek, at the northern end of the concept. Much of the area surrounding Roseland Creek is owned by the City of Santa Rosa. There are planned restoration efforts nearby outside the study area on property owned by the City and Sonoma Water.

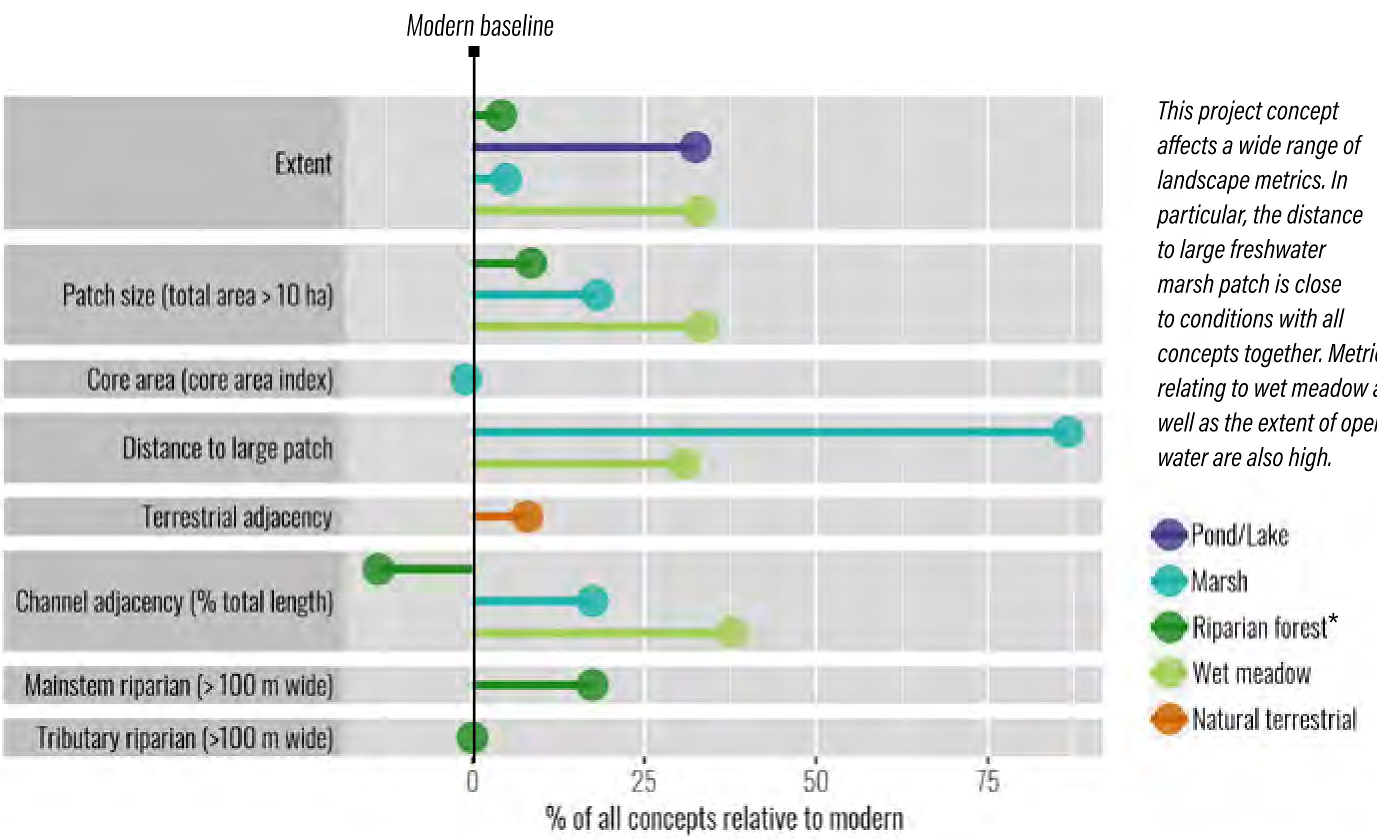
Dredging and deepening of the historical lake within this area may allow for restoration/management funding through phosphorous credits. Additionally, the newly dredged lake may help improve sediment dynamics for downstream concepts, acting as a sink for sediment carried by channelized tributaries upstream. Such potential benefits should be evaluated via modeling in the process of developing project designs. As with the Ballard Lake and Lake Jonive concepts, appropriate actions should be taken to minimize potential negative effects of remobilizing nutrients during dredging.

Due to high sedimentation rates in the upstream portion of the Laguna, the value of the newly dredged lake as deep water habitat may not be as great as other downstream lakes. However, by capturing large amounts of sediment, it could improve the management and ecological benefits of the downstream lakes and ponds. Initial and periodic dredging of nutrient-laden fine sediment from this lake could also serve as funding sources for ongoing management through phosphorus credit trading.

Some areas within this concept may have been historically drained to support agriculture and reduce floodplain inundation. In order to support the re-introduction of wet meadow habitat, the configuration of existing drainage channels may have to be modified. This is an important consideration for further restoration decisions.

LANDSCAPE METRICS COMPARISON

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.

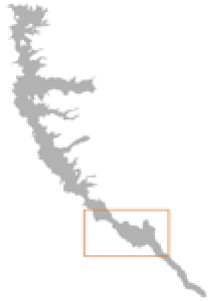


This project concept affects a wide range of landscape metrics. In particular, the distance to large freshwater marsh patch is close to conditions with all concepts together. Metrics relating to wet meadow as well as the extent of open water are also high.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

RESTORATION PROJECT CONCEPT FOR

BELLEVUE-WILFRED

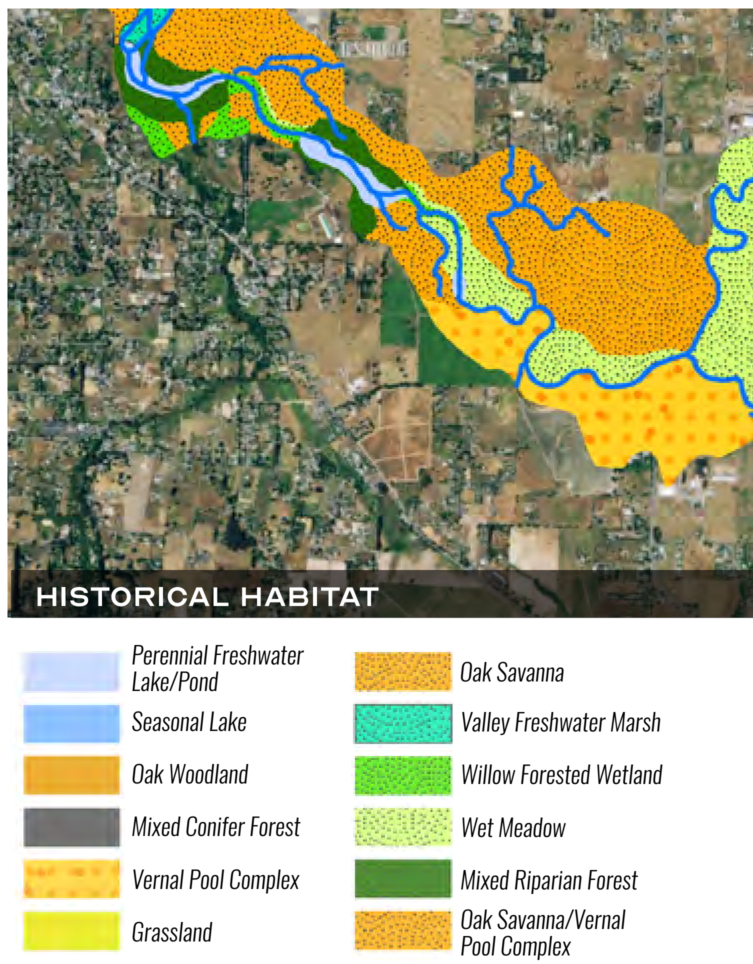


INTRODUCTION

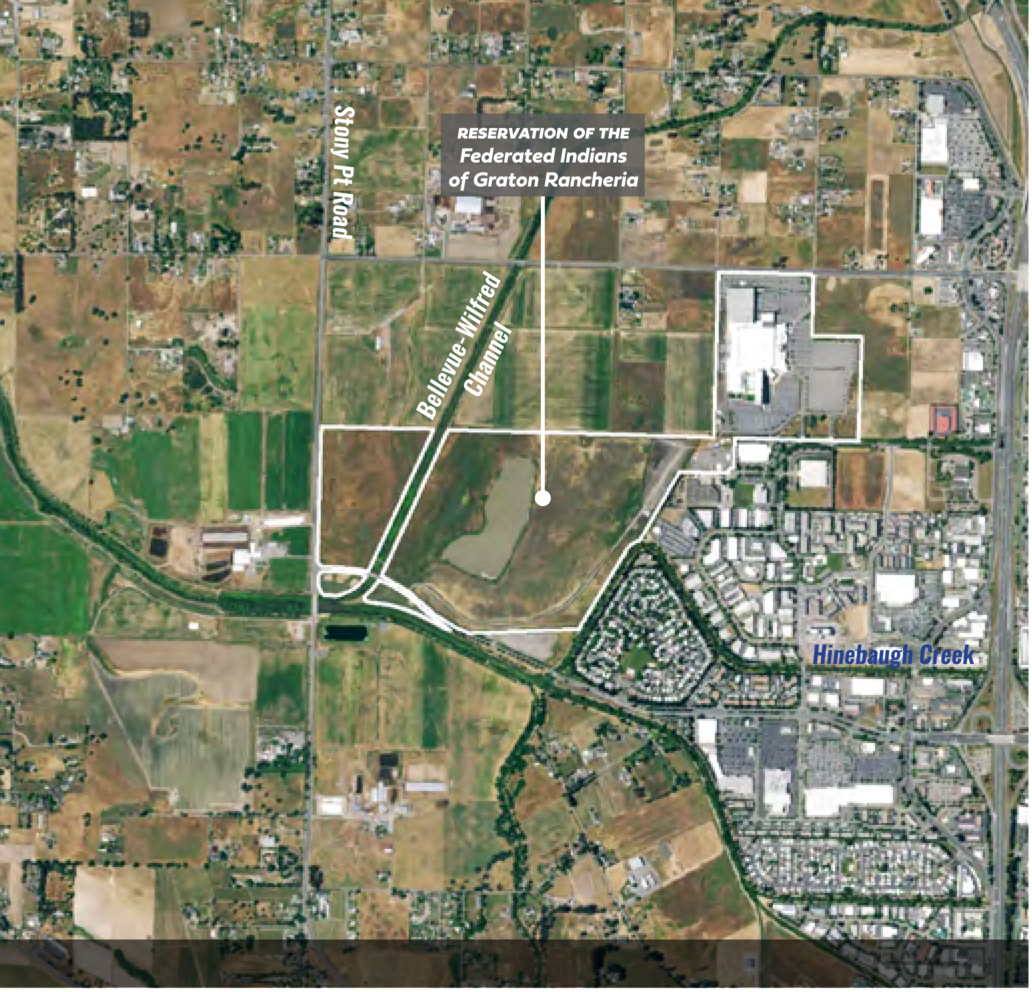
The restoration project concept area that lies largely downstream of the confluence between the Laguna and Bellevue-Wilfred channel is at the southern end of the Laguna 100-year floodplain. Through this area, the Laguna has been rerouted and leveed, reducing hydrologic connectivity with the adjacent floodplain. In addition, rerouting and leveeing of the tributaries that run through the City of Rohnert Park have contributed to in-channel sedimentation in the Laguna. The areas surrounding the channelized Laguna and its tributaries have largely been converted from wet meadow and oak savanna/ vernal pool complexes to pasture and hayfields. Invasive *ludwigia* spp. has invaded portions of Bellevue-Wilfred flood control channel and the Laguna. Sediment removal in the Laguna has decreased favorable conditions for the invasive plants by enhancing drainage through the floodplain and channel, and by planting native riparian vegetation to prevent future invasive plant establishment.

This restoration project concept is expected to take several steps to improve hydrologic connectivity, expand and enhance native plant communities, and manage sediment and nutrient imbalances both for the immediate area, as well as the Laguna floodplain downstream. The most notable change is the restoration and expansion of ~124 ha of wet meadow habitat around the Laguna mainstem, the most of any proposed concept. Enhancement of existing oak savanna habitat could include some restoration of vernal pool habitat. Included is the dredging and restoration of a historical perennial lake just south of the WWTP, with surrounding riparian forest expansion. Adjacent to this lake, this concept includes a small proposed freshwater marsh, fed by a spring to the south.

CONTEMPORARY LANDSCAPE

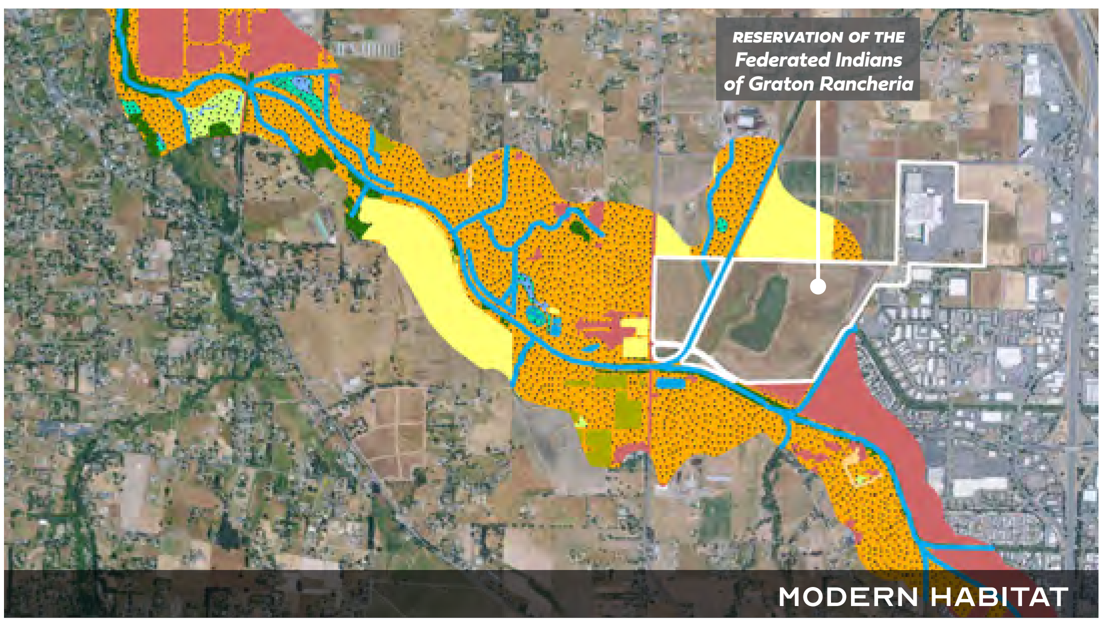


HISTORICAL HABITAT



N
1,500 FEET
500 METERS
1:27,000 SCALE

Historical and modern habitat maps and aerial imagery depict the significant landscape changes that have affected the southern end of the Laguna, where Bel-levue-Wilfred Creek meets the mainstem. Previously sinuous and complex channels have been straightened and leveed with increased agriculture and the expansion of the City of Rohnert Park. These channel changes have led to decreased hydrological connectivity between the mainstem channel and adjacent floodplain. Two historical perennial lakes have been infilled, and ecologically valuable vernal pools were transformed to pasture and hayfields decades ago. Remaining habitat, such as oak savanna depicted in orange on both habitat maps, has been diminished in ecological function with fewer mature valley oaks, decreased hydrological connectivity, and increased invasive species.

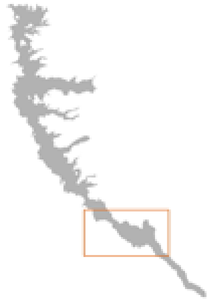


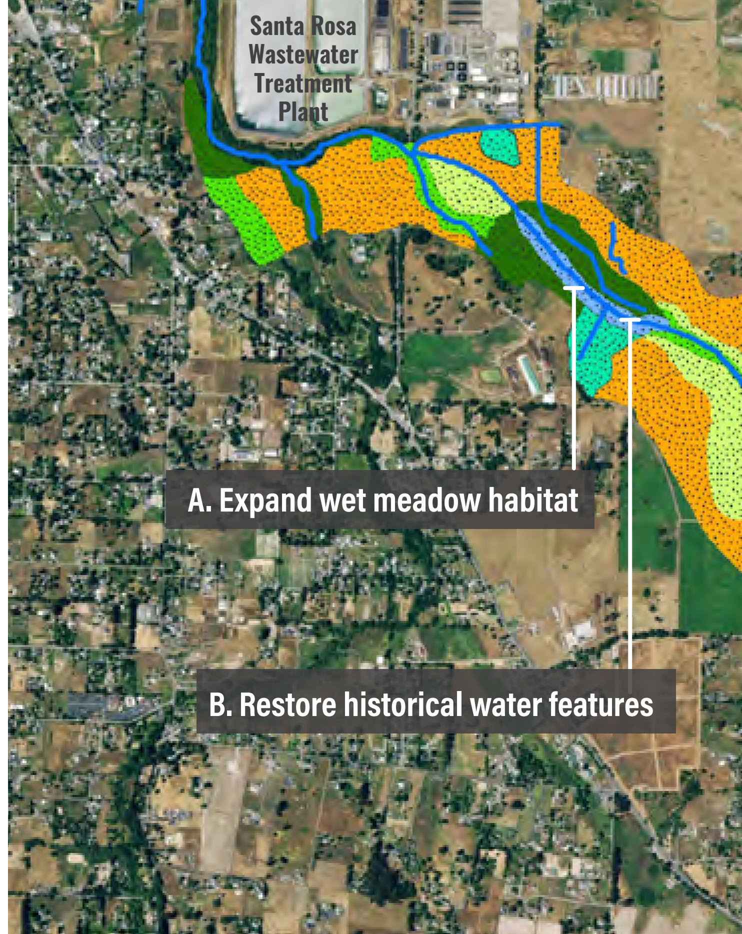
N
2,000 FEET
600 METERS
1:44,000 SCALE

Developed/Disturbed
Forested Wetland and Mixed Riparian Forest/Scrub
Hayfield/Pasture/Vernal Pool Complex
Oak Savanna or Woodland/Vernal Pool Complex/Valley Grassland
Other Agriculture
Other Upland
Perennial Freshwater Lake/Pond
Storage Pond
Valley Freshwater Marsh
Wet Meadow

RESTORATION PROJECT CONCEPT FOR

BELLEVUE-WILFRED





RESTORATION PROJECT CONCEPT

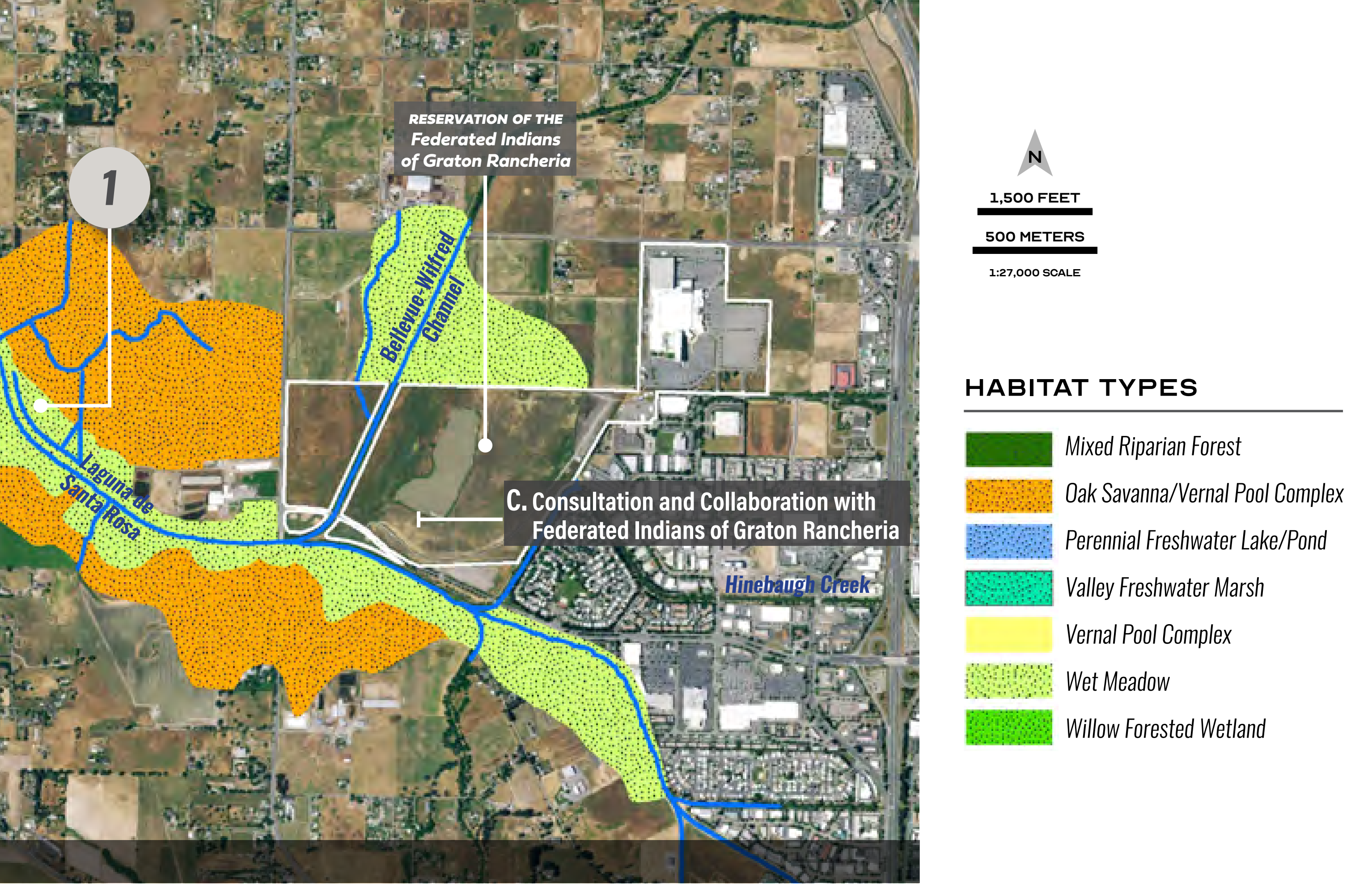
A. Expand wet meadow habitat Proposed restoration within this area includes the largest expansion of wet meadow habitat among all the concepts (~124 ha). In an area of the Laguna that has been highly channelized and hydrologically disconnected, the restoration of seasonally inundated habitat would provide resources to wildlife that access both the Laguna and surrounding uplands. Much of the hydrologic connectivity necessary to support wet meadow habitat could be accomplished by setting current levees back to widen the floodplain.

B. Restore historical water features This concept proposes the restoration of historical water features, which are critical resources for ecosystem functions as well as fish and wildlife. The dredging and restoration of a historical perennial lake would offer deep water habitat to fish, and trap sediment, providing benefits downstream. This area of the floodplain would also benefit greatly from the restoration of vernal pool complexes within the oak savanna habitat, which were particularly numerous to the south of the channel historically.

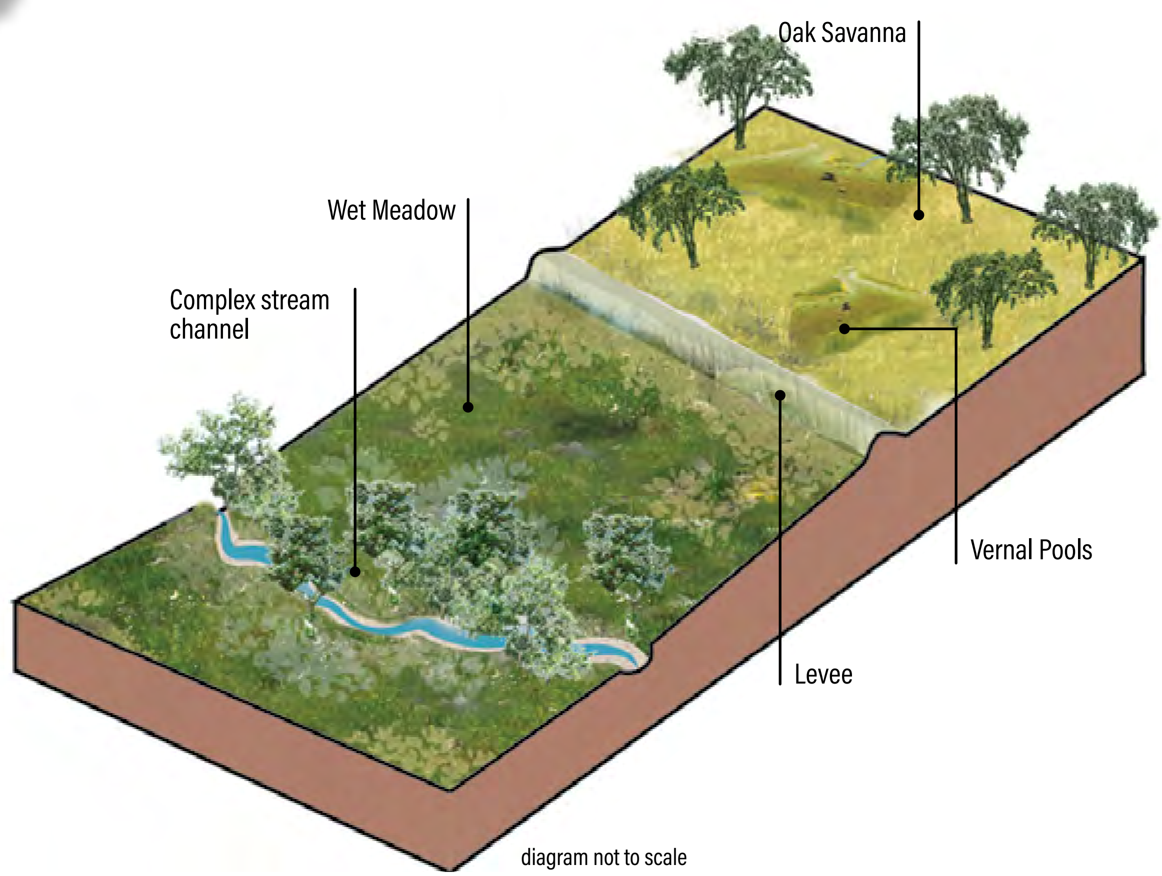
C. Consultation and Collaboration with Federated Indians of Graton Rancheria

Advancing this project concept will require buy-in from all affected landowners and stakeholders, and extensive input from FIGR. Restoration leads should work collaboratively with the Tribe on the full suite of restoration design elements, particularly the development of plans for long-term land stewardship, site access, environmental review, and the protection of Tribal Cultural Resources.


PLANT SURVEYING IN VERNAL POOL HABITAT. PHOTO: LAGUNA DE SANTA ROSA FOUNDATION

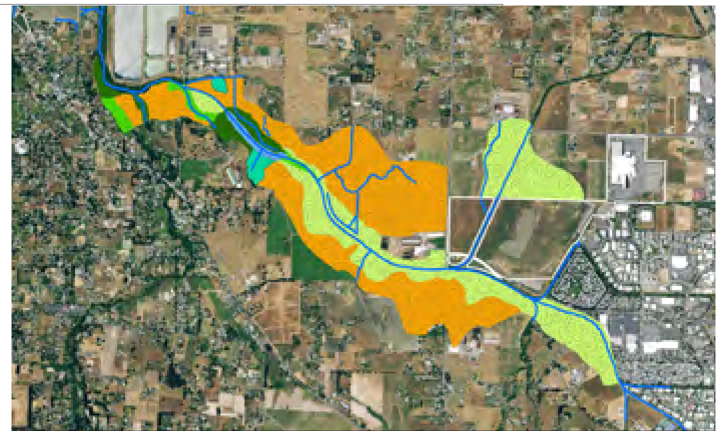


1 Example habitat gradient within the restoration project concept



RESTORATION PROJECT CONCEPT FOR

BELLEVUE-WILFRED



RESTORATION PROJECT CONCEPT

BENEFITS OF THE PROJECT

A ~124 ha increase of historical wet meadow habitat would provide benefits as a food and nesting resource for native wildlife. It would also increase uptake and assimilation of nutrients from surrounding lands, which include several dairies and pastures, which are large sources of nitrogen. Wet meadow restoration would increase the length of channel adjacent to this habitat type by 11.4 km, by far the most of any concept, allowing for greater connectivity between aquatic and terrestrial habitats for a host of species.

Dredging of the historical lake south of the WWTP would not only create cold and deep water refugia for native fish, but would likely benefit many downstream habitats by acting as a sediment trap for a significant amount of sediment transported into the Laguna by channelized tributaries upstream.

KEY CONSIDERATIONS

Much of this reach is privately owned, with the eastern end of the concept bordering the FIGR reservation, a federally recognized tribe of Coast Miwok and Southern Pomo peoples. Development of restoration projects in this concept area in particular, but for other concept areas as well, will require tribal consultation. The Tribe's involvement in establishing restoration designs and planting palettes, as well as protecting Tribal cultural resources, will improve the likelihood of success and provide greater overall benefits.

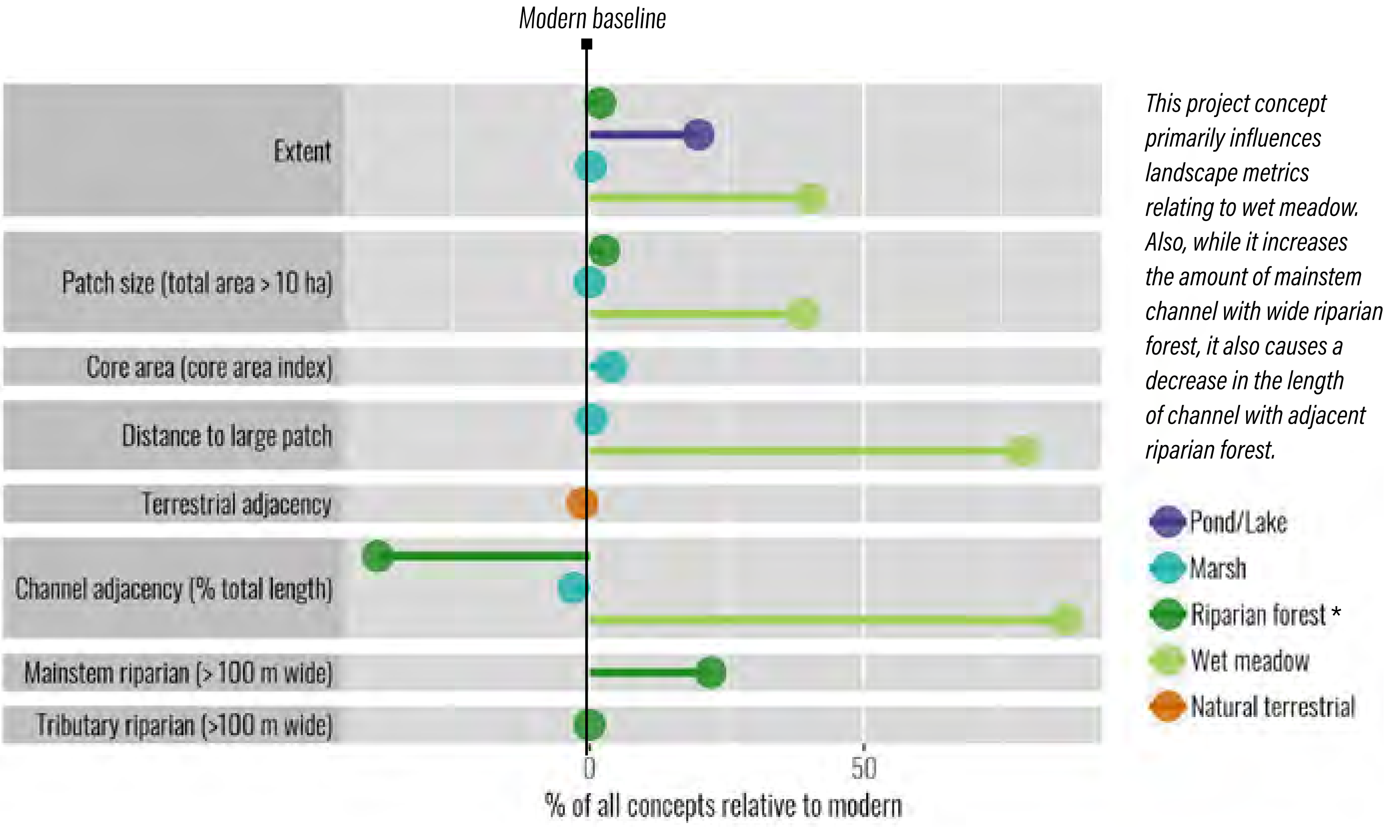
Due to high anticipated sedimentation rates, the value of the newly dredged lake as deep water habitat may not be as great as other downstream lakes. However, by capturing large amounts of sediment, it could improve the management and ecological benefits of the downstream lakes and ponds. Initial and periodic dredging of fine nutrient-laden sediment from this lake could also offset project costs for ongoing management through phosphorus credit trading.

There are several existing restoration efforts within this area that are not captured by most recent land cover data. These include a channel recontour of the Laguna mainstem within existing levee boundaries to lower sustained water levels and dry out invasive *Ludwigia* spp., promoting native cattail and tule growth, as well as a small wet meadow restoration on the north side of the channel just downstream of the Bellevue-Wilfred confluence. Successful wet meadow restoration along the length of the Laguna will require that the levees be set back several tens of meters, to allow hydrological connection with the Laguna mainstem.

OAK SAVANNA / VERNAL POOL COMPLEX. PHOTO: SFEI.

LANDSCAPE METRICS COMPARISON (below)

For each of the landscape metrics below, the contribution of this project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). For example, 50% means that a project concept achieves half of the landscape target of all concepts together. Note that the scale of the x-axis varies across project concepts. For the calculated metric values, see Appendix A.



This project concept primarily influences landscape metrics relating to wet meadow. Also, while it increases the amount of mainstem channel with wide riparian forest, it also causes a decrease in the length of channel with adjacent riparian forest.

* Includes both Willow Forested Wetland and Mixed Riparian Forest

Prioritization and Sequencing

Moving from restoration project concepts to project implementation requires an understanding of what restoration actions should be prioritized and whether certain actions should occur before others. The prioritization criteria and sequencing considerations provided here are meant as tools to help planners and project proponents evaluate and advocate for projects by highlighting how potential projects might interrelate and assessing how restoration project concepts relate to management objectives.

PRIORITIZATION CRITERIA

Twelve prioritization criteria were developed to evaluate the potential contribution of each of the nine restoration project concepts towards achievement of four of five of the overarching Management Objectives (Table 3-1). The prioritization criteria cover several categories of ecosystem improvements, including increased habitat extent and connectedness, improved water quality, increased support for native species, and improved streamflow patterns. The prioritization criteria discussed here are not necessarily equal in weight to each other, and thus it is up to planners and project proponents to determine which priorities are of greatest value.

For each criterion, concepts were assigned a rating of "high," "medium," low," or "none." The method used to determine the rating varied by criterion: for some criteria, ratings were based on quantitative information about habitat extent and configuration derived from the landscape metrics (see Chapter 2); for other criteria, data limitations made it necessary to assign qualitative ratings representing best approximations of the likely ecosystem improvements associated with each restoration project concept. In some cases, a single landscape metric was used as the basis for evaluating multiple criteria, reflecting the multi-benefit nature of certain restoration actions (for example, increasing the extent of valley freshwater marsh both supports native wildlife and improves water quality through nutrient assimilation).

For each criterion, high ratings were given to concepts that stood out as particularly beneficial, and the remaining concept ratings were generally split evenly between medium and low. For criteria based on habitat extent metrics, concepts marked with "none" include negative values, zero, and negligibly small positive values. These ratings are not meant to be additive for individual concepts; the goal is to show where each concept scores high and scores low, rather than to determine an overall "most" and "least" valuable concept. Information about the method used to develop ratings for each criterion is provided in Appendix B.

While the scores in the prioritization matrix represent anticipated outcomes for each project concept, the achievement of the management objectives will ultimately depend on the specific details of project design

Table 3-1. Effectiveness of each Restoration Project at addressing one of nine prioritization criteria. These criteria are tied to the management objectives introduced at the beginning of this document.

		Restoration Project Concept Rating								
MANAGEMENT OBJECTIVES	**Prioritization Criteria (Ecosystem improvements that help meet Management Objectives)"**	**Mark West A**	**Mark West B**	**Mark West C**	**Mark West D**	**Ballard Lake**	**Occidental - Guerneville**	**Lake Jonive**	**HWY12-WWTP**	**Bellevue-Wilfred**
Enlarge riparian and wetland habitat patches and improve their connectedness	A. Expands valley freshwater marsh and/or enhances connectivity	None	None	None	None	Medium	High	None	Medium	Low
	B. Expands forested wetland and mixed riparian and/or enhances connectivity	High	Medium	Medium	Low	Low	Medium	High	Medium	Low
	C. Expands wet meadow and/or enhances connectivity	None	None	None	None	None	Low	Medium	High	High
Decrease sediment and nutrient delivery to the Laguna, especially at areas of high deposition/accumulation rates. Move sediment from accumulation areas where appropriate	D. Improves water quality through biological uptake of nutrients (in habitats with high assimilative capacity)	Medium	Low	Low	Low	Medium	High	Medium	Medium	Low
	E. Improves water quality through reduction of sediment in the main channel through natural floodplain deposition	Medium	Low	Low	Low	High	High	Low	Medium	Low
	F. Improves water quality by removal of sediment through active management (dredging)	Low	Low	Low	Low	High	Low	High	Medium	Medium
Control the extent of invasive plant species, and encourage conditions that enable native species	G. Increases shade and canopy cover through riparian enhancement	Medium	Medium	Medium	Low	Low	Medium	High	Low	None
	H. Increases competition with invasive *Ludwigia* spp. via native habitat types (wet meadow and bulrush)	None	None	None	None	Medium	High	Medium	High	High
	I. Decreases invasive *Ludwigia* spp. opportunities by increasing water depth	None	None	None	None	High	None	High	Medium	Medium
Improve late spring/summer water quality through improved drainage and flow conveyance	J. Decreases perennial shallow slow moving water	High	Medium	Medium	Medium	None	Medium	None	None	None
	K. Relieves flow constrictions and impeded flow due to channel alignment	High	Medium	Medium	Medium	Low	Medium	Low	Low	Low
	L. Expands seasonally inundated habitats while reducing late-season or perennial shallow water inundation	High	Low	Low	Low	Medium	High	Medium	High	High

and implementation as well as subsequent management. The prioritization criteria may also be useful for monitoring progress towards restoration objectives. There are additional considerations that are important for prioritizing projects that were not included as criteria here because they could not be evaluated with the level of detail available at the concept level. For example, the overall changes to hydrologic, hydraulic, and geomorphic processes associated with the concepts will need to be assessed with quantitative analyses and numerical modeling tools. Also, concerns about the potential for fish stranding will need to be considered in the design phase by assessing a range of physical and hydrologic/hydraulic factors. Additionally, *Ludwigia* spp. invasion is a high priority concern and pre-emptive control of invasive aquatic plants should be considered in the design phase.

A review of the prioritization matrix reveals the expected benefits of each project concept relative to each other. No single project concept scored as high or higher than all of the other concepts in all of the prioritization criteria. Occidental-Guerneville and Mark West A had the highest number of "high" ratings (five and four, respectively) of all the concepts. Occidental-Guerneville was the only concept to receive a high rating for expanding valley freshwater marsh and/or enhancing connectivity and for improving water quality through biological uptake of nutrients. Mark West A was the only concept to receive high ratings for all three of the criteria related to the management objective of improving late spring/summer water quality through improved drainage and flow conveyance. In contrast, the other three alternative Mark West routes (B, C, and D) did not receive high ratings for any of the prioritization criteria. Mark West A and Lake Jonive were the two project concepts to receive high ratings for expanding forested wetland and mixed riparian forest and/or enhancing connectivity, while Lake Jonive was the only concept to receive a high rating for increasing shade and canopy cover through riparian forest enhancement. Ballard Lake received the only high rating for decreasing *Ludwigia* opportunities by increasing water depth. HWY12-WWTP and Bellevue-Wilfred were the two project concepts to receive high ratings for expanding wet meadow and/or enhancing connectivity.

(TOP) MIXED RIPARIAN VEGETATION. (BELOW) WET MEADOW. PHOTOS: SFEI

SEQUENCING CONSIDERATIONS

There are many considerations that go into deciding which restoration projects should be implemented first. The sequencing criteria developed for this effort address some of the key considerations related to project sequencing, without going so far as to recommend which projects should be done first. Sequencing should consider how projects will affect one another, which projects will provide the most benefits, and how feasible each project is. For example, if a project is likely to significantly affect the hydrology, depositional environment, or vegetative composition of nearby sites, restoration planners may want to consider implementing that project first so that the design specifications for later projects can be fitted to the proper conditions. These sorts of interdependencies highlight the need for rigorous site evaluation and project design by interdisciplinary teams of restoration scientists and engineers (e.g. wetland ecologists, aquatic botanists, fish and wildlife biologists, hydro-geomorphologists, civil engineers).

Landowner interest and willingness is the primary precondition for any restoration project to be implemented. There are additional components that all projects should include, such as a long-term management and stewardship plan and engagement with local community stakeholders and tribal representatives. These preconditions should be satisfied before moving towards implementation of any restoration project.

SEQUENCING CONSIDERATIONS

Tribal Cultural Beneficial Uses

- Will there be impacts to a Tribal Cultural Resource of areas considered important to Tribes?
- Will restoration support the needs of Tribes who rely on the land and plant communities?

Greatest Potential Ecological Benefits *(overlaps with prioritization, trade-off with feasibility)*

- Is there a potential for negative impacts from restoration actions?
- Do potential projects score well according to the criteria in the prioritization table (high in at least one category or medium in several categories)?
- Does the project lead to more benefits sooner than other projects?
- Does the project provide other ecosystem services (e.g., carbon storage, flood risk reduction, groundwater recharge)?
- Does the project contribute to climate change resilience or mitigation?

Physical/Ecological Interdependencies

- Will restoration actions alter flow dynamics and sediment deposition patterns in a way that benefits offsite land uses or contributes to the achievement of management objectives upstream or downstream (e.g, allowing for floodplain inundation that alleviates offsite backwater conditions/flooding impacts and promotes floodplain sediment deposition/storage, promoting sediment trapping that decreases lake infilling downstream)?
- Will restoration actions increase hydrologic connectivity of wetlands upstream?
- Will restoration actions be achievable under the current flow, sediment, and nutrient regime driven by watershed factors and influenced by TMDL implementation?
- Will restoration actions potentially help improve water temperature or dissolved oxygen conditions downstream?
- Will restoration actions that increase hydrologic connectivity of wetland habitat help achieve native plant community goals at other sites rather than facilitating increased plant invasions?

Logistical Interdependencies

- Will restoration actions still allow for access to other potential restoration sites in the future?
- Will restoration actions make future projects easier to fund or permit?

Feasibility

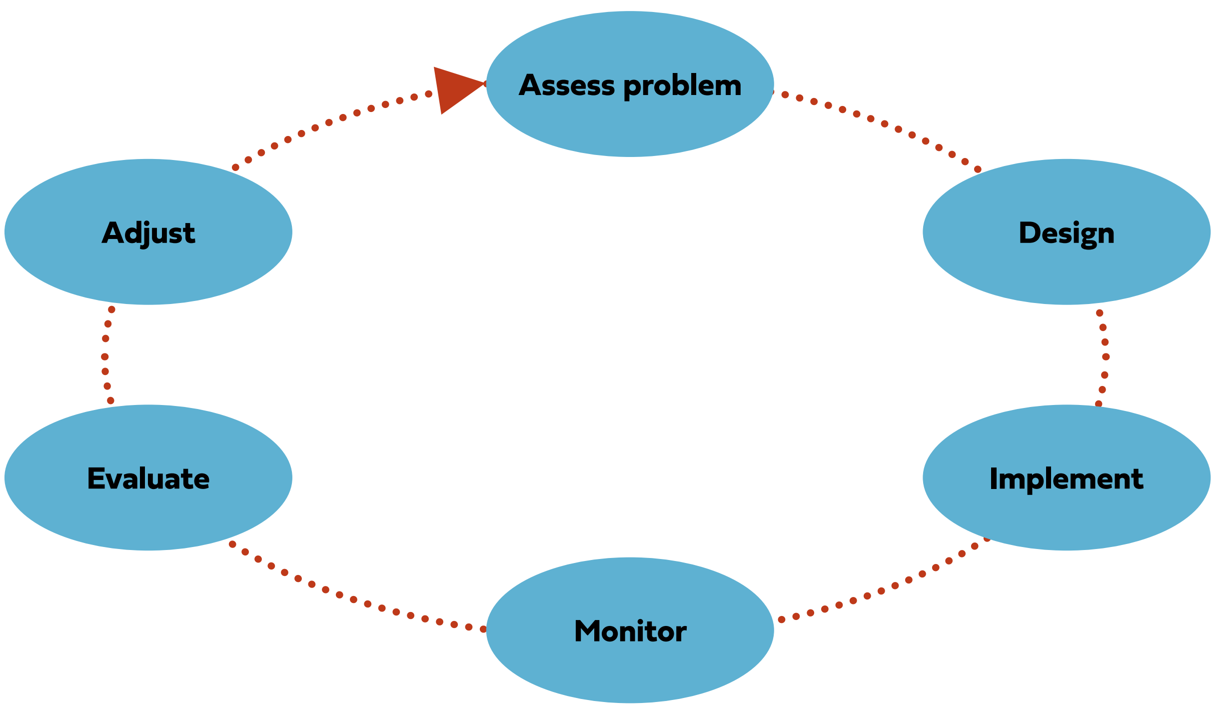
- Key considerations
  - Are project costs low? Is funding available or more likely for this project than others?
  - Can the project be done in one phase?
  - Are permitting and coordination requirements (e.g., number of landowners) simple relative to other potential projects?
- Is there potential for mitigation credits or credits for trading within the Water Quality Trading Framework?
- Is there landowner willingness and buy in?
- Is there a plan for long-term management and stewardship (e.g., permanent land protection agreement in place)?

Experimentation and Support for Other Projects

- Does this project provide an opportunity for pilot projects that will help with design and permitting of later projects?
- Does this project provide opportunities for learning and adaptive management?
- Does this project provide seed sources or other resources for future projects?

4. Moving from Restoration Concepts to Restoration Projects

This Laguna Restoration Plan puts forth a suite of Laguna restoration project concepts adapted from the Restoration Vision that are focused on bringing back lost habitat, improving water quality, and enhancing the Laguna ecosystem for both wildlife and people. Moving from these idealized restoration project concepts to successful restoration projects will require several steps: an improved understanding of both local and landscape-scale physical and biological processes; an understanding of the ecosystem benefits associated with the sequencing of projects; the development of detailed project designs; and the development of plans for maintaining and monitoring restoration projects over the long-term. Successful completion of these steps will require adequate funding and coordination among tribal representatives, local landowners, regulatory agencies, and existing restoration/management efforts within the Laguna and its contributing watershed. Here we provide a discussion of some of the key considerations associated with moving the Laguna restoration project concepts forward.



Adaptive Management Cycle . Adapted from Murphy, Dennis, & Weiland (2014).

Addressing Key Data and Knowledge Gaps

There is a wide range of data and knowledge gaps that should be addressed to develop successful restoration projects within the Laguna. These relate to the range of metrics presented in the restoration planning framework in Chapter 2 (see Table 2-1). Many of the key knowledge gaps relate to the efficacy of restoration actions in reaching desired habitat goals or ecosystem conditions. For example, there is a need to better understand the ability of different wetland plant communities that will be part of the restoration palette to filter and process nutrients and capture fine sediment. There is an inherent assumption that more wetlands in the Laguna will lead to improved water quality, but more research is needed to understand the wetland plants that have the biggest impact in the various landscape settings within the Laguna. There are also many unknowns with respect to landscape suitability for restoration concepts (e.g., appropriate groundwater levels for supporting wet meadow), landscape capacity to produce native plant propagules in restored areas, and appropriate restoration features for supporting native fish and wildlife in different parts of the Laguna. In addition, there are unknowns with respect to the hydrodynamics of the Laguna and the movement of water, sediment, and nutrients during high flow and low flow conditions, and anticipated sediment and nutrient deposition dynamics within restored wetland and open water features. Focused analyses and experimental investigations are needed to address these data and knowledge gaps and the results need to be incorporated into the next phase of project design.

There are also many knowledge gaps related to the long-term impacts of watershed management and climate change on restoration projects within the Laguna. For example, more information is needed to understand how management and restoration actions in the watersheds that drain to the Laguna could impact the delivery of water, sediment, and nutrients, which in turn can be combined with a Laguna hydrodynamic analysis to understand the ultimate impact on restoration projects. Similarly, the anticipated impacts of climate change on evapotranspiration and soil moisture, watershed vegetation, wildfire risk, large storm frequency, and the delivery of flow, sediment, and nutrients to the Laguna need to be assessed to help understand the likely trajectory of Laguna restoration sites. The analyses needed to address these knowledge gaps should include the full Laguna watershed area, which will require coordination among a variety of entities involved in Laguna watershed management. This will take time to develop, so Laguna restoration planning and implementation must move forward while analyses are being completed. Also, projects should be adaptively managed and used to gain knowledge regarding successful project design and implementation.

Inclusion of Tribal Perspectives in Project Development

This Plan considers a range of concepts that can be implemented across many parts of the Laguna. Among these places are the ancestral lands of the FIGR. Design and implementation of the restoration concepts should include a commitment to work in partnership with FIGR in their traditional territory. This may include early tribal consultation and field visits to develop project ideas in a collaborative manner. The inclusion of FIGR's perspectives increases the success and impact of these restoration projects by allowing for new and different implementation ideas. Their voices are critical for emphasizing the importance of cultural resource protection and tribal access in restoration planning.

Specific ideas for how to include tribes in restoration project execution include narrowing knowledge gaps, data sharing, and funding partnerships. Crucial missing information, including historical ecology information, may be addressed by hearing from those who have been here the longest and their input can address or identify potential knowledge gaps. There are also many funding opportunities available for restoration projects that include and improve the land for Tribes. Developing partnerships between restoration project leads and Tribes can benefit projects as a whole and expand the restoration possibilities with additional sources of funding. Restoration project leads should work with FIGR representatives to seek outside funding needed for tribal engagement in restoration efforts.

Sequencing and Scenario Planning

Utilizing the sequencing considerations described in Chapter 3 is a critical next step for determining which restoration project concepts should be the first to move forward to restoration project design. This starts with an assessment of landowner interest and includes conducting a wide range of analyses, from quantitative assessment of restoration impacts on physical processes and water quality to qualitative assessments of overall ecological benefits, as well as interdepencies with other restoration projects.

After assessing sequencing, it can then be helpful to consider the cumulative ecosystem benefits and potential impacts of multiple restoration projects together. Restoration scenarios, made up of multiple restoration projects, can be assessed to highlight benefits at a landscape scale that may not be as obvious when considering projects individually. For example, multiple projects that focus on different wetland types can contribute more to overall habitat diversity, and the location of projects in relation to one another can affect the degree to which landscape connectivity is improved for wildlife populations. Understanding project costs (using first-cut estimates) also needs to be considered for balancing maximum ecosystem benefits with practical constraints for each scenario. With this information in hand, tradeoffs between the different combinations of concepts (or scenarios) can then be evaluated.

As with addressing key knowledge gaps, sequencing and scenario planning requires coordination that will take time. Therefore, project implementation needs to move forward while sequencing and scenario planning efforts are being developed.

Design and Permitting

The Laguna restoration project concepts provide a foundation from which to build detailed restoration designs for projects that restore lost habitat and promote a better functioning Laguna. Moving from the restoration project concepts presented here to project design plans starts with an alternatives analysis (or feasibility study) for each restoration project site. The alternatives analysis should identify site conditions (e.g., soils, topography, hydrology, infrastructure, biological and cultural resources), identify key project constraints that restrict restoration design options (e.g., the need to protect critical infrastructure and provide flood protection), develop and evaluate a suite of restoration project alternatives based on the restoration concepts, and identify a preferred alternative. Alternatives can be compared by evaluating selected metrics from the Restoration Planning Framework (see Chapter 2). This process can also include analyses on the degree to which alternatives help reach management goals for the Laguna (e.g., nutrient assimilation for TMDL support). The preferred alternative will then go through the project design process, which includes the development of 30%, 65%, and 100% design plans, and the permitting process, which includes obtaining permits from state and federal regulatory agencies.

As with the Vision and Restoration Plan development process, the restoration project design process should continue to include collaboration with local landowners and the Tribe as well as with agency representatives. There should continue to be forums to keep local landowners and representatives from the FIGR apprised of the status of restoration projects, and to receive traditional ecological knowledge input from FIGR tribal representatives, such as the use of culturally important plants in restoration design.

Developing Maintenance and Monitoring Plans

The long-term success of implemented Laguna restoration projects will depend largely on the development and execution of strong Maintenance Plans and Monitoring Plans. These plans lay out the approaches for maintaining restoration projects according to project plans, and monitoring the evolution of restoration projects relative to project goals. The major components of Maintenance and Monitoring Plans are as follows:

Project Maintenance Plan - identifies anticipated operation and maintenance activities, maintenance standards, a maintenance schedule, and maintenance responsibilities over a multi-year period. Maintenance activities could include, but may not be limited to, initial seed/plant installation, remedial seed/plant installation, irrigation, non-native plant control, trash removal, and pest control. This plan should cover all critical long-term project site management or stewardship activities and include an approach for funding these activities.

Project Monitoring Plan - identifies metrics or performance standards that indicate the restoration project is meeting established site-specific restoration project targets, monitoring methods, a monitoring schedule, and details of monitoring report elements. The development of monitoring plans should connect to the restoration planning framework (see Chapter 2), which can be adapted and expanded to include site-specific metrics and targets. Metrics could relate to plant survivorship, native cover, native recruitment, non-native cover, invasive cover, as well as non-vegetation site characteristics such as water quality, and inundation depth/frequency/duration. Monitoring methods could relate to site preparation/installation monitoring, qualitative monitoring associated with performance standards, and technical maintenance (or effectiveness) monitoring that includes field measurements for tracking performance standards. The findings can then be used to inform the need for site adaptive management (i.e., updates to project goals given the realities of project performance) and can help inform the design of subsequent restoration projects.

OAKS IN A FLOODED LAGUNA. PHOTO: SFEI

5. Summary and Next Steps

The Laguna de Santa Rosa is a vital ecosystem that has experienced a range of changes over the past two centuries, impacting both people and wildlife. Looking to the future, the Laguna landscape will continue to change as the local population increases and climatic conditions continue to shift. Rehabilitating, sustaining, and enhancing the many ecosystem functions and services of the landscape will require coordinated management and restoration actions both within the Laguna and in its contributing watershed. This Master Restoration Planning Project put forth a long-term Resilient Landscape Vision for the Laguna (SFEI-ASC 2020) that highlights opportunities for multi-benefit habitat restoration and land management based on an understanding of landscape patterns and processes from past, present, and potential future perspectives. From the Vision came the Laguna Restoration Plan presented here, which provides guidance for restoration efforts in the Laguna, and was developed in coordination with technical advisors, agency partners, local landowners, and tribal representatives.

This Restoration Plan provides three key elements for developing restoration projects within the Laguna that help meet the Management Goals and Objectives:

- **Restoration Planning Framework** - The restoration planning framework outlines key elements of large-scale restoration planning, and describes the landscape metrics and associated targets used to evaluate restoration project concepts relative to the Management Goals and Objectives. The framework provides an overall planning structure for landscape-scale restoration that connects physical and ecological parameters to desired functions and services, and can be expanded and refined over time to support future ecosystem restoration efforts in the Laguna and its watershed. For this effort, landscape metrics were selected to assess the benefits associated with the developed restoration concepts. Future efforts could include additional metrics to help with both project design and monitoring plan formulation.

- **Restoration Concepts** - Implementing the suite of restoration project concepts developed from the Vision could provide considerable ecosystem benefits, from increased wildlife habitat to improved water quality. Each concept offers unique opportunities, and contributes in different ways to the overall large-scale restoration envisioned. All concepts combined could result in a >100 hectare increase in mixed riparian forest/willow forested wetland, a >100 hectare increase in valley freshwater marsh, a >300 hectare increase in wet meadow, and a 10 hectare increase in perennial freshwater lake/pond habitat. The Mark West Creek concept has over half the total amount of restored mixed riparian forest/willow forested wetland, the

Occidental-Guerneville concept has approximately three-quarters of the restored valley freshwater marsh habitat, the HWY12-WWTP and Bellevue-Wilfred concepts each contain approximately one-third of the restored wet meadow habitat, and the Ballard Lake concept has approximately half of the restored perennial freshwater lake/pond habitat. The increased habitat extent would greatly benefit native fish and wildlife species who utilize these habitat types for part or all of their lifecycle. In addition, the restored areas would help improve water quality through fine sediment trapping and nutrient assimilation, and decrease conditions favorable for *Ludwigia* spp.

- **Prioritization and Sequencing** - The prioritization criteria and sequencing considerations developed for the restoration concepts are intended to help planners and project proponents evaluate and advocate for restoration projects in the Laguna. The twelve prioritization criteria considered for the project concepts illustrate the degree to which each of the concepts helps achieve Management Objectives. There is no one concept that scored high for all the criteria, but there are a few concepts that have high and medium scores for several criteria. This information is not only useful for comparing the relative impact of each concept, but can also be useful for illustrating the degree to which a given concept addresses criteria important to funding sources. The sequencing considerations developed for this effort address some of the key physical, ecological, cultural, logistical, and feasibility considerations related to the appropriate sequencing of projects. These considerations are not ranked by importance; however, there is a recognition of the need to consider ecosystem benefits and project interdependencies when making decisions regarding project implementation order.

With the Restoration Vision and Restoration Plan completed, the Laguna community now has tools for initiating actions to improve the overall functioning of the Laguna ecosystem. The utilization of these tools and the ultimate success of restoration efforts in the Lagua will first and foremost require local landowner support and adequate funding to implement the restoration and manage and sustain the benefits through long-term stewardship. It will also require coordination among all the agencies responsible for managing the land and water within the Laguna and its surrounding watershed. The path forward will be challenging, but with commitment and collaboration the Laguna community is well on its way toward a reconciled Laguna landscape that supports desired ecosystem functions for people and wildlife.

EDUCATION IN THE LAGUNA. PHOTO: LAGUNA DE SANTA ROSA FOUNDATION

6. References

Alsterberg, C., Roger, F., Sundbäck, K., Juhanson, J., Hulth, S., Hallin, S., Gamfeldt, L. 2017. Habitat diversity and ecosystem multifunctionality—The importance of direct and indirect effects. Science Advances 3(2), e1601475. https://doi.org/10.1126/sciadv.1601475

Baumgarten, S., Beller, E., Grossinger, R., Striplen, C., Brown, H., Dusterhoff, S., Salomon, M., and Askevold, R. 2014. Historical Changes in Channel Alignment along Lower Laguna de Santa Rosa and Mark West Creek. SFEI Publication #715, San Francisco Estuary Institute, Richmond, CA.

Baumgarten, S.A., Grossinger, R.M., Beller, E.E. 2017. Historical Ecology and Landscape Change in the Central Laguna de Santa Rosa. SFEI Publication #820, San Francisco Estuary Institute, Richmond, CA.

Beechie TJ, Richardson JS, Gurnell AM, Negishi J. 2013. Watershed Processes, Human Impacts, and Process-Based Restoration. In: Roni P, Beechie T (eds) Stream and Watershed Restoration. John Wiley & Sons, Ltd, pp 11–49

Beechie TJ, Sear DA, Olden JD, Pess GR, Buffington JM, Moir H, Roni P, Pollock MM. 2010. Process-based principles for restoring river ecosystems. BioScience 60:209–222. https://doi.org/10.1525/bio.2010.60.3.7

Beller EE, Spotswood EN, Robinson AH, Anderson MG, Higgs ES, Hobbs RJ, Suding KN, Zavaleta ES, Grenier JL, Grossinger RM. 2019. Building Ecological Resilience in Highly Modified Landscapes. BioScience 69:80–92. https://doi.org/10.1093/biosci/biy117

Benoit LK, Askins RA. 2002. Relationship between Habitat Area and the Distribution of Tidal Marsh Birds. The Wilson Bulletin 114:314–323

Bernhardt ES., Palmer MA. 2007. Restoring streams in an urbanizing world. Freshwater Biology 52:738–751. https://doi.org/10.1111/j.1365-2427.2006.01718.x

Butkus, S. 2010. Nutrient Loading Estimates for Laguna TMDL Source Analysis. North Coast Regional Water Quality Control Board.

Butkus, S. 2011. Development of the Laguna de Santa Rosa Watershed Pre-European Settlement Spatial Data Model. North Coast Regional Water Quality Control Board.

Crutsinger GM, Collins MD, Fordyce JA, Sanders NJ. 2008. Temporal dynamics in non-additive responses of arthropods to host-plant genotypic diversity. Oikos 117:255–264. https://doi.org/10.1111/j.2007.0030-1299.16276.x

Dawson, A., Sloop, C. 2010. Laguna de Santa Rosa Historical Hydrology Project Headwaters Pilot Study. Sonoma Ecology Center.

Fletcher Jr RJ, Didham RK, Banks-Leite C, Barlow J, Ewers RM, Rosindell J, Holt RD, Gonzalez A, Pardini R, Damschen EI, Melo FP. 2018. Is habitat fragmentation good for biodiversity? Biological Conservation 226:9–15. https://doi.org/10.1016/j.biocon.2018.07.022

Forman RTT. 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, U.K.

Frazier AE., Kedron P. 2017. Landscape Metrics: Past Progress and Future Directions. Curr Landscape Ecol Rep 2:63–72. https://doi.org/10.1007/s40823-017-0026-0

Henning JA., Gresswell RE., Fleming IA. 2006. Juvenile Salmonid Use of Freshwater Emergent Wetlands in the Floodplain and Its Implications for Conservation Management. North American Journal of Fisheries Management 26:367–376. https://doi.org/10.1577/M05-057.1

Hilty JA., Merenlender AM. 2004. Use of Riparian Corridors and Vineyards by Mammalian Predators in Northern California. Conservation Biology 18:126–135. https://doi.org/10.1111/j.1523-1739.2004.00225.x

Hobbs RJ., Higgs E., Harris JA. 2009. Novel ecosystems: implications for conservation and restoration. Trends in Ecology & Evolution 24:599–605. http://dx.doi.org/10.1016/j.tree.2009.05.012

Holmes AL., Humple DL., Gardali T., Geupel GR. 1999. Songbird habitat associations and response to disturbance in the Point Reyes National Seashore and Golden Gate National Recreation Area. Point Reyes Bird Observatory Report

Honton, J., Sears, A.W. 2006. Enhancing and Caring for the Laguna. Santa Rosa, CA: Laguna de Santa Rosa Foundation.

Kaushal SS., Groffman PM., Mayer PM., Striz E., Gold AJ. 2008. Effects of Stream Restoration on Denitrification in an Urbanizing Watershed. Ecological Applications 18:789–804. https://doi.org/10.1890/07-1159.1

Koebel JW., Bousquin SG. 2014. The Kissimmee River Restoration Project and Evaluation Program, Florida, U.S.A. Restoration Ecology 22:345–352. https://doi.org/10.1111/rec.12063

Laguna de Santa Rosa Foundation. 2011. Ecology of the Laguna. http://www.lagunafoundation.org/about_ecology.html

Laymon SA., Halterman MD. 1989. A Proposed Habitat Management Plan for Yellow-Billed Cuckoos in California. In: Proceedings of the California Riparian Systems Conference: protection, management, and restoration for the 1990s. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, pp 272–277

Leitão AB., Ahern J. 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning 59:65–93. https://doi.org/10.1016/S0169-2046(02)00005-1

Lindenmayer DB., Fischer J. 2006. Habitat Fragmentation and Landscape Change: An Ecological and Conservation Synthesis. Island Press, Washington, D.C.

Liu L., Wood J., Nur N., Salas, L., Jongsomjit, D. 2012. California Clapper Rail (Rallus longirostris obsoletus) Population monitoring: 2005-2011. Final Technical Report. PRBO Conservation Science, Petaluma, CA

McGarigal K., Marks BJ. 1995. FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR

Mitsch WJ., Gosselink JG. 1993. Wetlands. Wiley. New York

Moyle PB. 2014. Novel Aquatic Ecosystems: The New Reality for Streams in California and Other Mediterranean Climate Regions. River Research and Applications 30:1335–1344. https://doi.org/10.1002/rra.2709

Opperman JJ., Moyle PB., Larsen EW., Florsheim JL., Manfree AD. 2017. Floodplains: Processes and Management for Ecosystem Services. Univ of California Press

Ovaskainen O. 2002. Long-Term Persistence of Species and the SLOSS Problem. Journal of Theoretical Biology 218:419–433. https://doi.org/10.1006/jtbi.2002.3089

Palmer MA., Bernhardt ES., Allan JD., Lake PS., Alexander G., Brooks S., Carr J., Clayton S., Dahm CN., Follstad Shah J., Galat DL. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208–217. https://doi.org/10.1111/j.1365-2664.2005.01004.x

PWA (Philip Williams & Associates, Ltd.). 2004. Laguna de Santa Rosa Feasibility Study: Year One Geomorphic Investigation: Final Report. Vol. Ref. #1411-08.

Robinson A., Fulfrost B., Lowe J., Nutters H., Bradt J. 2017. Transition Zone Mapping Methodology: Integrating the Bay Margin and Upper Boundary Methods. San Francisco Estuary Partnership, San Francisco Estuary Institute, Richmond, CA

Rosenzweig ML. 2003. Win-Win Ecology: How the Earth's Species Can Survive in the Midst of Human Enterprise. Oxford University Press, Oxford, New York

SCWA (Sonoma County Water Agency), City of Santa Rosa, City of Sebastopol, CDFW (California Department of Fish and Game), Sonoma County Agricultural Preservation and Open Space District, and Laguna de Santa Rosa Foundation. 2016. Restoration Planning in the Laguna de Santa Rosa: A Science-Based Partnership between Non-Profit Agencies and Public and Private Land Owners. Poster.

Semlitsch RD., Bodie JR. 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. Conservation Biology 17:1219–1228

SER (Society for Ecological Restoration International Science & Policy Working Group). 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, www.ser.org & Tucson

SFEI-ASC. 2014. A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta. Publication # 729. Richmond, CA

SFEI-ASC. 2020. Restoration Vision for the Laguna de Santa Rosa. An SFEI-ASC Resilient Landscapes Program report developed in cooperation with Sonoma Water, the Laguna de Santa Rosa Foundation, a Technical Advisory Committee, and a Management Advisory Committee. Publication # 983. Richmond, CA.

Skidmore P., Beechie T., Pess G., Castro J., Cluer B., Thorne C., Shea C., Chen R. .2013. Developing, Designing, and Implementing Restoration Projects. In: Roni P, Beechie T (eds) Stream and Watershed Restoration. John Wiley & Sons, Ltd, pp 215–253

Sloop C, Honton J, Creager C, Chen L., Andrews ES., Bozkurt S. 2007. The Altered Laguna: A Conceptual Model for Watershed Stewardship. The Laguna Foundation, Santa Rosa, CA

Sloop, C., Honton, J., Creager, C., Chen, L., Andrews, E.S., and Bozkurt, S. 2007. The Altered Laguna: A Conceptual Model for Watershed Stewardship. Santa Rosa, CA: Laguna de Santa Rosa Foundation.

Sloop, C. 2009. Ramsar Designation of the Laguna de Santa Rosa Wetland Complex as a Wetland of International Significance. SOL Poster.

Spautz H., Nur N. 2002. Distribution and abundance in relation to habitat and landscape features and nest site characteristics of California black rail (Laterallus jamaicensis coturniculus) in the San Francisco Bay estuary. US Fish and Wildlife Service, Sacramento, CA

Spautz H., Nur N., Stralberg D. 2005. California Black Rail (Laterallus jamaicensis coturniculus) Distribution and Abundance in Relation to Habitat and Landscape Features in the San Francisco Bay Estuary

Taddeo S., Dronova I. 2020. Landscape metrics of post-restoration vegetation dynamics in wetland ecosystems. Landscape Ecol 35:275–292. https://doi.org/10.1007/s10980-019-00946-0

Teels BM., Rewa CA., Myers J. 2006. Aquatic Condition Response to Riparian Buffer Establishment. Wildlife Society Bulletin 34:927–935. https://doi.org/10.2193/0091-7648(2006)34[927:ACRTRB]2.0.CO;2

Tetra Tech. 2015a. Laguna de Santa Rosa Nutrient Analysis (Revised). Research Triangle Park, NC: Tetra Tech, Inc.

Tetra Tech. 2015b. Laguna de Santa Rosa Sediment Budget. Research Triangle Park, NC. Tetra Tech, Inc.

Toth LA., Anderson DH. 1998. Developing expectations for ecosystem restoration. Orlando, FL

USFWS (US Fish and Wildlife Service). 2005. Santa Rosa Plain Conservation Strategy. Sacramento, CA: US Fish and Wildlife Service.

USFWS (US Fish and Wildlife Service). 2016. Recovery Plan for the Santa Rosa Plain. Sacramento, CA: US Fish and Wildlife Service.

Wenger S., Fowler L. 2000. Protecting stream and river corridors: creating effective local riparian buffer ordinances. Carl Vinson Institute of Government, the University of Georgia, Athens, GA

Wintle BA, Kujala H, Whitehead A, Cameron A, Veloz S, Kukkala A, Moilanen A, Gordon A, Lentini PE, Cadenhead NC, Bekessy SA. 2019. Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. PNAS 116:909–914. https://doi.org/10.1073/pnas.1813051115

Appendix A

Landscape metrics for project concepts

This table provides results from the selected landscape metrics to compare restoration project concepts for the Laguna Restoration Plan. It includes each of the project concepts as well as historical conditions (ca. 1850), modern (ca. 2015), and all project concepts together (a representation of "target" conditions). Note that the scenario with all concepts together includes Mark West A (not B, C, or D). The metrics are explained in Chapter 2 of the Laguna Restoration Plan document. The calculated values for each metric are provided in the first column of each scenario (the "metric unit" column provides the units for those values). These are each calculated for the whole of the Laguna study area (the 100-year floodplain extent). This means that each project concept is burned into the modern baseline conditions, allowing for comparison across project concepts. The second column for each scenario presents, as a percentage, the difference between the project concept and the modern baseline conditions divided by the difference between all concepts together and the modern baseline conditions. That is, a project concept is presented as a percentage of the concept's contribution to total values for all concepts combined, using the modern Laguna landscape as the baseline (i.e., increases or decreases relative to current conditions). Thus, the scenario with all project concepts together can be viewed as the "target", with each project concept expressed as some percentage of the way toward that target from the modern baseline conditions. These percentage values of all concepts together are the values shown in each of the landscape metrics comparison plots in Chapter 3 of the Restoration Plan.

Landscape metric	Description	Habitat type group	Metric unit	Mark West A		Mark West B		Mark West C		Mark West D		Ballard Lake		Occidental-Guerneville		Lake Jonive		HWY-12-WWTP		Bellevue-Wilfred		Historical		Modern		All Concepts	
				Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Extent	Total area	Pond/Lake	ha	446.2	61.1	359.3	11.6	351.2	6.9	346.6	4.3	348.0	5.1	351.4	7.0	375.4	20.7	346.4	4.2	342.5	1.9	537.6	113.2	339.1	0	514.4	100
		Marsh	ha	32.4	0.0	32.4	0.0	32.4	0.0	32.4	0.0	37.6	49.9	32.3	-0.8	32.3	-1.5	35.8	32.5	34.5	19.9	53.2	199.9	32.4	0	42.8	100
		Riparian forest	ha	60.7	0.0	60.7	0.0	60.7	0.0	60.7	0.0	87.5	18.2	174.1	76.9	60.5	-0.2	67.9	4.9	61.0	0.2	315.8	173.0	60.7	0	208.2	100
		Wet meadow	ha	232.8	-0.3	232.0	-0.5	232.3	-0.4	232.6	-0.3	231.7	-0.6	264.9	10.2	286.3	17.2	334.5	33.0	357.4	40.4	887.9	213.9	233.6	0	539.5	100
Patch size	Total area >10 ha patch size	Marsh	ha	391.9	57.1	304.3	11.1	295.1	6.3	290.5	3.9	291.9	4.7	297.9	7.8	321.4	20.1	299.2	8.5	288.1	2.6	469.1	97.5	283.0	0	473.8	100
		Riparian forest	ha	11.4	0.0	11.4	0.0	11.4	0.0	11.4	0.0	38.2	16.5	117.9	65.3	11.4	0.0	41.1	18.2	11.4	0.0	295.8	174.6	11.4	0	174.3	100
		Wet meadow	ha	179.0	0.0	179.0	0.0	178.1	-0.3	178.0	-0.3	178.4	-0.2	216.3	11.4	233.0	16.6	288.2	33.5	305.5	38.8	862.8	209.5	179.0	0	505.4	100
Core area	Total core area index (total core area/total area)	Marsh	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	36.1	0.5	100.4	0.0	0.0	0.0	-1.0	0.1	3.9	0.5	97.0	0.0	0	0.5	100
Distance to large patch	% total area within 500 m of a large >10 ha patch	Marsh	m	5739.3	0.0	5739.3	0.0	5739.3	0.0	5739.3	0.0	5436.9	7.1	4432.1	30.7	5777.4	-0.9	2049.7	86.7	5723.6	0.4	699.9	118.5	5739.3	0	1486.1	100
		Wet meadow	m	1184.9	0.8	1223.9	-7.1	1205.7	-3.4	1190.6	-0.3	1213.3	-5.0	1103.9	17.4	1190.1	-0.2	1037.6	30.9	802.5	78.9	520.0	136.6	1189.0	0	699.1	100
Terrestrial adjacency	% area of terrestrial habitats types within a wetland habitat buffer (140 m)	Natural terrestrial	%	56.4	52.8	54.6	7.1	54.7	8.6	54.5	5.2	54.7	10.1	54.4	2.1	55.3	24.2	54.6	8.0	54.3	-1.3	64.8	271.7	54.3	0	58.2	100
Channel adjacency	% of channel length with adjacent wetland habitat types	Marsh	%	39.0	51.8	37.9	16.8	37.6	5.3	37.5	2.6	37.3	-5.4	37.9	13.5	40.1	90.6	37.1	-13.7	36.3	-38.6	28.1	-318.9	37.5	0	40.4	100
		Riparian forest	%	5.4	-1.0	5.5	-0.2	5.5	-0.1	5.5	0.0	5.8	6.2	9.6	82.1	5.4	-1.9	6.4	17.4	5.3	-2.9	17.6	240.7	5.5	0	10.5	100
		Wet meadow	%	12.3	-2.4	12.2	-3.9	12.4	-1.4	12.4	0.0	12.4	-0.5	12.2	-5.7	11.6	-18.0	14.2	37.6	16.5	87.0	22.9	225.6	12.4	0	17.1	100
Riparian width	% of channel length with riparian buffer >100 m wide	Riparian forest, mainstem	km	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0	3.1	0.0	3.8	15.1	5.0	44.2	3.9	17.4	4.1	22.1	13.7	247.4	3.1	0	7.4	100
		Ripaian forest, tributary	km	4.9	72.4	3.1	30.4	2.6	18.8	2.7	22.7	2.6	19.5	2.4	13.8	1.8	0.0	1.8	0.0	1.8	0.0	2.0	5.5	1.8	0	6.1	100

Appendix B

Prioritization Criteria Assessment Methods

The prioritization criteria table is a tool to compare different restoration concepts to each other with regards to certain ecological benefits and outcomes. Some of the criteria are more quantitative (such as habitat extent), while others are a best approximation of the likely benefits of a concept given that some conditions (e.g., topography, hydrodynamics) are difficult to determine at this stage in concept development or given available data and research. More precise benefits for these criteria will be clearer in later stages of concept design. Several criteria are assessed based on the same metrics or habitat types. These are not meant to be redundant, but rather are meant to reflect the multi-benefit nature of certain habitats. For example, a large restored valley freshwater marsh will both support native wildlife and improve water quality through nutrient assimilation. These are assessed separately in the prioritization table.

Concepts are rated for each criteria as "high," "medium," low," or "none." High ranks are reserved for standout values for each concept, and remaining concepts rankings are generally split evenly between medium and low. For habitat extent criteria, concepts marked with "none" include negative values, zero and negligibly small positive values. General explanations for rating concepts for each criterion are detailed in the table below.

MANAGEMENT OBJECTIVES	PRIORITIZATION CRITERIA		METHOD FOR DETERMINING SCORE
Enlarge riparian and wetland habitat patches and improve their connectedness	A	Expands valley freshwater marsh and/or enhances connectivity	Prioritization scores were based on metric scores for valley freshwater marsh. Metrics included habitat extent, patch size (total area>10ha), core-to-edge ratio, distance (mean) to large patch, and network connectivity. Overall prioritization score for each concept was determined from the most common or mode ranking across metrics, rounding up with a tie.
	B	Expands forested wetland and mixed riparian and/or enhances connectivity	Prioritization scores were based on metric scores for forested wetland and mixed riparian habitat types. Metrics included habitat extent, patch size (total area>10ha), distance (mean) to large patch, habitat width, and mainstem and major tributary length with forested wetland or mixed riparian habitat >100m width. Overall prioritization score for each concept was determined from the most common or mode ranking across metrics, rounding up with a tie.
	C	Expands wet meadow and/or enhances connectivity	Prioritization scores were based on metric scores for wet meadow. Metrics included habitat extent, patch size (total area>10ha), core-to-edge ratio, distance (mean) to large patch, and network connectivity. Overall prioritization score for each concept was determined from the most common or mode ranking across metrics, rounding up with a tie.

MANAGEMENT OBJECTIVES	PRIORITIZATION CRITERIA		METHOD FOR DETERMINING SCORE
Decrease sediment and nutrient delivery to the Laguna, especially at areas of high deposition/ accumulation rates. Move sediment from accumulation areas where appropriate	D	Improves water quality through biological uptake of nutrients (in habitats with high assimilative capacity)	Prioritization scores were based on increases in habitat types associated with high assimilative capacity (valley freshwater marsh, wet meadow) and increases in width of riparian habitat types.
	E	Improves water quality through reduction of sediment in the main channel through natural floodplain deposition	Prioritization scores were based on changes in the extent of valley freshwater marsh or changes in tributary confluence likely to support deposition. These changes are assumed to increase the potential for sediment deposition outside of the channel through floodplain expansion.
	F	Improves water quality by removal of sediment through active management (dredging)	Prioritization scores were based on the degree of mechanical sediment removal, through dredging and subsequent deposition in deeper water, expected to result from the creation or deepening of channels and ponds.
Control the extent of invasive plant species, and encourage conditions that enable native species	G	Increases shade and canopy cover through riparian enhancement	Prioritization scores were based on the extent of tree-dominated habitats assumed to provide shade (forested wetland and riparian habitat).
	H	Increases competition with ludwigia via native habitat types (wet meadow and bulrush)	Prioritization scores were based on the change in the extent of habitat types thought to compete with *Ludwigia* spp.; specifically, valley freshwater marsh or wet meadow (whichever is higher).
	I	Decreases invasive *ludwigia* spp. opportunities by increasing water depth	Prioritization scores were based on the amount of increase or enhancement of deep water habitat through dredging.
Improve late spring/ summer water quality through improved drainage and flow conveyance	J	Decreases perennial shallow slow moving water	Prioritization scores were based on potential for increasing drainage due to regrading during restoration.
	K	Relieves flow constrictions and impeded flow due to channel alignment	Prioritization scores were based on the degree of channel realignment.
	L	Expands seasonally inundated habitats while reducing late-season or perennial shallow water inundation	Prioritization scores were based on the extent of wetland habitat.