



# Santa Rosa Plain Wetlands Profile:

## A Demonstration of the California Wetland and Riparian Area Monitoring Plan

Prepared by:

Josh Collins

Sarah Lowe

Sarah Pearce

Chad Roberts

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## Table of Contents

Executive Summary.....	1
Wetland Abundance and Diversity .....	1
Wetland Condition and Stress.....	1
Looking Forward .....	2
Introduction .....	3
Purpose .....	3
WRAMP Overview.....	4
Methods.....	5
Study Area.....	5
Surface Waters Mapping .....	6
Surface Waters Classification.....	6
Visualizing Riparian Areas .....	6
Level 2 (CRAM) Sample Frames .....	7
Level 2 (CRAM) Sample Draw .....	8
Level 2 (CRAM) Field Work .....	8
Level 2 (CRAM) Analyses.....	9
Results.....	11
Abundance and Diversity of Wetlands .....	11
Riparian Extent.....	13
Wetland Condition .....	15
Stressors.....	21
Landscape Patterns in Wetland Condition .....	22
Discussion.....	27
Wetland Management and Wetland Condition .....	27
Exotic Plant Species and Wetland Condition .....	28
WRAMP and Water Quality Control Planning .....	29
Looking Forward .....	31
General Guidelines for Wetland Project Siting.....	31
General Guidelines for Wetland Project Design .....	33
Wetland Project Assessment and Tracking .....	37
References .....	38
Appendix .....	41



## Santa Rosa Plain Wetlands Landscape Profile

### Executive Summary

The Wetland and Riparian Area Monitoring Plan (WRAMP) is a framework and toolset for developing and organizing information to protect, design, manage, and assess wetlands and other surface waters. A WRAMP demonstration was conducted during 2013-14 for the Santa Rosa Plain, Sonoma County, CA. This demonstration answered the following question: *what are the abundance, diversity, and condition of wetlands on the Santa Rosa Plain?*

### Wetland Abundance and Diversity

The total length of riverine wetlands (streams) in the Study Area is 430 mi. The total area of all non-riverine wetlands (depressional wetlands, lacustrine wetlands, slope wetlands, and vernal pools) is about 8 mi<sup>2</sup> (5,296 acres). Half the non-riverine wetland area consists of vernal pool systems (pools plus their upland matrix). Depressional and slope wetlands contribute about equally to the other half of the non-riverine area (about 23% and 24%, respectively). Lacustrine wetlands (including retention basins) make up the remaining 3% of the non-riverine wetlands.

More than 80% of the riverine wetlands have riparian areas that are less than 2m wide. These areas lack riparian trees or shrubs, including commercial grapes or other tall crops, and are instead bordered by hardscape or pasture. About half of these wetlands are ditches and other unnatural channels. Almost all of the remaining riparian areas (about 13%) consist of higher-order natural channels bordered by trees or tall shrubs that constitute riparian areas 30-40m wide. These results indicate that more than 80% of the riverine riparian areas provide little or no riparian function. They might provide some filtration of low-velocity surface runoff, but they are not stabilizing the channel banks, shading the wetlands between the banks, or providing inputs of organic matter. They provide very little benefit to wildlife.

### Wetland Condition and Stress

Condition was assessed for depressional wetlands, slope wetlands, and riverine wetlands (streams) using the California Rapid Assessment Method (CRAM). Vernal pools were not assessed. Some general conclusions about wetland condition are summarized as follows.

- Slope wetlands are generally in better condition than depressional wetlands, which are generally in better condition than riverine wetlands.
- The overall condition of these three wetland types is fair, relative to their best achievable conditions. Their condition generally decreases with distance upslope away from the Laguna and toward the urban landscapes.
- The overall condition of the Laguna is consistent with high levels of wetland function. A general perception exists that the Laguna is severely degraded, and while there is evidence to support that perception from several perspectives, this application of WRAMP indicates that the Laguna supports substantial, positive wetland functions. Management approaches that maintain the positive aspects of the Laguna's condition should be considered, as other, negative aspects of its condition are addressed.

## Santa Rosa Plain Wetlands Landscape Profile

- For depressions and slope wetlands, the important stressors are mowing, intensive grazing and artificial drainage or other forms of artificial water management.
- For riverine wetlands, the important stressors are hydromodification resulting from upstream development, channel revetment and other channel engineering, excessive human visitation, excessive trash, and mowing or grazing of buffer zones.
- Exotic plant species are prevalent in each wetland type and one species, reed canary grass, is showing signs of predominance in depressional wetlands.

## Looking Forward

A major purpose of WRAMP is to support watershed-based approaches to avoid or minimize impacts of human activities on aquatic resources, or to compensate for unavoidable impacts. Findings of this WRAMP demonstration suggest that the following aspects of a watershed approach to wetland protection on the Plain should be considered.

- Develop a matrix relating wetland restoration design and landscape position to wetland beneficial use attainment, and use the matrix to envision the ideal landscape.
- Use the historical form of the Plain in plan-view and profile as a large-scale spatial template for restoration design. That is, regard the Plain as a system of generally self-similar but divergent distributaries on alluvial fans having an array of wetlands and riparian areas typical of fans in the region, as explained in this report.
- The drainage density of the Plain has been artificially increased, such that its ability to process runoff through filtration and infiltration has been greatly decreased. Efforts to protect and enhance the aquatic resources of the Plain should focus on lengthening the drainage pathways. This can be achieved by replacing ditches with new or restored wetlands and by building elements of Low Impact Development (LID) into storm drains and irrigation return flow systems.

CRAM can be used as a framework for wetland and stream restoration and mitigation conceptual design. CRAM Metrics can be used to identify what specific physical and biotic elements might be added to a site to improve its function. The conceptual designs based on CRAM can be translated into site construction specifications and project performance criteria. CRAM can later be used to assess project performance.

WRAMP includes tools specifically designed for tracking projects intended to improve aquatic resource condition. These tools are Project Tracker, Online 401, and the Landscape Profile Tool. Project Tracker allows users to map projects and share project information via online interactive project maps. Online 401 is designed specifically for regulatory personnel who issue and manage 401 Certifications. The Landscape Profile Tool summarizes environmental information for user-defined areas. In addition to serving regulatory and management programs, this tool can help educators, students and the general public learn about the aquatic resources near them. Through these tools, WRAMP can help establish stronger public support for the care and protection of the state's aquatic resources.

## Santa Rosa Plain Wetlands Landscape Profile

### Introduction

#### Purpose

The Wetland and Riparian Area Monitoring Plan (WRAMP) is a framework and toolset for developing and organizing information to protect, design, manage, and assess wetlands and other surface waters (see Appendix).

The focus of this WRAMP demonstration is the Santa Rosa Plain, including the Laguna de Santa Rosa, in Sonoma County, CA. This application of WRAMP, like all others, is driven by an environmental regulatory or management question. In this case, the question is: *what are the abundance, diversity, and condition of wetlands on the Santa Rosa Plain?*

The answer to a question of this kind is called a Wetlands Landscape Profile, or Wetlands Profile. This Profile was produced between spring 2013 and fall 2014. It meets four common objectives of WRAMP demonstrations:

- Develop a digital inventory of the surface waters of the Study Area suitable for local and regional land use planning, management, and regulation;
- Assess the overall condition of one or more types of wetlands;
- Use repeatable methods that generate scientifically sound, comparable Wetland Profiles over time and for different landscapes; and
- Make the data and information contained in the Wetland Profile available to the public through one or more online information delivery systems.

In addition to meeting these four main objectives, this WRAMP demonstration also provided three additional products:

- Estimates of riparian area for classes of riparian width corresponding to suites of riparian functions, as a model approach to riparian buffer design;
- A tentative framework for specifying water quality objectives for wetlands, based on expected relationships between wetland condition and wetland Beneficial Uses; and
- Site-specific and landscape-scale guidelines for the design and siting of wetland restoration and enhancement projects. This is an extension of the planning work already provided by others (e.g., Sloop et al 2007).

There are many emerging opportunities to address environmental problems on the Plain, especially with regard to the conservation of vernal pool resources<sup>1</sup> and the health of the Laguna. The Laguna is known to be impaired by excessively high water temperatures and

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<sup>1</sup> See <http://www.spn.usace.army.mil/Missions/Regulatory/RegulatoryOverview/PoliciesontheSantaRosaPlain.aspx> for a summary of vernal pool ecology and the elements of a regulatory program that incorporate responses to the ecological knowledge.

## Santa Rosa Plain Wetlands Landscape Profile

excessive inputs of fine sediment and nutrients, particularly nitrogen and phosphorus.<sup>2</sup> This WRAMP demonstration is not intended to directly address these concerns. It is a contribution to the continued discovery of the natural and human history of the Plain (e.g., Honton and Sears 2006, Sloop et al 2007, Curtis et al. 2012, Nishikawa 2013). These and other studies have focused on particular elements of the geology, hydrology, geomorphology and ecology of the Plain and the Laguna. Fully integrating the findings of these studies with the results of this WRAMP demonstration is beyond its scope. However, this demonstration of WRAMP constitutes the first systematic assessment of wetland condition for the Santa Rosa Plain that employed a standardized assessment methodology already in use throughout California. The results have broad implications for managing the Plain in the future.

### WRAMP Overview

WRAMP is a framework and toolset for developing and organizing information to protect, design, manage, and assess wetlands and other aquatic resources. According to WRAMP, the information can be organized into three categories or levels. The regulatory decisions or management questions that drive WRAMP applications information can be similarly classified. The levels differ from each other based on their spatial scale and specificity.

*Level 1* consists of data derived from maps and remotely sensed data. They mostly address questions about the abundance and diversity of aquatic resources across landscapes. The primary Level 1 tool used in this WRAMP demonstration is the California Aquatic Resource Inventory (CARI), a standardized statewide method of mapping and classifying surface waters of the state.

*Level 2* consists of standardized rapid field assessments of overall condition or stress. These data mostly support broad questions about the potential of aquatic resources to support high levels of their intrinsic ecosystem services. The Primary Level 2 tool used in this WRAMP demonstration is the California Rapid Assessment Method for wetlands and wadeable streams (CRAM). To learn more about CRAM, go to: [www.cramwetlands.org](http://www.cramwetlands.org).

*Level 3* consists of quantitative field measures of selected aspects of health or stress. Estimates of wildlife population size and contaminant concentrations are examples of Level 3 data. These data tend to be relatively expensive. According to WRAMP, special care must be taken to make sure all Level 3 data are necessary to address a clearly stated management or regulatory decision or question. The question driving this WRAMP demonstration (see Introduction) could be answered without Level 3 data.

WRAMP includes data and information delivery systems for each WRAMP tool. These are web-based systems designed to shorten the time between the collection of data and their use in regulatory or management decisions. For example, CARI is supported by a database that tracks updates and versions. There is a project tracking tool that enables users to map their projects

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<sup>2</sup> For an explanation of the impairment of the Laguna de Santa Rosa and supporting technical memoranda and reports, see [http://www.swrcb.ca.gov/northcoast/water\\_issues/programs/tmdls/laguna\\_de\\_santa\\_rosa/](http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/laguna_de_santa_rosa/).



## Santa Rosa Plain Wetlands Landscape Profile

and share information through an interactive project map, the basemap for which is CARL. CRAM is supported by eCRAM, a database that enables CRAM practitioners to manage their CRAM data. It also enables anyone to sort and view CRAM results. EcoAtlas is a web-based system that enables users to aggregate and view data and information from WRAMP databases and other sources. The Landscape Profile tool enables EcoAtlas users to summarize selected types of data and information for user-defined areas. To learn more about projecting tracking and the Landscape Profile Tool, explore the projects database and the tools section in EcoAtlas at [www.Ecoatlas.org](http://www.Ecoatlas.org).

## Methods

### Study Area

The Study Area is the Santa Rosa Plain and the Laguna de Santa Rosa (Figure 1). Numerous tributaries to the Laguna are not separately identified by name in CARL, but all tributaries were included in the inventory and assessment of aquatic resources.

This report adopts the regional convention that Mark West Creek is a tributary to the Laguna, such that the Laguna continues below its confluence with Mark West Creek and constitutes the common discharge stream to the Russian River from the entire Study Area. The Study Area's boundary was defined by the northern, western, and southern portions of the Watershed Boundary Dataset HUC10 watershed unit. The eastern Study Area boundaries were defined using a 12-percent slope threshold to separate the Santa Rosa Plain from the foothills to the east and west of the plain, based on the USGS 10-meter National Elevation Dataset.

The Study Area includes urban areas, croplands, and areas that were subject to dairying for nearly two centuries. As other studies have shown, these land uses have directly affected conditions in the Laguna. The Study Area excludes less-disturbed areas in the headward reaches of the Laguna's major tributaries above the Santa Rosa Plain.

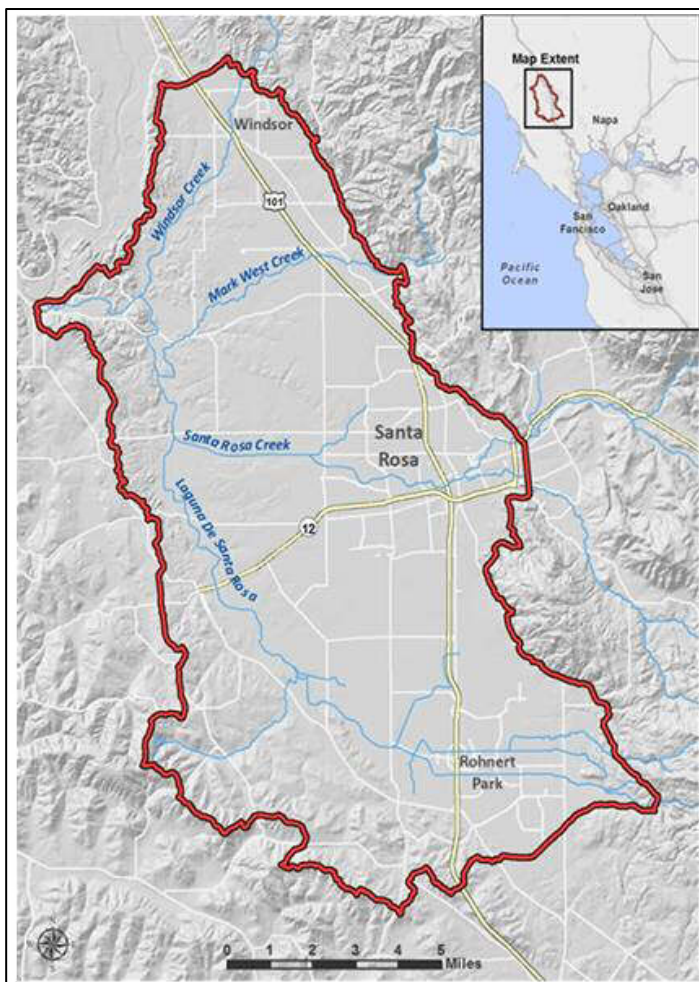


Figure1. Map of the Santa Rosa Plain as the WRAMP Demonstration Study Area.

## Surface Waters Mapping

Surface waters were initially mapped by compiling existing Level 1 data<sup>3</sup>. The draft inventory was then intensified by applying the CARI 1.0 SOP (SFEI 2013).

CARI 1.0 is designed to provide the detail and accuracy needed to support local land use planning, but is consistent with the standards of the Federal Geographic Data Committee. Comprehensive application of the CARI 1.0 SOP results in a digital map of all surface waters visible in aerial images viewed at scales of 1:2500 to 1:5000, depending on the type of surface water feature. A variety of ancillary Level 1 data were used to support the image interpretations. The limitations on viewing scale cause some very small features to be excluded. For example, very narrow and shallow ditches may be overlooked. Small vernal pools are automatically included in the maps as integral components of vernal pool systems

Existing maps of surface waters were expanded and intensified using the CARI 1.0 SOP. Field visits were then conducted by mapping teams that included experienced wetland and stream scientists. These field visits served to enhance and validate the draft maps. These visits did not involve formal delineation of wetlands and other surface waters. However, all field personnel were familiar with commonly accepted standards for wetland identification and delineation, and the study adopted the convention that a potential CRAM Assessment Area (AA) that did not meet these standards should be rejected.

## Surface Waters Classification

Surface waters included in CARI 1.0 were classified as riverine wetlands, depressional wetlands, slope wetlands, lacustrine wetlands, or vernal pool systems. The waters were further classified as natural or artificial based on CARI guidelines. The open water and vegetated portions of the depressions and lacustrine areas were mapped and classified separately. The CARI classification system can be cross-walked directly to the CRAM classification system.

A public workshop was hosted by the Laguna Foundation in late 2013 to enable residents in the Study Area and other stakeholders to provide input on the draft inventory of surface waters. This input was used to finalize CARI 1.0 for the Study Area.

## Visualizing Riparian Areas

Riparian areas were added to the inventory of surface waters after it was finalized. The extent of riparian areas was estimated for all surface waters on the Santa Rosa Plain, including the Laguna, using a beta test version of the Riparian Width Estimator Tool (RipZET). This tool generates different widths for different suites of functions based on the distribution and planform of surface water features (as evident in CARI), the height of the associated vegetation

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<sup>3</sup> CARI incorporates the National Hydrographic Dataset (NHD), National Wetlands Inventory (NWI), Sonoma County 2011 High Resolution Imagery, Laguna Foundation 1k Hydrography, Laguna Foundation vernal pools map.

## Santa Rosa Plain Wetlands Landscape Profile

overstory, and the steepness of the adjoining landscape. RipZET is based on the riparian definition provided by the National Research Council (NRC 2002), and generalized relationships between riparian width and riparian function (e.g., Wenger 1999, Collins et al 2006). Site-specific relationships might vary significantly from these generalizations.

RipZET consists of separate modules relating to different sets of riparian functions. In this application of RipZET, the vegetation module was used to generate riparian widths relating to bank stability, shading, allochthonous input, and runoff filtration. It is expected that the riparian widths estimated by this module might underestimate the riparian areas required to fully support some ecological functions (e.g., dispersal and migration of amphibians, nesting and foraging by riparian avifauna, etc.), or to accommodate functions related to flooding (e.g., flood water storage, flood stage desynchronization, suspended sediment deposition, riparian vegetation rejuvenation, etc.). The RipZET modules for estimating riparian widths for these ecological and flood-related functions are still being developed.

The vegetation module first creates an intersection between a digital map of vegetation and the digital map of surface waters. The vegetation data used in this demonstration was CALVEG produced by the U.S. Forest Service. The vegetation is classified as trees, shrub-scrub, grasses and forbes, or bare ground. For each type of vegetation except trees, the module provides a default value for riparian width, termed a Standard Buffer Distance (SBD). Trees are treated differently because of their greater importance as sources of shade and allochthonous material. Levels of these particular functions are positively related to tree height, which varies with tree species and tree age. The module provides default values of expected heights for mature trees of each species. The user must join the vegetation data to the spreadsheet of default tree heights and SBD values. The user can edit the default values as needed to represent local conditions. The module also enables the user to make the functional riparian width equal to any multiple of tree height. This can be necessary to account for allochthonous input from trees at different distances away from aquatic features. For example, windthrow in the first two or three rows of trees along a stream can account for much of their input of large woody debris. There is a minimum riparian width of 1m for bare ground or pavement. There is no functional riparian width where one aquatic feature intersects another, such as where the flow from a riverine wetland enters a depression. The vegetation module estimates functional riparian width independently for the left and right banks of a riverine wetland.

### Level 2 (CRAM) Sample Frames

CARI 1.0 for the Study Area was used to create sample frames for Level 2 field assessments of wetland condition for natural and artificial wetlands of three types: riverine, depressions, and slope wetlands. Lacustrine wetlands (wetlands fringing open water areas larger than 8 hectares and having an average depth greater than 2 meters) were deemed too uncommon in the Study Area to warrant inclusion in the condition portion of the landscape profile. Vernal pools were excluded from the assessment of condition for three reasons. First, the optimal annual period for assessing vernal pools using CRAM is restricted to a few weeks in early spring that was outside the single field season available for this study. Second, vernal pools are by nature

## Santa Rosa Plain Wetlands Landscape Profile

essentially isolated from flow pathways connecting sources of sediment or other pollutants to the Laguna and therefore are not expected to be a significant component of plans to improve Laguna water quality. Finally, funding for the project was not adequate to assess more than three common wetland types. Riverine wetlands identified in CARI as first-order were excluded from the riverine sample frame because evidence from other Level 2 surveys indicates that first-order riverine wetlands tend to get erroneously low CRAM scores due to their general lack of physical and biotic complexity (CWMW 2013).

### Level 2 (CRAM) Sample Draw

A probabilistic sample draw was conducted to identify 30 AAs for each wetland type to be assessed using CRAM. Each sample draw followed the Generalized Random Tessellation Stratified (GRTS) approach developed by the USEPA for the National Environmental Monitoring and Assessment Program.<sup>4</sup> This approach allows the results of the assessment to be reported in terms of the percent of each assessed wetland type above or below any given CRAM score.

Draft sample draws were inspected to assure adequate representation of each wetland type. For example, some riverine wetlands that were historically second- or third-order but that had lost their tributaries due to agriculture or urbanization were initially excluded from the riverine sample frame because they had become first-order. Such riverine wetlands were added back into the riverine sample frame. Inspection of the draft sample frame in conjunction with field visits resulted in some reclassification of slope wetlands as depressional wetlands.

The final sample draws for each wetland type included more AAs than could be assessed. These overdraws allowed for the replacement of AAs rejected due to inaccurate mapping, misclassification, or lack of access.

### Level 2 (CRAM) Field Work

Field assessments of wetland condition were conducted using the California Rapid Assessment Method (CRAM).<sup>5</sup> The assessments were conducted between July and October, 2013, which is consistent with the preferred period of CRAM assessment for the three targeted wetlands types (riverine, depressional, and slope wetlands). Three teams of two practitioners conducted the assessments, using the current versions of CRAM Field Books (version 6.1). The team leaders are experience practitioners who have served as CRAM developers and trainers.

CRAM is a cost-effective and scientifically defensible rapid assessment method for monitoring the condition of wetlands throughout California. It is designed for assessing ambient or baseline wetland conditions as well as for assessing the performance of wetland and stream mitigation and restoration projects. The assessments are conducted within and around standardized

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<sup>4</sup> See [http://www.epa.gov/nheerl/arm/designing/design\\_intro.htm](http://www.epa.gov/nheerl/arm/designing/design_intro.htm). For additional information about the GRTS methodology see Stevens and Olsen (2004), Stevens and Jensen (2007).

<sup>5</sup> See [www.cramwetlands.org](http://www.cramwetlands.org). Guidance materials for CRAM applications, field books for assessments, information about the CRAM program, and data downloads are available on this website.

## Santa Rosa Plain Wetlands Landscape Profile

Assessment Areas (AAs), based on visual indicators used to score Metrics of condition for four Attributes: landscape connectivity and buffer, hydrology, physical structure, and biotic structure. For each AA, the Metric scores are summed to produce Attribute scores, which are summed to produce an Index score. In addition, each assessment includes the identification of likely stressors operating within or near the AA, based on a standard stressor checklist.

In practice, assessment teams use the online user interface of the CRAM database to produce a digital map of each AA, and to upload their scores and other supporting information as attributions of the map. The database provides a series of automated QAQC procedures that help assure the completeness of the dataset for each assessment.

The CRAM assessments proceeded according to the GRTS methodology. AAs were assessed in the order listed in the probabilistic sample draws. A total of eight AAs were replaced with other AAs from the sample draw, following the GRTS methodology. The replacements were necessary because of misclassification of the wetlands in CARI (6 cases), conversion to non-wetland land cover after CARI was produced (1 case), and denied access (1 case).

### Level 2 (CRAM) Analyses

CRAM can be used to compare different types of wetlands based on their condition. This is because, for each wetland type, CRAM measures condition relative to the best achievable condition. Therefore, two wetland areas of different type having the same CRAM score are assumed to have the same condition relative to their respective best achievable condition. This does not mean that they provide the same levels of the same wetland functions; it means that they are likely to provide similar levels of their respective functions, whatever they may be.

The cumulative distribution function plot (CDF) of CRAM scores for each wetland type can be used to assess the percent of the resource (total area for wetlands or total length in the case of streams) within the Study Area that is likely to score above or below any given score. For example, the CDF for the Riverine Index scores (Figure 2) shows that scores ranged from 45 to 83, and that half of the total riverine stream length is likely to have an Index score of 61 or less. To be more exact, there is a 95% chance that half the riverine habitat would have an index score equal to or less than a value between 58 and 70. If the condition of riverine wetlands were to improve over time, the CDF plot would be expected to shift to the right, such that the 50<sup>th</sup> percentile score would increase.

Each score can be assigned to a category of condition based on the range of scores to which it belongs. For this WRAMP demonstration, three categories of condition were determined by dividing the full range of possible CRAM scores into three equal segments. For example, since the Index scores can range from 25 to 100, the condition categories are 25-50 (poor condition), 51-75 (fair condition), and 76-100 (good condition). This categorization allows wetland classes to be compared based on the distribution of scores among the condition categories (Figure 2).

Box plots are used to display CRAM summary statistics for each wetland class (Figure 3). In each plot, the mean of the scores is represented by a diamond. The median score is shown by a bold horizontal line inside the box. The box top and bottom correspond to the first and third



### Santa Rosa Plain Wetlands Landscape Profile

quartiles (Q1 and Q3, respectively, also referred to as the 25th and 75th percentiles). The vertical lines (also termed “whisker”) extending from the top and bottom of the box and end at the maximum score that is within 1.5 x IQR, where IQR is the inter-quartile range, or distance between the first and third quartiles. Any scores beyond the end of either whisker are presumed to be outliers.<sup>6</sup> Actual CRAM scores were overlaid on the box plots to show the actual distribution of scores (Figure 3).

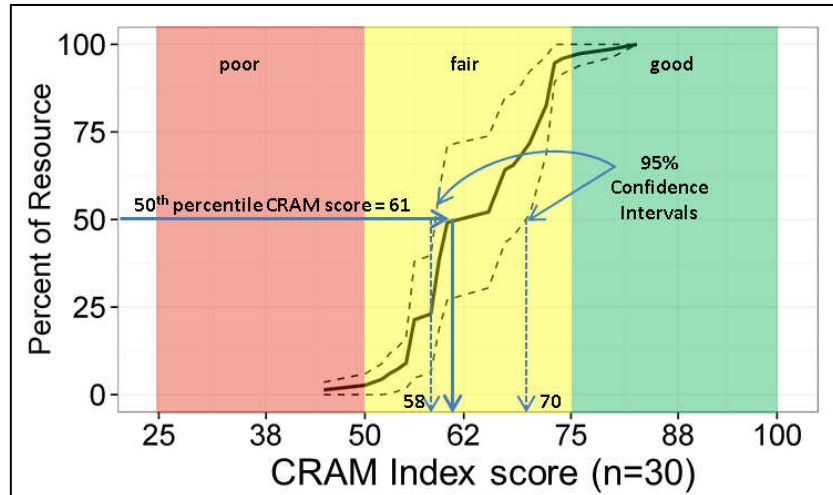


Figure 2. Anatomy of a Cumulative distribution function plot (CDF), based on CRAM Index scores for riverine wetlands, indicating a 95% chance that 50% of the total length of riverine wetland has an Index score between 58 and 70, and that most riverine wetlands have mid-range scores representing fair condition.

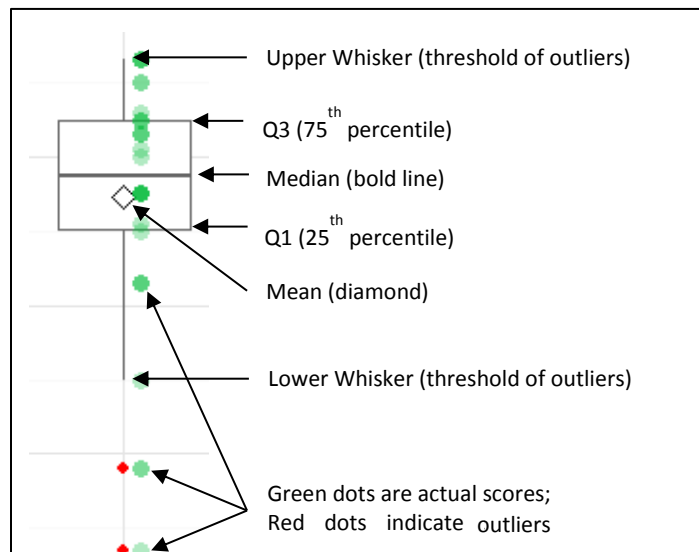


Figure 3. Anatomy of a box plot, showing summary statistics of CRAM scores among AAs.

<sup>6</sup> Description of the plot generated by “geom\_boxplot” in R. <http://docs.ggplot2.org/0.9.3.1/index.html> (McGill and others 1978).

## Results

### Abundance and Diversity of Wetlands

The Study Area covers 132 mi<sup>2</sup> (84,569 acres). Based on CARI 1.0, the total length of riverine channels in the Study Area is 430 mi. The total area of all non-riverine wetlands (depressional wetlands, lacustrine wetlands, slope wetlands, and vernal pool systems) is about 8 mi<sup>2</sup> (5,296 acres). Half of the non-riverine wetland consists of vernal pool systems (Figure 4). Depressional and slope wetlands contribute about equally to the other half of the non-riverine area (about 23% and 24%, respectively). Lacustrine wetlands (including retention basins) make up the remaining 3% of the non-riverine wetland area. Since the average maximum depth of the open water portions of these features is less than 6 ft, they could be classified as depressions. However, given the large areas of open water that they attend, it is assumed that these features function more as lacustrine wetlands than as depressional wetlands.

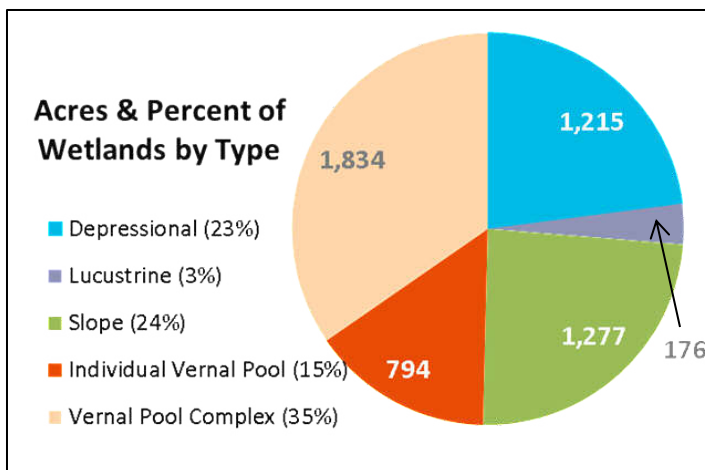


Figure 4. Relative proportions and acres of non-riverine wetlands on the Santa Rosa Plain.

Individual vernal pools are mapped separately from vernal pool complexes if they are large enough to be accurately mapped using 1.0 m pixel resolution imagery viewed at a scale 1:2,500. Many of these relatively large vernal pools are situated in vernal pool complexes. Care was taken not to double count the areas of individual pools.

There are vernal pools and riverine features that are not represented in the current CARI 1.0 for the Santa Rosa Plain. Using imagery to map vernal pool complexes that are fragmented by land use or otherwise disturbed is complicated by the variability in their visual indicators. There also may be vernal pools hidden from view under trees. It is expected that the current inventory represents more than 90% of the vernal pool areas for the Plain as a whole. Small ditches are also difficult to map comprehensively. The current inventory excludes numerous small ditches extending various distances in directions normal or oblique to local topographic slopes that are faintly visible in the highest-resolution imagery available at this time. These ditches may comprise a very important network of artificial drainages affecting the abundance and condition of non-riverine wetlands. A local CARI stewardship program is being developed whereby local experts knowledgeable of field conditions revise the inventory.

CARI 1.0 for the Santa Rosa Plain includes many small wetland areas that are not visible when the inventory is viewed at small scale (Figure 5). However, the data have been incorporated into EcoAtlas, where they can be viewed online at multiple scales on various backgrounds to enhance their visibility.

# Santa Rosa Plain Wetlands Landscape Profile

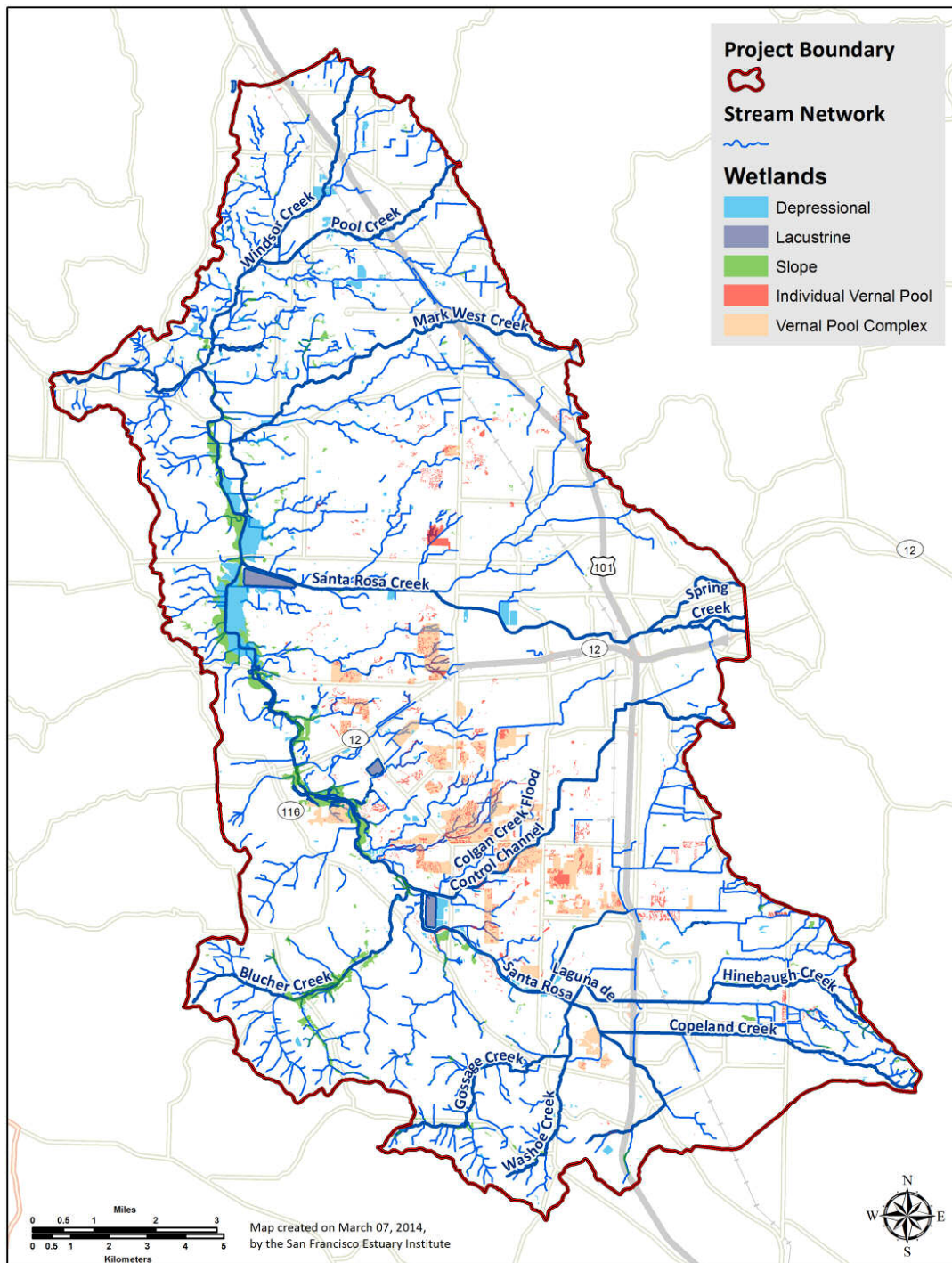


Figure 5. CARI 1.0 for the Santa Rosa Plain Study Area.



## Santa Rosa Plain Wetlands Landscape Profile

## Riparian Extent

Riparian extent along the riverine channels and non-riverine wetlands was estimated for the Santa Rosa Plain (Figure 6) using a beta test version of the vegetation module of the Riparian Zone Estimator Tool (see methods section above).

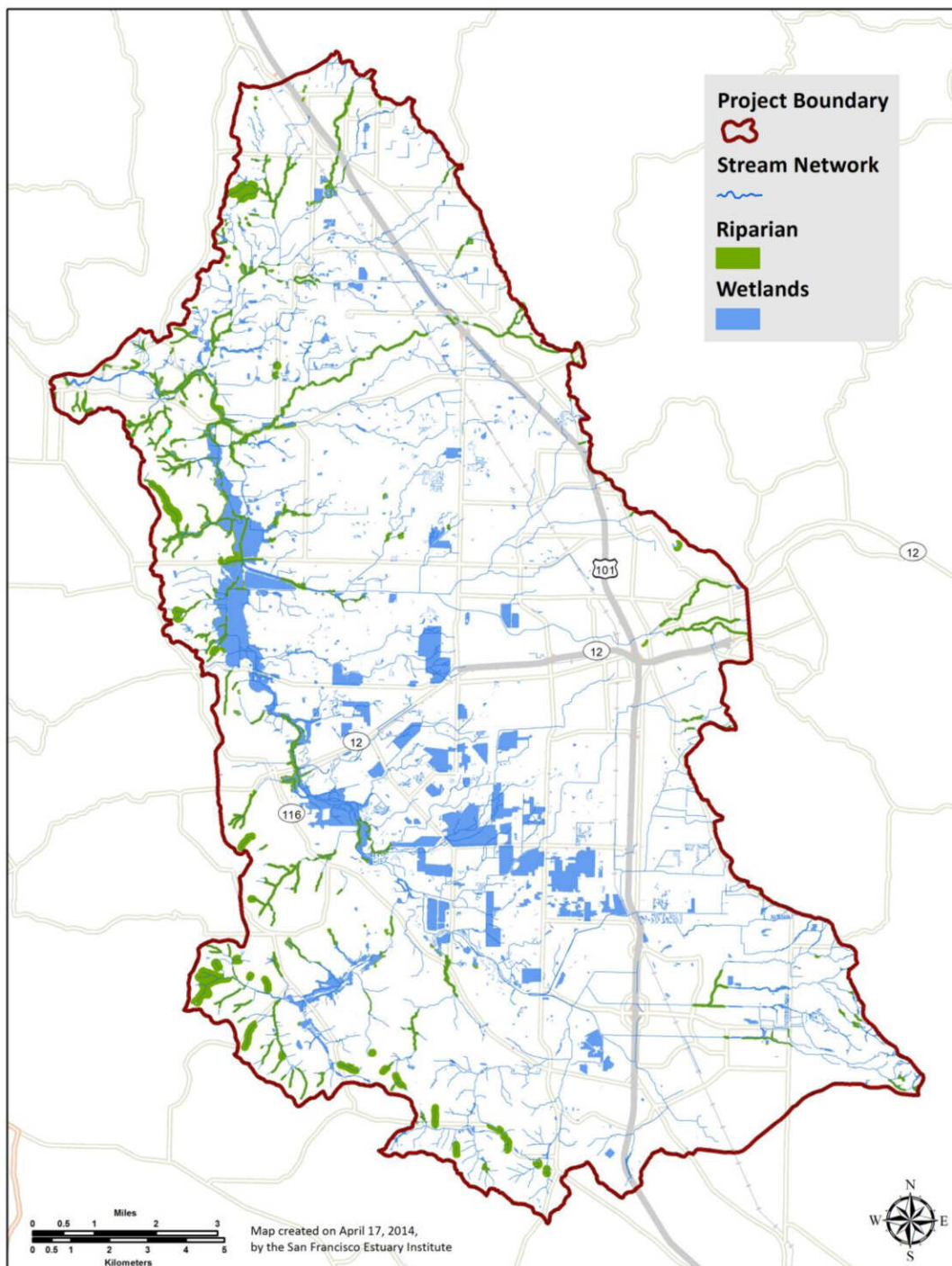


Figure 6. Riparian Extent for on the Santa Rosa Plain based on the Riparian Zone Estimator Tool.

### Santa Rosa Plain Wetlands Landscape Profile

The distribution of riverine riparian areas among width classes can provide some insights into the kinds of functions the areas are able to provide. A substantial body of scientific and planning literature provides the basis for deducing general relationships between riparian width, as estimated by the vegetation module of RipZET, and the likelihood of the riparian area supporting shading, bank stabilization, runoff filtration, and allochthonous input. As a general rule, the diversity and level of these functions increases with riparian width, up to a width of about 50m. Other hydrological and ecological functions that are not represented by the vegetation module might require greater or lesser width, depending on the function and site-specific conditions.

The RipZET results for the Santa Rosa Plain indicate two categories of riverine wetlands (Figure 7). More than 80% of the riverine wetlands have riparian areas that are less than 2m wide. These areas lack riparian trees or shrubs, including grapes or other tall crops, and are instead characterized by hardscape or pasture. About half of these wetlands are ditches and other unnatural channels. Almost all of the remaining riparian areas (about 13%) are higher-order natural channels boarded by trees or tall shrubs that constitute riparian areas 30-40 m wide.

These results indicate than more than 80% of the riverine riparian areas on the Santa Rosa Plain provide little or no riparian function. They might provide some filtration of low-velocity surface runoff, but they are not stabilizing the channel banks, shading the wetlands between the banks, or providing inputs of organic matter. Given that they tend not to be deep, their banks are probably not eroding, despite the lack of stabilizing vegetation. If these areas are eroding, they are probably providing fine inorganic sediment to the wetlands. At times of high flow, these wetlands could be conveying the eroded sediments downstream.

In contrast, the riparian areas 30-40 m wide have the potential to provide high levels of all the functions relating directly to vegetation structure. As noted earlier, these areas may need to be wider to support their full complement of ecological functions. They might also involve invasive species of non-native vegetation that would decrease their ecological value.

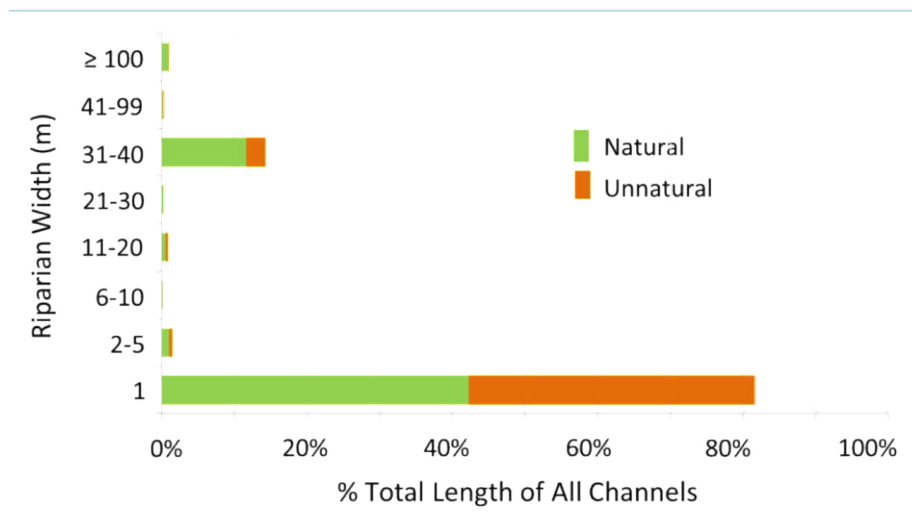


Figure 7. Distribution of natural and unnatural riverine riparian areas among riparian width classes. A riparian area is classified as unnatural if it borders an unnaturalized artificial channel.

## Santa Rosa Plain Wetlands Landscape Profile

### Wetland Condition

Box plots of CRAM Index scores indicate that the condition of the CRAM AAs ranged broadly from poor to fair for all three types of wetlands (Figure 8).

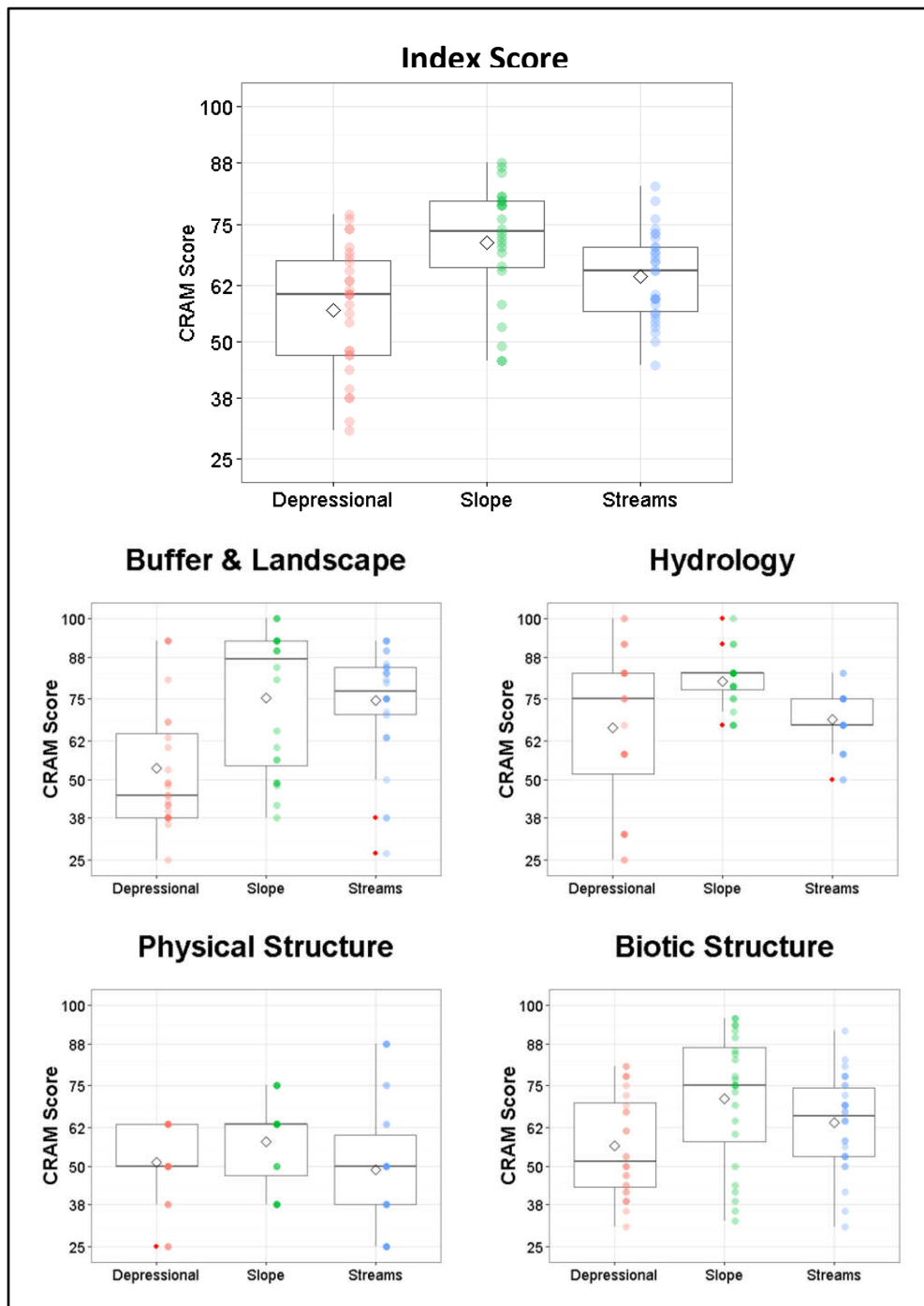


Figure 8. Box plots of CRAM Index and Attribute Scores for depressions, slope wetlands, and riverine wetlands (streams) on the Santa Rosa Plain.

### Santa Rosa Plain Wetlands Landscape Profile

The box plots for Index scores show that the overall condition was more variable but generally better for the slope wetland AAs.<sup>7</sup> Box plots for Attribute scores suggest that, for all wetland types, the Index scores were lowered mainly by physical structure scores. In essence, the wetlands tended to be much less complex than wetlands of having higher levels of more functions. The Index scores for depressional wetland AAs were also lowered by their scores for landscape connectivity and buffer. This reflects the fact that many depressions are unnatural features situated in disturbed landscape and hydrologically isolated from other wetlands.

The mean and variance of the CRAM scores and other summary statistics from the probabilistic survey of each wetland type are reported in Table 1.

Summary Statistics for CRAM Index Scores	Wetland Type		
	Depressional (n=28)	Slope (n=24)	Streams (n=30)
Mean	69	71	64
(Std. Deviation)	(11)	(12)	(8)
Minimum Score	31	46	45
Maximum Score	77	88	83
Range of Scores	46	42	38

Table 1. Summary statistics for CRAM Index scores derived from the probabilistic surveys of wetland condition

CDF plots of the Index scores and Attribute scores for depressional wetlands, slope wetlands, and riverine wetlands are presented below (Figures 9-11). Based on these plots, the 50<sup>th</sup> percentile scores for each CRAM Attribute can be estimated for each wetland type (Table 2).

The CDF plots can also be used to show the proportion of each wetland type in different categories of condition. As stated in the methods section, the maximum possible range of CRAM scores was divided into three equal sub-ranges corresponding to poor, fair, and good condition. For Attribute scores as well as Index scores, the thresholds between poor and fair condition is a score of 50, and the threshold between fair and good is a score of 75. The proportion of each wetland type having poor, fair, or good condition can be determined by identifying the scores on the CDFs that correspond to these threshold scores between the condition categories.

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<sup>7</sup> CRAM can be used to compare different types of wetlands based on their condition. This is because, for each wetland type, CRAM measures condition relative to the best achievable condition. Therefore, two wetland areas of different type having the same CRAM score are assumed to have the same condition relative to their respective best achievable condition. This does not mean that they provide the same levels of the same wetland functions. It means that they are likely to provide similar levels of their respective functions, which may be site-specific.

## Santa Rosa Plain Wetlands Landscape Profile

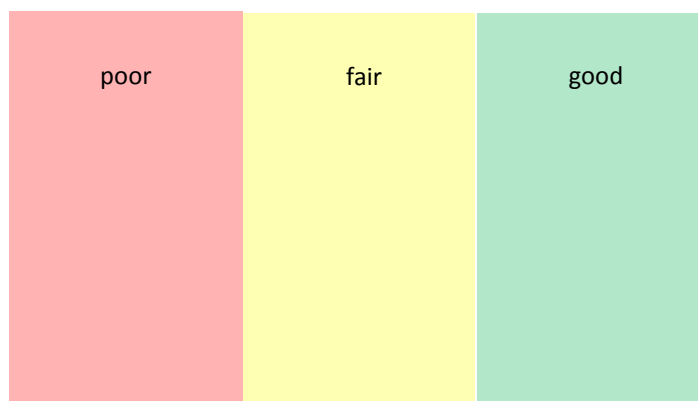
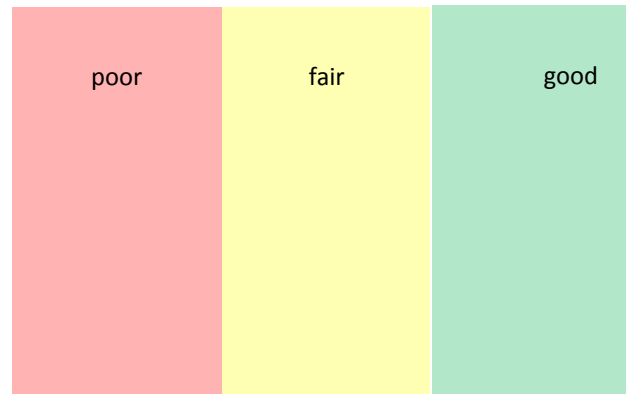


Figure 9. Cumulative distribution function and condition categories of CRAM Index and Attribute scores for depressional wetlands on the Santa Rosa Plain.

## Santa Rosa Plain Wetlands Landscape Profile



**Index Score (n=24)**

Figure 10. Cumulative distribution function and condition categories of CRAM Index and Attribute scores for slope wetlands on the Santa Rosa Plain.

## Santa Rosa Plain Wetlands Landscape Profile

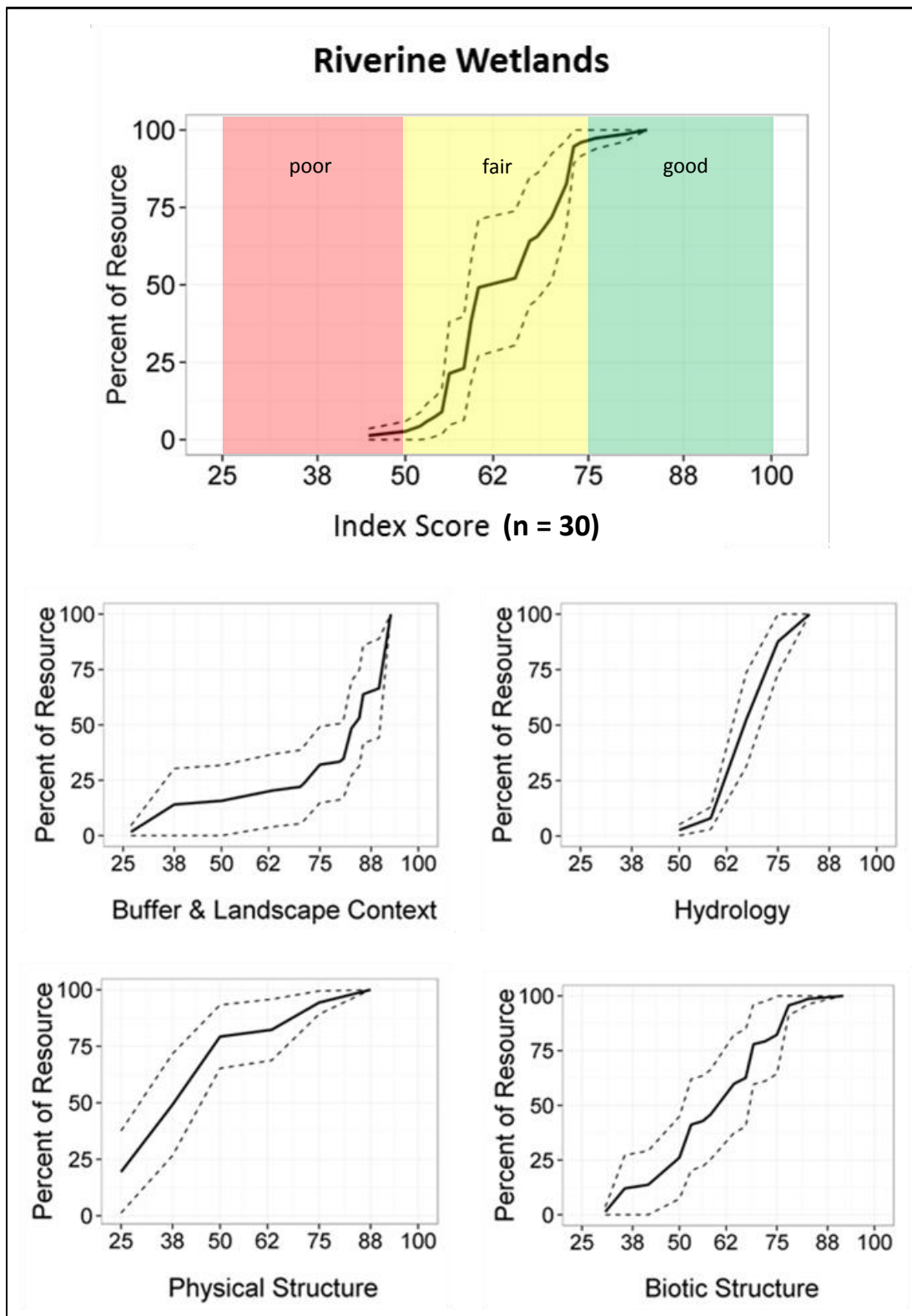


Figure 11. Cumulative distribution function and condition categories of CRAM Index and Attribute scores for riverine wetlands on the Santa Rosa Plain.

## Santa Rosa Plain Wetlands Landscape Profile

Wetland Type	Attribute Scores				Index Score
	50 <sup>th</sup> percentile score for Landscape & Buffer	50 <sup>th</sup> percentile score for Hydrology	50 <sup>th</sup> percentile score for Physical Structure	50 <sup>th</sup> percentile score for Biotic Structure	50 <sup>th</sup> percentile score
Depressions	86	87	49	52	72
Slope Wetlands	87	81	54	76	73
Riverine Wetlands	86	68	40	59	61

Table 2. 50<sup>th</sup> percentile CRAM Attribute scores and Index scores for three wetland types on the Santa Rosa Plain, derived from their CDFs and color-coded for their category of condition (red = poor; yellow = fair; green = good).

Some general conclusions can be drawn from the results of the Level 2 (CRAM) survey of wetland condition for the Santa Rosa Plain. These are summarized as follows.

- Slope wetlands are generally in better condition than depressional wetlands, which are generally in better condition than riverine wetlands.
- The landscape connectivity and buffer condition are fair or better for most of the total length of riverine wetlands and for most of the total area of depressions and slope wetlands. This reflects the fact that most of the Study Area is rural and agricultural, rather than urbanized.
- The overall condition of depressional wetlands, as indicated by the mean value of their AA Index scores (Figure 8 and Table 1), the shape of their CDF for Index scores (Figure 9), and the 50<sup>th</sup> percentile Index score derived from their CDF (Table 2), is mainly constrained by their relatively low scores for Physical Structure and Biotic Structure. Their Physical Structure scores are especially low. Examination of the component Metric scores for this Attribute revealed that most of the depressions lack both the topographic complexity and diversity of physical elements characteristic of depressions that provide high levels of most of their intrinsic functions. It should also be noted that the riparian areas of these wetlands tend to be narrow due to a lack of riparian trees. The Biotic Structure scores tended to be relatively low due to a lack of plant layering and the prevalence of exotic species.
- The overall condition of slope wetlands, as indicated by the mean value of their AA Index scores, (Figure 8 and Table 1), the shape of their CDF for Index scores (Figure 10), and the 50<sup>th</sup> percentile Index score derived from their CDF (Table 2), is mainly constrained by their relatively low scores for Physical Structure. Examination of the component Metric scores for Physical Structure revealed that most slope wetlands lack the diversity of physical elements characteristic of slopes that provide high levels of most of their intrinsic functions. It should also be noted that the riparian areas of these wetlands tend to be narrow due to a lack of riparian trees. The scores



## Santa Rosa Plain Wetlands Landscape Profile

for Hydrology were relatively high for slope wetlands, suggesting they are supported in part by natural processes of groundwater emergence, although it is noted that most slope wetlands are located in areas subject to irrigation with reclaimed waters (Nishikawa 2013).

- The overall condition of riverine wetlands, as indicated by the mean value of their AA Index scores, (Figure 8 and Table 1), the shape of their CDF for Index scores (Figure 11), and the 50<sup>th</sup> percentile Index score derived from their CDF (Table 2), is mainly constrained by their relatively low scores for Physical Structure. Examination of the Metric scores for Physical Structure revealed a lack of physical complexity, including a lack of large woody debris in the perennial channels, and the extremely simplistic form and structure of large and small ditches. However, the Index scores were also constrained by relatively low scores for Hydrology and Biotic Structure. The low Hydrology scores for the mostly natural, perennial riverine wetlands reflect their historical degradation (past incision that has caused the channel to abandon its historical floodplain) and concomitant reduction in topographic complexity. The low Hydrology scores for ditches reflect their unnatural water sources. The relatively low Biotic Structure scores for the mostly natural, perennial riverine wetlands reflect a prevalence of exotic species. The relatively low Biotic Structure scores for ditches reflect both the prevalence of exotic species as well as a lack of plant layering. It should be noted that the scores for natural riverine AAs were almost always much higher than the scores for ditches. It should also be noted that the widest riparian areas were associated with natural riverine wetlands (see Figure 7).

Many details about the condition of wetlands on the Santa Rosa Plain can be inferred from the results of the Level 2 (CRAM) survey. Such inferences can be translated into hypotheses about cause-and-effect relationships that could be tested with field research. WRAMP recognizes the need for research (see Appendix), but is beyond the scope of this WRAMP demonstration.

## Stressors

Stressors are kinds of activities or events managed or caused by people that tend to reduce or degrade the condition of an aquatic resource or that prevent it from having or developing a better condition. The general expectation is that an inverse relationship tends to exist between the number and/or severity of stressors and aquatic area condition, and that this relationship can be mediated by the presence and condition of a buffer.

The results from each CRAM AA include a completed Stressor Checklist for each Attribute that indicates the obvious presence of stressors in the AA and buffer, and whether or not they are likely to be affecting an Attribute score. Present stressors that are deemed likely to be affecting one or more Attribute scores are classified as severe. The results from the CRAM survey of wetland condition on the Santa Rosa Plain regarding stressors can be summarized as follows.

- For depressions and slope wetlands, the most important stressors are land uses and management activities within or adjacent to the wetlands that degrade their buffer

## Santa Rosa Plain Wetlands Landscape Profile

or negatively modify their hydrology. The activities most often noted as severe are mowing, intensive grazing, and artificial drainage or other forms of artificial water management. It is expected that the history and ongoing presence of these activities help explain the prevalence of exotic plant species in many AAs. A lack of adjacent aquatic resources due to their historical conversion to development or intensive agriculture was often noted for depressions at mid-elevation or higher on the Plain.

- For riverine wetlands, the stressors most often noted included hydromodification resulting from upstream development, channel revetment and other channel engineering, excessive human visitation, excessive trash, and mowing or grazing within the buffer zone.

Many AAs were dominated by exotic plant species (i.e., species not known to have naturally occurred historically in the Santa Rosa Plain, although possibly native to other parts of California or the United States). Observed exotic species that are known to be associated with wetland structural modifications in California or elsewhere include purple loosestrife (*Lythrum salicaria*), Himalayan blackberry (*Rubus armeniacus*), southern cattail (*Typha domingensis*), perennial pepperweed (*Lepidium latifolium*), reed canary grass (*Phalaris arundinacea*), marsh pennywort (*Hydrocotyle ranunculoides*), and at least one species of water primrose (*Ludwigia hexapetala* or *L. peploides* subsp. *montevidensis*, or both, and/or possibly a third species). Numerous other exotic plant species were observed in the Study Area, and it is clear that many of the wetlands are dominated by exotic plant species.

### Landscape Patterns in Wetland Condition

The Santa Rosa Plain is a complex of alluvial fans built by multiple riverine wetland systems emanating from the southwestern slopes of the Mayacamas Mountains. The fan complex occupies a tectonic depression formed by the Windsor Syncline (McPhee et al. 2007). The Laguna wraps around the toe of this fan complex, in its far western reaches (Curtis et al 2012).

As a complex of alluvial fans, the Plain was historically a self-organized system of divergent distributaries with losing reaches and active floodplains of relatively coarse alluvium serving as recharge zones at mid- and higher elevations (Nishikaw 2014), and between which at mid and lower elevations were deposits of fine sediments. The deposits of coarse and fine sediments would vary in depth and location, overlapping in time as the distributaries moved back and forth across their fans, building them upwards and extending them outwards.

The fact that the Plain is a complex of alluvial fans is the basis for much of the landscape-scale interpretation of the Level 1 and Level 2 results of this WRAMP demonstration. For example, the processes that maintain an alluvial fan explain the general plan form of the perennial riverine wetlands, notwithstanding their anthropogenic modifications. These are the main products of the overlapping fans, and they generally diverge from each other (see Figure 12). Vernal pool complexes, minor distributaries, and slope wetlands are also arrayed in a predictable pattern on the Plain, given that it is a complex of alluvial fans. Vernal pools are associated with areas of very fine sediment (fine silts and clays) that inhibit infiltration (Witham

### Santa Rosa Plain Wetlands Landscape Profile

1998). On the Plain, vernal pools are concentrated in an arc between minor distributaries at mid elevation, where the deposition of fine sediments would be expected (see Figure 12). Vernal pools are much more abundant in the central and southern extent of the elevation range, however, for reasons that are not entirely certain. Perhaps some vineyards, which are more common in the northern reaches of the Plain, have replaced vernal pools. The minor distributaries originate at mid elevation, where groundwater tends to emerge during the wet season. Slope wetlands are concentrated in the far western reaches of the Plain, along the base of the fan, where groundwater emergence is typically more persistent (e.g., Winter et al 1998).

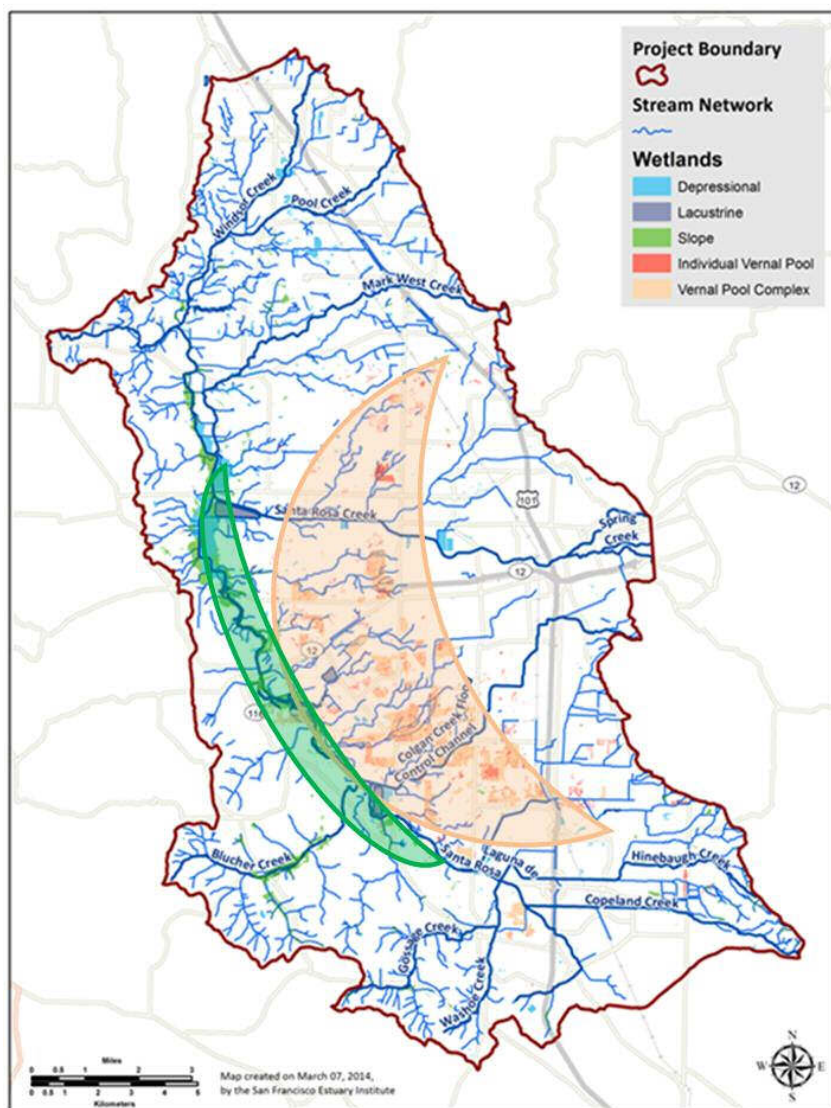


Figure 12: Map of Santa Rosa Plain showing that the distribution of surface waters is generally consistent with the spatial model of an alluvial fan. Main distributaries are generally divergent. Vernal pools (pink area) are concentrated in an arc at mid and low elevations. Slope wetlands (green area) are most abundant along the fan base

## Santa Rosa Plain Wetlands Landscape Profile

CARI yielded a geo-referenced map of the Santa Rosa Plain in which the locations of all of the AAs of this Level 2 (CRAM) survey are plotted (Figures 13 and 14). The AAs are color-coded based on the category of condition represented by their Index scores (Figure 13) or Attribute scores (Figure 14). That is, red indicates poor condition (score 25-50); yellow indicates fair condition (51-75); and green indicates good condition (score >75).<sup>8</sup>

One consequence of the probabilistic survey design is that the spatial distribution of AAs reflects the spatial distribution of wetlands. In general, most of the riverine, depressional, and slope wetlands, as well as their AAs, are concentrated in the western area of the Plain. This reflects the facts that wetlands are naturally uncommon at the uppermost reaches of alluvial fans, and that the upper reaches of the Santa Rosa Plain are densely urbanized.

With regard to wetland condition, three general spatial patterns are evident, as summarized immediately below.

- There is an inverse relationship between overall condition of depressional wetlands, as indicated by their CRAM Index scores, and distance upslope from the Laguna onto the Plain. Depressional wetlands in the vicinity of the Laguna are likely to have Index scores representing fair or good condition. In areas more distant from the Laguna, depressional wetlands are likely to have scores representing fair or poor condition. The probabilistic survey of condition encountered no depressions in good condition.
- The condition of riverine wetlands is unrelated to elevation or distance upslope from the Laguna. For example, good conditions are likely to be found all along the Santa Rosa Creek, spanning the breadth of the Plain. Fair conditions are likely to be found among riverine wetlands elsewhere on the Plain, regardless of their elevation.
- Poor conditions of depressional and slope wetlands are most likely to be encountered at mid-elevation across the Plain. Neither the Level 1 data (CARI) nor the Level 2 data (CRAM) completely explain this finding. However, an examination of the spatial distribution of the Attribute scores for these wetland types (Figure 14) suggest that these low Index scores are due to low scores for Landscape connectivity and Buffer, as well as Physical Structure. Since these Attributes are strongly related to land use, it is hypothesized that the poor condition of depressional and slope wetlands at mid-elevation is due to a combination of past and perhaps ongoing agricultural practices. Urban land use and related runoff are less likely to be implicated because they are not directly, hydrologically involved with the slope or depressional wetlands. It must be noted that, based on CRAM Index scores, the use of reclaimed water for irrigation nearer the Laguna does not seem to have substantially negative effects on the associated slope and depressional wetlands.

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<sup>8</sup> CRAM scores for each AA can be accessed online through EcoAtlas by turning on the CRAM scores on the data layer menu and then either clicking on individual AAs or using the Landscape Profile Tool to draw a polygon around multiple AAs, and then using the Landscape Profile Tool to list the associated CRAM scores.



## Santa Rosa Plain Wetlands Landscape Profile

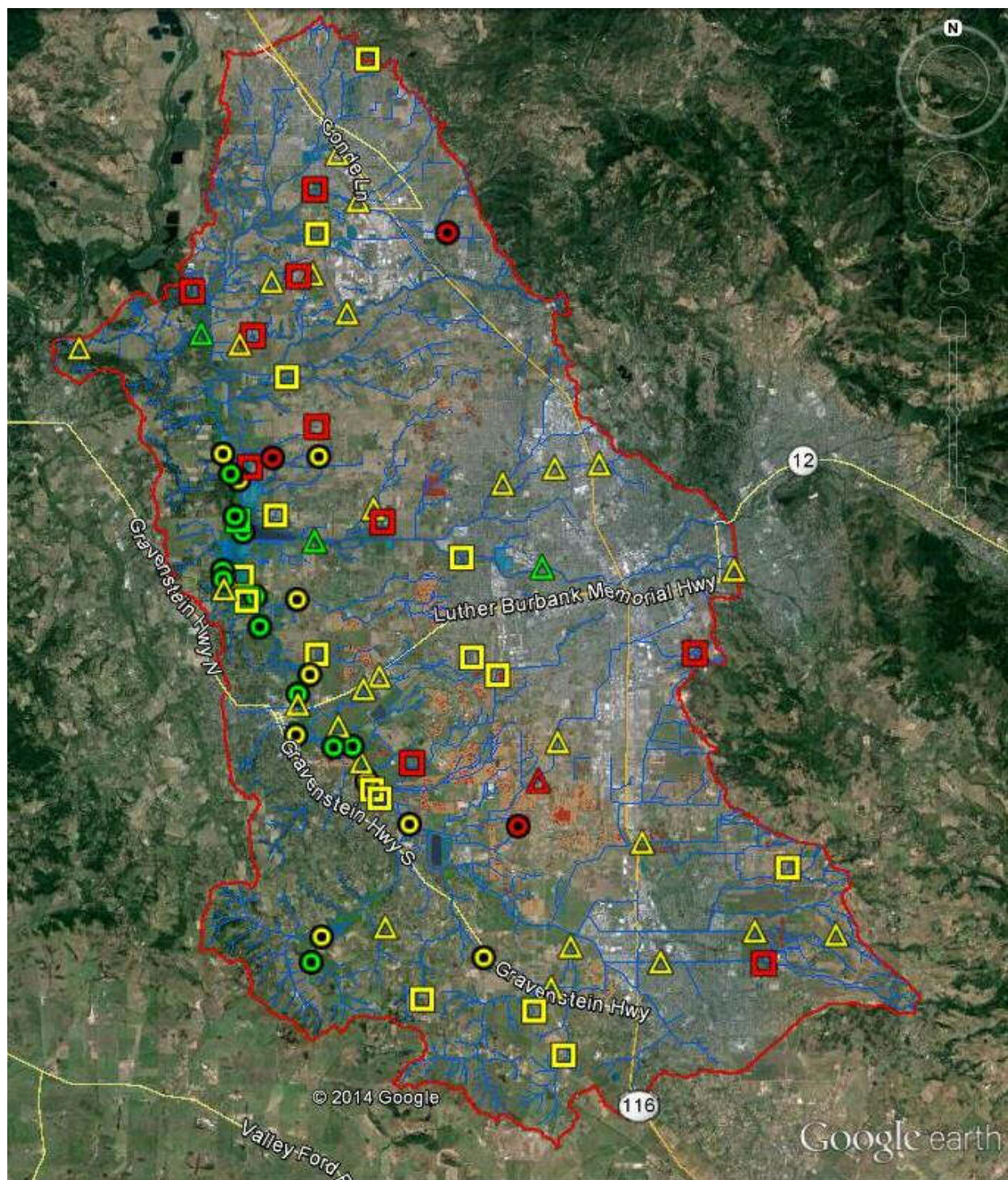


Figure 13. Locations of CRAM AAs for riverine, depressional, and slope wetlands on the Santa Rosa Plain, color-coded to represent condition categories based on their Index scores (squares = depressions, circles = slope wetlands; triangles = riverine wetlands; red = poor condition; yellow = fair condition, green = good condition).



# Santa Rosa Plain Wetlands Landscape Profile

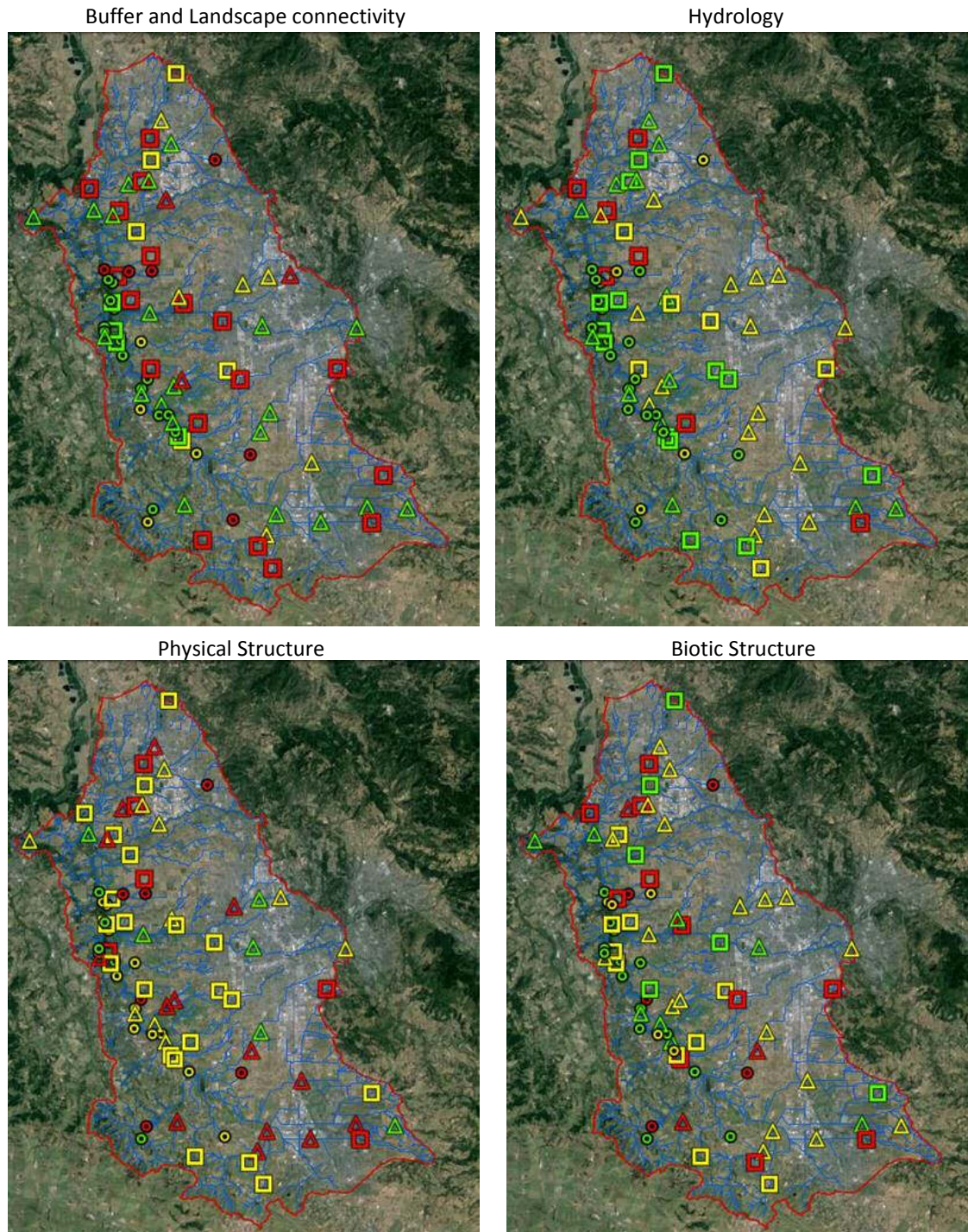


Figure 14. Locations of CRAM AAs for riverine, depressional, and slope wetlands on the Santa Rosa Plain, color-coded to represent condition categories based on their Attribute scores (squares = depressional, circles = slope wetlands; triangles = riverine wetlands; red = poor condition; yellow = fair condition, green = good condition).

## Discussion

### Wetland Management and Wetland Condition

The probabilistic survey of wetland condition across the Santa Rosa Plain revealed spatial patterns among CRAM Index and Attribute scores related to historical and ongoing land use practices. The basic pattern is characterized by fair-to-good conditions among non-riverine wetlands at low elevation on the Plain, near the Laguna, and fair-to-poor conditions among non-riverine wetlands at mid-elevations. Fair-to-good conditions were evident for mostly natural, perennial riverine wetlands at elevations spanning the Plain.

This geographic pattern is accentuated by urbanization in the uppermost, eastern area of the Plain, and the incorporation of wetlands into managed parks in the lowermost, and naturally wettest, western area of the Plain.<sup>9</sup> The south-central area of the Plain retains enough open space that historical non-riverine wetland features are still evident, although past and ongoing land use practices in this area have directly reduced the condition of these wetland remnants.

In a general sense, the intensity of use or management of a wetland can adversely affect its condition. For example, inspection of the depressional wetland AAs revealed a notable difference in condition between artificial depressions (i.e., depressional wetlands created and/or actively managed for one or a few specific purposes, such as storage for irrigation, livestock watering, effluent detention, etc.) and depressions that are natural or that have been allowed to naturalize. The more natural depressions tend to get higher CRAM scores for many Metrics, mainly because they are physically and ecologically more complex (Figure 15).

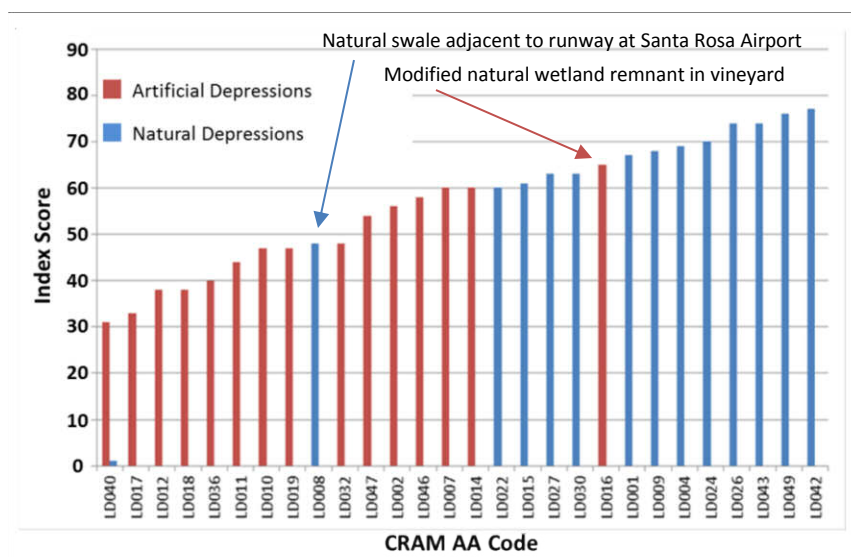


Figure 15. Plot of CRAM Index scores for artificial and natural or naturalized depressional wetlands on the Santa Rosa Plain. AA codes can be used through eCRAM to view the AAs on EcoAtlas.

<sup>9</sup> One of the riverine wetland AAs that achieved a “good” Index score is a section of Santa Rosa Creek that has been subject to ecological and hydro-geomorphic restoration.

## Santa Rosa Plain Wetlands Landscape Profile

The main tributaries to the Laguna show the usual evidence of increased runoff due to upstream increases in impervious surface area and increased drainage density. Some reaches of these systems have been channelized (straightened and deepened), and vegetation has been removed in the same and other reaches to enhance their drainage performance. The channels have responded to these increases in runoff and subsequent management practices by incising. This response, termed hydromodification in modern literature (e.g., Coles et al 2012), is typical and well documented. At many of these riverine AAs, the channel has incised enough to abandon its historical floodplain. Incision and vegetation removal can substantially reduce the overall complexity of riverine wetlands, which is clearly reflected by their CRAM scores.

The Laguna itself benefits from the concern of many interests that seek to protect and restore its ecological health. Its large size, especially during winter flooding, has helped protect it from being dedicated to agricultural and urban drainage (Sloop et al 2007). The slope wetlands associated with its floodplain probably help buffer the Laguna from surrounding stressors.

### Exotic Plant Species and Wetland Condition

Dominance or co-dominance by exotic plant species can affect CRAM scores by reducing plant species richness, reducing plant layers, and simplifying physical structure. Relatively low CRAM Index scores are commonly correlated to the prevalence of exotic plants.

Control of invasive exotic plant species has become an important management objective for the Laguna (Horton and Sears 2006, Sears et al 2010). This WRAMP demonstration was not focused directly on questions about exotic species, but the demonstration revealed some interrelationships among exotic and/or invasive plant species and wetland condition that should be considered further. In general, exotic plant species favor stressed habitats, and given that many wetlands are stressed, it is very difficult to prevent their colonization by exotic plants adapted to wetland conditions. Invasion by exotic plants is not necessarily less likely among wetlands that support a high diversity of native plant species (e.g., Stohlgren et al 2008).

Exotic species of *Ludwigia* persist as a major concern for the Laguna. *Ludwigia* spp. apparently require (respond best to) areas of open sunlight. Laguna AAs that were either densely vegetated by native herbaceous species or that were completely shaded by dense tree canopies did not support *Ludwigia*. This is a pattern of *Ludwigia* distribution in the Laguna that has previously been noted (memorandum from PR Baye to J Meisler, Laguna Foundation, 24 July 2008). Baye further recommended a bio-control element for *Ludwigia* management that emphasized establishing stands of streamside herbaceous species, including river bulrush (*Bolboschoenus fluvialis*), a species that he had personally observed preventing establishment of *Ludwigia* along Laguna channel margins, and tall riparian vegetation such as red willow (*Salix laevigata*) that is native to the Laguna. Again, field observations made during the WRAMP demonstration were consistent with these recommendations. That is, channel segments with dense streambank vegetation and/or dense overhead willow canopy almost always lacked *Ludwigia*. Other candidate species for bio-control might include herbaceous species with dense vegetative growth, such as tule (*Schoenoplectus acutus*), bur-reed (*Sparganium eurycarpum* var.



## Santa Rosa Plain Wetlands Landscape Profile

*eurycarpum*), and possibly cattail (*Typha latifolia*). *Ludwigia* control efforts seem most successful along well-defined, relatively steep channel banks, suggesting that bio-control might work best in combination with sustainable geomorphic channel modifications.

Based on the field observations conducted during the condition survey, another exotic plant species has colonized wetlands on the Santa Rosa Plain. Reed canary grass (*Phalaris arundinacea*) is present in most of the slope wetlands between Highway 12 and River Road. In most of these wetlands, it is present at low relative abundance (often less common than its congener Harding grass, *P. aquatica*). In a few scattered sites, however, *P. arundinacea* forms dense monotypic mats or upright stands, with negative effects on species as varied as bulrush (*S. acutus*), Oregon ash (*Fraxinus latifolia*), and valley oak (*Quercus lobata*). Reed canary grass has already become a significant invasive species in the Humboldt Bay area, particularly in the City of Arcata. Increased attention to its presence on the Santa Rosa Plain seems warranted.

### WRAMP and Water Quality Control Planning

The Wetland and Riparian Area Monitoring Plan (WRAMP) is a framework and toolset for developing and organizing information to address environmental regulatory or management decisions or questions about wetlands and other surface waters.

A fundamental tenet of WRAMP is that the total of all environmental management and regulatory activities in a watershed or other landscape should not degrade the abundance, diversity, or condition of wetlands and their riparian buffers. One major purpose of the WRAMP toolset is therefore to support comprehensive watershed-based approaches to wetland impact avoidance, minimization, compensatory mitigation, assessment, and reporting.

CRAM is an integral component of the WRAMP toolset. It meets the need for a cost-effective, scientifically sound methodology for repeated assessments of wetland health, meaning the potential of wetlands to support high levels of their intrinsic functions. These services can usually be cross-walked to the beneficial uses of wetlands that are assigned to surface waters by the State Water Board and its Regional Boards (Table 3). To be more specific, CRAM can help protect the beneficial uses of wetlands by contributing to a weight-of-evidence approach for establishing water quality objectives and for assessing their attainment.

CRAM scores can also be used to help identify some causes of wetland impairment. For example, CRAM can be used to assess invasion by exotic plant species, a common cause of wetland impairment. Excessive nutrient input, which impairs the Laguna, can be inferred from elements of the Stressor Checklist relating to runoff from feed lots, stormwater inputs, intensive grazing, etc. CRAM metrics used to assess riverine channel stability pertain directly to the established problem of excessive sedimentation in the Laguna. The CRAM metrics for water source and plant layering can be helpful in assessing groundwater inflow and shadiness as controls on water temperature, which is also a concern for the Laguna. However, CRAM is not known to be sensitive to some forms of aquatic chemical pollution, such as heavy metals and trace metals, or contaminants of emerging concern, such as polybrominated diphenyl ethers

### Santa Rosa Plain Wetlands Landscape Profile

(PBDEs) and perfluorinated compounds (PFCs). Level 3 methods (i.e., quantitative measures of site-specific aspects of condition or stress) are needed to assess these and similar kinds of chemical pollution.

Laguna Hydrologic Subarea Beneficial Uses	CRAM Metrics											
	Landscape Connectivity	Buffer Condition	Water Source	Hydroperiod	Channel Stability	Hydrological Connectivity	Structural patch Richness	Topographic Complexity	Plant Community Composition	Horizontal Dispersion	Vertical Biotic Structure	Plant Life Forms
Agricultural Supply												
Industrial Service Supply												
Groundwater Recharge												
Freshwater Replenishment												
Navigation												
REC-1 Water Contact Recreation												
REC-2 Non-Contact Water Recreation												
Commercial and Sport Fishing												
Warm Freshwater Habitat												
Cold Freshwater Habitat												
Wildlife Habitat												
Rare, Threatened, or Endangered Species												
Migration of Aquatic Organisms												
Spawning, Reproduction, and/or Migration												
Native American Culture												
Flood Peak Attenuation/Flood Water Storage												
Wetland Habitat												

Table 3. Matrix showing expected relationships between the beneficial uses of the Laguna de Santa Rosa and good scores for CRAM Metrics, color-coded for relationship strength (white = no relationship or weak relationship; yellow = moderately strong relationship; green = strong relationship). Source of the beneficial use is the Basin Plan of the North Coast Regional Board.

A probabilistic, Level 2 (CRAM) survey of wetlands can help establish watershed-based anti-degradation thresholds for the abundance, diversity, and condition of wetlands. The first survey in a watershed or other landscape can function as the baseline wetland profile against which future changes in wetland abundance, diversity, and condition can be measured. Repeated surveys can help assess the performance of water quality control plans.

## Looking Forward

This WRAMP demonstration has generated a profile of the abundance, diversity, and condition of wetlands, including wadeable streams, for the Santa Rosa Plain in Sonoma County, CA. The information generated by this demonstration, plus additional environmental information about the Plain has been summarized in a Landscape Profile Report that was generated using the Landscape Profile Tool of EcoAtlas.

It is clear from this demonstration that WRAMP has potential to support wetland protection in multiple ways. The intended relationship between WRAMP and water quality control planning is summarized in the preceding section. The basic message of that section warrants repeating: A major purpose of WRAMP is to support comprehensive watershed-based approaches to wetland impact avoidance, minimization, compensatory mitigation, assessment, and reporting.

The need for a comprehensive plan to restore the Santa Rosa Plain and the Laguna de Santa Rosa is gaining support among regional and local interests. WRAMP can help develop and implement this plan by assisting with wetland and mitigation project siting, design, assessment, and tracking, as outlined below.

## General Guidelines for Wetland Project Siting

Findings of the WRAMP demonstration suggest the following aspects of a landscape approach to wetland restoration and mitigation siting should be considered.

- Use the historical form of the Plain in plan-view and profile as a large-scale spatial template for restoration design. That is, regard the Plain as a system of approximately self-similar but divergent, distributaries with the following attributes:
  - losing reaches at mid- and higher elevation;
  - gaining reaches at low elevation;
  - active floodplains of varying width related to discharge volume that serve as recharge zones;
  - areas between the active floodplains at mid and lower elevations with ancient surface deposits of fine sediments supporting vernal pool complexes;
  - areas between the active floodplains at low elevations with slope wetlands supported by groundwater emergence bordering the Laguna.
- Add bypass channels to direct the peak flows of some perennial channels into off-channel depressions to increase riverine wetland stability and to store and filter flushing flows from urban and agricultural lands.
- Increase near-surface groundwater levels through the restoration of floodplains and depressional wetland as recharge areas.

### Santa Rosa Plain Wetlands Landscape Profile

- To increase Laguna base flows and lower Laguna water temperatures, allow the emergence of elevated groundwater to form slope wetlands along the lower elevations of the Plain.
- Greatly increase the extent of riverine riparian tree cover at least 30 m wide on active floodplains to provide shade as required to lower riverine wetland temperature, increase large woody debris inputs, and generally increase the overall complexity of perennial riverine wetlands.
- Consider that a mixture of designs resulting in a range of CRAM scores increases the diversity of function at the landscape scale. In other words, consider that not all wetlands need to support high levels of all their intrinsic functions, and that some functions should be emphasized for some wetlands.
- Develop a matrix that relates wetland restoration design and landscape position to wetland beneficial use attainment, and use the matrix to conceive and envision the ideal landscape design.
- Use the historical wetland landscape profile to guide decisions about the future diversity of wetland types and their relative abundance across the Plain.
- Use the Landscaper Profile Tool in EcoAtlas to compare and contrast alternative plans for wetland restoration and mitigation relative to the ideal design.
- It is clear from this WRAMP demonstration and others that historical land use practices have emphasized increasing the drainage efficacy of the Plain, meaning increasing its ability to rapidly shed water. As a result, the drainage density (i.e., the number of channels per unit area) has been artificially increased. The corollary is that the ability of the Plain to retain and process runoff through filtration and infiltration has been greatly decreased. One major objective of any effort to re-design the Plain for the protection and enhancement of its aquatic resources should be to lengthen the drainage pathways. This can be achieved by replacing selected ditches with new or restored depressional wetlands and by building Low Impact Development (LID) elements into storm drains and irrigation return flow systems.
- Consider using the storm and annual hydrograph that are expected to be generated by the ideal landscape design as overall performance criteria for the Plain as a cohesively designed and managed landscape.

An ancillary approach to restoring the hydrological and ecological functions of the Plain and thus improve its water quality is to restore the first-order channels and their immediate source areas in the headward reaches of the watersheds draining to the Plain. Alterations due to intensive ranching and farming in some of these reaches has evidently increased their yields of runoff and fine sediment, which have in turn negatively impacted aquatic resources downstream. The integral relationship between the condition of these most headward reaches of a drainage system and its downstream reaches cannot be over-emphasized (Winter et al. 1998, ELI and TNC 2014).

## General Guidelines for Wetland Project Design

Wetland projects must be designed with ample understanding of local hydrological, geomorphological, ecological, climatic, and land use processes to assure that the projects are resilient and sustainable in the long-term. Projects have natural and anthropogenic constraints, including budgetary and policy considerations that affect project designs (Rieger et al. 2014).

However, general project design guidelines that relate directly to levels of wetland functions or services for different types of wetlands can be helpful to envision the ideal projects and to explicitly identify their functional limits. This can be especially useful when setting project goals, objectives, and performance standards.

CRAM can be a useful framework for wetland project conceptual design. Based on current draft versions of the State Water Board Wetland Protection and Dredge and Fill Permitting Policy, and the emerging USACE guidance for its watershed approach to mitigation planning, CRAM is likely to be an integral component of mitigation planning and compliance monitoring. Project performance criteria are likely to incorporate a range of acceptable CRAM scores or to specify that projects track appropriate performance curves<sup>10</sup> based on CRAM. Furthermore, the CRAM Metrics and associated worksheets and scoring tables provide specific guidance on designs necessary to achieve high CRAM score. However, while CRAM might serve as a useful framework for the conceptual design of wetland projects, it cannot replace careful, science-based engineering needed to create successful construction plans (see Rieger et al. 2014).

Results from the Level 2 (CRAM) survey of wetland condition on the Santa Rosa Plain illustrate how CRAM might be used to design wetland projects. Photographs of AAs representing different CRAM scores for selected wetland types (Figures 16-18) show how CRAM scores can be improved by increasing the structural complexity of the AAs. The CRAM Metrics and their scoring tables can be used to identify what specific physical and biotic elements of complexity might be added to low-scoring AAs to improve their Attribute and Index scores. For example, an existing site in poor condition might be enhanced in ways that achieve fair or good conditions, based on CRAM, and the resulting difference in CRAM scores could be used as an estimate of the amount of functional lift that enhancement achieved. During the planning process, the intended changes in site structure can then be translated into construction design specifications and project performance criteria. CRAM can later be used to assess project performance.

CRAM can also be used to identify ways to improve the buffer of a wetland project. Ways to improve the landscape connectivity of a site can be revealed by re-scoring sites based on different landscape designs, as discussed in the above section on project siting.

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<sup>10</sup> Performance Curves represent expected rates in the improvement in the performance of new projects over time, based on the history of performance of comparable kinds of projects (e.g., Kentula et al. 1992). Performance Curves are being developed for different types of wetlands as defined by CARI and based on CRAM assessments.



## Santa Rosa Plain Wetlands Landscape Profile



Figure 16. Examples of depressional wetland Assessment Areas (AAs) for the Level 2 (CRAM) survey of wetland condition on the Santa Rosa Plain. The Cram Index score for each AA is circled in red. The scores following each Index score are, in order, the Attribute scores for landscape connectivity and buffer, hydrology, physical structure, and biotic structure. Each AA could be enhanced to achieve higher Attribute scores by using the Metric scoring tables to adjust its physical and biotic structure.

## Santa Rosa Plain Wetlands Landscape Profile



Figure 17. Examples of slope wetland Assessment Areas (AAs) for the Level 2 (CRAM) survey of wetland condition on the Santa Rosa Plain. The Cram Index score for each AA is circled in red. The scores following each Index score are, in order, the Attribute scores for landscape connectivity and buffer, hydrology, physical structure, and biotic structure. Each AA could be enhanced to achieve higher Attribute scores by using the Metric scoring tables to adjust its physical and biotic structure.



## Santa Rosa Plain Wetlands Landscape Profile



Figure 18. Examples of riverine wetland Assessment Areas (AAs) for the Level 2 (CRAM) survey of wetland condition on the Santa Rosa Plain. The Cram Index score for each AA is circled in red. The scores following each Index score are, in order, the Attribute scores for landscape connectivity and buffer, hydrology, physical structure, and biotic structure. Each AA could be enhanced to achieve higher Attribute scores by using the Metric scoring tables to adjust its physical and biotic structure.



## Wetland Project Assessment and Tracking

WRAMP includes tools specifically designed for tracking projects and for sharing information about them. These tools are the Project Tracker Tool, Online 401 Tool, and the Landscape Profile Tool. The Project Tracker and Online 401 tools are supported by dedicated online databases. The Landscape Profile Tool aggregates data from these and other databases.

Project Tracker is designed to allow its users to map projects online, and to subsequently upload all kinds of data, including images, video, URLs, reports, and data tables to the project database such that the data are accessible via the project map. In essence, the project map becomes the user interface to a repository of information about the project. Permission to upload or access project information can be granted to the public or selected users and changed over time. Online 401 is a special version of the Project Tracker that is designed specifically for regulatory personnel who issue and manage 401 certifications.

The Landscape Profile Tool has been described elsewhere in this report. It is anticipated that different versions of the Landscape Profile Tool will be developed as needed to serve different environmental policies and programs. At this time, the Landscape Profile Tool is mainly designed to support the watershed approaches to wetland protection being developed by the US Army Corps of Engineers and the State Water Board.

In addition to serving specific regulatory and management programs, the Landscape Profile Tool can also support outreach and education about aquatic resources. It can summarize a variety of environmental information for user-defined areas throughout California. It can help researchers, educators, students and the general public learn about the abundance, diversity, and condition of wetlands and other aquatic resources near them. Anyone can input any street address into EcoAtlas and see its location in the context of a Landscape Profile. For those interests most concerned with public outreach and communication, the Landscape Profile Tool can be used to identify the numbers of people and the languages they speak for any area in the state, and it can be used to establish lines of communication through EcoAtlas about any particular place or project that is included in CARI or Project Tracker. Through these tools, WRAMP can help establish stronger public support for the care and protection of the state's aquatic resources.

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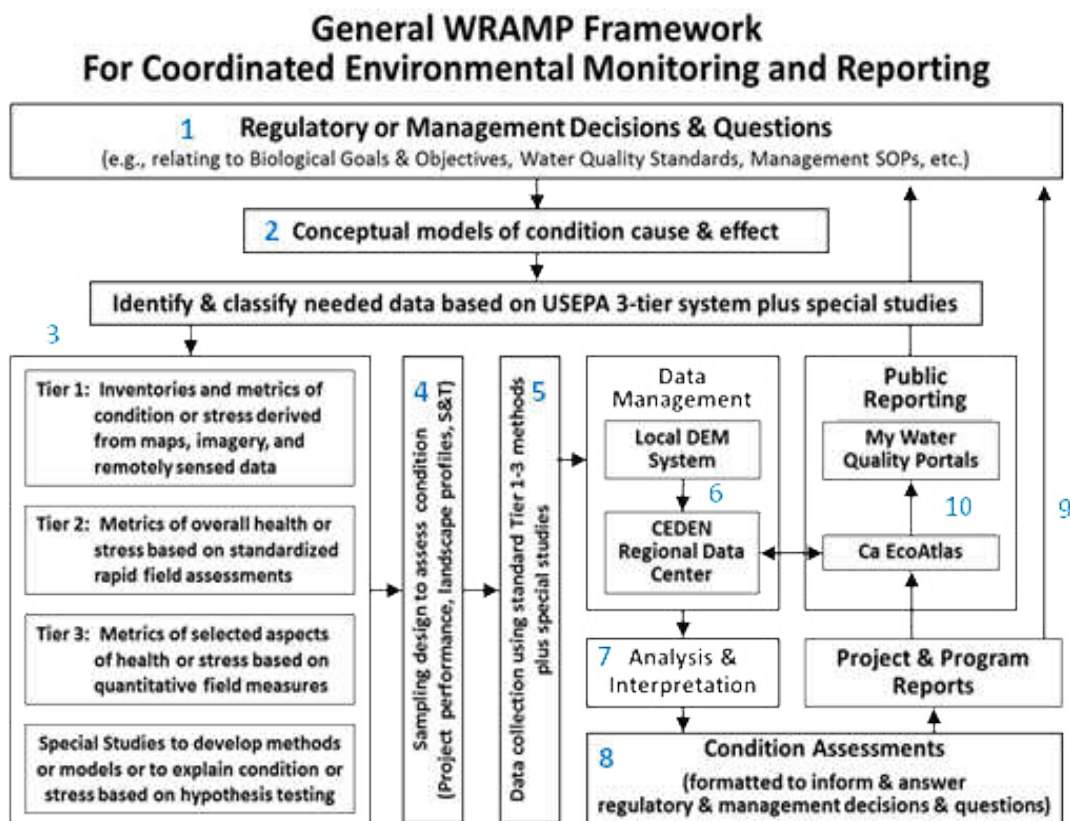
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## Appendix

Below is the basic diagram of the Wetland and Riparian Area Monitoring Plan (WRAMP). The following annotations of the diagram help explain its usage.



1. Applications of WRAMP are driven by regulatory decisions or management questions.
2. Conceptual models are used to outline expected relationships among natural processes and human operations affecting condition of aquatic resources, and to explicitly document all assumptions underlying the models.
3. The possible roles of Level 1-3 data for addressing the driving decisions and questions are carefully considered.
4. Special studies are designed as needed to fill critical data gaps or to explain relationships evident in the Level 1-3 data.
5. Level 1-3 data are collected using standard methods according to designs that can reveal the effects of local decisions or management actions on the status and trends (S&T) in aquatic resource condition.

## Santa Rosa Plain Wetlands Landscape Profile

6. Data are managed by their authors before being uploaded to Regional Data Centers of the California Environmental Data Exchange Network (CEDEN).
7. Methods of data analysis and interpretation are identified before data are collected.
8. Interpreted data are formatted to address the driving decisions and questions.
9. Findings are reported directly to the decision-makers and managers.
10. Findings are also reported to the My Water Quality Portals through EcoAtlas, which can also harvest data and information from CEDEN.

The “My Water Quality Portals” named in the box titled “public Reporting” on the right side of the diagram refer to public websites maintained by the California Water Quality Monitoring Council to enable the public to access information about aquatic resources throughout the state (for more information about these websites go to: <http://www.mywaterquality.ca.gov/>).