This Master's Project

LINKING COMPENSATORY MITIGATION AND RESTORATION OF RIPARIAN WETLAND FUNCTIONS AND VALUES

By

Emily Mecke

is submitting in partial fulfillment of the requirements for the degree of:

Master of Science
in
Environmental Management

at the

University of San Francisco

Submitted: Received:

-- --

Emily Mecke May 14, 2018 Gretchen Coffman, Ph. D. May 14, 2018

Table of Contents

List of Tables

List of Figures

List of Acronyms

CDFW	California Department of Fish and Wildlife
CRAM	California Rapid Assessment Method
EPA	Environmental Protection Agency
HGM	Hydrogeomorphic Method
NPDES	National Pollutant Discharge Elimination System
RWQCB	Regional Quality Control Board
SER	Society of Ecological Restoration
USACE	U.S. Army Corps of Engineers
WET	Wetland Evaluation Technique

Abstract

Riparian wetlands are vital ecosystems with many functions that provide important ecosystem services. In California's Central Valley, approximately 95 percent of the historic riparian habitat has been lost due to human activity. U.S. Federal and State regulations in California laws began protecting and regulating aquatic resources, including riparian wetlands, in the 1970s. These regulations require compensatory mitigation for impacts to aquatic resources. Compensatory mitigation projects often do not result in restoration of wetland functions relative to the impacted wetlands. The U.S Army Corps of Engineers 2015 Mitigation and Monitoring Guidelines contain requirements for developing ecological performance standards for compensatory mitigation projects. These guidelines require ecological mitigation performance standards relate to five categories: physical characteristics, hydrology, flora, fauna, and water quality. These five performance standard categories correlate to important ecosystem services provided by riparian wetlands and should all be used in evaluating restoration sites. This paper provides recommendations to improve compensatory mitigation plans for riparian restoration projects in California's Central Valley to ensure successful restoration of riparian wetland functions and values. To achieve this research objective, I reviewed three assessment methods (Wetland Evaluation Technique, Hydrogeomorphic method. and California Rapid Assessment Method) and determined the effectiveness of each method at assessing riparian wetland functions. I also evaluated performance standards developed for three riparian mitigation banks in the Central Valley. Finally, I developed recommendations for mitigation performance standards for riparian mitigation banks and permittee-responsible riparian restoration projects to better evaluate restoration of riparian wetland functions. My analysis determined the following: (1) it is critical to use a reference standard to develop and monitoring performance standards; (2) a project should develop performance standards for all five performance standard categories (3) a project should use the best fit functions from each of the assessment methods instead of one assessment method entirely; (4) a project should use functions that are likely to change and/or develop over time and are easily measured in a mitigation monitoring scenario, and (5) a project develop interim monitoring standards with thresholds that increase incrementally over the monitoring period.

1.0 Introduction

Riparian wetlands are vital ecosystems with many functions that provide important ecosystem services such as flood control and protection, improving water quality and supporting biodiversity. Unfortunately, human activity has led to the loss or degradation of the majority of naturally occurring wetlands. In California's Central Valley, approximately 95 percent of the historic riparian habitat has been lost due to human activity (Griggs 2009). There is a need to protect remaining riparian habitat, as well as restore degraded areas, to preserve and prevent further loss of riparian habitat and the ecosystem services riparian habitats provide. Since the 1970s, U.S. Federal and State regulations in California require compensatory mitigation for impacts to aquatic resources, including wetland restoration. However, while many compensatory mitigation projects may comply with the permit conditions and mitigation requirements imposed by regulatory agencies, compensatory mitigation projects often do not result in restoration of wetland function and values comparable to naturally occurring wetlands (Ambrose et al. 2006, Sudol and Ambrose 2002). One reason for this deficit is a disconnect between performance standards (also commonly referred to as success criteria) established by compensatory mitigation projects and actual function of naturally occurring wetlands (Sudol and Ambrose 2002). Thus, implementation of wetland mitigation in the U.S. has resulted in an overall loss of wetland functions that provide important ecosystem services.

1.1 Riparian Wetlands

Riparian wetlands are typically defined as the transition between the aquatic and terrestrial environments (Gregory et al. 1991, Nilsson and Svedmark 2002). More specifically, riparian wetlands are bound by the bankfull height (height of channel when water starts to flow into the floodplain) of a stream or river channel and the edge of upland area where vegetation is influenced by a high water table and periodic flooding, often referred to as the floodplain (Nilsson and Svedmark 2002, R. K. Naiman et al. 1993). Vegetation that occurs in riparian wetlands are adapted to flooding (pulse) events and other terrestrial disturbances including fire, wind, plant disease, and insect outbreaks (Gregory et al. 1991). Additionally, riparian wetlands provide important ecosystem services including flood storage and protection, water quality improvement, biodiversity, groundwater recharge, recreation, cultural resources, and aesthetic resources (Duffy and Kahara 2011).

Riparian wetlands are influenced by natural stressors and human impacts. Riparian ecosystems are non-equilibrium systems and are subject to seasonal variation in natural conditions, such as temperature and precipitation (flooding) (Seavy et al. 2009). Plant species that occur in and wildlife species that use riparian wetlands are adapted to changing conditions, which also makes riparian ecosystems naturally resilient to changing conditions due to climate change (Gregory et al. 1991, Seavy et al. 2009). However, humans have also had a huge impact on riparian areas, which has led to rapid loss and degradation of riparian wetlands globally and in California (Duffy and Kahara 2011, Naiman et al. 1993). Loss and degradation of riparian wetlands is primarily due to flood control (dams and levees), conversion for agriculture, urban development and infrastructure, nutrient runoff (pesticides and herbicides), and introduction of nonnative species (Duffy and Kahara 2011, Alpert et al. 1999).

1.2 Federal and State Regulations and Compensatory Mitigation

Federal and State laws have been enacted since the 1970s to protect and regulate aquatic resources in the U.S. and California. Riverine wetlands (another term for riparian wetlands) are one of the many types of aquatic resources regulated by the Federal and State laws. The Federal Clean Water Act includes Sections 404 and 401, which regulate dredge and fill into Waters of the U.S. The U.S. Army Corps of Engineers (USACE) is the implementing agency of Section 404 of the Clean Water Act. In California, implementation of Section 401 of the Clean Water Act is delegated to the State Regional Water Quality Control Boards (RWQCB). State regulations that protect aquatic resources include the Porter Cologne Water Quality Act or California Water Code, implemented by the State RWQCBs and Section 1600 of the Fish and Game Code, implemented by California Department of Fish and Wildlife (CDFW).

The USACE, RWQCB, and CDFW, in enforcing the respective regulations, require compensation for loss or impact to aquatic resources acreage and functions. The USACE has a national goal of “no net loss” of aquatic resources, which refers to no net loss of acreage and function of aquatic resources. To achieve this goal, the USACE requires compensatory mitigation for impacts to aquatic resources that cannot be avoided or minimized (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency 2008). In 2008, the USACE published the *Compensatory Mitigation for Losses of Aquatic Resources; Final Rule* (2008 Mitigation Rule) to establish standards and requirements for compensatory mitigation. The State RWQCBs and CDFW will often require compensatory mitigation for unavoidable impacts to aquatic resources similar to what is required by the USACE because they have not developed a current formal mitigation rule. Overall, regulatory agencies require some form of compensatory mitigation for unavoidable impacts to aquatic resources, including riparian wetlands.

Forms of compensatory mitigation include permittee-responsible mitigation, purchasing credits from an agency-approved mitigation bank, and paying into an in-lieu fee program. This paper covers restoration of riparian habitat associated with permittee responsible mitigation and mitigation bank credits. This paper does not discuss in-lieu fee programs in which fees collected are to fund future large-scale mitigation projects. This paper specifically looks at three riparian mitigation banks within the Central Valley of California. These banks include: Cosumnes Floodplain Mitigation Bank owned and operated by Westervelt Ecological Services, Bullock Bend Mitigation Bank owned and operated by Westervelt Ecological Services, and River Ranch Mitigation Bank owned and operated by Wildlands, Inc. This paper will also consider permittee-responsible riparian restoration mitigation projects, which are usually smaller in scale compared to mitigation bank restoration projects.

1.3 Assessment Methods

Assessment methods have been developed to evaluate the functions and/or condition of wetlands. The primary functional/condition assessment methods that have been used in California since the 1980s include: Wetland Evaluation Technique (WET), Hydrogeomorphic assessment (HGM) approach for riverine wetlands, and California Rapid Assessment Method (CRAM) and CRAM for Wetlands Riverine Wetland Fieldbook. WET was developed in 1987 by the Wetland Research Program for the USACE and the U.S. Department of Transportation Federal Highway Administration to be used as a rapid approach to evaluate wetland function and values (Adamus et al. 1991). The HGM approach for evaluating riverine wetlands was also developed by the Wetland Research Program for the USACE to assess wetland functional condition of riverine wetlands (Brinson et al. 1995). The CRAM for Wetlands Riverine Fieldbook was developed by California Wetland Monitoring Workgroup to provide a rapid assessment of riverine wetland condition in California (California Wetlands Monitoring Workgroup 2013a).

1.4 Research Objectives

Studies looking at success of past compensatory mitigation projects for impacts to wetlands, including riparian wetlands, have shown that compensatory mitigation projects, even when in compliance with permit conditions, do not result in restoration of wetland functions relative to the wetlands lost due to impacts (Ambrose et al. 2006, Matthews and Endress 2008, Sudol and Ambrose 2002, Zedler and Callaway 1999). My primary research objective is to provide recommendations to improve compensatory mitigation plans for riparian restoration projects in California's Central Valley to ensure successful restoration of riparian wetland functions and values. To achieve this research objective, I first determined the important and measurable riparian wetland functions using existing literature, mitigation guidelines, and existing riparian restoration plans for mitigation banks in California. I then reviewed three functional/condition assessment methods and determined the effectiveness of each assessment method at assessing riparian wetland functions. I also evaluated the performance standards developed for three riparian mitigation banks in the Central Valley. Finally, I provided recommendations on how mitigation performance standards can be improved for riparian mitigation banks and smaller-scale, permittee-responsible riparian restoration projects to be better linked to riparian wetland functions.

2.0 Methods

This paper focuses on understanding how performance standards for riparian restoration compensatory mitigation projects can more adequately assess restoration of riparian wetland functions. I conducted a literature review of peer-reviewed articles that focused on riparian wetland ecosystems, riparian restoration, and evaluation of agency requirements and compensatory mitigation projects. I reviewed regulations, requirements, guidelines, and agency reports published by Federal and State agencies that regulate impacts to riparian wetlands in California, including the USACE, RWQCB, and CDFW. I also reviewed guidelines published by the International Society of Ecological Restoration. Additionally, I reviewed habitat development plans for three riparian mitigation banks within the Central Valley of California. I conducted an interview with Tara Collins, the ecological resources manager of Westervelt Ecological Services, a private mitigation banking company located in Sacramento, California. Finally, I reviewed guidebooks and published methods for three functional/condition assessment methods: WET, HGM, and CRAM (collectively referred to as "assessment methods" herein).

I used the information obtained from my literature review to evaluate the effectiveness of each assessment method to evaluate riparian wetland function and values. For each assessment method, I identified the functions evaluated; the processes, variables, or indicators used to evaluate the function; whether equipment was needed for the assessment; whether expertise was needed for the assessment; and the overall level of effort required. I also evaluated whether the functions were likely to change or develop when monitored based on attributes of the wetland only and not climate or other non-wetland factors. I then compared the riparian wetland functions evaluated by each of the assessment methods to the agency requirements for performance standards for compensatory mitigation. I identified the functions and assessment method most appropriate to use to develop performance standards. I then used this analysis, as well as information about restoration of riparian wetlands to develop recommendations for developing and monitoring performance standards for riparian wetland compensatory mitigation projects. I also compared the recommended performance standards in habitat development plans for riparian mitigation banks in the Central Valley of California to determine shortfalls and provide recommendations to improve performance standards for mitigation banks, as well as smaller-scale permittee-responsible riparian restoration projects in the Central Valley of California.

3.0 Riparian Wetlands in the Central Valley of California

California's Central Valley is a sedimentary basin that is bound by the Coast Range to the west, the Sierra Nevada Range to the east, the Klamath Mountains and Cascade Range to the north, and the Tehachapi Range to the south (Figure 1). The Central Valley is further subdivided into three hydrologic regions: Sacramento Valley, San Joaquin Valley, and Tulare Valley (Barbour et al. 2007, Duffy and Kahara 2011). The Central Valley is characterized by a Mediterranean climate with warm, dry summers and wet, mild winters. The majority (90 percent) of the rainfall occurs between November and May. It has a relatively flat topography with elevations ranging from slightly below sea level to 120 meters above sea level (Duffy and Kahara 2011).

Riparian wetlands are the transitional zone between aquatic and terrestrial habitats. They are defined as the area between the bankfull discharge boundary of a stream channel and the adjacent terrestrial area that is influenced by flooding, a high water table, and high soil-water-holding capacity (Nilsson and Svedmark 2002). Typically, riparian wetlands are linear in form (along riverine systems), extend perpendicular from the stream channel, are open systems, and are functionally connected to upstream and downstream ecosystems (Brinson et al. 1995, Mitsch and Gosselink 2015).

Riparian wetlands within the Central Valley are areas influenced by the two major rivers, the Sacramento and San Joaquin rivers and their tributaries (Figure 2) (Barbour et al. 2007). Hydrology plays a major role in the diversity of riparian ecosystems within the Central Valley, and rivers with natural levels produce the largest and most diverse riparian ecosystems. In general, watercourses throughout the Central Valley have well-developed riparian ecosystems (Sands 1985). The following section provides descriptions of the hydrology, vegetation, and soil characteristics of riparian wetlands that occur in the Central Valley, as well as ecosystem services, natural stressors, and human impacts to these riparian wetlands. Representative photographs of riparian wetlands through the Central Valley are provided in Figure 3.

3.1 Hydrology, Vegetation, and Soil Characteristics

Hydrology plays a major role in the diversity of riparian ecosystems within the Central Valley and is critical to maintaining important functions of riparian wetlands (Larsen and Alp 2015). The flood-pulse concept is the driving force of Central Valley river-floodplain systems, their productivity, and the interaction of biota between the channel and floodplain. The flood-pulse concept accredits the connection of aquatic and terrestrial areas of riverine systems by the pulse flows caused by bankfull discharge and floodplain inundation (Junk et al. 1989). Streams are non-equilibrium systems, and riparian wetlands are constantly disturbed by the flooding and debris flow that occur during flood-pulse events. Riparian wetlands are dependent on disturbance. The delivery of water, woody debris, and sediment from flood-pulse events are the primary force influencing the ecological functions of riparian wetlands (Naiman et al. 1993). Water sources influencing the hydrology of riparian wetlands in the Central Valley are overbank (bankfull) flow from the stream channel, subsurface hydraulic connections (groundwater discharge), interflow and return from the uplands, overland flow from uplands, tributary inflow, and precipitation (Brinson et al. 1995). Water sources in the Central Valley can be natural such as riverine flows, snowmelt, precipitation, and groundwater or they can be unnatural such as irrigation runoff and stormwater runoff from storm drains (California Wetlands Monitoring Workgroup 2013b).

Riparian wetlands have high plant biodiversity due to the intensity and frequency of floods and terrestrial events (e.g., fire, wind). Additionally, the variations in topography, soils and climate influences the vegetation structure (Naiman et al. 1993). In the Central Valley, riparian vegetation is categorized as invaders, endurers, resisters, and avoiders. Riparian wetlands are characterized by primary and secondary successional species that are adapted to the natural hydrologic regime. Primary successional species include: *Salix*, *Platanus*, *Populus*, and *Alnus*; secondary successional species include *Acer*, *Fraxinus*, *Juglans*, and *Quercus* (Barbour et al. 2007). Riparian vegetation in the Central Valley is adapted to and depends on flooding (pulse) events (Alpert et al. 1999, Gregory et al. 1991). Many of the riparian trees are also phreatophytic, meaning the trees have the ability to access groundwater with deep roots, allowing the trees to adapt to variable flooding events (Nilsson and Svedmark 2002). Some riparian plants that occur in the Central Valley, such as *Populus fremontii*, have adapted seed dispersal to occur during flooding events (Griggs 2009).

The soil, referred to as alluvium in riparian wetlands, is developed by the frequent flooding of the landscape. Nutrients from upstream areas along a river or stream system are deposited as alluvium during flooding events. Nutrients in the river or stream system typically result from fish or other aquatic carcasses, as well as sediments that absorb nutrients from the water. The continuous input of nutrients during flooding events results in a highly productive alluvium (Griggs 2009). Furthermore, alluvium in riparian wetlands is often subject to continuous erosion and deposition from flooding events. Adjacent upland areas can contribute to the alluvium of riparian wetlands from mudslides or other events that could result in soil disturbance (Nilsson and Svedmark 2002).

3.2 Ecosystem Services

Riparian wetlands have several functions that provide important ecosystem services to people. Typically, ecosystem services are classified into four categories: provisioning services, regulating services, cultural services, and supporting services. Provisioning services are services directly tied to resources, such as food or water. Regulating services are services that provide actions, such as flood protection or control and water quality improvement. Cultural services are services that have a cultural significance, such as spiritual or aesthetic. Supporting services are services provide support to other services, such as nutrient cycling or primary production (Brauman et al. 2007). The most important ecosystem services of riparian wetlands include: flood storage and protection, water quality improvement, biodiversity, wildlife corridor, groundwater recharge, recreation, cultural resources, and aesthetic resources (Griggs 2009, Barbour et al. 2007, Duffy and Kahara 2011). Ecosystem services are often interrelated and connected to each other (Brauman et al. 2007), and eliminating of once service may also affect another service. Riparian wetlands have certain functions that provide the ecosystem services listed above, and these services are optimized when the riparian wetland function is highest (Griggs 2009). For example, the service of flood protection is best provided when the riparian wetland is hydrologically connected to the river system, which allows for the wetland to absorb high flows, as described by the flood-pulse concept (Junk et al. 1989). Additionally, many of the ecosystem services provided by riparian wetlands, including water quality improvement, biodiversity, and wildlife corridors, rely on the plant communities and structure often supported by riparian wetlands (Griggs 2009).

Another important service of riparian wetlands is their resilience to climate change. Riparian wetlands are naturally resilient to climate change because the plants and wildlife species that occur within them are adapted to dynamic conditions such as periodic flooding and seasonal variations in precipitation and temperature (Seavy et al. 2009). Also, as climate change continues to result in shifts of habitats and unpredictable climate conditions, riparian wetlands will be extremely important. Riparian wetlands will continue to provide ecological corridors between the terrestrial and aquatic environment, expansion of thermal refugia for fish to combat rising water temperatures, reduction of extreme flood events, and supporting biodiversity in the face of climate change (Griggs 2009, Seavy et al. 2009). Therefore, it is critical to restore degraded riparian wetlands to reduce potential effects of climate change (Seavy et al. 2009).

3.3 Natural Stressors and Human Impacts

Riparian wetlands experience multiple natural stressors from the adjacent aquatic and terrestrial ecosystems. The Mediterranean climate of the Central Valley experiences cool, wet winters and hot, dry summers, which results in seasonal variation of precipitation and temperature. Seasonal variation intensifies natural stressors such as flood and drought (Seavy et al. 2009). Riparian wetland are non-equilibrium systems that are subject to varying levels of inundation and sediment deposition. The flood-pulse hydrologic regime is the driving force in riparian wetlands. Plants in and wildlife that use riparian areas are exposed to varying degrees of flooding from pulse events that occur within the channel and out into the floodplains (Junk et al. 1989, Nilsson and Svedmark 2002). These pulse or flooding events often deposit sediment from the upstream channel and may cause erosion from the upland areas (Naiman et al. 2005, Frayer et al. 1989). Riparian wetlands also experience dry conditions, when flood waters retreat and flows within the stream channel are low. Therefore, plant and wildlife species are also exposed to dry periods, usually in the summer and early fall in California's Central Valley. Riparian wetlands also experience stressors from the terrestrial or upland areas. These terrestrial stressors include fire, wind, plant disease, and insect outbreaks (Gregory et al. 1991). Overall, natural stressors from the aquatic ecosystems (flood events) as well as terrestrial stressors that are intensified by the Central Valley's varying climatic conditions require adaptations from plant and wildlife species that occur within or use riparian wetlands.

Since the 1800s, humans have altered riparian areas in the Central Valley (Frayer et al. 1989), resulting in loss of approximately 95 percent of the naturally occurring riparian habitat within the Central Valley (Griggs 2009). One of the main factors driving riparian wetland loss is the change of hydrologic regime through constructing dams on large rivers. Within the Central Valley drainage basin, there are approximately 100 dams, as well as water delivery canals and streambank flood control projects that manage the water flow (Frayer et al. 1989). Flood or pulse events are muted or eliminated when the hydrologic regime is controlled by dams or redirected with water delivery canals. Additionally, streambank flood control projects construct levees or berms to further control flood flows. These structures disconnect the riparian area from the adjacent stream channel completely or are managed to prevent vegetation growth and wildlife usage (Alpert et al. 1999, Frayer et al. 1989, Griggs 2009). By the 1920s, approximately 70 percent of the wetlands in the Central Valley, including riparian wetlands, were converted or modified due to construction of dams and flood control structures (Duffy and Kahara 2011, Alpert et al. 1999).

Construction of dams and flood control structures led to agricultural development and urbanization. Conversion of riparian wetlands to agriculture or use for livestock grazing resulted in the overall loss or degradation of riparian wetlands in the Central Valley (Frayer et al. 1989, Griggs 2009, Alpert et al. 1999). Riparian wetlands contain productive soils from input of nutrients and other organic matter during flooding events, resulting in soils ideal for growing crops. Agricultural conversion of riparian wetlands intensified with construction of the Sacramento Flood Control Project in 1910 and construction of levees within the Sacramento-San Joaquin River Delta (or California Delta) in the 1930s. These projects reduced the immediate threat of flooding, allowing for draining and cultivation of riparian wetlands. Construction of the

State Water Project in 1951 further artificially controlled the water regime in the Central Valley (Frayer et al. 1989). The main cause of recent riparian wetland loss is urbanization, including construction of housing, commercial buildings, and roads. Human development also results in overall degradation of riparian wetlands from increased runoff of nutrients and introduction of nonnative, and sometimes invasive, species (Duffy and Kahara 2011).

4.0 Regulatory Background

4.1 Federal and State Regulations

The purpose of the Clean Water Act is to protect the chemical, physical, and biological integrity of all Waters of the U.S. Section 404 of the Clean Water Act prohibits the discharge of dredged or fill material into Waters of the U.S. without a permit from the USACE. The U.S. Environmental Protection Agency (EPA) also has authority over wetlands and may override a USACE regulatory action. The definition of Waters of the U.S. includes rivers, streams, estuaries, the territorial seas, ponds, lakes, and wetlands (often including riparian wetlands) that are connected to a navigable water body. The jurisdiction of the Section 404 of the Clean Water Act has been further defined through significant court cases such as *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers, Rapanos v. United States, and Carabell v. United States* (U.S. Environmental Protection Agency and U.S. Army Corps of Engineers 2008).

The California RWQCBs implement water quality regulations under Section 401 of the Federal Clean Water Act and the California Porter-Cologne Water Quality Act. These regulations require compliance with the National Pollutant Discharge Elimination System (NPDES), including compliance with the California Storm Water NPDES General Construction Permit for discharges of stormwater runoff associated with construction activities. The RWQCB regulates actions that involve discharge of waste or potential to discharge waste into or adjacent to any Waters of the State, under the Porter-Cologne Water Quality Act (Water Code 13260(a)). Waters of the State include all surface water or groundwater, including saline waters, occurring within California's state boundary. The RWQCB regulates all such activities, as well as dredging, filling, or discharging materials into Waters of the State, that are not regulated by USACE due to a lack of connectivity with a navigable water body. The RWQCB may require issuance of a Waste Discharge Requirement for these activities.

Section 1600 of the California Fish and Game Code protects the bed, channel, bank, and associated riparian habitat within rivers, streams and lakes that occur within California. Specifically, Section 1602 of the California Fish and Game Code requires submittal of a Streambed Alteration Notification to the CDFW for any activity that has the potential to impact natural flow or the bed, channel, bank, or associated riparian habitat of any river, stream, or lake. The CDFW reviews the proposed actions and, if necessary, submits proposed measures to protect affected fish and wildlife resources to the applicant.

4.2 Agency Mitigation Guidelines/Requirements

The USACE is the only regulatory agency that has adopted and provided detailed guidelines to develop mitigation and monitoring plans for compensatory mitigation projects. However, before compensatory mitigation is considered, the USACE requires avoidance and minimization to reduce impacts to Waters of the U.S. In 1987, the National Wetlands Policy Forum recommended the USACE adopt a "no net loss" goal. The purpose of this goal was to achieve no overall net loss of the U.S. remaining wetlands and to create and restore wetlands, where feasible, to increase the quantity and quality wetlands that occur within the U.S. In 1989, President George H.W. Bush's administration adopted the United States' "no net loss" goal (Robertson 2000). Since adoption of the "no net loss" goal, the USACE has issued guidance on how to comply with the goal. The most recent mitigation document published is the USACE 2008 Mitigation Rule, which uses the no net loss of functions and values standard for compensatory mitigation for impacts to Waters of the U.S. Additionally, since the 1980s, USACE has standardized four methods of compensatory mitigation to achieve the "no net loss" goal. The four methods are restoration, enhancement, establishment (creation), and preservation, which can be implemented using one of three mechanisms: permittee-responsible mitigation, mitigation banks, and in-lieu fee (U.S. Army Corps of Engineers and U.S. Environmental Protection Agency 2008).

In 2015, the South Pacific Division of the USACE published the *Final 2015 Regional Compensatory Mitigation and Monitoring Guidelines for South Pacific Division USACE* (USACE 2015 Mitigation and Monitoring Guidelines). The purpose of the USACE 2015 Mitigation and Monitoring Guidelines was to standardize mitigation in the region and to provide guidance on how to prepare mitigation plans for successful mitigation (U.S. Army Corps of Engineers 2015). The USACE 2015 Mitigation and Monitoring Guidelines have requirements for developing ecological performance standards for compensatory mitigation projects. These guidelines require that ecological mitigation performance standards should be measurable and verifiable and assess a variety of environmental factors that correlate to ecological function or condition. Specifically, the guidelines recommend developing performances standards related to five categories: physical characteristics, hydrology, flora, fauna, and water quality (U.S. Army Corps of Engineers 2015).

5.0 Mitigation and Monitoring Plans

Mitigation and monitoring plans need to provide clear guidance to ensure successful restoration of ecosystem function and values (McDonald et al. 2016). Elements that should be included in a mitigation and monitoring plan will be largely dependent on the goals and objectives of the mitigation project (Collins 2018). The USACE 2015 Mitigation and Monitoring Guidelines provide a recommended outline for components that should be included in a mitigation and monitoring plan. Key components that are applicable to wetland restoration projects include objectives, assessment of baseline conditions, ecological performance standards, and a monitoring plan (U.S. Army Corps of Engineers 2015).

The Society of Ecological Restoration (SER) has also published international standards for the practice of ecological restoration, which includes key concepts that should be incorporated into mitigation projects that include ecological restoration (McDonald et al. 2016). These key concepts are meant to apply to restoration of any ecosystem (aquatic or terrestrial), and they provide a good baseline for preparation of project-specific mitigation and monitoring plans for wetland restoration projects. SER's key concepts can be incorporated into the following components of a mitigation and monitoring plan: (1) identify a local reference site and conditions, (2) identify key attributes of the target ecosystem in terms of specific goals and objectives, (3) incorporate regeneration of processes, not just reconstruction, (4) develop strategies for long-term, continuous improvement (adaptive management), (5) employ use of local and interdisciplinary knowledge, and (6) engage of all stakeholders (McDonald et al. 2016).

Mitigation and monitoring plans should be designed to increase predictability of restoration projects, incorporate a set of performance standards applicable to a variety of ecosystem function, and require benchmarks for compliance based on reference sites and conditions of the surrounding landscape (Matthews and Endress 2008). Incorporation of reference sites is a critical component that has often been overlooked in past restoration projects. Reference sites should be used to identify the objectives and ideal trajectory of the restoration project and assist in monitoring and assessing interim success (Collins 2018). Performance standards included in mitigation and monitoring plans should be based on conditions that can be achievable in the natural landscape. Therefore, it is also important that reference sites, including sites that exhibit various time periods along a restoration trajectory, are used to inform the development of realistic and appropriate performance standards (Van den Bosch and Matthews 2017).

6.0 Riparian Mitigation Banks in the Central Valley of California

This paper looks at habitat development plans for three riparian mitigation banks within the Central Valley: Cosumnes Floodplain Mitigation Bank, Bullock Bend Mitigation Bank, and River Ranch Wetland Mitigation Bank. The Cosumnes Floodplain Mitigation Bank is located in southern Sacramento County at the confluence of the Mokelumne and Cosumnes Rivers (Figure 1). The habitat development plan was written in 2009, prior to the USACE 2015 Mitigation and Monitoring Guidelines. This is important because the USACE 2015 Mitigation and Monitoring Guidelines established the five performance standard categories. The bank restoration consisted of floodplain mosaic wetlands and floodplain riparian habitat within the historic floodplain (Westervelt Ecological Services 2009). Using the *Classification of wetlands and deepwater habitats of the United States* (Cowardin et al. 1979), the floodplain mosaic wetlands are similar to the palustrine forested wetland, seasonally flooded (PFOC) habitat and the floodplain riparian habitat is similar to palustrine forested wetland, temporarily flooded (PFOA), intermittently flooded (PFOJ) habitats (Westervelt Ecological Services 2009). The Cosumnes River Preserve, located just north of the bank location, is a reference site for the development of the restoration design and performance standards. The Cosumnes River Preserve was an ideal reference site for the bank because it has early and late-successional riparian habitat, as well as areas that were actively planted with native riparian species (Westervelt Ecological Services 2009).

The Bullock Bend Mitigation Bank is in Yolo County, California, adjacent to the Sacramento River (Figure 1). The site was chosen for development of a mitigation bank because it is located next to the Sacramento River but isolated from river flood events. The surrounding land uses are also harmonious with a mitigation bank, and there is need in the area for mitigation for impacts to salmonid and riparian habitts (Westervelt Ecological Services 2016). Restoration efforts at the site consisted of returning natural hydrologic connectivity (flooding) to the area by notching a constructed berm that separated the site from the Sacramento River and constructing backwater channels to create habitat complexity. The mitigation bank consists restoration of floodplain riparian habitat that is classified as other Waters of the U.S. by Section 404 of the Clean Water Act (Westervelt Ecological Services 2016). A total of five reference sites were selected in designing the mitigation bank. Four potential reference sites are located on remnant areas of riparian habitat along the Colusa and Verona reaches of the Sacramento River. Only one of these sites was used as a reference site because it was available for access and data collection. Additionally, a reference site in the Sacramento River National Wildlife Refuge area was chosen, because it had public access and was a previously successful restored riparian site. A previously restored site was used to provide information on progression of a previously restored site in the region (Westervelt Ecological Services 2016).

The River Ranch Wetland Mitigation Bank is located in eastern Yolo County along the Sacramento River, within existing agricultural development (Figure 1). Construction of the bank consisted of restoring two freshwater marsh complexes surrounded by a strip of riparian scrub habitat. Both habitats are considered Waters of the U.S. under Section 404 of the Clean Water Act. The goal of the restored riparian scrub habitat is to provide habitat for plants and wildlife species within the region. The River Ranch Wetland Mitigation Bank used a reference site located within the River Ranch area, as well as, previously successful riparian mitigation banks in the region: Aitken Ranch Mitigation Bank and Fremont Landing Mitigation Bank. Both reference mitigation banks have similar riparian habitats to the River Ranch Mitigation Bank and are consistently monitored with permanent plots every year (Wildlands Inc. 2010).

7.0 Assessment Methods

Assessment methods have been developed to evaluate wetland function and condition. The U.S. EPA has established three levels (Level 1-2-3 Framework) of monitoring. Level 1 includes general habitat and landscape assessments; Level 2 includes rapid assessment methods; and Level 3 includes more intensive, often quantitative assessment methods (Stein et al. 2009). This paper evaluates three assessment methods for use in developing and monitoring performance standards for mitigation projects: WET and CRAM would be classified as Level 2 assessment methods, and HGM would be classified as a Level 2 or 3 assessment method. A brief description of each of the assessment methods are provided in the following sections.

7.1 Wetland Evaluation Technique (WET)

The USACE Wetland Research Program, a program that conducts wetland research on behalf of the USACE, developed WET as a rapid approach to evaluate wetland function and values. WET evaluates wetland functions by looking at wetland attributes related to the physical, chemical, and biological process that are important to wetland ecosystems. WET also considers wetland values, which are defined as attributes that have a significance to society (Adamus et al. 1991). This assessment method evaluates a wetlands ability to perform 11 functions and values including: ground water recharge, groundwater discharge, floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, product export, aquatic diversity and abundance, wildlife diversity and abundance, recreation, and uniqueness and heritage. WET evaluates these functions and values by looking at specific processes that have been associated with the function or value (Adamus et al. 1991). Brief descriptions of the functions and the process associated with each function assessed by WET (Adamus et al. 1991) are provided below.

- *Groundwater recharge and discharge* refers to the movement of water in between groundwater and surface water. The processes associated with this function are groundwater flow rates and storage capacity; direction and location of groundwater movement; and evapotranspiration.
- *Floodflow alteration* refers to the capacity of the wetland to retain or delay floodwaters before moving downstream. The processes associated with this function are magnitude and duration of storms; runoff from upslope areas; aboveground storage capacity; morphology of the wetland; frictional resistance (resistance by microtopography or vegetation) of the wetland surface; below-ground storage capacity; and the position of the wetland in the watershed.
- *Sediment stabilization* refers to the ability of the wetland to retain sediment and dissipate erosive forces. The processes associated with this function are energy of erosive forces; frictional resistance of the wetland; position of the wetland to the upland and erosive forces; ability of wetland plants to anchor the soil; and the erodibility of uplands.

- *Sediment and toxicant retention* refers to the retention of suspended solids or chemical contaminants within a wetland. The processes associated with this function are amount of incoming sediment; particle size and density of suspended sediment; difference in energy levels of suspending forces in wetland versus upcurrent areas; vertical layering caused by salinity and temperature in waters; flocculation (clumping of fine particles), agglomeration (collection of masses), and precipitation; bioturbation (disturbance of sediment by living organisms) and mobilization of sediment; and storage capacity of the wetland.
- *Nutrient removal and transformation* refers to the storage of nutrients within the wetland and the transformation of inorganic nutrients to organic forms, as well as the removal of nutrients, such as nitrogen. The processes associated with this function are biological uptake and processing; sedimentation and accumulation of organic matter in the substrate; adsorption and nutrient interactions with sediments; and chemical and microbial processes such as denitrification, nitrogen fixation, and ammonia volatilization.
- *Production export* refers to the export of large amounts of organic materials (carbon) from the wetland to downstream or adjacent wetland areas. The processes associated with this function are productivity of potential food sources; nitrogen-fixing ability of potential food sources; and dispersal and cycling of potential food sources.
- *Aquatic diversity and abundance* refers to the ability of the wetland to support diversity and/or abundance of fish and aquatic invertebrates. The processes associated with this function are water quality (physical and chemical); water quantity; amount of cover; substrate, including interspersion (overlap of plant communities and layers); and availability and quality of food sources.
- *Wildlife diversity and abundance* refers to the ability of the wetland to support diversity and abundance of wildlife, such as wetland-dependent birds. The processes associated with this function are wetland area size; availability of cover; availability of food; availability of specialized habitat; isolation from disturbance; and absence of contaminants.
- *Recreation* refers to consumptive and non-consumptive (passive use) recreation activities that are water dependent and occur in wetlands. There are no specific processes identified with this function.

- *Uniqueness and heritage* refers to using a wetland for aesthetic enjoyment, nature study, education scientific research, open space, preservation of rare or endemic species, protection of archaeologically or geologically unique features, maintenance of historic sites, or other potential uses. There are no specific processes identified with this function.

WET uses three different evaluation techniques depending on the objectives of the wetland evaluation (Adamus et al. 1987). The social significance evaluation technique evaluates the societal value using 31 questions to assess the natural features, economic value, official status, and strategic location of the wetland. The effectiveness and opportunity evaluation technique assesses the effectiveness and opportunity of a wetland to perform functions and values with a serious of questions to evaluate the probability of the wetland to perform the 11 function and values. The habitat suitability technique evaluates the wetland habitat suitability for waterfowl and fish species. This technique focuses on the physical, chemical, and biological processes attributes of the wetland (Adamus et al. 1987). WET would likely be considered an EPA Level 2 assessment method because it is a relatively rapid assessment of wetland function that does not include specific or detail data collection.

7.2 Hydrogeomorphic (HGM) Approach

The USACE Wetland Research Program developed HGM to classify wetlands (Brinson 1993), which included the development of the HGM Riverine Guidelines. The HGM Riverine Guidelines were developed to provide an approach for evaluating riverine wetlands and to assess functional condition of riverine wetlands. The HGM Riverine Guidebook was intended to inform development of regional guidebooks and not be used to conduct assessment; however, it provides a good overview of the functions evaluated by HGM. A regional guidebook has not been developed for riverine wetlands in the Central Valley; therefore, the HGM Riverine Guidebook was reviewed for this analysis. HGM focuses on the use of reference wetlands as a way to evaluate the function of the wetlands assessed. This approach evaluates four riverine wetland function categories: hydrologic, biochemical, plant habitat, and animal habitat. Specific functions are defined within these categories and the guidebook provides several variables associated with these functions that can be used to quantitatively assess the riverine wetlands ability to perform the function compared to the reference wetland. The variables considered for each function are given a score between 1 and 0 depending on how they compare to the variable at the reference site. The scores of the variables are then complied using an equation that is specific to each function to determine the overall score for that particular function (Brinson et al. 1995). HGM would likely be considered an EPA Level 2 and potentially a Level 3 assessment method because some of the functions evaluated may require more extensive studies that are beyond the rapid approach of Level 2 monitoring. Brief descriptions of the functions and the variables used in HGM to assess each function (Brinson et al. 1995) are provided below.

- *Surface water storage* refers to capacity of a riparian wetland to retain surface water from overbank flow. Variables used to evaluate this function are frequency of overbank flow; average depth of inundation; and site roughness. Site roughness includes microtopographic complexity, shrub and sapling density, biomass, percent cover, tree density, tree basal area, and coarse woody debris.
- *Energy dissipation* refers to the ability of the wetland to dissipate energy from floodwaters. Variables evaluated for this function are reduction in flow velocity; frequency of overbank flow; and site roughness.
- *Subsurface storage of water* refers to storage capacity of water below the surface. Variables used to evaluate this function are soil pore space availability for water storage and fluctuation of the water table.
- *Moderation of groundwater flow or discharge* refers to the riparian wetlands ability to control the rate of groundwater flow or discharge from upgradient sources. Variables used to evaluate this function are subsurface flow into the riparian wetland and subsurface flow from the riparian wetland to the aquifer or base flow.
- *Nutrient cycling* refers to the conversion of nutrients and other elements through abiotic and biotic processes in the wetland. Variables used to evaluate this function are aerial net primary productivity and annual turnover of detritus.
- *Removal of imported elements and compounds* refers to the riparian wetlands ability to intercept nutrients and contaminants and remove them from surface water. Variables used to evaluate this function are frequency of overbank flow; surface water inflow; subsurface water inflow; microtopographic complexity; surfaces for microbial activity; sorptive (retention) properties of soils; and tree basal area.
- *Retention of particulates* refers to the riparian wetlands ability to retain inorganic and organic particulates in the water column using physical processes. Variables used to

evaluate this function are frequency of overbank flow; surface water inflow; site roughness; and amount of retained sediments.

- *Organic carbon export* refers to the export of organic carbon from a riparian wetland through leaching, flushing, displacement, or erosion. Variables used to evaluate this function are frequency of overbank flow; surface water inflow; subsurface water flow; surface hydraulic connections with the channel; and amount of organic matter in the wetland.
- *Maintain characteristic plant community* refers to the plant species composition and characteristics of the living biomass. Variables used to evaluate this function include species composition for each plant strata (tree, sapling, shrub, and ground cover); regeneration from seedlings or saplings and/or clonal shoots; percent canopy cover; tree density; and tree basal area.
- *Maintain characteristic detrital biomass* refers to the amount, including production, accumulation, and dispersal of dead plant biomass. Variables used to evaluate this function include density of standing dead trees (snags); amount of coarse woody debris; decomposing logs; and amount of fine woody debris accumulating in active channel or side channel.
- *Maintain spatial structure of habitat* refers to the riparian wetlands ability to provide habitat to support animal populations. Variables used to evaluate this function are density of standing dead trees (snags); abundance of mature trees; overall vegetation patchiness; and presence of canopy gaps.
- *Maintain interspersion and connectivity* refers to the riparian wetlands ability to allow connection to the channel for aquatic organisms to enter and leave using permanent or ephemeral surface channels, overbank flow, or unconfined aquifers. Variables used to evaluate this function are frequency of overbank flow; duration of overbank flow; microtopographic complexity; surface hydraulic connections; subsurface hydraulic connections; and contiguous vegetation cover and/or corridors between wetland and upland, between channels, and between upstream and downstream areas.
- *Maintain distribution and abundance of invertebrates* refers to the riparian wetlands ability to support diversity and abundance of aquatic, semi-aquatic, and terrestrial invertebrates. Variables used to evaluate this function are distribution and abundance of

invertebrates in the soil; distribution and abundance of invertebrates in leaf litter and coarse woody debris; and distribution and abundance of invertebrates in aquatic habitats.

- *Maintain distribution and abundance of vertebrates* refers to riparian wetlands ability to support a diversity and abundance of aquatic, semi-aquatic, and terrestrial vertebrates. Variables used to evaluate this function are distribution and abundance of resident and migratory fish; distribution and abundance of amphibians and reptiles; distribution and abundance of resident and migratory birds; distribution and abundance of permanent and seasonally resident mammals; and beaver activity.

7.3 California Rapid Assessment Method (CRAM)

CRAM was first developed in 2010, when the California Water Quality Monitoring Council delegated development of an EPA Level 2 rapid assessment method that could be used by all State agencies to assess condition of wetlands and riparian areas in California to the California Wetland Monitoring Working Group (San Francisco Estuary Institute 2018). The overall purpose of CRAM is to provide a method for assessing the condition of a population of wetlands and/or the condition of individual wetlands. It has been designed to be conducted in in approximately half a day by two to three trained practitioners and is an EPA Level 2 assessment method (California Wetland Monitoring Workgroup 2013b).

CRAM evaluates four wetland attributes: buffer and landscape, hydrology, physical structure, and biotic structure. Additionally, CRAM includes an analysis of potential stressors that may result in low scores. The buffer and landscape attribute looks at the surrounding landscape and the elements that may protect a wetland from anthropogenic stressors. The hydrology attribute defines the water source, channel stability, and hydrological connection to other aquatic resources. The physical structure attribute looks at distinct elements such as structural patch richness and topographic complexity and how they are organized to provide habitat for biota. The biotic structure attribute evaluates the plant communities, including percent invasion by nonnative species, and the horizontal and vertical structures of the plant communities within the wetland. The four attributes are assessed using the defined metrics, and each metric is given a letter score, which is then used to calculate an overall attribute score. The four attribute scores are then combined and averaged, resulting in an overall wetland CRAM score (California Wetlands Monitoring Workgroup 2013b). A description of each of the metrics and the indicators used to assess each metric (California Wetlands Monitoring Workgroup 2013a) is provided below.

- *Stream corridor continuity* refers to continuity of the stream corridor or riparian area upstream and downstream and the lack of bridges, dams, or developments. The indicators used to assess this metric are the amount of continuous corridor 500 meters upstream and downstream of the riparian (or riverine) wetland.
- *Buffer* refers to the area around the riparian wetland that is in a natural or semi-natural state and can protect the area from potential anthropogenic stressors. The indicators used to assess this metric are percent of a buffer around the wetland; the average width of the buffer; and the overall buffer condition (e.g., percent invasive species or amount of soil disturbance).
- *Water source* refers to the water flowing into the riparian wetland. The indicators used to assess this metric are percent natural and unnatural water sources within approximately two kilometers upstream of the riparian wetland.
- *Channel stability* refers to the status of the channel within the riparian wetland and how increasing and decreasing flows affect the channel. Indicators used to assess this metric are the characteristics of the area that represent aggradation or degradation of the channel.
- *Hydrologic connectivity* refers to the ability of water to flow in and out of the riparian wetland and/or ability of the wetland to accommodate floodwaters. The indicator used to assess this metric is the entrenchment ratio of the channel. The entrenchment ratio is calculated by comparing the bankfull and flood prone widths to determine the amount of entrenchment (ratio between the bankfull depth and the floodprone depth).
- *Structural patch richness* refers to the number of different patch types within a riparian wetland. Patches are physical surfaces or features that may provide habitat for wildlife and plant species. This metric is assessed by identifying what patches are present in the riparian wetland. Patches considered include: abundance of wrackline or organic debris in channel or floodplain; bank slumps or undercut banks; cobbles and/or boulders; debris jams; filamentous macroalgae or algal mats; large woody debris; pannes or pools in floodplain; plant hummocks and/or sediment mounds; point bars and in-channel bars; pools or depressions in the channel; riffles or rapids; secondary channels on floodplain;

standing snags (dead tree); submerged vegetation; swales on floodplain; variegated foreshore; and vegetated islands above higher water.

- *Topographic complexity* refers to micro-and macro-topographic structure of the riparian wetland. Indicators used to assess this metric are the presence of benches on the floodplain and/or presence of abundant micro-topography throughout the channel and floodplain.
- *Plant community* refers to characteristics of the plant species present within the riparian wetland. Indicators used to assess this metric are the number of plant layers; the number of co-dominant species (10 percent within a distinct layer); and the percent of co-dominant species that are considered invasive by the California Invasive Plant Council.
- *Horizontal interspersion* refers to the amount and interspersion of plant zones within the riparian wetland. This metric is assessed by identifying the different plant zones (congregations of species and/or plant layers) and the amount of overlap between these zones.
- *Vertical biotic structure* refers to the amount of overlap between plant layers identified in the plant community metric. This metric is assessed by identifying the extent of overlap (e.g., trees over short grasses).

The CRAM for Wetlands Riverine Wetland Fieldbook, which would be used to evaluate riparian wetlands, was developed specifically to assess condition of riverine wetlands in California (California Wetlands Monitoring Workgroup 2013a). The CRAM for Wetlands Riverine Wetland Fieldbook classifies riparian wetlands as either confined or unconfined. Confined riparian areas are generally found in lower-order streams or highly urbanized areas and are defined by the width that can be traveled before running into a hillside or terrace that is less than twice the typical bankfull discharge. Conversely, an unconfined riparian area has a width greater than twice the typical bankfull discharge and often occurs along valleys (California Wetlands Monitoring Workgroup 2013ba). This paper focuses on unconfined wetlands, as these are the majority of the wetlands that occur within the Central Valley.

8.0 Results and Discussion

8.1 Performance Standard Agency Requirements

The USACE 2015 Mitigation and Monitoring Guidelines established five performance standard categories that mitigation projects should consider. These five categories are physical structure, hydrology, flora, fauna, and water quality (U.S. Army Corps of Engineers 2015). I correlated these five performance standard categories to important ecosystem services provided by riparian wetlands. I created Figure 4 to depict a crosswalk between these performance standard categories and riparian wetland ecosystem services. The physical structure performance standard category is linked to wildlife corridor, recreation, and cultural and aesthetic resources ecosystem services. The hydrology performance standard category is linked to flood storage and protection and groundwater recharge ecosystem services. The flora performance standard category is linked to biodiversity and cultural and aesthetic resources ecosystem services. The fauna performance standard category is linked to biodiversity, wildlife corridor, and cultural and aesthetic resources ecosystem services. The water quality performance standard category is linked to the water quality improvement ecosystem service. Ideally, riparian wetland compensatory mitigation projects should develop performance standards that align with these five performance standard categories to ensure restoration of important riparian wetland ecosystem services. The following analysis used the five performance standard categories to assess possibilities for developing performance standards that are correlated to riparian wetland functions that provide ecosystem services.

8.2 Evaluation of Individual Assessment Methods

In this paper I evaluated three assessment methods that can be used to assess function and/or condition of riparian wetlands. Because of the major differences between the assessment methods' structure, methodology, and functions assessed, each method was evaluated individually. Each assessment method was analyzed to determine what functions the method evaluated; the variables, processes, or metrics used to assess the function; whether the assessment for the function was equipment heavy; whether expertise was needed; the overall level of effort required; and whether the functions were likely to change or develop based on attributes of the wetland only when monitored over time. These categories were assessed to provide information on what and how the assessment method analyzed wetland function or condition, as well as the feasibility of that method to be used as a performance standard. For a performance standard to be feasible, it must be cost effective and able to be monitored over time within the constraints of the monitoring protocol and budget (Collins 2018). Therefore, it is important to identify potential constraints (e.g., equipment, expertise, amount of effort) that may render that method not feasible for a performance standard. A summary of the analysis for each assessment is provide below (Tables 1 – 3).

8.2.1 WET

In my analysis of WET, I focused on the effectiveness and opportunity evaluation method, as this evaluation included all 11 functions and values similar to the HGM and CRAM methods. The WET effectiveness and opportunity evaluation method uses a series of questions for each function and value to determine the probability (high, moderate, low) that the wetland will provide that function or value. The questions are focused on evaluating the wetlands ability to perform the processes identified to be associated with the particular function or value (Adamus et al. 1987). The 11 functions and values evaluated in WET include groundwater recharge, groundwater discharge (recharge and discharge were combined for the analysis), floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, product export, aquatic diversity and abundance, wildlife diversity and abundance, recreation, and uniqueness and heritage (Adamus et al. 1987). Only four of the five performance standard categories are represented in the WET effectiveness and opportunities evaluation (Table 1). Functions associated with the physical structure performance standard category include recreation and uniqueness and heritage. Functions associated with hydrology performance standard category include groundwater recharge and discharge and floodflow alteration. Functions associated with the fauna performance standard category include aquatic diversity and abundance and wildlife diversity and abundance. Functions associated with the water quality performance standard category include sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, and product export. There were no functions evaluated that were specific to the flora performance standard category. The water quality performance standard category was the most highly represented in WET.

WET did not describe any specific processes or provide any questions to evaluate the two values in this evaluation, recreation and uniqueness and heritage. Therefore, an analysis of these two values could not be conducted and only the remaining eight functions are discussed further and summarized in Table 1. Only the sediment/toxicant retention function specifically requires equipment to assess the function. This function requires equipment to measure suspended solids and/or toxins in the water. Four of the eight functions required some level of expertise to evaluate. The overall level of effort varied across the eight functions from high to low amounts of effort. Sediment/toxicant retention was rated as high level of effort; groundwater recharge and discharge, product export, and aquatic abundance and diversity were rated as medium level of effort; and floodflow alteration, sediment stabilization, nutrient removal/transformation, and wildlife abundance and diversity were rated as low level of effort. Seven of the eight functions were determined to have some level of potential to change or develop over time. Groundwater recharge and discharge was the only function analyzed that will not likely change over time as the wetland develops. The processes used to evaluate this function (groundwater flow rates and storage capacity, direction and location of groundwater movement, and evapotranspiration) are not likely to change significantly over time based on attributes of the wetland only (e.g., not likely to change due to changes in climate or factors outside the wetland). Overall, WET can evaluate wetland restoration projects over time for eight wetland functions by giving probability ratings to assess overall wetland function.

8.2.2 HGM

My analysis of HGM focused on the HGM Riverine Guidebook. The HGM Riverine Guidebook for the U.S. is intended to inform development of regional guidebooks and not be used to conduct assessment. However, because there is no regional riverine guidebook for the Central Valley, the HGM Riverine Guidebook was used as it provides a good overview of the functions evaluated by HGM. There are 13 riverine (riparian) wetland functions included in HGM, including: surface water storage (dynamic and long-term), flood protection/energy dissipation, ground water recharge and discharge, nutrient cycling, retention of particles, removal of imported elements and compounds, organic carbon export, maintain characteristic plant communities, maintain characteristic detrital biomass, maintain spatial structure of habitat, maintain interspersion and connectivity, maintain distribution and abundance of invertebrates, and maintain distribution and abundance of vertebrates (Brinson et al. 1995).

The functions of HGM fit into all five of the performance standard categories (Table 2). Functions associated with the physical structure performance standard category include maintaining spatial structure and habitat and interspersion and connectivity. Functions associated with the hydrology performance standard category include surface water storage, flood protection/energy dissipation, and groundwater recharge and discharge. Functions associated with the flora performance standard category include maintaining characteristic plant communities and characteristic detrital biomass. Functions associated with the fauna performance standard category include maintaining distribution and abundance of invertebrates and distribution and abundance of vertebrates. Functions associated with the water quality performance standard category include nutrient cycling, retention of particles, removal of imported elements and compounds, and organic carbon export. The HGM functions were relatively equally distributed across the five categories; however, the water quality performance standard category was the most highly represented.

HGM provides both a direct and indirect way to measure variables for each function. For my analysis, the indirect measure was evaluated unless the direct measure was more appropriate or there was no indirect measure (Table 2). None of the functions had variables that required large amounts of equipment to measure. However, if the direct measure was used to assess the variables, equipment, such as water gauges, would be necessary for the majority of the variables related to hydrology functions. Four of the 13 functions require some level of expertise to complete the assessment, primarily related to the ability to interpret specific soil data. One function (maintain the distribution and abundance of vertebrates) may also require specific expertise in certain vertebrate species, depending on the species of concern and level of evaluation needed. With the exception of one function, all functions were rated medium level of effort. This was primarily because all functions also require assessment of a reference site; therefore, two sites (reference and subject site), versus just the subject site, must be evaluated to complete the assessment. The groundwater recharge and discharge function was given a high rating for level of effort, because it requires a measure of soil pore space availability. Ten of the 13 functions are measured by looking at establishment of plants or other wetland components. Therefore, these ten functions were determined to have some potential to change or develop over time. Two functions, surface water storage and groundwater recharge and discharge, were both determined to not likely to significantly change or develop over time based on the variables used by HGM to assess these functions. Surface water storage will be established during initial restoration and the variables (morphology, evaporation, infiltration and subsurface storage, basin relative morphology, channel roughness) will not likely change much from year to year. Similar to WET, groundwater recharge and discharge is influenced by variables that are not directly controlled by the wetland, unless the restored area was previously paved, and no groundwater recharge or discharge was previously prohibited in the restored area. Overall, HGM provides a comprehensive evaluation of a riparian wetland; however, it is necessary to identify at least one reference site available to conduct the evaluation.

8.2.3 CRAM

I analyzed the CRAM for Wetlands: Riverine Wetlands Fieldbook (Version 6.1), which assesses the condition of riparian wetlands instead of function like the WET and HGM. The CRAM for Wetlands Riverine Wetlands Fieldbook assesses four attribute categories: buffer and landscape, hydrology, physical structure, and biotic structure. Each attribute category is evaluated using metrics and sometimes submetrics (California Wetlands Monitoring Workgroup 2013a). In this analysis, I considered the metrics associated with each of the four attributes as functions. There are ten metrics or functions: water source, channel stability, hydrologic connection, structural patch richness, topographic complexity, plant community, horizontal interspersion, vertical biotic structure, aquatic area abundance, and buffer (Table 3). Only three of the five performance standard categories are evaluated by CRAM. Performance standard categories evaluated by CRAM are hydrology, physical structure, and flora. The fauna and water quality performance standard categories were not evaluated by CRAM. Functions associated with hydrology performance standard category are water source, channel stability, and hydrologic connection. Functions associated with physical structure performance standard category are structural patch richness, topographic complexity, aquatic area abundance, and buffer. Functions associated with flora performance standard category are plant community, horizontal interspersion, and vertical biotic structure. Overall, the physical structure performance standard category is the most well represented category; however, the hydrology and flora performance standard categories are also well represented by the CRAM metrics.

CRAM evaluates wetland condition by giving scores to different metrics and submetrics in different attribute categories, which are then accumulated to provide an overall CRAM score (California Wetlands Monitoring Workgroup 2013b). None of the ten functions (metrics) required large amounts of equipment (Table 3). The purpose of CRAM is to provide a rapid assessment method that can be repeated by trained practitioners in the field. To become a trained practitioner, a five-day CRAM class is required, which includes a field practicum (California

Wetlands Monitoring Workgroup 2013b). Therefore, while no specific expertise is required, all ten functions require trained practitioners to complete. Additionally, the plant community, horizontal interspersion, and vertical biotic structure functions (metrics) require at least one trained practitioner with botany expertise. Seven of the ten functions (metrics) require a half day field effort to complete the evaluation and were therefore rated as low level of effort. Three of the functions (metrics), water source, aquatic area abundance, and buffer are rated medium level of effort because they required some level of office preparation and work separate from the field effort to complete. Seven of the ten functions (metrics) were determined to be likely to change or develop over time because of the potential for the wetland structure and establishment of plants to develop from year to year. Three of the functions (metrics), water source, aquatic area abundance, and buffer, were all determined not likely to change because these would be established during initial restoration. Also, the aquatic area abundance and buffer functions (metrics) are dependent on surrounding land uses that cannot always be controlled by the wetland or the restoration project. Overall, CRAM does provide rapid assessment of wetland condition; however, not all performance standard categories and functions of a riparian wetland are evaluated.

8.3 Comparison of Performance Standard Requirements and Assessment Methods

All three assessment methods in this evaluation were compared to determine which methods were appropriate to inform development of performance standards for compensatory mitigation projects. Based on my research, it is important that performance standards are measurable over time and feasible to achieve (U.S. Army Corps of Engineers 2015, Collins 2018, Van den Bosch and Matthews 2017). I evaluated WET, HGM, and CRAM techniques for each function and assessment, how applicable each was to the performance standard category, and the overall feasibility to measure and monitor the function over time (Table 4).

All three assessment methods included functions in the physical structure category (Table 4). WET functions, recreation and heritage and uniqueness, do not measure any specific processes related to riparian wetland function and therefore would not make good performance standards. HGM evaluates a riparian wetlands ability to maintain spatial structure and habitat and maintain interspersion and connectivity. Both these functions have variables that are measurable and can be assessed over time. If a reference site or standard is available, both these functions have the potential to be used to develop physical structure related performance standards. CRAM evaluates physical structure by looking at structural patch richness, topographic complexity of the wetland and the surrounding aquatic area abundance and buffer. The structural patch richness and topographic complexity functions can be used as performance standards, as specific indicators (number of patch types, channel benches, and microtopography) can be measured and will likely change and develop over time. The aquatic area abundance and buffer functions would not make good performance standards. These functions cannot necessarily be controlled by the restoration project and will likely not change overtime unless there is significant change to the surrounding landscape. Overall, HGM and CRAM both evaluate physical characteristic functions that should be considered when developing performance standards related to physical structure.

All three of the assessment methods include functions that are considered in the hydrology performance standard category (Table 4). WET assesses two functions, groundwater recharge and discharge and floodflow alteration. However, the groundwater recharge and discharge function processes evaluated are difficult to measure and monitor, whereas, several processes evaluated for the floodflow alteration function could be used as a performance standard as they are measurable and can be monitored over time. HGM assesses three functions, groundwater recharge and discharge, flood protection/energy dissipation, and surface water storage. Similar to WET, groundwater recharge and discharge should not be used for a performance standard because the variables are difficult to measure and monitor. Surface water storage is also not ideal for a performance standard because the necessary soil data may be difficult to obtain and expertise is likely needed to interpret it. Flood protection/energy dissipation could be used as a performance standard because the variables can be easily measured and monitored over time. CRAM also evaluates three functions, water source, channel stability, and hydrologic connection. Water source should not be used as a performance standard because this should be established as part of the restoration planning stage and should not significantly change over time. Channel stability and hydrologic connection can be used to develop performance standards because the metrics are simple and can be measured over time. All three assessment methods evaluate functions that have potential to be used to develop performance standards.

Two of the three assessment methods evaluate functions that could be used to develop the flora performance standard category (Table 4). WET does not include specific functions that correlate to the flora performance standard category. HGM assesses a riparian wetland's ability to maintain characteristic plant communities and maintain characteristic detrital biomass. Both these functions are feasible and measurable over time, and therefore, can be used as performance standards if a reference site or standard is available. CRAM evaluates a riparian wetland's overall plant community, horizontal interspersion, and vertical biotic structure. All of these metrics are measurable and will develop over time as they are directly related to the plant species present within the riparian wetland. As plants continue to establish and grow, all of the CRAM functions will likely change over time. The CRAM functions related to flora can also be used to develop performance standards.

Two of the three assessment methods evaluate functions that could be used to develop the fauna performance standard category (Table 4). CRAM does not include an assessment of functions related to the fauna performance standard category. WET evaluates functions related to aquatic diversity and abundance and wildlife diversity and abundance. Both of these functions are measurable, may change over time, and can be used to develop performance standards. HGM assesses a riparian wetland's ability to maintain distribution and abundance of invertebrates and maintain distribution and abundance of vertebrates. Similar to WET, both these functions are measurable and may change over time. Therefore, they can both also be used to develop performance standards.

Two of the three assessment methods evaluate functions that could be used to develop the water quality performance standard category (Table 4). CRAM does not evaluate functions directly related to the water quality performance standard category. WET and HGM each evaluate four water quality functions, all of which are similar to each other. WET looks at sediment stabilization and HGM assesses retention of particles. Both of these functions are measurable and will develop over time as plant communities establish. WET and HGM also look at nutrient removal/transformation and nutrient cycling, respectively. Both these functions can be used to develop performance standards as they are measurable and will develop over time as plant communities become established in the riparian wetland. Thus, WET and HGM functions can both be used to develop performance standards. Functions determined to be insufficient to develop performance standards are sediment/toxicant retention and product export (WET) and removal of imported elements and compounds and organic carbon export (HGM). These functions are difficult to evaluate and monitor, and therefore, are not feasible to use as performance standards. Overall, both WET and HGM evaluate functions related to water quality that can be used to develop performance standards.

8.4 Evaluation of Riparian Mitigation Bank Performance Standards

I reviewed habitat development plans for riparian mitigation banks in the Central Valley of California to evaluate the methods for developing performance standards for the mitigation banks. Three mitigation banks were assessed: Cosumnes Floodplain Mitigation Bank owned and operated by Westervelt Ecological Services, Bullock Bend Mitigation Bank owned and operated by Westervelt Ecological Services, and Sacramento River Ranch Mitigation Bank owned and operated by Wildlands, Inc. A summary of my analysis of performance standards for each of the three mitigation banks is provided below, and a comparison of the three banks is provided in Table 5.

8.4.1 Cosumnes Floodplain Mitigation Bank

The Cosumnes Floodplain Mitigation Bank restored floodplain mosaic wetlands and floodplain riparian habitat. I reviewed the performance standards for both the floodplain mosaic wetlands and floodplain riparian habitat, as they are both types of riparian wetlands. The target functions of the restored habitat were based on an evaluation of a reference site, as well as the development of a regional specific HGM assessment approach for the reference site and bank. *A Guidebook for Applying the Hydrogeomorphic Approach to Functional Assessment of the Riverine Floodplain of the Lower-Cosumnes / Lower-Mokelumne Rivers* (Cosumnes Bank HGM model) was developed specifically for monitoring the reference sites and mitigation bank (Westervelt Ecological Services 2008).

The functions included in the Cosumnes Bank HGM model were based on the overall HGM Riverine Guidebook and an evaluation of the habitats within the reference site. The functions evaluated by the model include: dynamic water storage, nutrient cycling, retention of particles, organic carbon export, and maintenance of characteristic plant community. The performance standards for the bank were developed using the functions evaluated by the Cosumnes Bank HGM model and the reference site as the standard. Overall survivorship of riparian plantings was also monitored annually. Each year, the habitats at the bank and the reference sites are assessed using the Cosumnes Bank HGM model. The performance standards are only considered to be attained if the Cosumnes Bank HGM model demonstrates the habitats are on a trajectory towards increasing functional capacity (Westervelt Ecological Services 2010). This means that functions evaluated at the bank must show improvement (better scores) each year until the functions shows similar capacity to the reference sites. Additionally, the riparian plantings are monitored each year for survivorship, with an ultimate planting survivorship goal of 60 percent at the end of the five-year monitoring period (Westervelt Ecological Services 2009).

8.4.2 Bullock Bend Mitigation Bank

The Bullock Bend Mitigation Bank consists of USACE jurisdictional floodplain riparian habitat (Westervelt Ecological Services 2016) and my analysis looked at the performance standards for the flood riparian habitat. HGM was used to identify functions characteristic of the two reference sites. The functions identified included hydrologic (surface water exchange, subsurface water exchange, and surface water conveyance), biogeochemical (removal, conversion, and release of elements and compounds and retention of particles), and biotic and habitat (maintenance of characteristic plant community, maintenance of characteristic faunal assemblages, and maintenance of habitat interspersion and connectivity among habitats) (Westervelt Ecological Services 2016). The performance standards were developed using the reference sites and were aligned with the USACE 2015 Mitigation and Monitoring Guidelines. Four out of the five performance standard categories were included in the performance standards. The physical structure performance standard requires less than 10 percent change in the notched berm elevation. The hydrology performance standard requires no more than 10 percent variation in extent and duration of inundation compared to the natural reference site. The three flora performance standards are tiered over the seven-year monitoring period. The following is required at the end of seven years: a minimum of 50 percent absolute percent cover, a minimum of 50 percent plant survivorship, and less than 10 percent absolute cover of nonnative invasive species. Water quality was the only performance standard category not included (Westervelt Ecological Services 2016). While the functions of the reference sites were associated with HGM, neither HGM nor any other assessment method was used to develop performance standards. However, the performance standard targets were developed based on characteristics found at the reference sites. Even though a specific assessment method was not used to develop the performance standards, the flora performance standards are similar to functions or metrics evaluated by HGM and CRAM.

8.4.3 River Ranch Wetland Mitigation Bank

The River Ranch Wetland Mitigation Bank consists of a freshwater marsh complex and USACE jurisdictional riparian habitat (Wildlands Inc. 2010). For my analysis, only the performance standards for the jurisdictional riparian habitat were reviewed. The performance standards for the bank were developed using a reference site located within the portion of River Ranch where the bank is located. The performance standards for the jurisdictional riparian habitat included hydrology (inundation to support wetland characteristics), plant survivorship, number of invasive species, canopy cover, and a wetland delineation to determine the total extent of jurisdictional wetland. The targets standards were tiered, and the standard of success increased every year over a five-year period (Wildlands Inc. 2010). Other Wildlands, Inc. riparian mitigation banks were also used as reference standards during performance standard monitoring: Aitken Ranch Mitigation Bank and Fremont Landing Conservation Bank. Both these banks have permanent monitoring plots that were being monitored along with the jurisdictional riparian areas within the River Ranch Wetland Mitigation Bank. The final performance standard targets at the end of year five included: canopy cover significantly higher (using a 95 percent confidence interval) than previously recorded in years one through four, relative percent cover not be significantly different (95 percent confidence interval) than the Fremont Landing Conservation Bank, the riparian areas will show evidence of natural recruitment of riparian species through the volunteerism of native woody vegetation, a USACE jurisdictional wetland delineation will show a minimum of 14.1 acres of riparian habitat, and percent invasive species will be less than 10 percent (Wildlands Inc. 2010).

8.4.4 Comparison of Mitigation Banks

I compared the performance standards for the three mitigation banks to determine which bank was the most successful at conforming with the USACE 2015 Mitigation and Monitoring Guidelines and developing performance standards related to riparian wetland functions (Table 5). All three of the mitigation banks used multiple reference sites to develop and monitoring performance standards. The Cosumnes Floodplain Mitigation Bank and the Bullock Bend Mitigation Bank both used HGM to evaluate the reference sites; however, Cosumnes Floodplain Mitigation Bank was the only bank that used HGM to also develop and monitor the performance standards. The Bullock Bend Mitigation Bank and the River Ranch Wetland Mitigation Bank both have flora performance standards that are similar to functions evaluated by HGM and metrics evaluated CRAM. The Bullock Bend Mitigation Bank was the only bank consistent with the USACE 2015 Mitigation and Monitoring Guidelines. The other two banks were developed before these guidelines were published. Overall, I rate the Bullock Bend Mitigation Bank as the most successful because HGM was used to evaluate the reference sites, some of the performance standards are related to HGM and CRAM, and it is consistent with the USACE 2015 Mitigation and Monitoring Guidelines.

9.0 Management Recommendations

The primary objective of this paper is to provide recommendations for restoration practitioners and regulators on developing performance standards that measure development of riparian wetland functions over time for mitigation projects. First, I provide general recommendations for all compensatory mitigation projects. Next, I provide recommendations for riparian mitigation banks based on my analysis of the three riparian mitigation banks in the Central Valley of California. Finally, I provide recommendations for permittee-responsible riparian restoration projects in the Central Valley of California. These recommendations are aligned with the five performance standard categories defined in the USACE 2015 Mitigation and Monitoring Guidelines and were developed based on my analysis of the three assessment methods (WET, HGM, and CRAM). The ultimate goal of this analysis was to provide recommendations to develop measurable and feasible performance standards that will result in improvements to riparian restoration projects and restoring lost ecosystem services provided by these ecosystems.

9.1 General Performance Standard Recommendations

As depicted in Figure 4, the five performance standard categories identified by the USACE 2015 Mitigation and Monitoring Guidelines correlate to important riparian wetland ecosystem services. Therefore, I recommend that all riparian wetland restoration projects include performance standards for all five categories to ensure restoration of important riparian wetland ecosystem services. To develop performance standards, it is critical that the objectives of a restoration project are clearly stated. If the objective is to restore functions lost by an impacted riparian wetland, then the restoration project should include performance standards similar to the conditions of impacted site. Additionally, prior to beginning any restoration project, it is crucial to establish a reference standard or site (or multiple sites) to use in the restoration planning and monitoring (Van den Bosch and Matthews 2017 and Collins 2018). Using data from reference sites ensure the performance standards are realistic and achievable for the location and ecosystem restored. Reference sites provide necessary baseline information about the hydrology, vegetation, soils, and wildlife that are characteristic of a riparian wetland in that location. It may also be appropriate to assess the reference site or sites using one of the three assessment methods to quantify specific riparian wetland functions. The data obtained from assessing the reference sites can then be used to develop the thresholds or targets for performance standards based on an assessment method.

Monitoring of reference sites as part of performance standard monitoring is also recommended by the USACE 2015 Mitigation and Monitoring Guidelines (U.S. Army Corps of Engineers 2015) and HGM (Brinson et al. 1995) and has been acknowledge by studies that evaluate success of compensatory mitigation projects (Van den Bosch and Matthews 2017). It may also be applicable to evaluate the impact site to understand the goals of the compensatory mitigation project to achieve no net loss of function of the aquatic resources. Riparian wetlands can also vary depending on the local conditions, river or stream dynamics, and plant species present. Therefore, not all performance standards will be applicable or appropriate for all restoration projects. It is recommended to evaluate a reference site with the desired performance standards and thresholds or targets to determine if (1) the standards are applicable to that area, (2) the standards are achievable based on natural conditions, and (3) monitoring of the standards is feasible. Many riparian wetland functions take time to develop within a restored area. Therefore, interim performance standards should be used to ensure the trajectory of the restoration project will meet the final performance standard by the end of the monitoring period (Matthews and Endress 2008). Because riparian vegetation may take longer to develop than annual grasses, it is recommended to have a minimum 10-year monitoring period to ensure the restoration project is successful (Van den Bosch and Matthews 2017).

9.2 Recommendations for Riparian Mitigation Banks

The three riparian mitigation banks analyzed varied in the methods used to develop performance standards, however, all three riparian mitigation banks used references sites. I recommend continuing to use multiple reference sites to develop the restoration design and performance standards for riparian mitigation banks (Van den Bosch and Matthews 2017 and Collins 2018). The Cosumnes Floodplain Mitigation Bank used multiple reference sites, including previously restored sites that were at different successional levels. If previous success restored sites (e.g., successful mitigation banks or local restoration projects) or riparian wetlands in different successional stages are available, I recommended to also use those sites as references sites because they provide direct data on different phases within the overall restoration trajectory (Van den Bosch and Matthews 2017). The River Ranch Wetland Mitigation Bank also monitored previous successful riparian mitigation banks as part of the performance standard monitoring. This is also recommended, as established and successful mitigation banks can be a good model to use when developing and monitoring a new bank.

The Cosumnes Floodplain Mitigation Bank and River Ranch Wetland Mitigation Bank were developed and approved prior to the issuance of the USAE 2015 Mitigation and Monitoring Guidelines, and therefore, do not include performance standards for each of the five performance standard categories. I recommend including performance standards for all five performance standard categories. The Bullock Bend Mitigation Bank was developed and approved in 2016, and therefore, is compliant with the USACE 2015 Mitigation and Monitoring Guidelines. The Bullock Bend Mitigation Bank describes monitoring of water quality functions. However, there is not a performance standard required for the water quality functions monitored. While the water quality performance standard is considered optional by the USACE 2015 Mitigation and Monitoring Guidelines, water quality functions are critical to riparian wetland functions that provide ecosystem services (Figure 4).

The Cosumnes Floodplain Mitigation Bank was the only bank that used an assessment method (HGM) to evaluate the reference sites and mitigation bank site. An HGM model was developed specifically for the mitigation bank area. The performance standards for the bank were directly correlated to the HGM model and the assessment of the reference sites with the HGM model. While the HGM model is useful for characterizing the reference sites and developing the restoration plan, I do not recommend directly using an HGM model for evaluating performance standards, as it may be difficult for agencies to track if the mitigation bank performance standards without in depth knowledge of HGM. Instead, I recommend using the variables for evaluating HGM functions (Table 2) to develop performance standards for each of the five performance standard categories. This will provide more palatable performance standards for the agencies that may not know HGM.

The Bullock Bend Mitigation Bank and River Ranch Wetland Mitigation Bank both do not use an assessment method to evaluate reference sites or develop performance standards. However, the Bullock Bend Mitigation Bank does describe the reference sites using HGM functions. Furthermore, some of the performance standards developed by the Bullock Bend Mitigation Bank and River Ranch Wetland Mitigation Bank can be correlated to the CRAM plant community metric and vegetation related variables (e.g. percent cover) used by HGM. These performance standards could be strengthened if the reference sites were evaluated using CRAM or HGM to provide a baseline to develop the thresholds for the performance standards. The performance standards for the physical structure, hydrology, and fauna categories are not easily correlated functions evaluated by WET or HGM or metrics evaluated by CRAM. I recommend using one of the three assessment methods to evaluate the reference site(s) and develop performance standards for each of these categories.

9.3 Recommendations for Permittee-Responsible Riparian Restoration Projects

The following section provides recommendations for developing performance standards compliant with the USACE 2015 Mitigation and Monitoring Guidelines for permittee-responsible riparian restoration projects in the Central Valley of California. These performance standard recommendations are based on functions used in each of the assessment methods identified as potential performance standards in Table 4. A summary of the recommended performance standards is provided in Table 6.

Physical structure of a riparian wetland is important for supporting important ecosystem services such as flood protection and wildlife corridors. Both HGM and CRAM evaluate physical structure functions and these functions can be used to develop performance standards. While some physical structure elements of a riparian wetland need to be considered as part of the initial restoration design (e.g., buffer and landscape, connection to stream channel), some elements develop over time. Physical structure elements identified by HGM and CRAM include structural patch richness, topographic complexity, tree density, abundance of mature tree, and channel development. I recommend using the CRAM structural patch richness metric to develop physical structure performance standards (Table 5). Ideally, the impact site and the reference site(s) should be assessed using CRAM to determine the physical structure objectives for the restoration site. Conducting a baseline assessment will provide a good understanding of what the restored site should aim to achieve. Interim performance standards should then be developed for each of the structure elements with the goal of showing that the restored site is on the right trajectory to achieve the final performance standards.

Hydrology is one of the key driving forces of riparian wetlands and is critical to the success of a riparian restoration project. Performance standards should always include a measurement of hydrology; however, a direct measure of hydrology may be difficult without using equipment or aerial photography. WET, HGM, and CRAM all evaluate functions related to hydrology that can be converted into measurable performance standards. All these methods use indirect measures of hydrology to assess important hydrology functions of riparian wetlands such as flood protection, channel stability, and hydrologic connection. Using indirect ways to measure hydrology can be a good alternative to more expensive direct measures that also provide more information about the restoration site. I recommend using the HGM flood protection and energy dissipation function to develop a hydrology performance standard (Table 5). This function uses factors that contribute to site roughness (e.g., plant community structure) and how they develop over time as a way to indirectly measure the riparian wetlands ability to accommodate and slow down flood waters. Using indirect measurements or indicators of hydrology functions can be helpful to develop measurable hydrology performance standards.

Performance standards related to flora, including percent cover, species richness, survivorship, and abundance of native or hydrophytic species, are common used in evaluating performance of compensatory mitigation projects (Matthews and Endress 2008). This is largely because these metrics are easy to measure and monitor. However, most of the flora related thresholds or targets are not always attainable or even representative of the wetland being restored. HGM and CRAM both provide assessments of flora related functions that can be used as performance standards. Similar to common flora performance standards, the variables or metrics evaluated by HGM and CRAM include the plant community structure, species composition, tree density, and canopy cover. I recommend using the CRAM plant community metric to develop a flora performance standard (Table 5). The key to developing achievable and applicable flora performance standards is using a reference site to develop the standard and monitor the standard over time. A reference site should be assessed using CRAM to determine the flora performance standard targets for the restoration site. This will assure that the performance standards are applicable to the restoration site and achievable. For example, it is not reasonable to establish a standard that no non-native species will be present in the restoration site, unless a reference site demonstrates this. An assessment of the percent cover or nonnative and invasive species at a reference site will provide valuable insight into the appropriate composition of native to non-native for the area. It is also important to consider that riparian vegetation takes time to develop, and interim standards should be put in place to evaluate the restoration sites trajectory to achieving the final performance standards. Vegetation is also highly subjective to climatic conditions such as precipitation and temperature, resulting soil moisture, shade, and nutrients. Therefore, it is important to monitor a reference site concurrently with the restoration site to account for fluctuations in vegetation communities due to annual variation in precipitation and/or temperature.

Unless the objective of the compensatory mitigation project is to restore habitat for a specific species, fauna performance standards are generally not considered. Even if the goal is not to provide habitat for a specific species, riparian wetlands provide habitat for many wildlife species, making fauna performance standards applicable to all riparian restoration projects. Direct measurements of species usage or presence may be difficult and not feasible to achieve as a performance standard. A combination of direct and indirect measurements of species usage or species habitat will likely be more appropriate to use as performance standards. WET and HGM both assess functions related to fauna. WET uses more indirect ways to evaluate a wetland's ability to support various wildlife species, while HGM uses more direct measurements of species abundance. I recommend using the WET wildlife abundance and diversity function to develop a fauna performance standard because WET evaluates this function by looking at elements of the riparian wetland that can provide habitat for a variety of wildlife species (Table 5). Similar to the flora performance standards, using a reference site to assist in developing the performance standards is critical to establishing measurable and achievable fauna performance standards. Reference sites will provide good insight into the usage of the habitat by certain species, which can inform realistic performance standard targets. It would not be feasible to require a restoration site to show usage by a particular species if that species is not even documented to use other habitat with the surrounding area. Additionally, monitoring reference site concurrently with the restoration site is important to consider climatic variations or presence of predators that could affect the presence of certain species in the area.

Performance standards related to water quality are not often considered in compensatory wetland mitigation projects. Riparian wetlands provide several functions related to water quality, and an evaluation of water quality functions should be incorporated into performance standards. Direct measurements of water quality functions are often time consuming and expensive, however, WET and HGM both provide indirect measurements of water quality functions. I recommend using sediment stabilization (WET)/retention of particles (HGM) functions to develop a water quality performance standard. Both the assessment methods use indirect processes or variables related to site roughness and plant communities to assess this function, which are recommended to use in developing performance standards for hydrology and flora. Therefore, indirect assessments of water quality functions could be associated with standards for those categories as well. Visual assessments of erosion and or sedimentation can also be used to evaluate sediment stabilization, as described by WET. Standards for the visual assessment should be based off the reference site(s) to account for annual variation in flow and flood waters that can influence this function.

Table 1. Evaluation of WET Assessment Method
(Sources: Adamus et al. 1987 and Adamus et al. 1999)

Performance Standard Category	**Function**	**Process**	**Equipment Heavy?**	**Expertise Needed?**	**Level of Effort (high, medium, low)**	**Likely to change or develop over time?**
Hydrology	Groundwater recharge and discharge	groundwater flow rates and storage capacity; direction and location of groundwater movement; evapotranspiration	No; unless using groundwater wells or piezometers, which are optional	Yes – Ability to interpret climatic, topography, and soils data	Medium – requires interpretation of climate, topography, and soil data that may require additional effort	No – the processes are not likely to change significantly over time.
Hydrology	Floodflow alteration	magnitude and duration of storms; run-off from upslope areas; above-ground storage capacity; morphology of the wetland; frictional resistance (width, density, rigidity of obstructions, vegetation); below-ground storage capacity; position of wetland in the watershed	No	Yes – Ability to interpret soil data	Low – minimal effort outside data collected during site visit	Potentially – the morphology of the wetland and frictional resistance processes may change over time
Water Quality	Sediment stabilization	energy associated with erosive forces; frictional resistance offered by the wetland; position of the wetland relative to the upland and incoming erosive forces; ability of wetland plants to anchor the soil; erodibility of uplands being protected	No	No	Low – all data can be collected during site visit	Yes – establishment of wetland plants and other topographic structures will develop over time
Water Quality	Sediment/toxicant retention	amount of incoming sediment; particle size and density of suspended sediment; difference in energy levels of suspending forces within the wetland versus upcurrent areas; vertical layering caused by salinity and temp. in waters bearing the sediment; flocculation, agglomeration, and precipitation; bioturbation and mobilization; storage capacity of the wetland	Yes – equipment needed to measure suspended solids and/or toxins	Yes – Ability to interpret water quality data	High – collection and interpretation of water quality data may require additional effort	Yes – while likely to change over time, many of the processes are influenced factors not controlled by the wetland
Water Quality	Nutrient removal/transformation	biological uptake and processing; sedimentation and accumulation of organic matter in the substrate; adsorption and nutrient interactions with sediments; chemical and microbial processes including denitrification, nitrogen fixation, and ammonia volatilization	No	No	Low – all data can be collected during site visit	Yes – like to change as plants and other wetland components establish
Water Quality	Product export	productivity of potential food sources; nitrogen-fixing ability of potential food sources; dispersal and cycling of potential food sources	No	Yes – interpretation of eutrophic condition required	Medium – interpretation of eutrophic condition may require additional effort	Yes – like to change as plants and other wetland components establish
Fauna	Aquatic diversity and abundance	water quality (physical and chemical); water quantity (hydroperiod, flow, and depth); cover, substrate, and interspersion; availability of food sources	No	No	Medium – requires information to be obtained about watershed and hydroperiod which may require additional effort	Yes – like to change as plants and other wetland components establish
Fauna	Wildlife diversity and abundance	area size; availability of cover; availability of food; availability of specialized habitat needs; spatial and temporal arrangement of the above factors; isolation from disturbance; absence of contaminants	No	No	Low – minimal effort outside data collected during site visit	Yes – like to change as plants and other wetland components establish
Physical Structure	Recreation	None identified	N/A	N/A	N/A	N/A
Physical Structure	Uniqueness and heritage	None identified	N/A	N/A	N/A	N/A

Table 2. Evaluation of HGM Assessment Method
(Source: Brinson et al. 1995)

Performance Standard Category	Function	Variable	Equipment Heavy?	Expertise Needed?	Level of Effort (high, medium, low)	Likely to change or develop over time?
Hydrology	Surface water storage (dynamic and long term)	morphology, evaporation, infiltration and subsurface storage, basin relative morphology, channel roughness	No	Yes – ability to interpret soil data	Medium – requires comparison to reference site; requires interpretation of soil data	Not likely – majority of the variables will be established during initial restoration and will likely not change much.
Hydrology	Flood protection/energy dissipation	reduction in flow velocity, frequency of overbank flow, site roughness	No	No	Medium – requires comparison to reference site	Potentially – establishment of plants will contribute to site roughness over time
Hydrology	Groundwater recharge and discharge	subsurface flow into the wetland, subsurface flow from wetland into aquifer or to base flow	No	Yes – ability to interpret soil data	High – requires direct measure of soil pore space availability	No – will not change much over time or is dependent on outside factors not related to the wetland
Water Quality	Nutrient cycling	aerial net primary productivity, annual turnover of detritus	No	No	Medium – requires comparison to reference site	Yes – will develop as plants establish
Water Quality	Retention of particles	frequency of overbank flow, surface inflow, subsurface inflow, roughness factors, retained sediments	No	No	Medium – requires comparison to reference site	Yes – will change as plants establish
Water Quality	Removal of important elements and compounds	Frequency of overbank flow, subsurface inflow, microtopographic complexity, surfaces for microbial activity, sportive properties of soils, tree basal area	No	Yes – ability to interpret soil data	Medium – requires comparison to reference site; requires interpretation of soil data	Yes – will change as plants and other wetland components establish
Water Quality	Organic carbon export	frequency of overbank flow, surface inflow, subsurface inflow, surface hydraulic connections with channel, organic matter in wetland	No	No	Medium – requires comparison to reference site	Yes – will change as plants establish
Flora	Maintain characteristics plant communities	Species composition for tree, sapling, shrub and ground cover strata; regeneration from seedlings, saplings and/or clonal shoots; canopy cover; tree density; tree basal area	No	No	Medium – requires comparison to reference site	Yes – will change/develop as plants establish
Flora	Maintain characteristic detrital biomass	density of standing dead trees (snags), coarse wood debris; logs in several stages of decomposition; fine woody debris	No	No	Medium – requires comparison to reference site	Yes – will changes/develop as plants establish
Physical Structure	Maintain spatial structure of habitat	density of standing dead trees (snags), abundance of very mature trees, vegetation patchiness, canopy gaps	No	No	Medium – requires comparison to reference site	Yes – will change/develop as plants establish
Physical Structure	Maintain interspersion and connectivity	frequency of overbank flow, duration of overbank flow, microtopographic complexity; surface hydraulic connections; contiguous vegetation cover and/or corridors between wetland upland, channels, and upstream and downstream area	No	No	Medium – requires comparison to reference site	Yes – will change/develop as plants establish
Fauna	Maintain distribution and abundance of invertebrates	distribution and abundance of invertebrates in soil; distribution and abundance of invertebrates in leaf litter and coarse woody debris; distribution and abundance of invertebrates in aquatic habitats	No	No	Medium – requires comparison to reference site	Yes – will change/develop as plants and other wetland components establish
Fauna	Maintain distribution and abundance of vertebrates	distribution and abundance of resident and migratory fish; distribution and abundance of herptiles; distribution and abundance of permanent and seasonally resident mammals; abundance of beaver	No	Yes – may require biologists with specific experience with certain species	Medium – requires comparison to reference site	Yes – will change/develop as plants and other wetland components establish

Table 3. Evaluation of CRAM Assessment Method
(Source: California Wetland Monitoring Workgroup 2013a)

Performance Standard Category	CRAM Attribute	Function (Metric)	Metric	Equipment Heavy?	Expertise Needed?	Level of Effort (high, medium, low)	Likely to change or develop over time?
Hydrology	Hydrology	Water source	Natural, unnatural, and indirect sources	No	Trained CRAM practioner	Medium – some preparation work required	No – will be established during initial restoration
Hydrology	Hydrology	Channel stability	Equilibrium; degree of channel aggradation and degradation	No	Trained CRAM practitioner	Low	Potentially – may change/develop with change in flows over time
Hydrology	Hydrology	Hydrologic connection	Ability of water to flow in and out of wetland; ability to accommodate rising flood waters	No	Trained CRAM practitioner	Low	Potentially – may change depending on structure and establishment of plants
Physical structure	Physical structure	Structural patch richness	Number of different patch types	No	Trained CRAM practitioner	Low	Yes – will change/develop as plants and other wetland components establish
Physical structure	Physical structure	Topographic complexity	Micro-and macro topographic relief and variety of elevations	No	Trained CRAM practitioner	Low	Yes – will change/develop as plants and other wetland components establish
Flora	Biotic structure	Plant community	Plant community metric; horizontal interspersion; vertical biotic structure	No	Trained CRAM practitioner; ability to identify plant species	Low	Yes – will change/develop as plants establish
Flora	Biotic structure	Horizontal interspersion	Interspersion of plant zones	No	Trained CRAM practitioner; ability to identify plant species	Low	Yes – will change/develop as plants establish
Flora	Biotic structure	Vertical biotic structure	Degree of overlap among plant layers	No	Trained CRAM practitioner; ability to identify plant species	Low	Yes – will change/develop as plants establish
Physical Structure	Buffer and landscape	Stream corridor continuity	Continuity of stream corridor upstream and downstream; non-buffer land	No	Trained CRAM practitioner	Medium – some preparation work required	No – will likely not change unless surrounding landscape is altered
Physical Structure	Buffer and landscape	Buffer	Percent of AA with buffer; average buffer width; buffer condition	No	Trained CRAM practitioner	Medium – some preparation work required	No – will likely not change unless surrounding landscape is altered

Table 4. Comparison of USACE 2015 Mitigation and Monitoring Guidelines Performance Standard Criteria and Functions Evaluated by WET, HGM, and CRAM

Performance Standard Category	WET		HGM		CRAM	
	Function Evaluated	Potential Performance Standard?	Function Evaluated	Potential Performance Standard?	Function (Metric) Evaluated	Potential Performance Standard?
Physical Structure	Recreation	No – no criteria provided	Maintain spatial structure of habitat	Yes – if reference site available	Structural patch richness	Yes
Physical Structure	Uniqueness/heritage	No – no criteria provided	Maintain interspersion and connectivity	Yes – if reference site available	Topographic complexity	Yes
Physical Structure	-	-	-	-	Aquatic area abundance	No – will likely not change over time unless surrounding landscape is altered
Physical Structure	-	-	-	-	Buffer	No – will likely not change over time unless surrounding landscape is altered; buffer should be considered in initial restoration design
Hydrology	Groundwater recharge and discharge	No – difficult to evaluate and monitor; likely won't change over time	Groundwater recharge and discharge	No – difficult to evaluate and monitor; likely won't change over time	Water source	No - water source should already be identified or established prior to restoration
Hydrology	Floodflow alteration	Yes	Flood protection/energy dissipation	Yes – if reference site available	Channel stability	Yes
Hydrology	-	-	Surface water storage	No – may be difficult to get necessary soil data; likely won't change over time	Hydrologic connection	Yes
Flora	-	-	Maintain characteristics plant communities	Yes – if reference site available	Plant community	Yes
Flora	-	-	Maintain characteristic detrital biomass	Yes – if reference site available	Horizontal interspersion	Yes
	-	-	-	-	Vertical biotic structure	Yes
Fauna	Aquatic diversity and abundance	Yes	Maintain distribution and abundance of invertebrates	Yes – if reference site available	-	-
Fauna	Wildlife diversity and abundance	Yes	Maintain distribution and abundance of vertebrates	Yes – if reference site available	-	-
Water Quality	Sediment stabilization	Yes	Retention of particles	Yes – if reference site available	-	-
Water Quality	Sediment/toxicant retention	No – high effort to evaluate and monitor	Removal of imported elements and compounds	No – may be difficult to get necessary soil data	-	-
Water Quality	Nutrient removal/transformation	Yes	Nutrient cycling	Yes – if reference site available	-	-
Water Quality	Product export	No – may be difficult to evaluate and monitor	Organic carbon export	No – may be difficult to evaluate and monitor	-	-

Table 5. Comparison of Three Riparian Mitigation Banks in the Central Valley of Caifornia (Sources: Westervelt Ecological Services 2009, Westervelt Ecological Services 2016, and Bullock Ben 2010).

Mitigation Bank	Reference Site(s) Used?	Assessment Method Used?	Consistent with USACE 2015 Mitigation and Monitoring Guidelines?
Cosumnes Floodplain Mitigation Bank	Yes – multiple reference sites	Yes -HGM model developed and used to develop and monitoring performance standards	No – bank was developed before guidelines were published.
Bullock Bend Mitigation Bank	Yes – multiple reference sites, including previously restored site	Yes – HGM model used but only to evaluate reference sites. No assessment method was used for performance standards. Flora performance standards are similar to HGM and CRAM.	Yes – developed after guidelines were published. Does not include the optional water quality performance standard.
River Ranch Wetland Mitigation Bank	Yes – multiple reference sites, including successful riparian mitigation banks	No – assessment method was not used for performance standards. Flora standards are similar to HGM and CRAM.	No – bank was developed before guidelines were published.

Table 6. Recommended performance standards for permittee responsible riparian restoration projects in Central Valley of California (Sources: Mecke 2018 developed from Adamus et al. 1987, Adamus et al. 1999, Brinson et al. 1995, California Wetland Monitoring Workgroup 2013b, and Collins 2018)

Performance Standard Category	Assessment Method	Function	Example Performance Standard
Physical structure	CRAM	Structural patch richness	The restoration area should have a similar number of patch types as the reference site(s). Patch types should be based on those found in the reference site(s) and/or impact site.
Hydrology	HGM	Flood protection and energy dissipation	The restoration area should demonstrate site roughness characteristics (shrub and sapling density, biomass, and cover; tree density; tree basal area; coarse woody debris) that will retain flood waters in the area. Characteristic site roughness should be based on the reference site(s). Additionally, evidence of flooding (e.g., wrack or organic debris, saturated soils) in the area should be observed after high flow events in the adjacent channel.
Flora	CRAM	Plant community	The restoration area should have a plant community similar to the reference site(s) and/or impact site. Characteristics to measures include: total number of plant layers, number of co-dominant species, and percent invasive species. Thresholds should be based off the reference site(s).
Fauna	WET	Wildlife abundance and diversity	The restoration area should have abundant habitat for a range of wildlife species. Habitat features should be based off the reference site(s) and/or impact site.
Water quality	WET/HGM	Sediment stabilization/retention of particles	The restoration area should demonstrate the ability to retain sediment. Minimal erosion should be visible and/or comparable the reference site condition. Plants and other site roughness factors (as monitored by the hydrology and flora performance standards) should be present and demonstrate ability to anchor sediment and retain particles.

Figure 1. Geographic extent of the Central Valley of California and locations of three riparian mitigation banks.
(Source: Developed by Hinkleman and Mecke 2018)

Figure 2. Major rivers in the Central Valley of California

(Source: Frayer et al. 1989)

Creek in City of Lincoln, Placer County, California
Photo credit: Daniel Wong

American River, Sacramento County, California
Photo credit: Griffin Cassara

San Joaquin River, Madera County, California
Photo credit: Emily Mecke

Figure 3. Representative photographs of riparian wetlands in the Central Valley of California

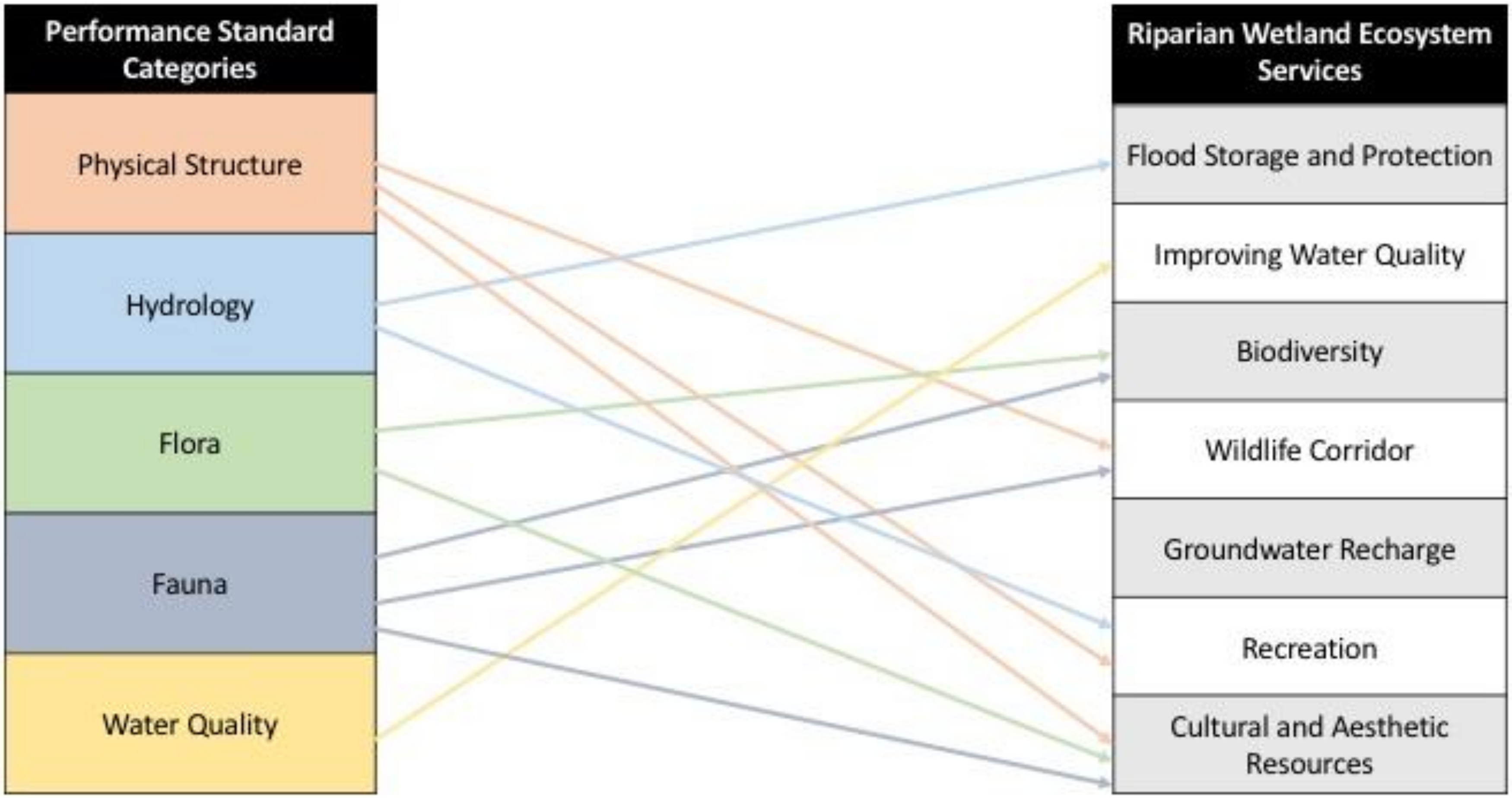

Figure 4. Comparison of USACE 2015 Mitigation and Monitoring Guidelines performance standard categories to riparian wetland ecosystem services
(Sources: Mecke 2018 developed from Barbour et al. 2007, Duffy and Kahara 2011, U.S. Army Corps of Engineers 2015)

Literature Cited

Adamus, P. R., I. Ara, E. J. Clairain JR., R. D. Smith, and R. E. Young. 1987. Wetland Evaluation Technique (WET) volume 2: methodology. Report Number 2. U.S. Army Corps of Engineers. Washington, D.C.

Adamus, P. R., L. T. Stockwell, J. Clairain, M. E. Morrow, L. P. Rozas, and D. Smith. 1991. Wetland Evaluation Technique (WET): volume 1, literature review and evaluation rationale. Report Number 1. U.S. Army Corps of Engineers. Washington, D.C.

Alpert, P., F. T. Griggs, and D. R. Peterson. 1999. Riparian forest restoration along large rivers: initial results from the Sacramento River project. Restoration Ecology **7**:360-368.

Ambrose, R. F., J. C. Callaway, and S. F. Lee. 2006. An evaluation of compensatory mitigation projects permitted under clean water act section 401 by the California state water quality control board, 1991-2002. State of California, California Environmental Protection Agency, California State Water Resources Control Board. Los Angeles, California.

Barbour, M., T. Keeler-Wolf, A. A. Schoenherr, and T. Keeler-Wolf. 2007. Terrestrial Vegetation of California, 3rd edition. University of California Press, Berkeley.

Brauman, K. A., G. C. Daily, T. K. Duarte, and H. A. Mooney. 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment & Resources **32**:67-98.

Brinson, M. M., R. D. Rheinhardt, F. R. Hauer, L. C. Lee, W. L. Nutter, R. D. Smith, and D. Whigham. 1995. A guidebook for application of hydrogeomorphic assessments of riverine wetlands. Technical Report WRP-DE-11.

California Wetlands Monitoring Workgroup. 2013a. California Rapid Assessment Method for wetlands; riverine wetlands fieldbook. **Version 6.1**:46.

California Wetlands Monitoring Workgroup. 2013b. California Rapid Assessment Method (CRAM) for wetlands. **Version 6.1**:67.

Collins, T. 2018. Phone interview.

Cowardin, L. M. . Carter, F. C. Golet, E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the united states. Fish and Wildlife Service, Washington, DC.

Duffy, W. G., and S. N. Kahara. 2011. Wetland ecosystem services in California’s Central Valley and implications for the Wetland Reserve Program. Ecological Applications **S18**:S30.

Frayer, W. E., D. D. Peters, and H. R. Pywell. 1989. Wetlands of the California's Central Valley, status and trends, mid 1939 to mid 1980s. U.S. Fish and Wildlife Service. Portland, Oregon.

Gregory, V. S., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience **41**:540-551.

Griggs, T. 2009. California riparian habitat restoration handbook. Second Edition. River Partners.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 *In* Dogde, D. P., editor. Proceedings of the international large rivers symposium, Can. Spec. Publication of Fisheries and Aquatic Science. 106.

Larsen, S., and M. Alp. 2015. Ecological thresholds and riparian wetlands: an overview for environmental managers. Limnology **16**:1-9.

Matthews, J., and A. Endress. 2008. Performance criteria, compliance success, and vegetation development in compensatory mitigation wetlands. Environmental Management **41**:130-141.

McDonald, T., G. D. Gann, J. Jonson, and K. W. Dixon. 2016. International standards for the practice of ecological restoration - including principles and key concepts.

Mitsch, W. J., and J. G. Gosselink. 2015. Wetlands. Wiley, New York, NY.

Naiman, R. K., H. Decamps, and M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications **3**:209-212.

Naiman, Robert J.; Décamps, H.; McClain, Michael E. 2005. Riparia: ecology, conservation, and management of streamside communities. Elsvier Academic Press, Burlington, MA.

Nilsson, C., and M. Svedmark. 2002. Basic principles and ecological consequences of changing water regimes: riparian plant communities. Environmental Management **30**:468-480.

Robertson, M. M. 2000. No net loss: wetland restoration and the incomplete capitalization of nature. Antipode **32**:463-493.

San Francisco Estuary Institute. 2018. Steering committee. Available at: https://www.cramwetlands.org/steeringcommittee. Accessed: April 30, 2018.

Seavy, N. E., T. Gardali, G. H. Golet, F. T. Griggs, C. A. Howell, R. Kelsey, S. L. Small, J. H. Viers, and J. F. Weigand. 2009. Why climate change makes riparian restoration more important than ever: recommendations for practice and research. Ecological Restoration **27**:330-338.

Stein, E. D., A. E. Fetscher, R. P. Clark, A. Wiskind, J. L. Grenier, M. Sutula, J. N. Collins, and C. Grosso. 2009. Validation of a wetland rapid assessment method: use of EPA's level 1-2-3 framework for method testing and refinement. Wetlands **29**:648-665.

Sudol, M. F., and R. F. Ambrose. 2002. The U.S. clean water act and habitat replacement: evaluation of mitigation sites in Orange County, California, USA. Environmental Management **30**:727.

U.S. Army Corps of Engineers. 2015. Final 2015 regional compensatory mitigation and monitoring guidelines for south pacific division USACE. U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. 2008. Compensatory mitigation for losses of aquatic resources; final rule. Federal Register **73**:19594-19703.

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2008. Clean Water Act jurisdiction following the U.S. Supreme Court's decision on Rapanos v. United States and Carabell v. United States. December 2, 2008.

Van den Bosch, K., and J. Matthews. 2017. An assessment of long-term compliance with performance standards in compensatory mitigation wetlands. Environmental management **59**:546-556.

Westervelt Ecological Services. 2016. Bullock Bend Mitigation Bank habitat development plan. Westervelt Ecological Services. Sacramento, California.

Westervelt Ecological Services. 2009. Cosumnes Floodplain Mitigation Bank habitat development plan. Westervelt Ecological Services. Sacramento, California.

Westervelt Ecological Services. 2008. A guidebook for applying the hydrogeomorphic approach to functional assessment of the riverine floodplain of the Lower-Cosumnes / Lower-Mokelumne rivers.

Wildlands Inc. 2010. Sacramento River Ranch Wetland Mitigation Bank development plan. Wildlands, Inc. Rocklin, California.

Zedler, J. B., and J. C. Callaway. 1999. Tracking wetland restoration: do mitigation sites follow desired trajectories? Restoration Ecology **7**:69-73.