STRATEGY FOR CHANGE

Landscape Architecture for Disaster Reduction and Response

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Landscape Architecture for Disaster Reduction and Response

A Senior Project Presented to the
Faculty of the Landscape Architecture Program,
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In Fulfillment of the Requirements for the Degree of Bachelors of Science in Landscape Architecture

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Abstract

The purpose of this project is to determine the integrity and management of the Central Valley flood control waterways to assist in developing design concepts for future planning. The California Central Valley is the backbone of the state's water supply and flood control system. This irreplaceable system is outdated and becoming increasingly fragile due to a constantly fluctuating system. The existing flood control and levee system was built for a different era and is no longer capable of withstanding to the pressures of the 21st century. Climate changes have increased temperatures, altered our precipitation patterns, changed the timings of peak river flows, and have caused sea levels to rise. The Sacramento-San Joaquin Delta is an important source for this system and is dependent on having stable flood control and strong levees. The Delta provides two thirds of California with drinking water, millions of gallons of water for irrigation of agriculture, a utility corridor, home to more than half a million people and is habitat for countless animal and plant species (National Geographic, 2009). In reviewing the current management standards and practices it is apparent the Central Valley flood control system needs to be reimagined. The Yolo Bypass is a critical piece of this system and the implementation of a multifunction design strategy could be the right step foward. This project will focus on a design to expand the Yolo Bypass as an integrated system for establishing flood control, habitat stability, agriculture, and public recreation.

Figure 1.
- The Yolo Bypass during a flood, displaying its role in managing flood waters (Source: Friedpez 2010).

Acknowledgements

I would like to thank my committee members

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- Determine the environmental and social impacts that could be created by a flood catastrophe in the Central valley.
- Determine the current management practices used to manage flood control waterways in California.
-Develop multifunctional landscape design solutions for the proposes Yolo Bypass expansion.

Introduction

Climate changes have begun to decrease snow packs in the Sierra Nevada Mountains, cause more intense rainfall events and have increased the frequencies, intensities, and durations of heat waves (Figure 2)(NASA, 2012). Climate change has increasingly become an evident part of life and has serious implications for the California Central Valley flood control and water conveyance system (Sciencedaily, 2008). The aging infrastructure of the Central Valley could not withstand a severe flooding event due to poor construction, inadequate foundations, and improper landscape maintenance and management (Department of Water Resources, 2007).

In light of Hurricane Katrina and the tremendous devastation that occurred, the United States has begun to review the disaster management practices currently in place. In 2009, the United States Army Corps of Engineers issued a mandate that calls for the removal of all woody vegetation from any levee in the state-federal flood protection system of California's Central Valley (The Department of Water Resources, 2012). The reasoning behind this ruling is enforced by no factual information that shows vegetation occurring along levee systems contributes to levee failures. The Army Corp's current policies have been ineffective in attempts at flood control for the Central Valley flood control system because they do not take into account landscape management approaches that enhance and maintain the benefits of natural riparian ecosystems. The California Flood Control System has the potential for a system of integrated flood control, riparian habitat, crop-specific agriculture, and recreational opportunities.

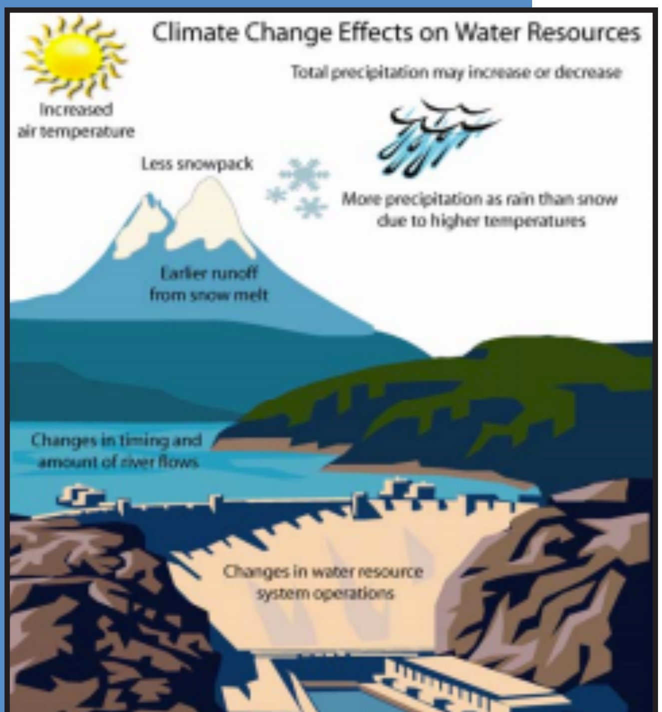


Figure 2. -California's water resources. (Source: ACWA, 2011)

A Changing Climate

Climate change in California has multiple implications for the future of this state. The state must establish and understand how the Central Valley will be affected by the decreasing snow pack in the Sierra's (our largest reservoir for water), record heat waves and warmer temperatures allowing storms to hold more precipitation for longer periods of time (Figure 3)(NASA 2012). In the Central Valley it should be fully understood that occasional floods will occur and they will need to spread.

According to the Federal Emergency Management Agency (FEMA) floods are one of the most common hazards to occur in the Unites States (FEMA, 2012). The National Oceanic and Atmospheric Administration (NOAA)reported that in 2011 alone we spent $8,410,469,500 because of flood damages and lost one hundred and thirteen lives (NOAA, 2012). In the past decade we have seen floods become more frequent, unpredictable, and intensive (ALNAP, 2012).

Floods are complex events caused by multiple human vulnerabilities, climate variability, and inappropriate planning and development. The potential of a flood becoming a disastrous event depends upon the location of people (FEMA, 2012). In California we have an economy and millions of people that depend upon a fragile Delta and its tributary rivers.

All of which are protected by an aging infrastructure that is becoming more vulnerable every day due to climate change, rising sea levels, and earthquake risk (ACWA, 2009).

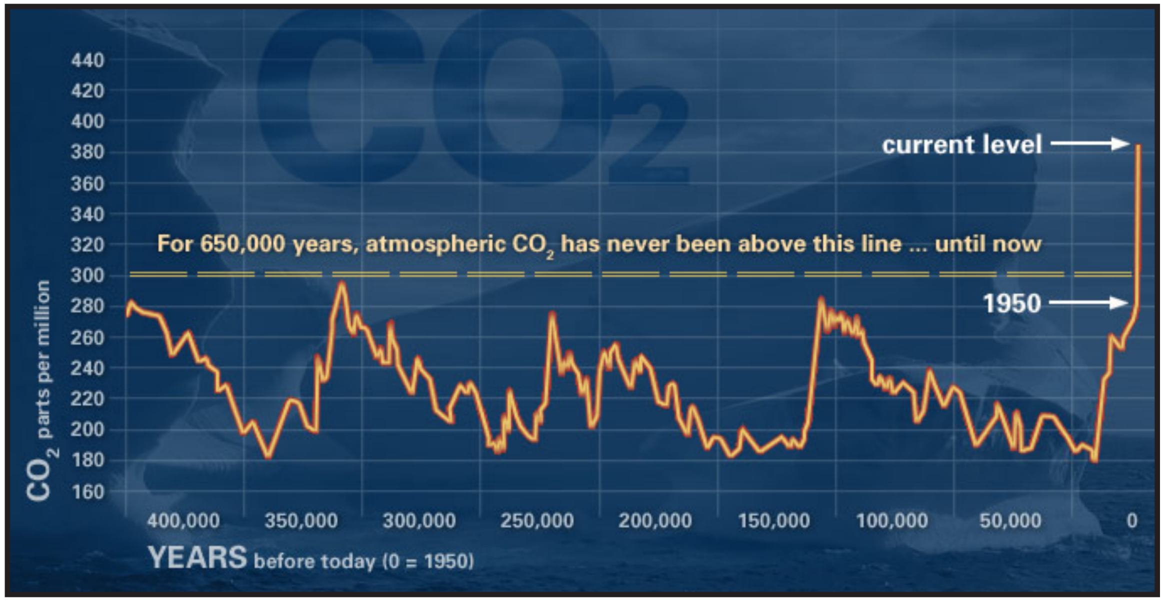


Figure 3.
- A graph of NASA's key indicators for climate change; atmospheric CO2 levels. Rising trend is no longer normal and now exceeding levels for the past 400,000 years. (Source: NASA, 2012)

Sacramento - San Joaquin Flood Control System

Figure 4.
- Meandering Sacramento River confined by levees on both sides (Source: explorations.ucsd.edu).

The California Central Valley is home to the largest estuary on the West Coast. The Sacramento - San Joaquin Delta consist of more than 1,000 miles of earthen levees, numerous sunken islands, countless wetlands and is an unequivocal treasure (Figure 4). As the confluence of the two largest rivers in California, it plays an important role for our agriculture, urban areas, industry, the environment and provides many recreational opportunities. Much of California's water supply has to pass through this system and about two thirds of California's population depends on the Delta for drinking water. While millions of acres of agricultural lands, an integral part of our economy, depends on irrigation provided by the Delta's waters. The region functions as a utility corridor, an important ecological resource, and supports a growing urban area of a half million people or more. The Sacramento - San Joaquin Delta is the single-most important link to our water supply and an irreplaceable part of the Central Valley's flood control system (National Geographic, 2012).

The backbone of this system is an interconnected series of aging earthen levees and floodways. The levees, many built during the 19th century, play a strategic role in protecting people, property, and from preventing salt-water intrusion from contaminating our largest source of fresh water. The Central Valley's 1600 miles of meandering levees protect over $47 billion dollars of infrastructure alone (DWR, 2007). The northern portion of the Delta that includes the Yolo Bypass, sometimes referred to as the North Delta, plays an imperative role in conveying flood waters away from Davis, West Sacramento, Sacramento, Yuba City, Marysville and Woodland (Greco, 2012). Billions of gallons of water drain from Northern California's watersheds into this outdated and fragile system (ACWA, 2009).

Could these aging man-made levees withstand the changing climate, a large flood occurrence, or a massive earthquake?

The Yolo Bypass is supposed to protect against a 100-year flood, but engineering analysis showed it might only withstand an 80-year flood (Greco, 2012).

Not only is the Yolo Bypass is the largest floodplain of the lower Sacramento River but it is also a very important resource for the people, agriculture and habitat in the central valley (Final Yolo Report, 2002).

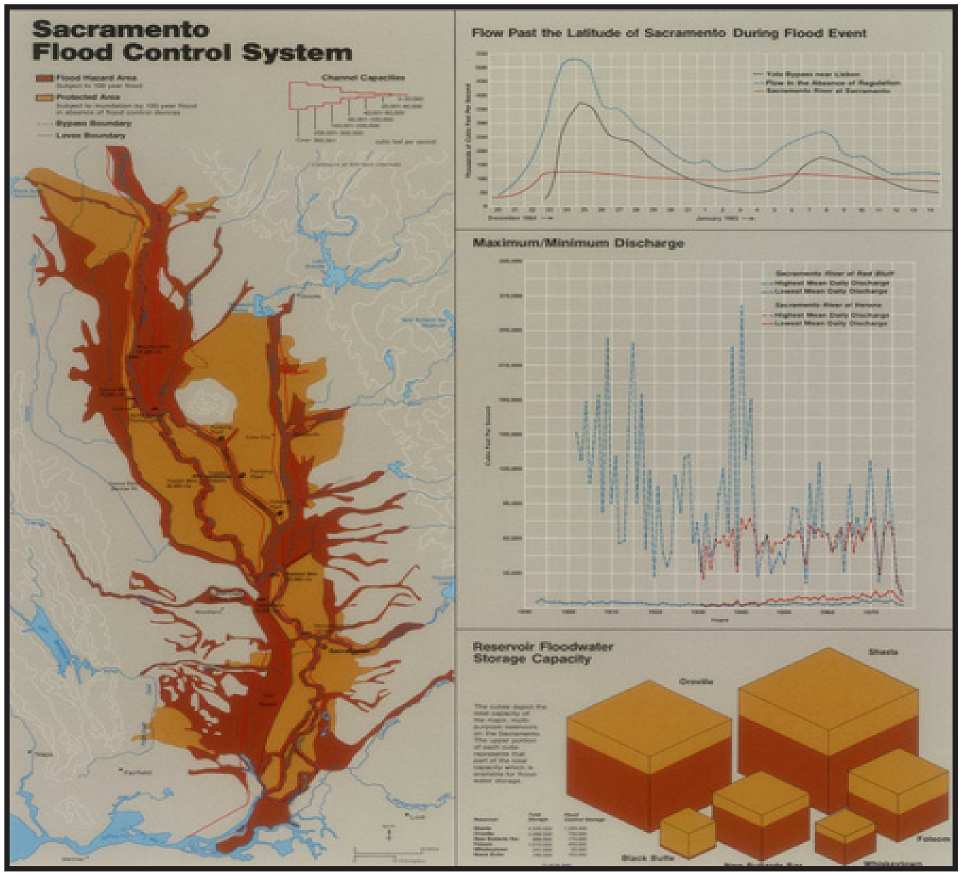
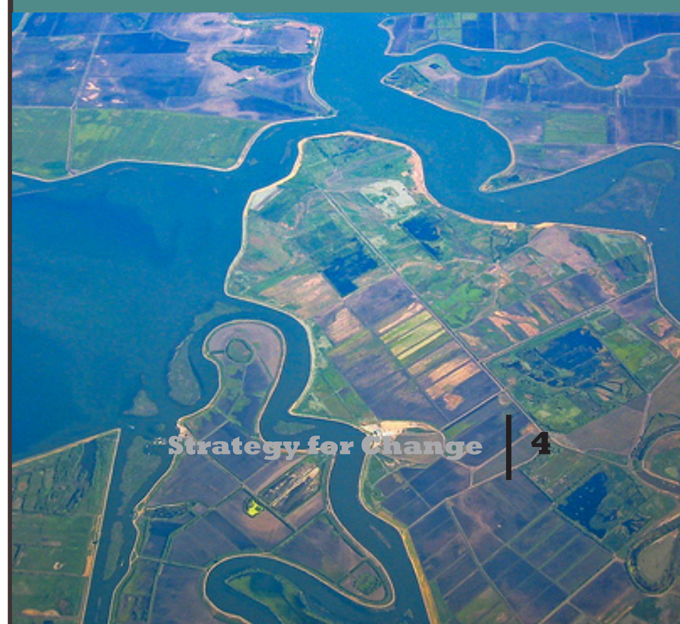


Figure 5.
- A map of the Sacramento Flood Control System showing the areas of flood hazard (red) and the areas of protection (orange). (Cal Water Atlas, 2012)

Figure 6.
-Aerial photograph of the Sacramento- San Joaquin Delta.



History of Flood Control

The Sacramento- San Joaquin Delta flood control system was originally constructed in the mid to late 19th century to prevent the natural flood occurrences of some of the nations most fertile farmland (DWR, 2012). The original levees were built by Chinese laborers who, arriving from the Gold Rush, used hand shovels and wheelbarrows to construct the levees (Figure 7). At this time most of the land was at sea level, so the workers tended to construct man-made levees on natural levees that formed dirt barriers routinely along the sloughs and rivers. The floodplains were an ideal source of peat soils, excellent for agriculture but inadequate as a foundation meant to contain a constant flow of water. Despite this fact, levees were constructed in this manner with the new addition of increased sedimentation and rising riverbeds due to hydraulic mining. As the interior islands were drained, cultivated, and tilled the peat soils became oxidized, thus blew away when dried out causing the land to subside. In the late 19th century the sidedraft-clamshell dredger was invented to construct and reinforce existing levees (Figure 8). In many areas of the delta the islands have reached well below 20' at sea level, making the risk of a levee failure a very serious issue and potentially the loss of life, infrastructure, and property (Figure 9). A system of levees is only as strong as the weakest link making constant monitoring and repair required to compensate for levee failure mechanisms (Wolf, 2003).

Figure 7.
- Chinese laborers constructing levees with wheelbarrow and shovels. (Department of Water Resources, 2012)

Figure 8.
- A sidedraft - clamshell dredger removing sediments from the river to construct a levee (Department of Water Resources 2012).

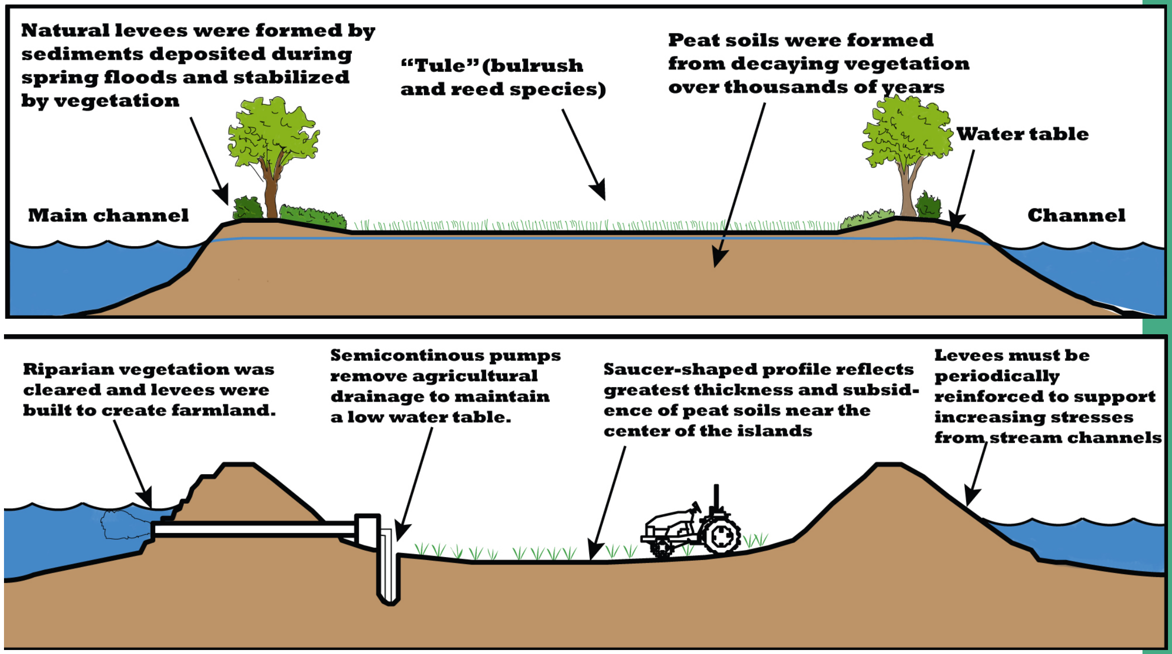


Figure 9.

- Levee and Island conditions prior to development of agriculture and post develop, showing the subsidence of soils due to agricultural practices (Source: M. Ikehara, 2011)

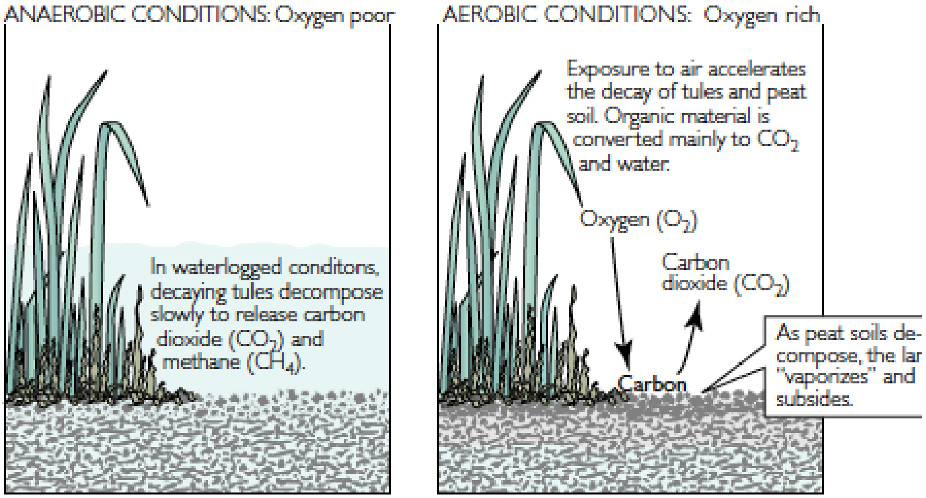


Figure 10.

- Illustration comparing anaerobic conditions to aerobic conditions. Aerobic conditions allow for faster decomposition thus causing the islands to subside within the levees (Source: M. Ikehara, 2011).

Levee Failures

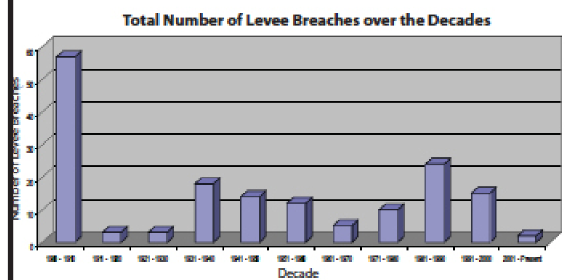
As a result of the 2005 catastrophe of Hurricane Katrina there has been many concerns with the countries levee systems in terms of both their construction and management (ACWA, 2009). The 20th century has witnessed more than 160 levee failures in California alone (Figure 13). Not only do these levee breaches threaten life and property but a failure large enough could allow saltwater intrusion and dramatically disrupt the statewide water supply and delivery system. To assess the risk of these failures an understanding of the timing of these flood events is important. During winter high flows, floods pose a risk of overtopping levees and inundating our urban areas. During the summer months a structural failure could result in salt-water infiltration and potentially result in billions of dollars in damages (DWR, 2009). One of the most recent levee failures occurred at Jones Tract on an ordinary day in 2004. This structural failure resulted in the flooding of 12,000 acres and approximately $90 million dollars in repairs (Figure 11). Furthermore this failure initiated the realization that if a levee breech was to be created by a major flood event or an earthquake the resulting damages could likely destroy two major export pumps, total billions of dollars, and cost many lives (ACWA, 2009). Typical mechanisms of levee failures include through-seepage, under seepage, slope instability, erosion, and overtopping (SAFCA, 2012).

Figure 11.
- Levee Failure at Jones Tract showing property destruction (University of California Davis, 2007)

Figure 12.
- Levee breech at Jones Tract in 2004 that occurred on a normal sunny day (DWR, 2009).

Distribution of Levee Failures Since 1900

DECADE	NUMBER OF ISLANDS	NUMBER OF BREACHES
1900 - 1910	28	57
1911 - 1920	2	3
1921 - 1930	3	3
1931 - 1940	15	18
1941 - 1950	12	14
1951- 1960	9	12
1961-1970	4	5
1971 - 1980	10	10
1981 - 1990	15	24
1991 - 2000	12	15
2001 - Present	2	2
TOTAL:	114	163



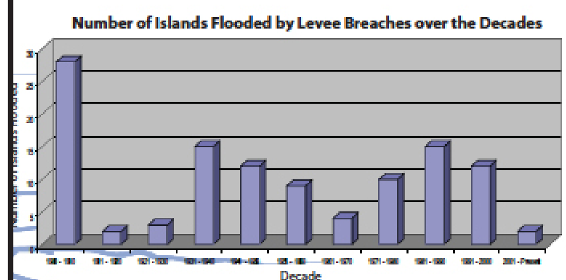


Figure 13.
- Distribution of levee failures in California since 1900.
(Source: Department of Water Resources, 2007)

Levee Failure Mechanisms

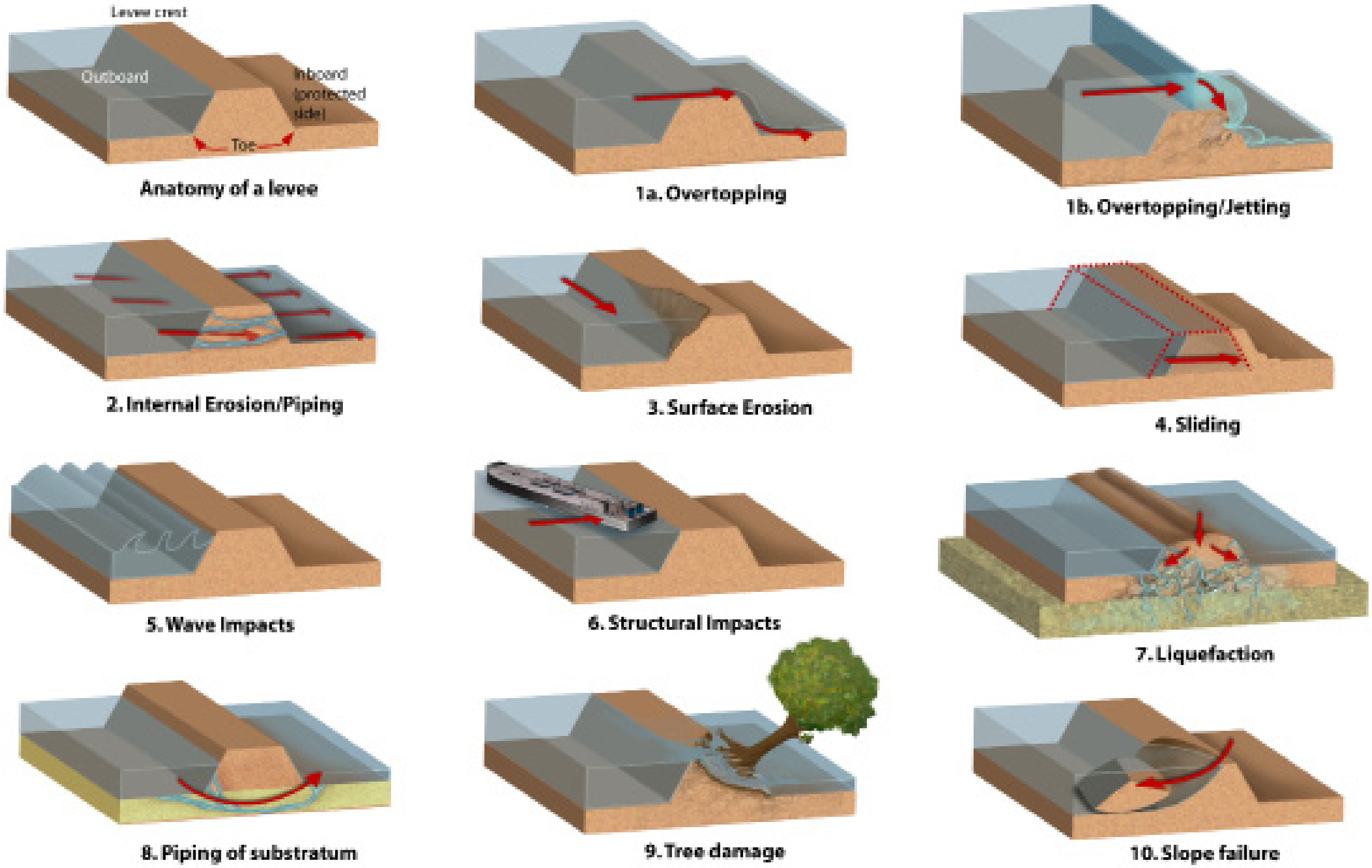


Figure 14.
Illustrations of levee failure mechanisms (Source: Sacramento Flood Control Agency 2012).

Management of Levees

Management practices were first developed to maintain the original levee system that was built on a foundation of peat, sand, and silt. These materials proved inadequate as a foundation and created problematic issues and susceptibility to breaches, seepage, and erosion.

In 1917, the Sacramento Flood Control Project was created for the purpose of assigning the USACE to reconstruct "project levees" designed for superior flood control protection. These levees consisted of more than 1,600 miles through out the Central Valley and more than 700 miles built and managed by land owners or reclamation districts. Following changes fueled by Hurricane Katrina, the USACE conducted a review to improve their levee standards in order to improve public safety. At the national level a policy was created that requires the removal of all woody vegetation larger than two inches in diameter from all levee systems in the country. These new policies were put into affect regardless of the fact that vegetation on levees did not cause any of the floodwall or levee failures that occurred as a result of Hurricane Katrina. The USACE's main concern is visibility in case of a flood fight occurring and because the funding is at the federal level California agencies must oblige to the policies set forth or risk losing federal assistance (DWR, 2009).The current management of levees in the Sacramento-San Joaquin Delta and Yolo Bypass, is managed by an effort between the Unites States Army Corps of Engineers, the Department of Water Resources, the Sacramento Flood Control Agency, and private owners (DWR, 2012).

In a technical letter dated in April 2009, the USACE outlined their "Guidelines for landscape planting and vegetation management at levees, floodwalls, embankments, dams, and appurtenant structures." The purpose of this Engineering letter was to provide guidelines so all "landscape planting and vegetation management provide aesthetic and environmental benefits without compromising the reliability of levees, floodwalls, embankment dams, and adjacent structures" (USACE, 2009).

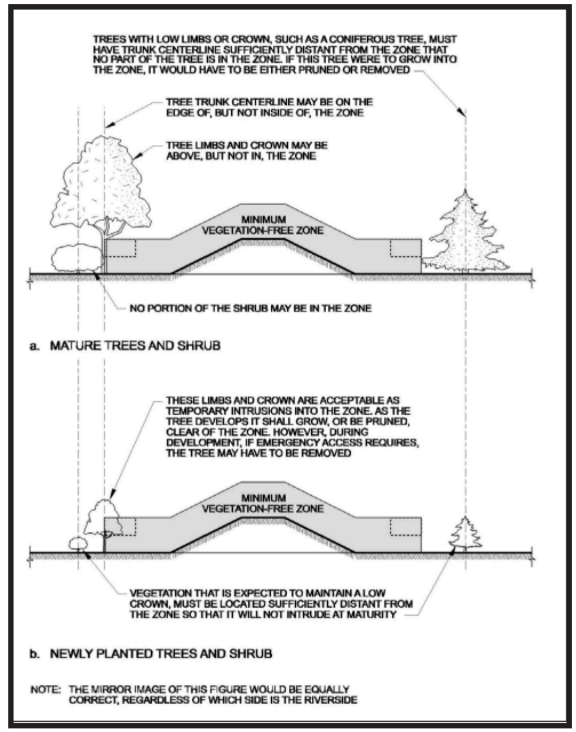


Figure 15.
- Sections of the USACE's minimal distances for the vegetation free zones of the levees. (USACE, 2009)

They created guidelines to set standard minimum dimensions for a root free zone and a vegetation free zone that establishes buffer distances between flood protection structures and vegetation (Figure 15). They specify the same guidelines for levees as they do with all flood control structures, expressing they all serve one related design purpose for preventing floods from occurring at particular times and to contain those waters. The USACE feels it is necessary to approach all landscape plantings and vegetation management with extreme caution because of their possibilities for long-term saturation (USACE 2009). Accordingly, the occurrences of "undesirable vegetation" might potentially inhibit the levee integrity and potentially lead to a failure. The vegetation management strategy mandates the control of vegetation to prevent root-related damages to flood controls structures, to limit habitat characteristics that might promote burrowing animal species (Figure 16) and to avoid any accidental growth and successive existence of endangered species that could inhibit management practices. The main requirements being that no landscape planting should impact flood-fighting or maintenance operations and must allow access for moving vehicles and emergency repairs. Typical design standards include a 15' minimum zone or distance to edge of normal water surface with all trunk centerlines at the edge of the 15' area, and an 8' height for the vegetation free zone (USACE, 2009).

Unfortunately the Army Corps does not firmly support a situation that would increase stability and protection of our flood control system. Rather they endorse the removal of all woody shrubs and trees from levees as the best management option for floodway and levee management. This ruling has no concrete evidence and would weaken the hundreds of miles of levees throughout the Sacramento-San Joaquin Delta.

Figure 16.
- Illustration of typical grassland landscape that is preferred by burrowing species such as the CA ground squirrel and the Botta s Pocket gopher. (Source: River Partners)

The proposals outlined in section 3-1 of the USACE's Engineering Technical Letter 1110-2-571 describes a one size fits all policy for all flood control structures whether a levee or a engineered floodwall. The Department of Water Resources found that the USACE's vegetation management policy would reduce public safety while promoting unnecessary and extensive environmental damage (DWR, 2012) The Army Corps is trying to address multiple and complex concerns with a narrow-minded process despite that it may cost up to 7.5 billion dollars to remove all vegetation from up to fifteen percent of California's levees (Contra Costa Times, 2011). Levee management of trees and other vegetation can coexist with the standards for public safety and flood control. The new policy basically ignores the devastating impact that would occur to the last remaining 5-10% of riparian habitats that predominately exist within the 15 foot free zones and on top of levees. Removal of trees could actually create negative impacts to the integrity of levees and require over-excavation or installation of sand filters to address seepage along decaying root systems. (DWR, 2012)

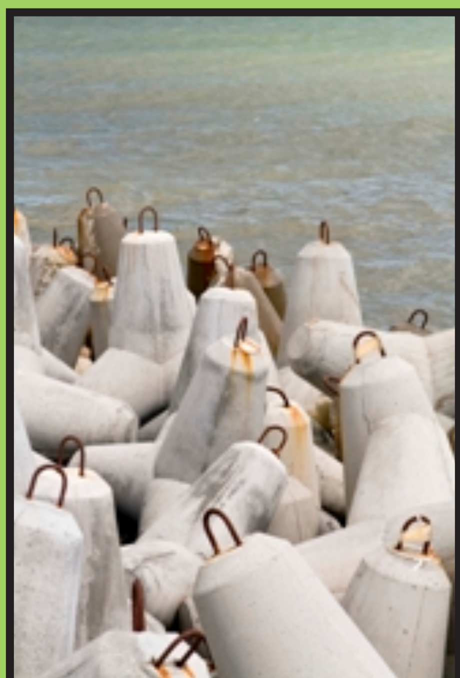


Figure 17.
- Riprap, a common alternative for vegetation to control erosion.(Source USACE 2009)

Figure 18.
- Aerial photograph of a levee in New Orleans with flood control structure to control erosion. Erosion typically occurs along hard-soft interface.
(Source: Berkeley Independent Investigation Team 2007)

About 90% of the Central Valley grasslands, riparian habitats *(left)*, old growth forests and wetlands of the state have disappeared. Irrigation canals, *right*, can harbor some aquatic species but cannot replace habitats created by rivers.

Figure 19.
-Comparison of natural stream corridor to typical Central Valley water corridors. (Source http://ucanr.org)

Concerns with Vegetation on Levees

The main concerns with vegetation on levees are those thought to contribute to the mechanisms of levee failures. One concern is with plant materials blocking visual inspections or obstructing maintenance responsibilities. Applicable design solutions can be developed to incorporate vegetation and allow for visibility and detection of any seepage occurring on the landside (Figure 20). In the case of a flood fight event there is concerns with vegetation affecting the ability of rescue efforts. Another concern is that tree roots will rot and cause piping. This has been determined despite any proof or photographic evidence. Likewise a study on the Sacramento River showed old root channels have been found to fill with sand (River Partners, 2012). Understanding the natural senescence of a tree will show that they die back slowly over time, rather than all at once which would occur if a tree were to be cut down. The Army Corps is also concerned with vegetation providing burrowing rodents with habitat and cover (USACE, 2009). Ironically the two burrowing rodents of concern, the Botta's pocket gopher and the California ground squirrel are both grassland species that prefer open space for visibility. These rodents are rarely seen living in woody vegetation due to predators and difficulties to burrow because of large roots. There are also concerns with trees toppling over due to high winds, weak levee foundations, or prolonged saturation caused by floods. Since groups of tree roots tend to create a network that hold one another together, tree toppling tend to occur with lone stand trees rather than within densely planted areas (River Partners, 2012).

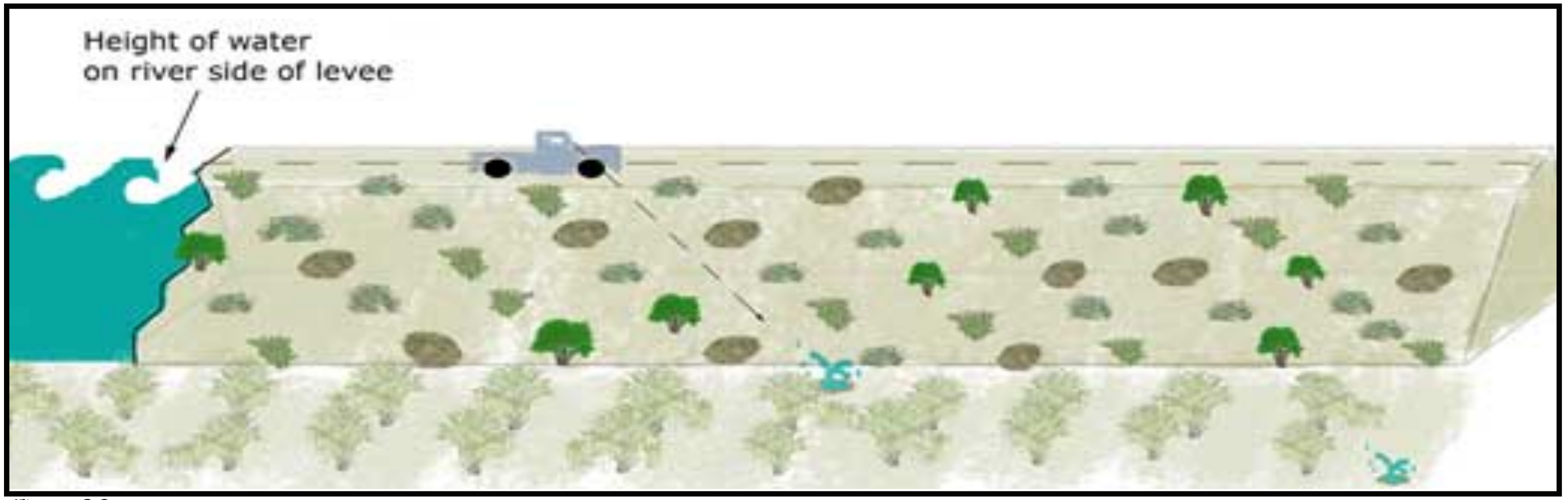


Figure 20.
- Design strategy for a levee that allows for vegetation and visibility (Source Info: River Partners, 2012)

Levee Design Strategies

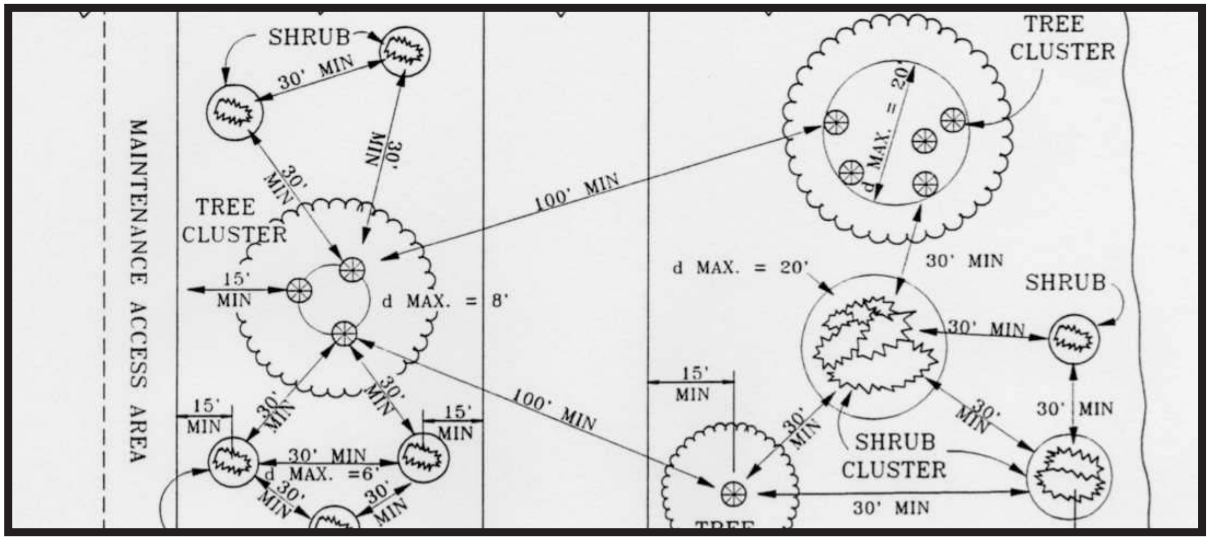


Figure 21.
- Levee design strategy that allows for visual corridors and levee inspection while maintaining trees and other vegetations (Source D. Gray 2007)

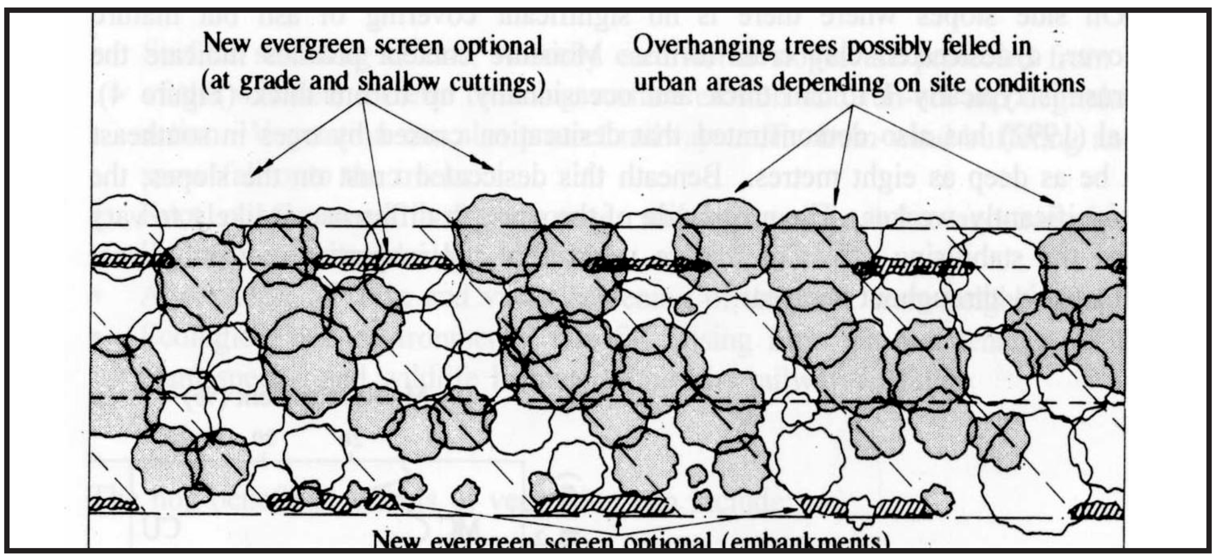


Figure 22.
- Clearing strategy for existing levee to allow visibility corridors in order to maintain some vegetation.
Source: D. Gray 2007)

Suitability of Plant Types For Different Engineering Applications

Type	Advantages	Limitations
1. Grasses	Versatile and Cheap. Wide range of tolerances. Quick to establish. Good dense surface cover	Shallow rooting. Regular maintenance required
2. Reeds & Sedges	Establish well on riverbanks and levees. Quick growing	Hand planting required. Expensive. Difficult to obtain.
3. Herbs & Forbs	Deeper rooting. Attractive in grass massing. Good intercpetion	Sometimes diificult to establish. Many species die back in winter
4. Legumes	Cheap to establish. Fix nitrogen. Mix well with grass	Not tolerant of difficult sites
5. Shrubs	Hardy and fairly cheap. Many species can be seeded Deeper rooting. Substanial ground cover. Low maintenance. Evergreen species	More expensive to plant. Some difficult to establish
6. Trees	Substantial and deep rooting. Multiple stablizing mechanisms. No greater root tensile strength. No maintenance once established	Long time to establish. Slow growing. Expensive Some species susceptible to toppling.
7. Willows & Poplars	Root easly from cuttings. Many planting techniques. Young willows have supple stems, bend over in flow and armor ground surface.	Care required in selecting corret type. Cannot be grown from seed. Shade tolerant

Figure 23.
- Table of plant suitabilities according to desired application. (Source: D. Gray)

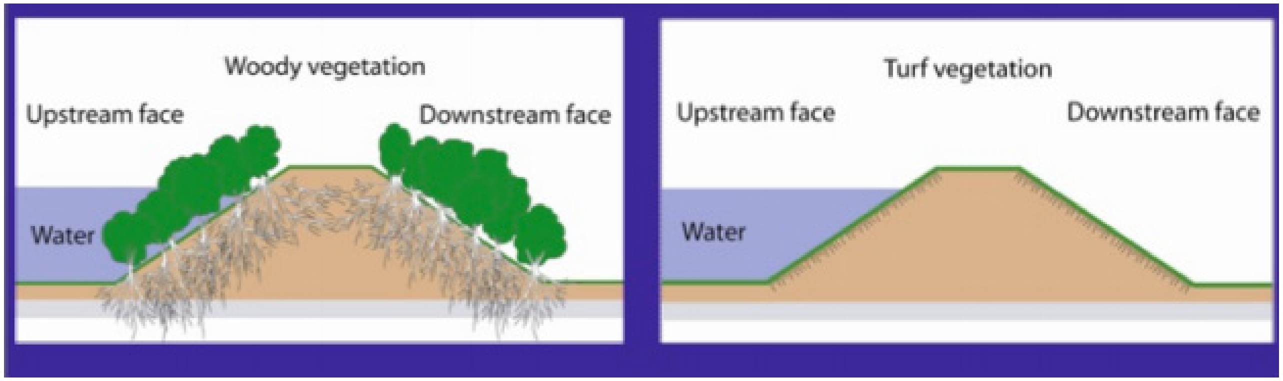


Figure 24
- Woody vegetated levee in comparison to typical grass covered levee. (Source D. Gray)

Understanding the Role of Vegetation on Levees

Today's levees are generally constructed using "ideal" textured soils as construction materials because they are easily compacted and result in strong, shear resistant levees. The addition of plant roots in the upper portions of these levees will help bind the soil particulates together and thus increase the overall shear strength of the levee. Tree roots perform the same function as rebar holding together concrete slabs by creating a network of support (Figure 25). The presence of roots will increase the cohesive binding properties essential to levees functionality and therefore require a much larger force to break up the bond. The key point is to have a series of many individual trees of several plant species in order to create a levee with strong upper layer network of tree roots. The network of support will assist in reducing tree failure due to high winds, weak levee foundations, or prolonged saturation caused by floods. Vegetation also decreases erosion at the toe of a levee by breaking up and dissipating wave or tidal energy (*RIver Partners 2012).*

Figure 25.
- Close relationship of tree roots in soil and rebar in concrete slabs
(Source: River Partners 2012)

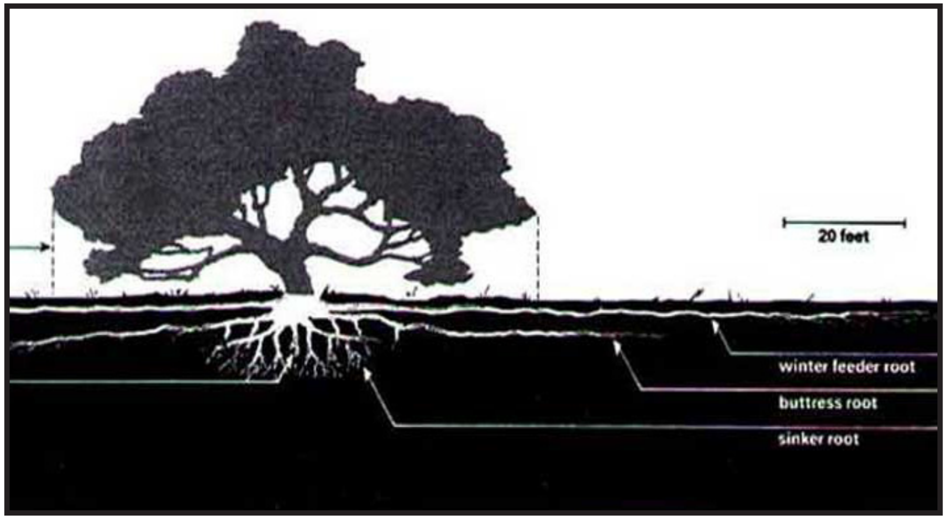


Figure 26
- Tree root section showing the proximity and extent of typical tree roots
(Source: RIver Partners 2012).

Berkeley Independent Investigation Team

In 2006, the Berkeley Independent Levee Investigation team did a study to investigate the New Orleans Levee System. They found that the majority of flood protection for New Orleans was dependant on the function and presence of the earthen levee systems to separate the land and water. The results concluded that the attributes, which contribute to a poor performance levee, included the utilization of low erosion-resistant construction materials, transition zones between different flood protection components (grass - floodwall interface) and lack of surface slope protection for erosion-susceptible soil levees. A portion of the study levees were highly vegetated and proved to be very affective in flood control and resistant to erosion mechanisms (Figure 27).

The current approach to establishing design standards is based on using a cost-benefit analysis rather than considering the loss of human life or the economic losses to cities, counties, and states. This study exemplifies the fact that there is a "systematic-under-valuation" of the benefits of investing funding, efforts, and resources to prevent disasters before they occur. Investigations found that levees were incapable of withstanding overtopping and resulted in catastrophic losses while the current design standards of the USACE and FEMA at he the time assumed that overtopping did not occur. The design guidelines were essentially based on deterministic factors of safety levels that did not account for the broad range of uncertainties or failure mechanisms to ensure an appropriate level of safety or ecological stability (Berkeley Investigation Team, 2006).

Figure 27.
- A stretch of a vegetated levee in New Orleans that was virtually unchanged by the events of Hurricane Katrina (Source: Berkeley Independent Investigation Team, 2006)

The Effect of Riparian Tree Roots on the Mass-Stability of River Banks

Dr. Bruce Abernethy and Ian Rutherfurd from the University of Melbourne conducted an experiment to asses the effect of riparian tree roots on the mass –stability of riverbanks. The study was looking to understand specific plant interactions with the process of erosion on rivers through the altercation of bank hydrology, flow hydraulics, and geotechnical properties. The two tree species examined, the Swamp Paperbark (*Melaleuca ericifolia*) and the River Red Gum (*Eucalyptus camaldulensis*), had roots that were found to provide high levels of bank protection. Trees located close to the potential failure zone created the greatest bank reinforcement such as the floodplain/ river bank interface or low on the bank to dissipate erosion forces, sometimes increasing the safety factor by six times. Understanding the vegetative influence on riverbanks is complex and requires knowledge of the underlying mechanics of bank failure and the potential mechanical features of plants. Field observations indicated that tension cracks typically occurred at sites with depleted vegetation and cover. Further investigations noted that root reinforcements could stabilize banks at any angle up to a height of 5 meters (Figure 28). It is imperative to the design and safety concerns of riverbanks to understand vegetation is a critical part of the riparian landscapes and supports a major role in stabilizing riverbanks and moderating erosion. In comparison to the traditional methods of hard engineering, applying natural vegetation will most likely achieve goals of bank stability while adhering to economic and ecological concerns (Abernethy and Rutherfurd, 1999).

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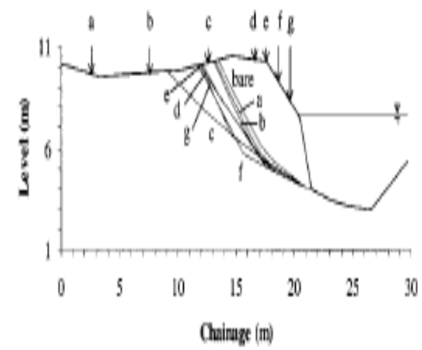


Figure 10. Profile 9L after 1·3 m of bed scour, showing the effect of River Red Gum position on critical failure plane position

Table III. The effect of River Red Gum position on the stability (F_s) of bank profile 9L with 1·3 m of basal scour

Simulation (Figure 10)	Tree position (distance from crest)	Safety factor
bare	–	1·00
a	15 m left	1·26
b	10 m left	1·43
c	5 m left	1·61
d	1 m left	1·43
e	At crest	1·48
f	1 m right	1·48
g	2 m right	1·51

Figure 28.
- River bank safety factors according to Tree Location. (Source Arbernethy and Rutherfurd, 1999)

California's Riparian Habitats

Up to ninety five percent of California's Central Valley riparian habitat has been destroyed as a result of anthropogenic pressures. Abiding to the Army Corp's proposed design standards would require the destruction of most all the last remaining five percent of the riparian forest that are essential to endangered species, flood control, and recreational uses. These remnant riparian areas are crucially important as habitat areas for birds, fish, and other species while providing shade, aesthetics and opportunities for recreational activities such as fishing, hunting, or nature observing. The removal of riparian vegetation could affect the livelihood of endangered or threatened species, going directly against both the federal and state Endangered Species Act. These species include the Chinook salmon, Central valley steelhead, Delta smelt, green sturgeon, long-fin smelt, giant garter snake, burrowing owl, riparian brush rabbit and the Swainson's hawk. Riparian vegetation has also been noticed to slow surface water velocities and increase ground water infiltration while simultaneously filtering pollutants and reducing bank erosion. Riparian vegetation on levees has been found to be compatible with flood control and can even improve public safety by reducing many potential mechanisms of failure (Figure 28) (Friends of the River vs. USACE, 2010).

Riparian zones consist of a unique composition of physical and ecological factors such as flooding, rich and productive soils, water table accessible by plant roots, species adapted to fluvial aspects of flooding, drought, sedimentation, and channel properties, and structural development of grasslands, meadows, shrublands, woodlands, and forest. California's riparian forest alone support more diversity of wildlife than any other habitat. These ecosystems also support people and wildlife by providing many benefits and ecosystem services. Many riparian areas such as those of the Yolo Bypass and Sacramento River provide many recreational opportunities such as wildlife viewing, hiking, boating, hunting, and fishing. These habitats act as wildlife migration corridors and are a vital part of the pacific flyway for migratory birds. Riparian habitats are also important for maintaining water quality, especially in the Sacramento- San Joaquin Delta that is suffering from ongoing pollution. (Riparian Handbook, 2009). Disturbed riparian areas are particularly vulnerable to damages and invasive species because of the availability of water (Harding, 2012). A healthy living river and riparian habitat will provide biological processing of pollutants and physically filter organic materials and sediments. Likewise these areas are the foundation of California's water and flood control systems by conveying floodwaters and delivering more than half of our water supply across the state. (Friends of River vs. USACE, 2010).

Landscape Planning and Ecological Design

Although our knowledge of the risk and nature of floods has increased greatly, we continue to see an increase in the loss of life and property damage. Much of this can be attributed to our continued development along rivers and in floodplains (7% of the U.S. boundaries lies within a 100-year floodplain). The typical response has been to "engineer" solutions. Since the 1920's the U.S. Army Corps has constructed reservoirs, levees, channels, and diversion in order to prevent floods. The greatest concern with rivers is the threat they pose during the largest annual flows or peak annual flows. With an understanding of this aspect we are able to better predict the probability of reoccurrence of a particular flow on a river.

To understand floods we must also understand the geomorphology of an area because certain characteristics of a river floodplain (size, shape, and topography) influence how floodwaters will move, where water will distribute, and locations of strengths or weaknesses. Typically floodplains of streams and rivers are characterized by riparian corridors. For these corridors to maintain their natural processes within a river, there must be an upland interior on both sides to act as a conduit for displaced species (Marsh, 2005). Important to the long term persistence of these areas it is also best for the river habitat to maintain a ladder type pattern in order to promote habitat rejuvenation, provide soil organic matter, and trap sediments during a flood (Dramstad, 1996).

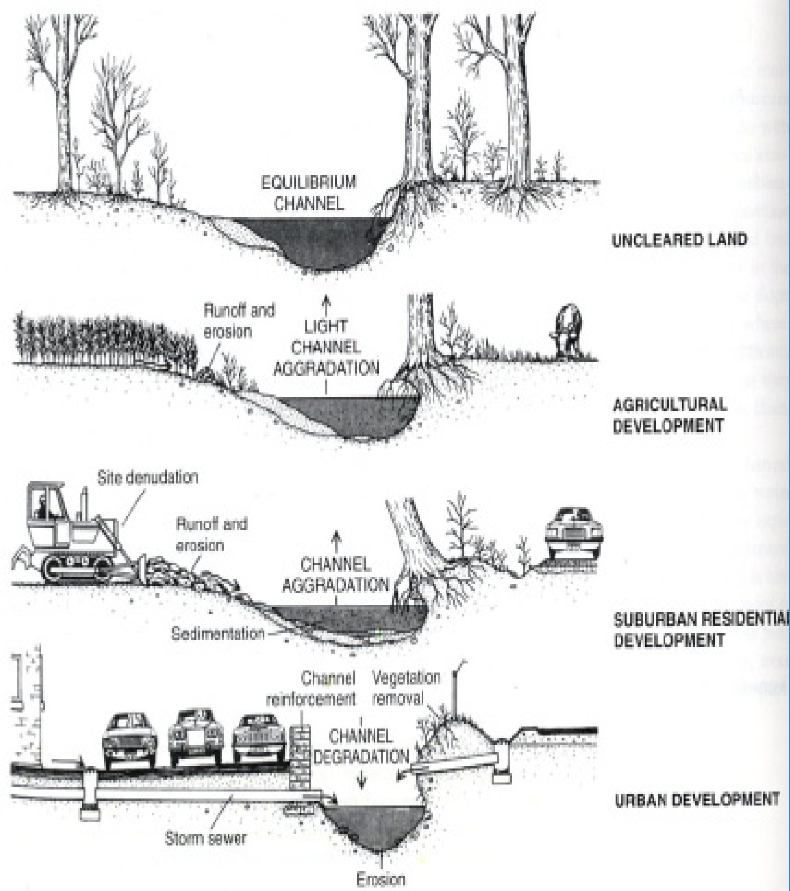


Figure 29: River section displaying the degradation that occurs due to anthropogenic pressures.

FloodSAFE California

In April of 2012 the state issued a draft report of the Central Valley Flood Control Project as a part of an on going project for a FloodSAFE California. The report found that around 300 miles of urban levees do not meet design criteria. Furthermore about 60% of 1,230 nonurban levees have a great potential for failure. Many of the levee-contained channels, about 1,016 miles, were also found to have a "potentially inadequate capacity to convey design flows" (Harris, Clark & Matheny, 2004). Research has resulted in plans to expand the Yolo Bypass. The bypass needs to accommodate more waters and improve the flood control capacity and functionality of the seasonally inundated floodplain. The Yolo Bypass is a major facility of the Sacramento Flood Control System for alleviating potential flood risk in the Sacramento River basin.

The expansion being proposed is meant to increase the floodplains ability to withstand peak flows during larger flood events (up to an additional 40,000 cfs). The plan promotes expanding the western most levees into Conaway Ranch and expanding both the Fremont and Sacramento Weir's (see design maps) to accommodate larger volumes of floodwater (Harris, Clark and Matheny, 2004). Test have indicated the Yolo Bypass is only capable of withstanding an 80 year flood . There is a needed expansion for this system to even withstand the occurrence of a 100 year flood (Figure 31) (DWR 2012). There is a great potential of this project in not only improving the flood control system and protecting nearby cities but also many opportunities for improving fish passage, aquatic habitat, and facilitate natural flow attenuation. If the Yolo bypass expansion were implemented it would have the potential of reducing 67% of overall expected flood damages, 49% reduction in life risk, 10,000 acres of new habitat, 25,000 acres of habitat compatible crops and a increasingly important resiliency to adaptability to future changes (Harris, Clark, and Matheny 2004).

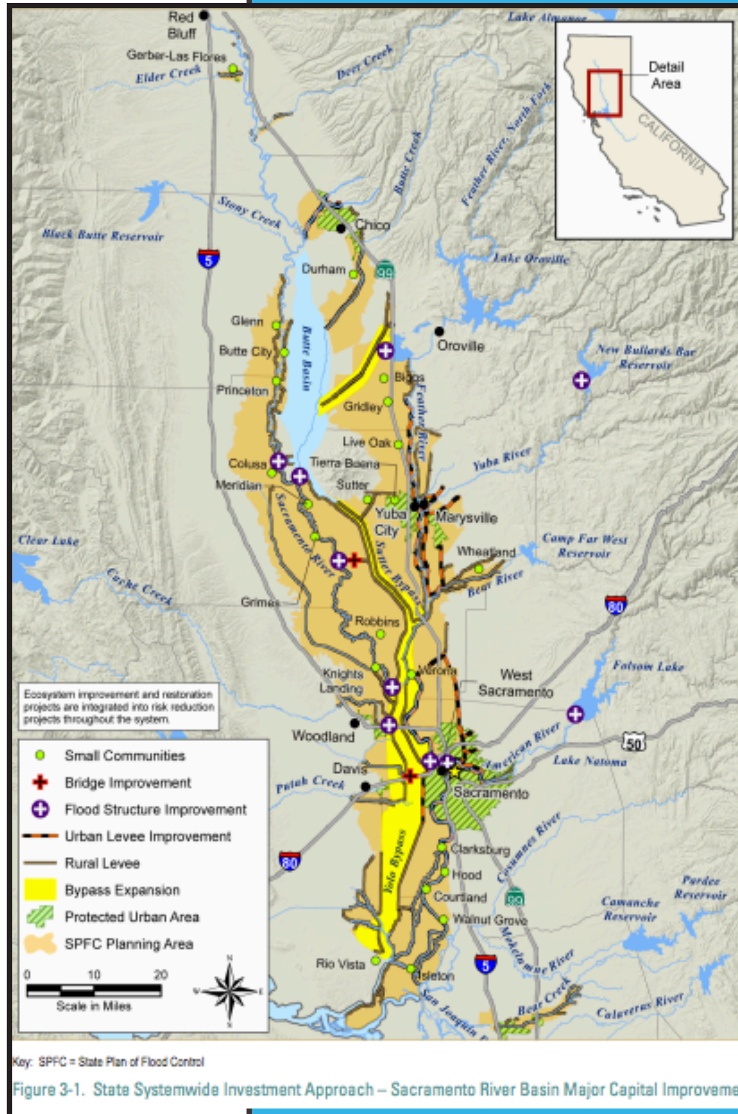


Figure 30: Map of the CVFCP showing areas of expansion for the Yolo Bypass (Source; CVFCP, 2012)

Conclusion

In determining the current state of California's Central Valley Flood Control system many questions have developed. It is understood that the system is in a state of fragility and if a flood disaster was to occur today there could very well be billions of dollars and thousands of people at risk. The current management practices by the leading federal authorities implicates there is a lack of knowledge and a communication gap within the current management system. It is apparent that there is an overall lack of understanding of the benefits to investing funding, efforts and resources to prevent and understand disasters before they occur (Berkeley Investigation Team, 2006). There is a common consensus between scientist and practicing professionals that trees and vegetation enforce bank stability and therefore the removal rule proposed by the Army Crops is illogical. Unfortunately until the Army Corps is willing to make a compromise, state agencies must continue to abide by federal standards, regardless of the particular threats to habitats and levee integrity. With proper communication and research, there can be a common goal and integrative balance of flood control, riparian habitat development, agriculture development, and opportunities for recreation. The Yolo Bypass expansion would be a critical piece for the entire valley's flood control system and would provide a great example for introducing an integrated design approach . This step forward could be one of many in reevaluating our system to serve a growing population and changing landscape.

Figure 31: Riparian habitat photo in the California Central Valley (Source http://www.trrp.net)

Design - Yolo Bypass Expansion

The Yolo Bypass is a 59,000 acre leveed floodplain that is designed to convey floodwaters from the Sacramento River, Feather River and other multiple tributary streams. This bypass is the largest contiguous floodplain on the lower Sacramento River and as one of the last remnant floodplains it serves a very important role as an ecological resource. In many wet years is capable of creating up to 60,000 acres of critical habitat for migrating birds and native fish populations. Research has also shown that when flooded, the bypass contributes to the entire food network of the San-Joaquin Delta ecosystem and increases the overall organic input into the Delta. The Yolo bypass is currently primarily used for flood conveyance, agriculture, wildlife habitat and recreational uses. Although the Yolo Bypass is currently addressing the goals of this project, there are still many issued that exist within this system (Yolo Final Report, 2002). As noted earlier engineering analysis revealed this system could only withstand an 80- year flood at most (Greco, 2012). Many fish species cannot travel upstream without adequate floodwaters and timings. There are also many other issues with multiple land use interest, water availability, legislative issues, and infrastructure problems.

Design Vision

The vision of this design is to create an a multifunctional Yolo Bypass that properly address the balanced uses of flood control, riparian habitat, agriculture, and recreation. The Sacramento - San Joaquin Delta is a highly changing and dynamic landscape system. Human intervention and development has always been necessary to live and deal with the periodic flooding that occurs in the Delta region. The flood control systems have been a vital part of the success in the Central Valley and will remain so for a changing future. As a system we must properly manage all aspects and uses in a balanced process to maintain the functionality and longevity of the region (Hermens, 2010).

Design Goals

Primary Goals

- To expand the flood control capacity of the Yolo Bypass to accommodate more seasonal flood waters (200-year flood), increasing the safety of the greater Sacramento area, restoring a historical floodplain and increasing the stability of the levee system.

Secondary Goals

- Create, develop, and contribute to the existing riparian habitat corridors and islands within the Yolo Bypass to increase ecological stability for endangered and threatened species

- Create a balanced system of multiple uses including the agriculture of suitable crops capable of withstanding seasonal inundation and recreational spaces

Project Elements

- Fremont Weir Expansion
- Sacramento Weir and Bypass Expansion
- Tule Canal Design and Restoration
- Levee Setback (West side of Yolo Bypass/ Conaway Ranch
- Riparian Habitat Islands and Corridors
- Restore Floodplain

Site Analysis - Context

The Yolo Bypass is located in the Central Valley of California just outside of Sacramento. The bypass is located in the south eastern corner of Yolo County and is the meeting point of Sutter, Solano, Sacramento and Yolo counties. The Yolo Bypass is the final flood plain of the lower Sacramento River before reaching the confluence of the San-Joaquin River and the Delta. The location of the bypass is important in understanding the extent of the watersheds that flow into this system and the populations that depend on this floodway for safety.

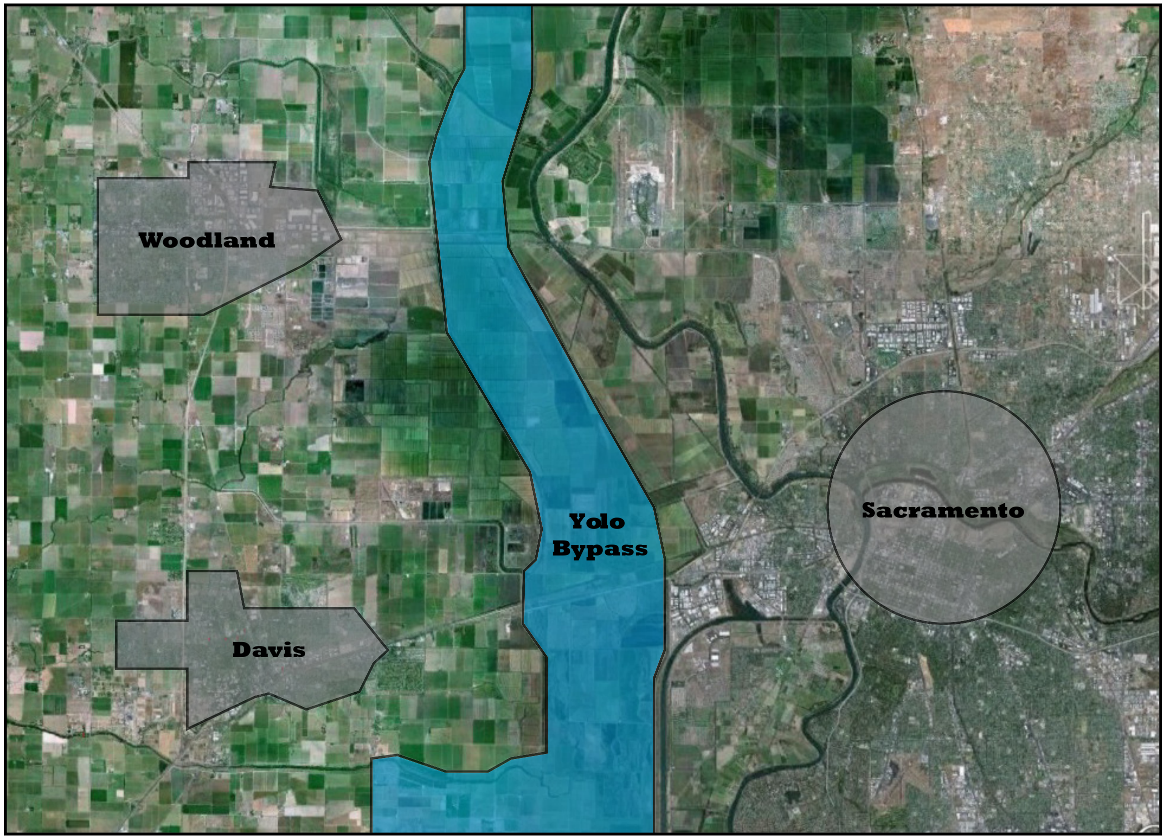


Figure 32.
- A satellite of the Yolo Bypass and the nearby communities that depend on the floodway for safety during flood events (Source: Google Earth, 2012)

Site Analysis- Population

The primary purpose of flood control is to assure and establish the safety of the public. The Yolo Bypass is critical for the protection of West Sacramento, Sacramento, Davis, Yuba City, Woodland, and Marysville. Outside of these cities are a few private establishments but for the most part rural farmlands and occasional service businesses. Both Yolo and Sacramento counties are projected to grow by 10-19% from 2010-2020. Furthermore many counties have zoned future developments along the Sacramento River and floodplains. The bottleneck of the Yolo Bypass' ability to withstand and convey waters of the next 100-year flood is critical to the safety of the populations residing in the adjacent central valley areas.

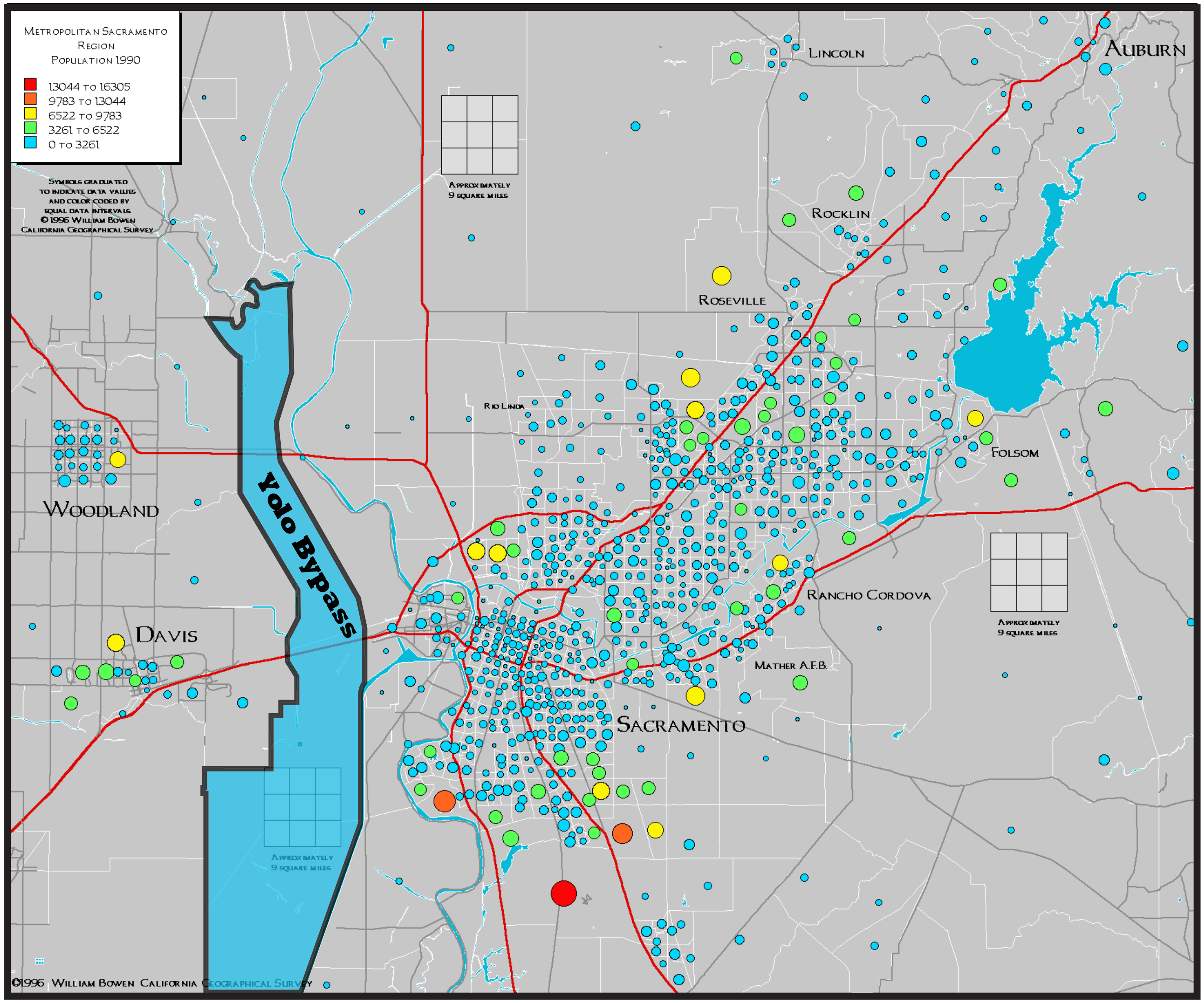


Figure 33.

- A Map showing the context of the Yolo Bypass to the neighboring communities (Source: William Bowen California, 1995)

Site Analysis - History

The periodic flooding of rivers and deltas is a natural occurrence and the reasoning for such rich and productive soils. These events have been both a burden and a gift since the earliest settlements of the Central Valley. The Great Flood of 1862 flooded over an area of 300 x 20 miles of the Sacramento –San Joaquin Valley. Cities like Knights Landing were completely destroyed and areas of Sacramento were flooded by up to 10 feet or more. A large flood in 1907 was estimated to inundate 300,000 acres of the valley at a flow of around 600,000 cfs. A few years later in 1909 another flood initiated actions that directed the USACE to construct a bypass system that closely resembled and functioned as the Sacramento Rivers natural floodplain. The 59,000-acre Yolo Bypass was constructed to safely convey floodwaters from the nearby communities. This flood system was eventually completed in the 1930's and included the east and west levees, Fremont weir, Sacramento weir and bypass. This is a very unique situation as typically flood control projects usually result in the channelization and isolation of rivers from their natural habitats and destroy any ecological function. The Yolo Bypass is essentially a key indicator for establishing flood control and habitat diversity (Final Yolo Report 2002).

Figure 34.
- Painting of Sacramento during the Great Inundation of 1850 (Source: University of California Berkeley, 2012)

Field Observations

Figure 35.1 -Open space below the railroad tracks that crosses the Yolo By-pass provide oppourtunities for trails and outdoor recreation

Figure 35.2 - Fine line between riparian areas and levee vegetation. Levees are completely disturbed and offten harbor invasive weed species. There is a great oppourtunity to use these disrtupted landscapes for habitat restoration

Figure 35.3 - Ponds, creeks, streams meander throughout the Yolo Bypass providing habitat for fish and other animal species. These areas are great spacesfor outdoor recreation such as bird watching and fishing.

Figure 35.4 - Open space allows for wetland establishiment not only for water fowl but as well as an ecosystem service to filter our polluted waters before releasing them into our waterways and Delta

Important Plant Species

Trees:

- Western Sycamore *(Platanus racemosa)*
- Western Cottonwood *(Populus fremontii)*
- Valley Oak *(Quercus lobata)*
- White Alders *(Alnus rhombifolia)*
- Willows *(Salix sp.)*
- Water Birch *(Betula occidentalis)*

Shrubs, etc:

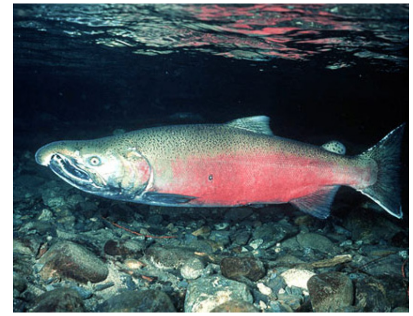
- California Wild Rose *(Rosa caliofornica)*
- Western Spice Bush *(Calycanthus occidentalis)*
- Western Mock-Orange *(Philadelphus leuisii)*
- Golden currant *(Ribes aureum)*
- California Grape *(Vitis californica)*
- Stream Sedge *(Carex nudata)*
- Rushes *(Juncus sp.)*
- Deer Grass*(Muhlenbergia regins)*
-Purple Needle Grass *(Nassella pulchra)*

Figure 36.
- Important animal species in Riparian Areas
(flickr.come)

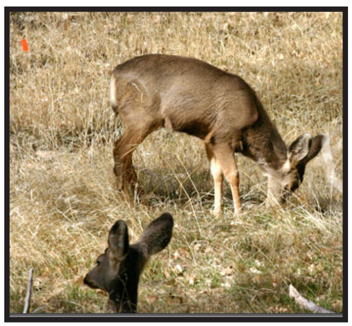
Important Animal Species

Yellow Billed Cookoo

Northern River Otter



Chinook Salmon



Mule Deer

Splittail

Bank Swallow

Giant Garter Snake

Delta Smelt

Figure 37.
- Important animal species in Riparian Areas (flickr.come)

Stakeholders & Infrastructure

Fold out

Hydric Soils

Fold out

Soils & Landformations

Fold out

Topography

Fold out

Hydrology

Fold out

Vegetation

Fold out

Central Valley Flood Protection Plan Expansion

Fold out

Conceptual Design

Fold out

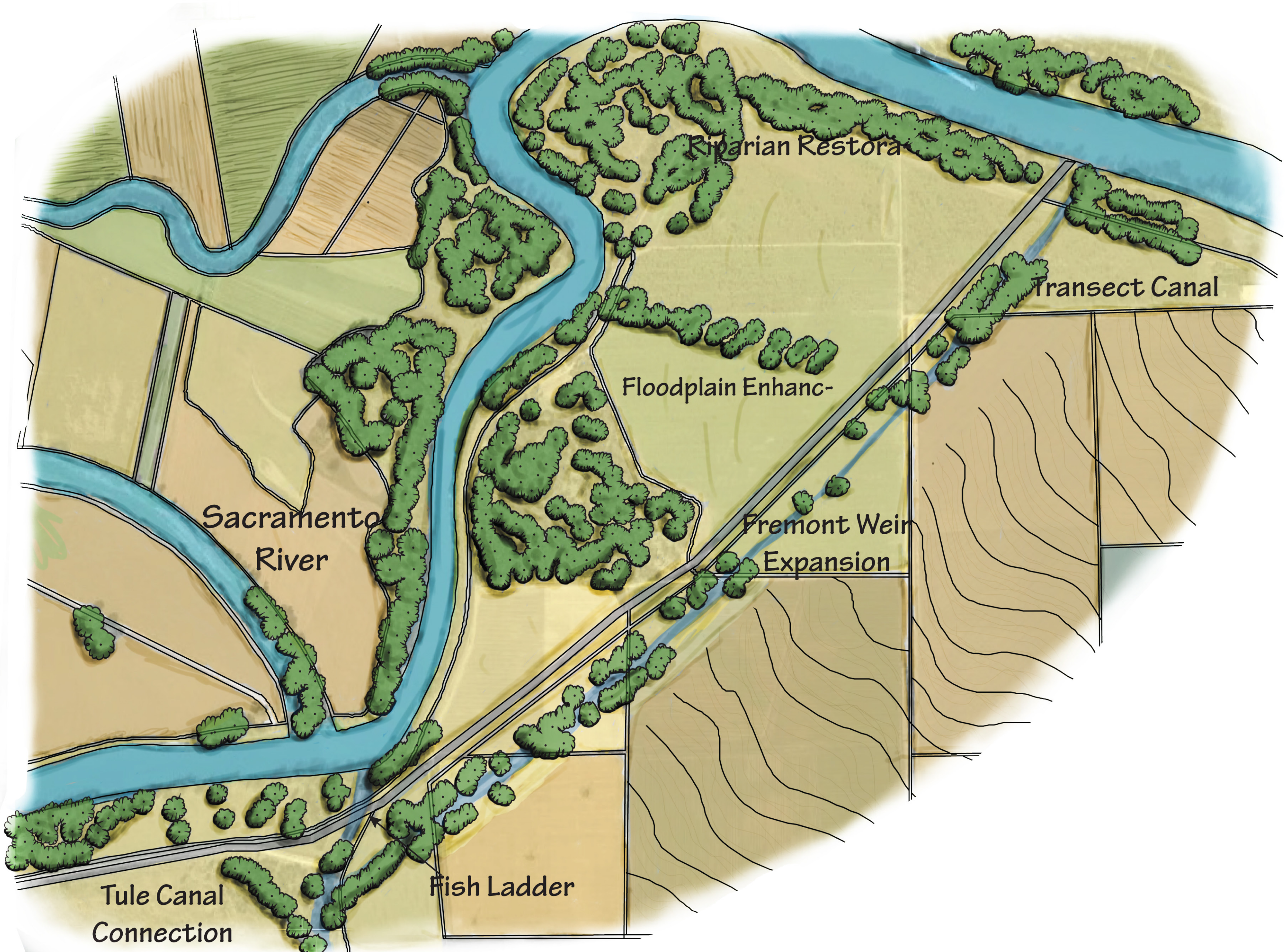
Master Plan

Fold out

Fremont Weir Expansion

The Fremont Weir Expansion is a proposal to expand the flood capacity of the Yolo Bypass. This area is a large confined floodplain that has lost its natural connection between the river biotic activity and upper flood plain. Expanding the Yolo Bypass could free up essential space for native riparian habitat.

Figure 45.
- Fremont Weir Expansion (Illustration)


Riparian Restora
Transect Canal
Floodplain Enhanc-
Sacramento
River
Fremont Weir
Expansion
Fish Ladder
Tule Canal
Connection

Sacramento Weir and Bypass Expansion

Expanding the Sacramento Bypass and Weir is essential for the Yolo Bypass to convey more floodwaters. This weir is the last flood control mechanism before the city and is rather small and out dated. Expanding the bypass at a minimum of 100' will allow for more floodwater conveyance and the restoration of native habitats for fish species and terrestrial species.

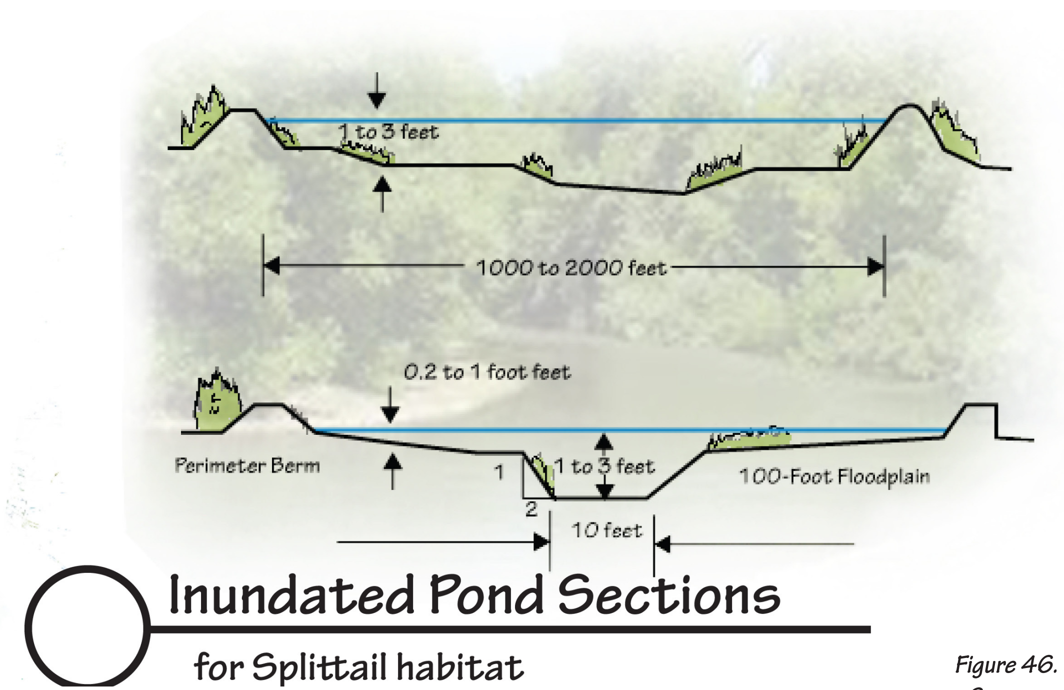
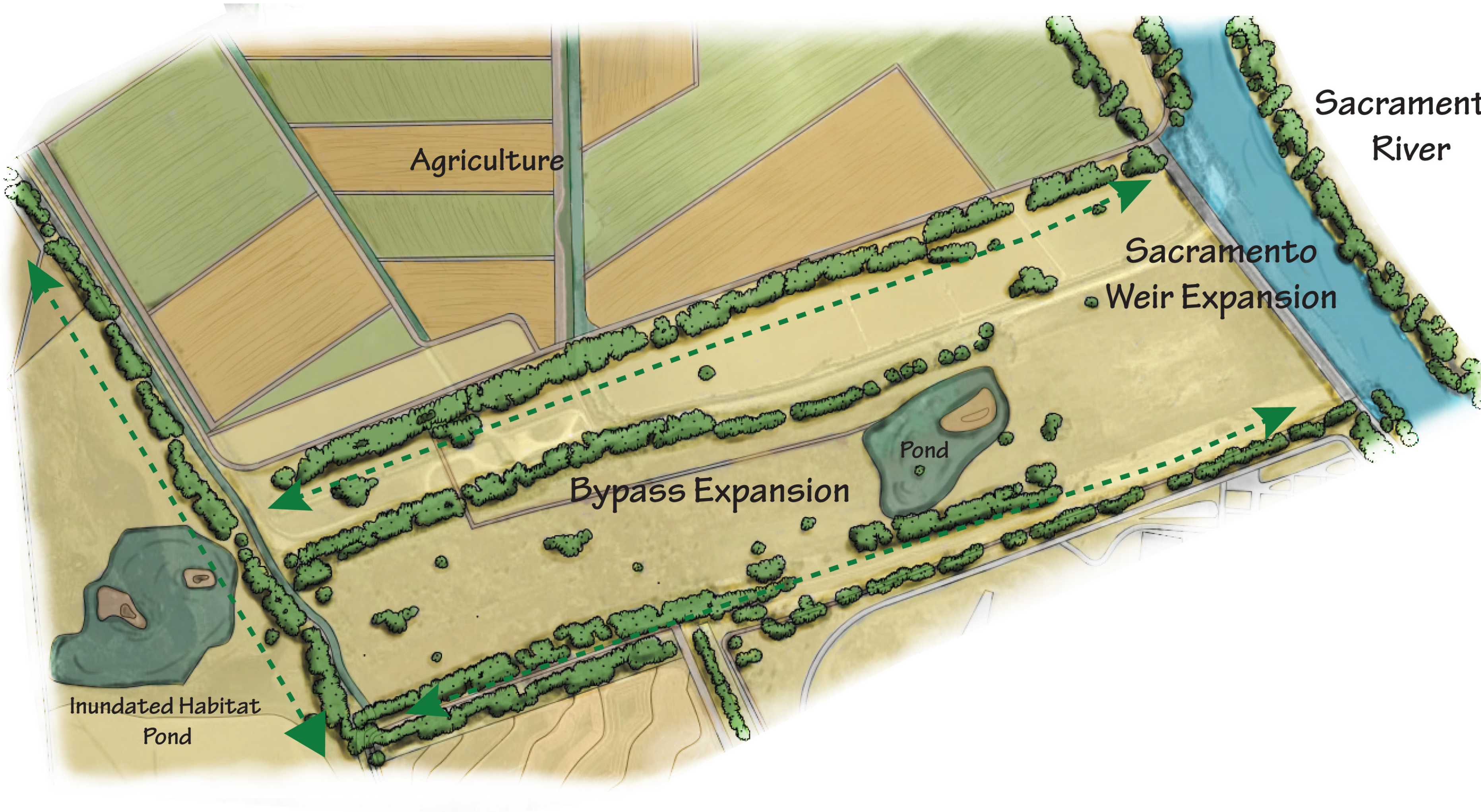
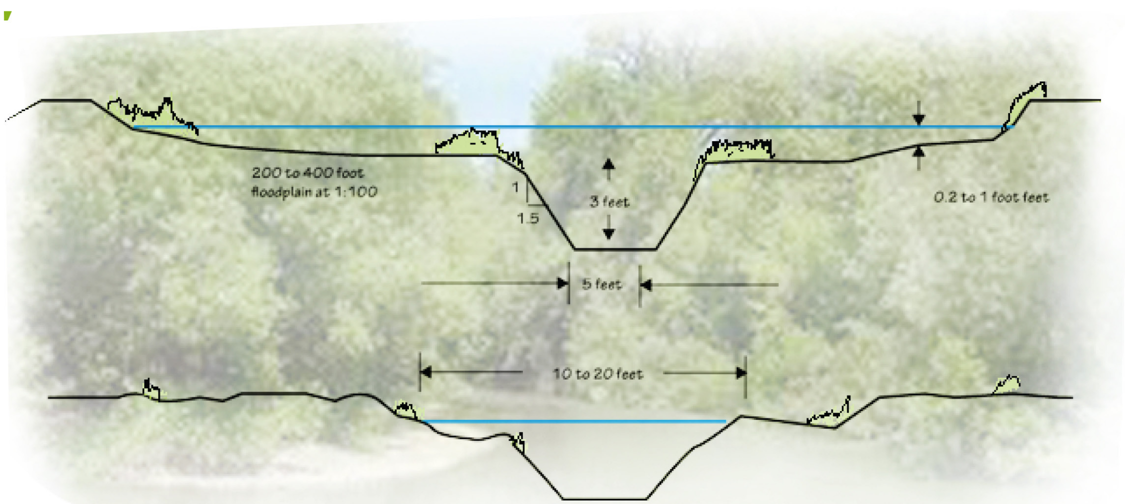


Figure 46.
- Sacramento Weir & Bypass Expansion (Illustration)


Sacramento
River
Agriculture
Sacramento
Weir Expansion
Pond
Bypass Expansion
Inundated Habitat
Pond

Tule Canal

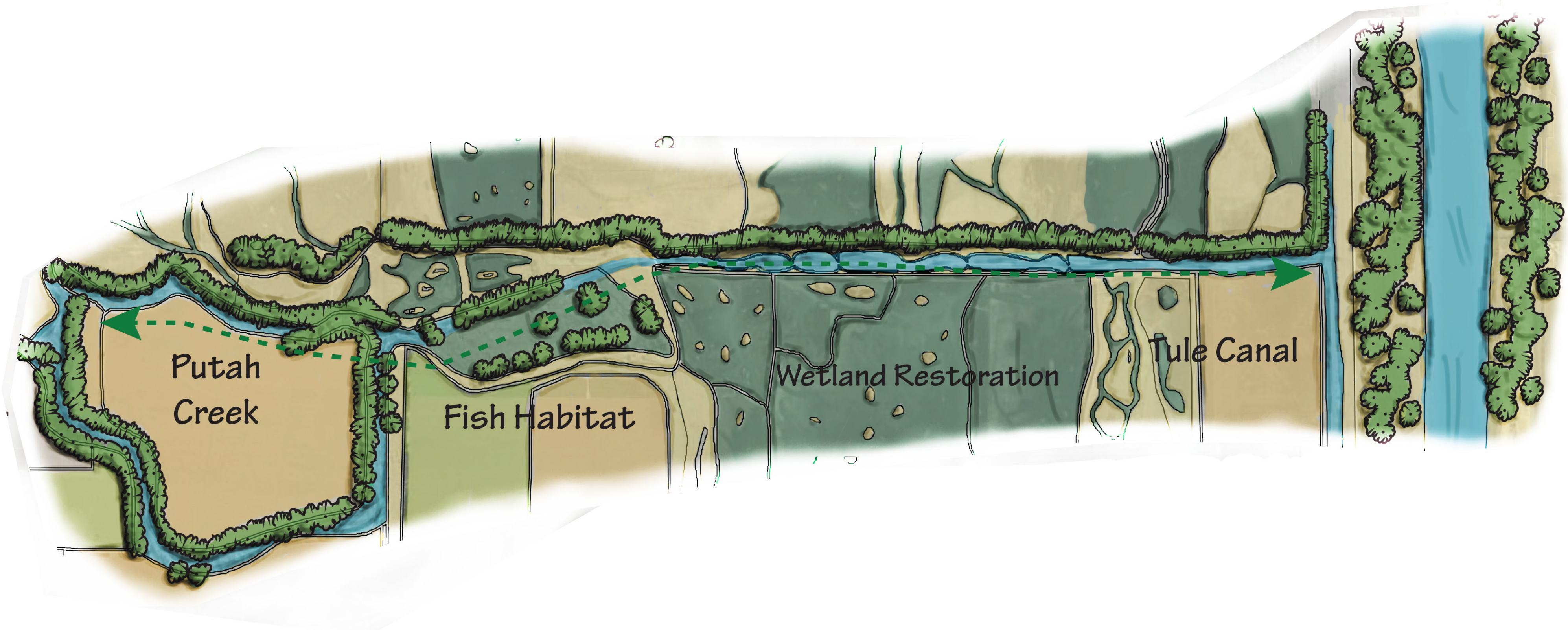
Putah Creek is a vital habitat connection to the Yolo Bypass. Many species such as otters and salmon have been seen traveling through out the extent of the Putah Creek. Many species cannot move farther north than the end of Putah Creek so the proposal of a small channel thaiweg and inundated floodplain could allow species to travel up the Yolo Bypass. Key to this strategy would be to restore the Tule Canal throughout the Yolo Bypass so specie can travel north to the Fremont Weir.



Tule Canal Connection

for fish passage

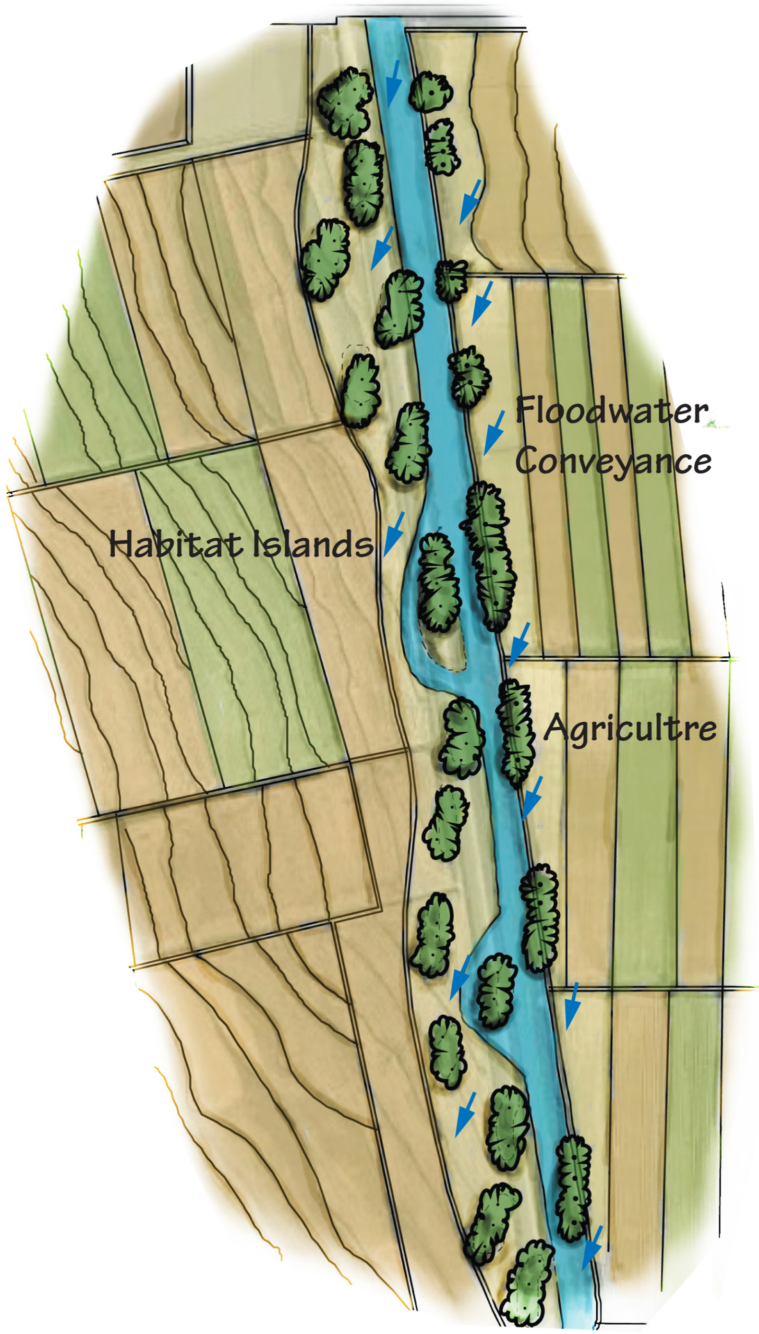
Figure 47.
- Tule Canal Connection


Putah
Creek
Fish Habitat
Wetland Restoration
Tule Canal

Habitat Islands

Habitat Islands can be created from the existing levee that wold become decommissioned if Yolo Bypass expansion were to occur. Instead of using resources to demolish the levee entirely, earth can be moved around to create habitat islands that connect green space. These islands can be designed in a parallel fashion with flood conveyance so not to slow flood waters or impede the overall conveyance of the water. These islands are particularly important during large scale floods as refuge islands for terrestrial species that would otherwise be drowned out

Figure 48.
- Habitat Islands (Illustration)


Floodwater
Conveyance
Habitat Islands
Agricultre

Vegetated Levee Setback

Levees can be designed for multiple functions that include flood control but also habitat function. Levees can be designed to have viewing corridors for both spotting failure mechanisms and recreational viewing.
The USACE standards specify 15' minimums from levee but their is the possibility for vegetation management strategies that use clearing techniques and low height standards to keep levee visibility high.

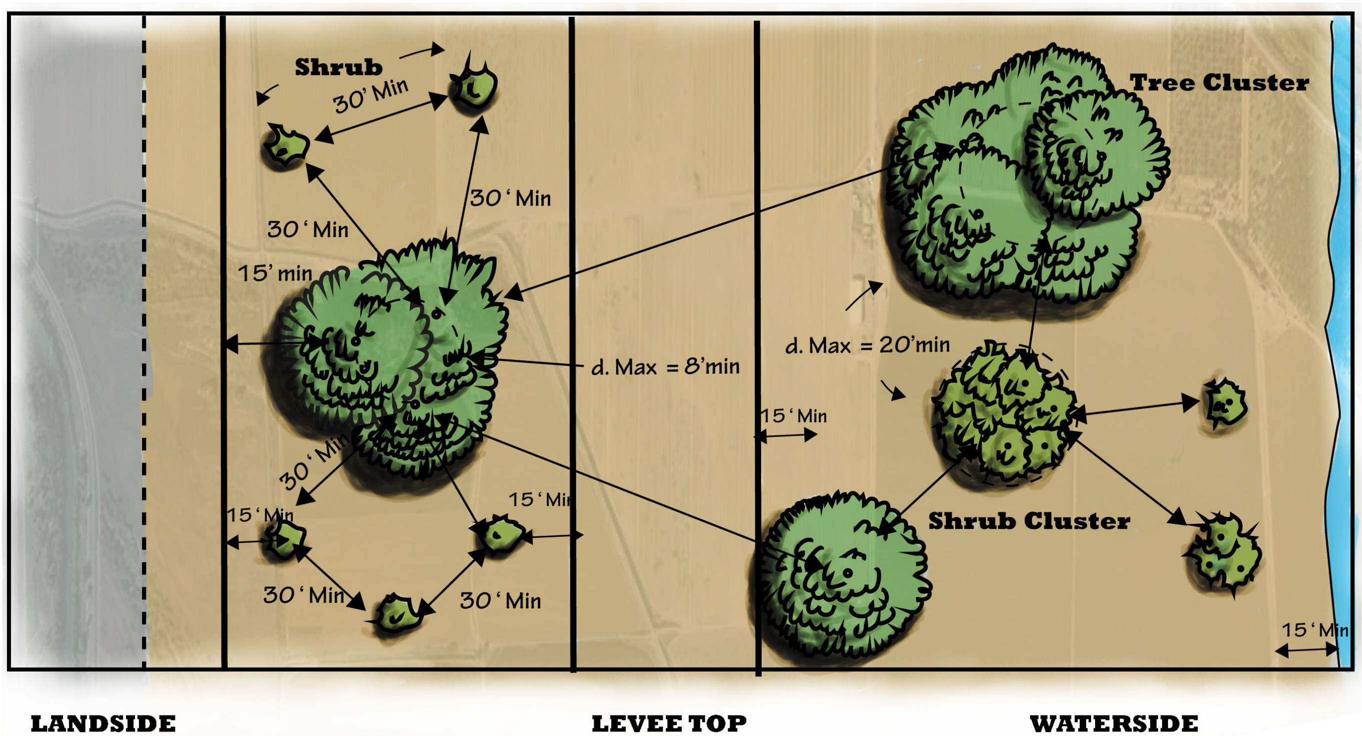


Figure 49.
-Vegetatied Levee Strategies (Illustration)


Agriculture
Levee Trail System
Levee Setback
Habitat Corridor
Riparian
Restoration

Agriculture

The Yolo Bypass is already a major area for agriculture. The areas that are just outside of the existing borders are most agriculture and would need to be re purposed for an expansion. Due to occasional flood water either crops capable of inundation such as rice or seasonal crops would have to be grown. There is also a new concept of carbon farming that focuses on soil carbon a the single most indicator of health. Benefits include healthier soils, better water usage, and high productivity. It is a suitable way to manage land for higher productivity and healthier profits while creating a buffer against unforeseen climate changes.

Figure 50.
-Carbon Farming (carbonfarminghandbook.com)

Recreation

Levees are a distinctive feature of the landscape that offer many amenities for recreation that are compatible with the long term structure and integrity of levee structures. The recreational activities include hiking , bicycling, fishing, birth watching, horseback riding and jogging. signage, information and design would help engage the public in outdoor activities while creating awareness about the importance of our flood control system of levees, canals and floodplains.

Figure 51.
-Yolo Bypass at sun set

Conclusion

In studying the site and flood control throught the California Central Valley many oppourtunities for landscape architecture exist. Due to climate changes and a deteriorating environmnet changes will be apart of the futre and it is our opputunity to design them. The Yolo Bypas should be expanded to atleast a 100 year flood level to secure the safety of the people and simultaneously the future of riparian habitat. For riparian corridors to maintain to their natural processes within a river watershed, there must be a n upland interior on both sides to act as a conduit for displaced species. Flood control is a seasoanl occurence and requires large amounts of open space great for recreational oppourtunities. Levee systems adjacent to habitat can provide recreational benefits as trail systems or green space for vegetaion and animals. Seasonal agricultre and crops capable of inundation could grow through out the floodplain of the bypass without impacting flood water conveyance. The Yolo Bypass could be the tool to secure our local communities from climate changes and floods while providing habitat, agriculture and recreational oppourtunities.

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