WETLAND DESIGN IN THE PUTAH CREEK PRESERVE

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LANDSCAPE ARECHITECTURE SENIOR PROJECT
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SIGNATURES

"WETLAND DESIGN IN THE PUTAH CREEK PRESERVE"

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ABSTRACT

The arboretum waterway is a detention basin which temporarily holds runoff from the UC Davis campus. The runoff contains many toxins and pollutants which are mixed with treated water from the campus wastewater treatment plant. This water is pumped into Putah Creek without further treatment. Although the treated wastewater has improved arboretum water quality, the water is still filled with contaminants which can harm already fragile riparian and river ecosystems.

This project aims to provide a viable method to filter the arboretum water before it flows into the creek by using a constructed wetland. This idea can be used in conjunction with plans for water treatment located in the arboretum itself.

The wetland site is located near the banks of Putah Creek in the Putah Creek Riparian Preserve, south of the UC Davis campus. It will add valuable habitat for many species while also providing recreational and educational opportunities for the community.

Included in this Senior Project are topographical maps, 3D models and site imagry.

The wetland design completed for this project is composed of small, interconnected ponds. This concept is intended to give a conceptual idea of what such a wetland might look like and perhaps to inspire the campus to construct a similar wetland.

ACKNOWLEDGEMENTS

I would like to thank members of my committee Steve Greco, Eric Larsen, and Andrew Fulks for helping me during the course of producing this project. I acknowledge Professor Steve Greco for bringing up the idea of constructing a wetland in the Putah Creek Riparian Preserve and for showing me how to build models in GIS. I would like to thank Eric Larsen for helping me along the way, especially with water quality and editing. Thank you to Andrew Fulks for his extensive knowledge on the happenings in the Preserve and for help with wetland layout and flow. Thank you to everyone not on my committee who contributed to this project, especially to David Phillips, for answering all of my questions.

Thank you to my family for supporting me during the past four years at UC Davis and to my classmates who created a strong support base for each other during the duration of the Landscape Architecture program at UC Davis.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES
ILLUSTRATIONS, MAPS AND PHOTOS

LIST OF FIGURES

Figure	Page

INTRODUCTION

WETLAND CONSTRUCTION IN THE PUTAH CREEK PRESERVE

This project is about solving an important problem. The problem is Arboretum Waterway water being pumped into Putah Creek without much prior treatment. The waterway acts as a detention basin for runoff from central campus. The water contains some substances which can harm wildlife and ecosystems in Putah Creek, along Putah Creek, and ultimately in the ocean. As a university, it is our responsibility to lead the way when it comes to sustainability and social stewardship. This issue provides a perfect opportunity for the university to do just that.

One solution to this problem is to build a wetland to filter the arboretum water. By building a wetland in the Putah Creek Riparian Preserve, UC Davis can drastically improve the quality of the water coming into the creek. The site selected for this wetland is a site which sits near the banks of Putah Creek, just south of the UC campus.

The wetland can not only improve water quality, but also habitat quality in the preserve. Its existence will take some stress away from the already severely altered Putah Creek. It is a viable solution to an issue the university has been dealing with for a long time. It can be built on its own, or in conjunction with water quality improvement plans taking place in the Arboretum Waterway itself.

RELATIONSHIP
PUTAH CREEK TO THE ARBORETUM WATERWAY

The Arboretum waterway and Putah Creek were once one and the same.

Before the University's establishment, the Arboretum Waterway was a flowing portion of Putah Creek. In the late 19th century, engineers diverted the creek to a southern route, and the remnant patch became the Arboretum Waterway. Originally, this isolated portion of Putah Creek flowed eastwards, but now it flows westwards due to dredging and grading. The storm water flows west, through a weir, into a pipeline, and then into the South Fork of Putah Creek (UC Davis Office of Resource Management and Planning, 2006).

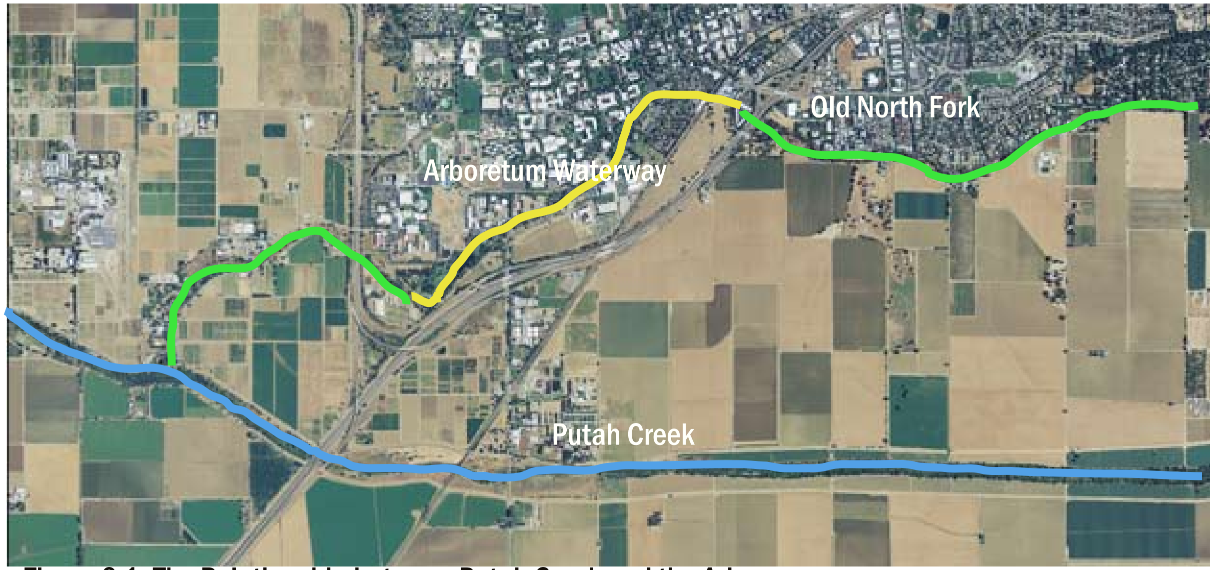


Figure 0.1: The Relationship between Putah Creek and the Arbore-

THE ARBORETUM WATERWAY

WHAT IS IT?

The Arboretum and its waterway are a integral part of the UC Davis campus. Students, faculty, and community members frequent the arboretum to enjoy its variable plant collections and to lounge on the grass bordering the waterway.

Volunteers help staff maintain the vegetation and propagate it. At the center of the Arboretum lies the waterway. Its water is murky, yet nonetheless, populated by animals such as ducks, geese, fish, and turtles.

The arboretum waterway is named as such because it is not quite a lake and not quite a river; it is a water detention basin. It temporarily holds all the water that runs off of the central UC Davis campus.

This is nutrient filled water containing all sorts of chemicals, pollutants, and garbage. The feces from animals inhabiting the arboretum adds to its putrid state and during the summer, algae blooms color the surface of the water a bright green hue. Even though the arboretum waterway flow seems stagnant, grading and pumping allows the water to flow westwards. Once it reaches a weir, the water flows into a pipe and directly into the local section of Putah Creek.

Figure 1.1: Arboretum Waterway. Source: http://www.onegate.com/go/og/blog/7-reasons-to-live-in-davis-ca/>

THE ARBORETUM WATERWAY

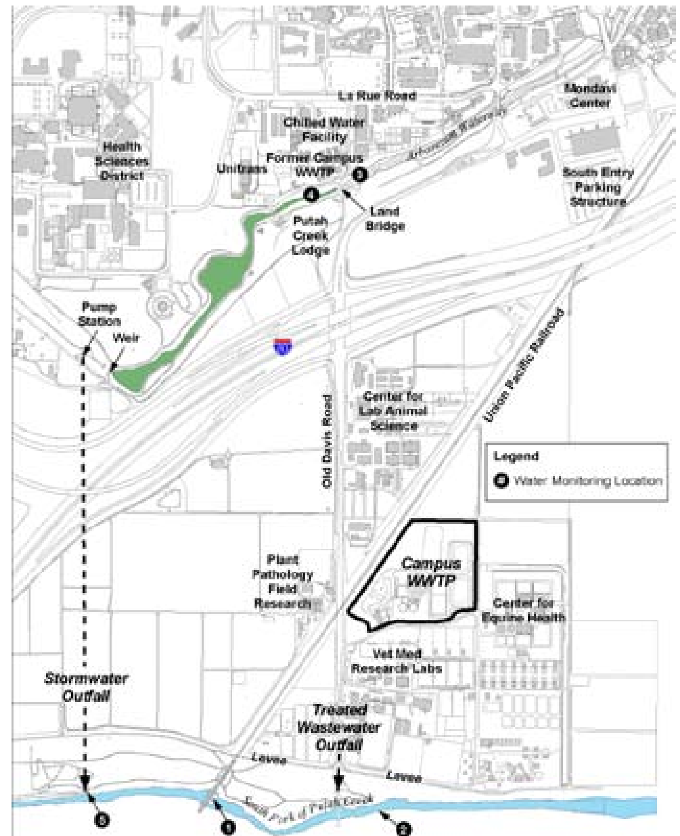
WATER IMPROVEMENT PROJECT

Wastewater Treatment Plant

In 2006, the campus decided to improve the water quality situation by pumping water into the arboretum from the campus Waste Water Treatment plant. The treated waste water improves water quality by keeping the water flowing year long. Before 2006, the water would remain stagnant during the summer. This project involves diverting the water into the east end of the Arboretum waterway using a previously abandoned 18" pipeline. Occasionally, the waste water is pumped directly into Putah Creek, so, nearly all of the campus waste water flows into the arboretum waterway (David Phillips, 2010)

Through grading and pumping, the water flows west through the arboretum, through a weir, then into a pump station which takes it into Putah Creek (UCD Office of Resource Management and Planning, 2006).

Figure 1.2: Effluent Flow Map



Map illustrates pathway water takes before reaching Putah Creek.
Source: David Phillips, Director of UC Davis Campus Facilities, 2010

FLOW IN AND OUT OF THE WATERWAY

According to a graph from David Phillips, Director of Facilities on campus, the mean daily flow of water from the WWTP into the arboretum is 1.5734 million gallons a day.

Unfortunately, when inquiring how much water is pumped from the arboretum waterway into Putah Creek, David Philips informed me that the campus has just recently installed meters to gauge flow in Putah Creek. So, no information is available yet.

I found this to be surprising, especially because the improvements project has been in place since 2006. What prompted campus to wait so long before finally installing measurement devices?

WATER QUALITY

Typical Contents of Runoff

Figure 1.3: Gunk building up in the West end of the waterway.

Stormwater runoff from the urban environment contains many substances harmful to humans and to wildlife. As this water flows over the constructed landscape it picks up a variety of contaminants.

One major contaminant in storm water is sediment from land uses such as construction. Sediment clouds the water and makes it difficult for plants to grow. Another major issue is excess nutrients from fertilizers used on lawns and landscaping vegetation. When the nutrients from fertilizers reach streams, they cause an increase in algae growth. When the algae dies, bacteira that consume it deplete the dissolved oxygen in the water which may cause major fish kills.

Bacteria and other pathogens from sources such as pet feces are another major problem, these are a health concern and can cause beach closures. Household hazardous wastes also end up in the storm water. This includes pesticides, cleaning solutions, painting solvents, motor oil, and other motor fluids. When these hazardous wastes end up in the water, they can poison the wildlife and contaminate drinking water.

Debris from the streets also ends up in the storm water. This includes used paper cups, plastic bags, six pack rings, etc. These are not only unsightly, but wildlife can also choke, suffocate, or become disabled by them

WATER QUALITY

Figure 1.4: Student taking water quality measurements Source: Putah Creek Project, 2008 < https://www.geology.ucdavis.edu/~pcp/photos/index.html >

Water Monitoring in the Arboretum

Over several years, a geology class taught at UC Davis has been working on the Putah Creek Project. As part of this project, the classes have been monitoring water quality in the waterway and analyzing the waterway's function as a system. The campus uses data collected to asses water quality. Although this project does not monitor levels of toxic chemicals, it does monitor levels of dissolved oxygen in the water. This is a useful indicator because it is effected by pollution and is instrumental for the survival of the aquatic organisms.

What is Dissolved Oxygen?

Many natural sources of dissolved oxygen in the water exist. Oxygen in the atmosphere exists in much higher levels (approximately 21 percent oxygen) than oxygen in water (Less than 1 percent).

So, on the surface of the lake, where air and water meet, the difference in levels is so large that oxygen molecules from the atmosphere dissolve into the water. More oxygen dissolves into the water when the water is turbulent because this increases surface area for the oxygen to dissolve into (Water on the Web, 2010).

WATER QUALITY

Photosynthesis by aquatic plants and algae also produces dissolved oxygen. Water temperature also affects dissolved oxygen levels in water. Cold water can hold more gasses than warm water. If the temperature is high enough, fish may not be able to survive in water even if it is 100 percent saturated. (Water on the Web, 2010)

Fish and other aquatic animals depend on oxygen to breath, as water passes through their gills, oxygen passes through and dissolves into their bloodstream. This process is very efficient, but only if dissolved oxygen content concentrations in the water are above a certain content. So, dissolved oxygen can be present in the water, even though organisms cannot process it. Oxygen is also needed by algae, Macrophytes, and several chemical reactions (Water on the Web, 2010).

In the Arboretum and other water bodies, seasonal changes also influence dissolved oxygen levels. Warmer temperatures during the summer months speed up the rate of photosynthesis and decomposition. When plants die at the end of the growing season and decompose, bacteira which consumes them takes up large amounts of oxygen which during some years, even causes fish kills in the arboretum.

Pollution impacts on Dissolved Oxygen

Pollution contributes some nutrients that demand oxygen (lawn clippings and sewage), and some nutrients that stimulate growth of organic matter (Such as fertilizer). Overall, pollution reduces dissolved oxygen concentrations in the water. If the organic matter, such as algae, is formed in the lake, than some oxygen is produced to offset the loss of oxygen from consumption of algae by bacteria. However, in lakes where much of the organic matter is brought in, oxygen production and consumption are not balanced.

Anoxia (lacking dissolved oxygen) occurs in some lakes during the summer.

WATER QUALITY

Typically, dissolved oxygen levels in the water rise during the winter and fall back down in the summer. Dissolved oxygen content may even fluctuate daily, as temperature changes.

Besides its effects on wildlife in the water, anoxia may cause increased release of phosphorous from sediments. This can further fuel algae growth in the upper portions of lakes. It leads to a build up of ammonium and hydrogen sulfide. These substances can be toxic to some organisms (Water on the Web, 2010).

Figure 1.5: Amounts of Dissolved Oxygen Organisms Need

Species type	life stage	no impairment	moderate impairment	limit to avoid death
salmonid	larvae or embryo	11	8	6
	other	8	5	3
non salmonid	early life stages	6.5	5	4
	other	6	4	3
invertebrates		8	5	4

Source: Water On The Web, 2010

How Much Dissolved Oxygen Do Organisms Need?

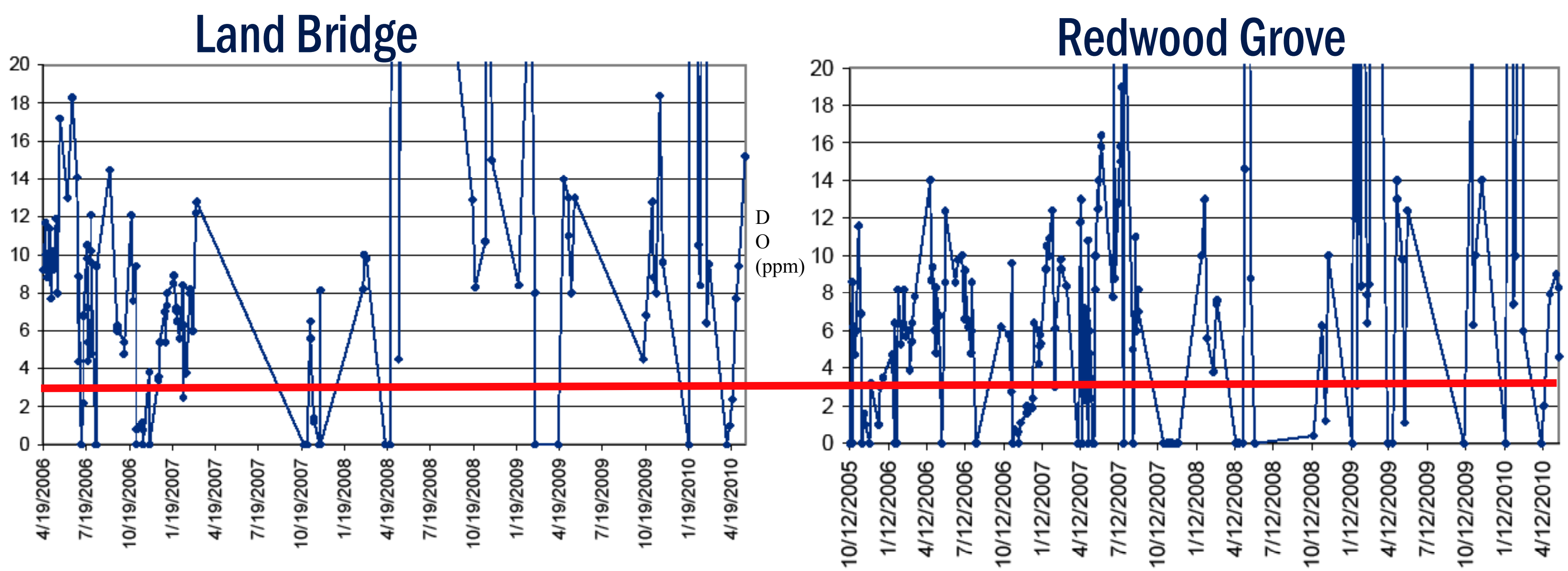
The table above shows amounts of dissolved oxygen aquatic organisms need in ppm (parts per million). The term Salmonid refers to fish of the Salmonid family or fish with similar characteristics to this family. This includes salmon, trout, and whitefish.

How Does This Apply to Arboretum Water Quality?

The UC Davis engineering class has been monitoring levels from different locations along the stream. For the purpose of demonstrating the issues with water quality in the arboretum waterway, I have graphed results from two locations. One is from the the redwood grove, in the eastern portion of the waterway. The second is from the land bridge, in a more western portion of the waterway.

WATER QUALITY

Figure 1.6: Water Quality Graphs



Graphs made from data provided by the Putah Creek Project, UC Davis.

WATER QUALITY

Graph Interpentation

The red line sits at 3 ppm, which is the minimum amount of dissolved oxygen for fishes to remain alive. Every point on the graphs below this line represents a lethal situation for wildlife.

The graphs show that levels of dissolved oxygen reached very low levels several times throughout the course of monitoring. This occurs even after 2006, when water from the wastewater treatment plant started getting pumped into the arboretum.

Potential Sources of Error

The dates on the graph indicate that measurements were usually taken only once daily (at most twice). Perhaps the low dissolved oxygen levels remained so low for very short intervals of time. Dissolved oxygen levels often change throughout the day as wind and temperature changes.

PUTAH CREEK BACKGROUND

Putah Creek is the main waterway in the Davis area. It originates from springs in the Mayacamas Mountains located northwest of campus. It flows into lake Berryessa, through Winters, along the south boundary of the UC campus, and into the Yolo Bypass. The North Fork of Putah Creek follows the historic channel, however, it currently has no natural flow.

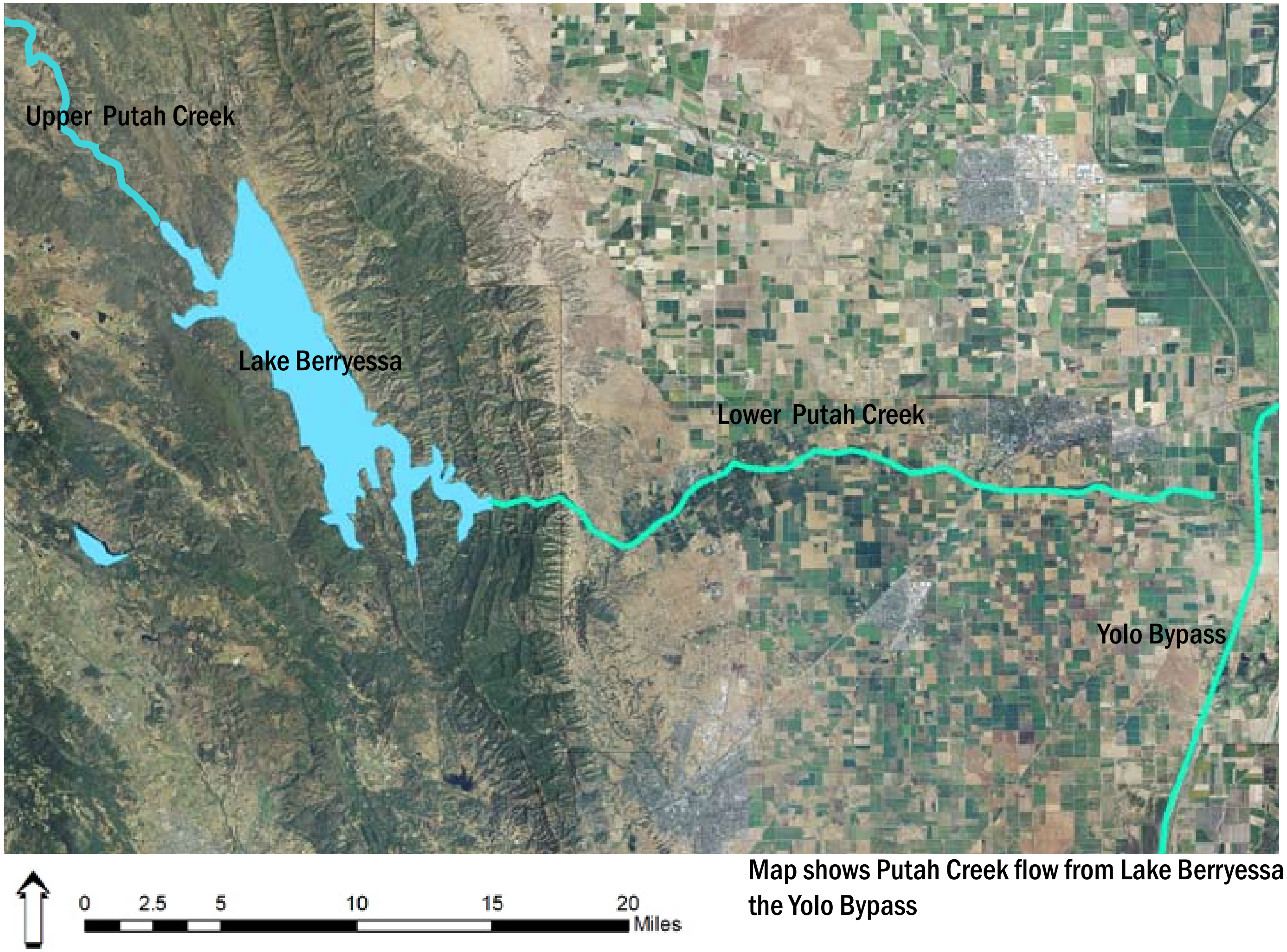
Several parts of the North Channel still contain historic riparian patches. Other parts are completely drained and used for raising of sheep and cattle (UCD Office of Resource Management and Planning, 2006).

Putah Creek is a valuable resource enjoyed by many of the locals and students. However, it is also an important resource for native wildlife, providing valuable remnant habitats and connective corridors for a variety of native species including birds, fishes, and invertebrates.

Human intervention along the creek and lands surrounding it, have significantly effected it. The damming of the creek has changed its structure, while agriculture and urban development have left portions of the creek degraded and in need of restoration. In some portions of the creek, only thin strips of riparian habitat remain. These are extremely valuable because only about 5 percent of riparian forests remain in tact today (Putah Creek Council, 2008).

Figure 2.1: Putah Creek and riparian vegetation.

Figure 2.2: CREEK FLOW MAP



Map shows Putah Creek flow from Lake Berryessa to the Yolo Bypass

THE MONTICELLO MONTICELLO DAM

Putah Creek is separated into two distinct sections by the Monticello Dam. The first section is the upper watershed which consists of 50 miles of river located above the dam. The lower Putah Creek is the second section which flows below the dam and spans 30 miles. The dam was completed in 1957 as part of the Solano Project and its existence created the reservoir called Lake Berryessa. The Solano project also included the Putah Diversion Dam and the Putah South Canal.

Dam's Effects on the Creek

The Dam effects Putah Creek structure in several ways. High floods occur more rarely, so the creek beds have become more silty. The dams also prevent gravel from the hills to reach lower Putah Creek.

Now, the main source of gravel to lower Putah creek is a tributary called Dry Creek. During floods, regulated water release from the dam cause Putah Creek water to flow below the level of its tributaries. This causes the water flow from the tributaries to accelerate as it converges with Putah Creek and leads to a faster than historical flow in Putah Creek. The faster flow leads to increased erosion and downcutting of streambanks (Putah Creek Council, 2008).

The Dam also blocks and restricts the passage of many species of fish to the lower portion of the creek causing species of fish in the upper portion of Putah Creek to be completely different from the species of fish found in the lower portion of the creek. Lower flows make it easier for invasive species to ground themselves along the shores.

Many of the invasive species grow in clumps along the creek. These clumps slow water flow and cause sediment buildup. In turn, the water is deflected into steambanks which causes even more erosion. (Putah Creek Counil, 2008).

Habitat Improvements

Habitats in and along the banks of the creek have been recovering due to several changes in management of Putah Creek, Lake Barryessa and the Putah Diversion Dam. In 1979, the California Department of Water Resources scaled back vegetation clearing in and along the creek. This increased vegetation cover, stabilized the creek bed and creating an overall more natural stream.

In 2000, the signing of the Putah Creek Accord, ensured a minimal flow to Lower Putah Creek. It required scheduled seasonal flows to ensure the passage of migratory fish such as the Chinook salmon and the steelhead. The Accord also secured permanent funding to monitor and restore Putah Creek habitats and appointed a streamkeeper to watch over the creek (Putah Creek Council, 2008).

Vegetation

Riparian woodlands are amongst the most valuable habitats in the central valley. The combination of surface water, ground water, fertile soils, nutrient availability, and layered vegetation in the riparian woodland, provides diverse conditions and habitats that can support a wide variety of species (US Army Corps of Engineers, 1996).

Figure 2.3: Landscape in the Putah Creek Riparian Preserve

The mixed riparian woodland along Putah Creek consists of a multi layered canopy which is dominated by deciduous trees and shrubs. The dominant trees in the overstory include Fremont's cottonwood, Goodding's Black Willow, black walnut and Valley oak. In the secondary layer, species such as Sandbar willow and Box Elder are typical. The herbaceous layer that grows along the creek banks includes several native and non native species. The native species in this area includes native wild rye, and purple needle grass. (US Army Corps of Engineers, 1996) Some of the predominant invasive species that grow in this habitat are arundo, eucalyptus, Himalayan blackberry, and wild oat.

Wildlife

The mature native trees along the creek provide habitat suitable for nesting and resting for a variety of birds. This includes Swainson's hawks, red-tailed hawks, great horned owls, wood ducks, and American crows. Some birds roost in mature trees and forage in the creek and uplands. These include Great blue herons, great egrets, snowy egrets, and black crowned night herons. Some species nest in cavities inside the mature strands such as western gray squirrels, woodpeckers, and bats US Army Corps of Engineers, 1996)

The river and riparian habitat also support a variety of insects and invertebrates. They provide food for resident and migratory birds and bats.

Lower Putah Creek supports at least 26 species of fish 17 of which are permanent residents. These species are composed of an-adramous fish, resident native fish, introduced resident game fish, and introduced resident non-game fish (Army Corps of Engineers, 1996).

Figure 2.4: Western gray squirrel
Source: North American Mammals , http://www.wildlifenorthamerica.com/ylang/es/Mammal/Western-Gray-Squirrel/Sciurus/griseus.html

Figure 2.5: Great Blue Heron
Source: Shari Green ,http://sharigreen.wordpress.com/2009/07/18/entertainment

Endangered Species

Several endangered species can be found in the vicinity of the site. Here is a brief list as listed by the US Army Corps of Engineers (1996).

Aleutian Canada goose (*Branta canadensis leucopareia*)

Listed as Federally Threatened.
It roosts in large marshes, flooded fields, stock ponds, and reservoirs. It forages in pastures, meadows, and grainfields and prefers corn.
Rare occurrences spotted in Yolo Bypass.

Above:Figure 2.6: Aleutian Canada geese
Source: Oceanwonderers mhttp://www.oceanwanderers.com/CAGO.Subspecies.html

Figure 2.8: American peregrine falcon
Source: Bird Forum, http://birdforum.net/opus/index.php?title=Peregrine_Falcon&diff=cur&oldid=119438

American peregrine falcon *(Falco peregrius anatum)*

Listed as Federally and California Endangered.
Nests on protected ledges of cliffs adjacent to water bodies that support large populations of birds.
Occasional winder occurrences in Yolo Basin and the Sacramento River.

Swainson's hawk *(Buteo swainson)*

Listed as California Threatened.
Nests on oaks or cottonwoods in or near riparian habitat. Forages in grasslands, irrigated pastures, and grain fields.
Nests along the Sacramento River, Yolo Bypass, and Putah Creek.

Left: Figure 2.7: Swainson's hawk
Source: Dana Beaton, http://www.buttehcp.com/

Figure 2.9 Chinook Salmon
Source: wildernessclassroom.com

Winter-run chinook salmon *(Oncorhynchus tshawytscha)*

Federally listed as Threatened.
Occurs in riverine habitats.
Occurs in the Delta and along the Sacramento river.

Giant Garter snake *(Thamnophis gigas)*

Listed as Federally and State Threatened.
Lives in sloughs, canals, and other small waterways. Prays on small fish and amphibians. Requires grass banks and emergent vegetation for basking and high ground protected from flooding.
Occurrences observed in Yolo Bypass.

Valley elderberry longhorn beetle (*Desmocerus californicus dimophus*)

Listed as Federally Threatened.
Lives in riparian and oak savannah habitats containing elder berry shrubs.
Suitable habitat in Yolo bypass.

Figure 2.10: Giant Garter Snake
Source: Wikipedia, http://en.wikipedia.org/wiki/Thamnophis_gigas

Figure 2.11: Valley elderberry longhorn beetle
Source: http://courses.cit.cornell.edu/icb344/abstracts/valley-elderberry-beetle.htm

Several species listed as Threatened or Endangered can benefit from the addition of a wetland in the Putah Creek Riparian Preserve. For example, the Canada goose can roost in the wetland habitat and forage in surrounding farmland and meadows. The Swainson's hawk can roost in cottonwoods planted near the wetland and forage in the nearby farmland.

CONSTRUCTED WETLANDS BENEFITS

Constructed wetlands are engineered water basins that aim to treat water by utilizing natural processes. Aside from treating runoff, wetlands can be utilized as the final treatments of sewage waste water.

Hydrological

Over time, humans have altered the natural hydrology of many landscapes by building dams and levees that restrict natural water flow. Wetlands have been routinely drained for other uses such as agriculture and urban development. This led to a 50 percent loss of wetlands in the United States, and in several particular states, wetland loss is as high as 90 percent.

Regions that have lost large percentages of wetlands also tend to suffer from flooding impacts. This is due to wetlands' ability to absorb excess stormwater runoff and then slowly release the stored water. This reduces peak flows while lessening chances of flooding. By constructing wetlands and restoring natural systems of wetlands, regions can benefit from less flooding and reduced peak flows (France,2003) .

Contaminant Sinks

Wetlands also act as contaminant sinks. This involves physical, chemical, and biological pathways.

Physically, contaminants are removed from the water as the water moves through the system through sedimentation, filtration, absorption, and volatilization (France, 2003).

Sedimentation refers to the process in which suspended solids in the water settle due to gravity. The rate in which debris settles relates to its characteristics (EB, 2010).

Filtration occurs when water passes through vegetation and soils in the wetland and separates the fluids from the solids thus, cleansing the water.

Absorption refers to the process in which the soils and plants take in nutrients and contaminants and retain them. Volatilization refers to the evaporation and vaporization of water and contaminants from the wetland.

BENEFITS

Chemical Breakdown

Chemical reactions within a wetland transform one compound into another. An example is the process of denitrification which involves the reduction of nitrates into nitrite. This process is aided by bacteria and enzymes which break down compounds (Merriam-Webster, 2010).

Wetlands cycle nutrients repeatedly through the process of growth and decomposition. This contributes to the accumulation of organic matter in wetlands. Removal mechanisms and rates depend on the specific wetlands and their surroundings (France, 2003).

Biodiversity

Wetland shorelines are dynamic and contain fluctuating water levels. This attracts a wide range of terrestrial and aquatic plant and animal species many of which are endangered. They are also among the most botanically productive ecosystems and support a high ratio of animals for their surface area. Varied water depths provide habitat suitable for the life history needs of many aquatic animals providing habitat for breeding, spawning, nesting, feeding, etc.

Downstream ecosystem also benefit from wetlands because they feed from the materials that flow down the river (France, 2003).

Humans

Wetlands have an aesthetic value and provide naturalistic open spaces. They can be used for recreational activities such as: jogging, biking, bird watching, walking, photography, painting, and picnicking. Additionally, they can be used as an educational resource for surrounding communities with the usage of informative signage, guided tours, and school field trips (France, 2003).

EFFICIENCY

Wetlands are efficient at removing toxins from the water. The table below shows representative removal rates reported by several different studies of retention and detention basins. Removal rates are usually higher for retention basins because they hold water permanently, or until it evaporates or dissolves into the ground.

Figure 5.1: Wetland Efficiency

Pollutant	Percentage Removal
Suspended sediment	40-75%
Total Phosphorus	20-50%
Total Nitrogen	15-30%
BOD	30-65%
Lead	40-90%
Zink	20-30%

Source: Marsh, 2005. Based on a compilation of various sources by Michael Sullivan Associates, Austin, Texas.

Figure 3.2: The Davis West Ponds, a functional constructed wetland system for runoff and flood management.

CONSTRUCTED WETLANDS
DESIGN AND CONSTRUCTION GUIDELINES

To function properly, wetlands must be graded and constructed properly. There are several main guidelines that come into play when it comes to constructed wetlands.

Here, I will briefly discuss several guidelines which I used to design the wetland in the Putah Creek Preserve.

Size

According to France, constructed wetlands must be a certain size in order properly serve their surroundings. In general wetland size should be two to four percent of the watershed it serves in order to hold enough water and treat it. This number can be reduced to one or two percent if pre-treatment of water is incorporated.

It should take the water ten to fifteen days to pass through the system for it to effectively remove most contaminants. It will take variable amounts of time for each contaminant to be removed.

Structure

Several small wetlands offer an opportunity to more easily avoid sensitive areas on site. They also increase the surface area interface (France, 2003).

When it comes to maintenance, a wetland with multiple cells is much easier to manage because one or two ponds can be drained at a time without closing the entire wetland complex. It also allows for more control of the water levels in the complex and for cells to specialize in removal of a particular contaminant (EPA, 2000).

Shape

Constructed wetlands must avoid rectangular shapes, straight channels, and rigid edges. They should be constructed with sinuous paths and borders and incorporate existing landforms when possible (EPA 2000). This minimizes impact on site, raises surface area, and reduces chances of dead edges (edges with no water movement).

They should also incorporate a variety of different side slopes. This increases the surface area interface and allows for increased interactions between the water, soil, plants, and animals. It provides more irregular shorelines which add habitats for animal populations . Additionally, rounded edges minimize the possibility of dead edges, which are areas where water filtration does not occur. This naturalistic approach to design also adds aesthetic value to the wetlands(France, 2003).

Slopes

Slopes are also an important aspect because they help to regulate water flow. Longitudinal slopes should be very gradual and not exceed 0.5-1.0 percent. On level sites, treatments can include berms and dikes and on sloped sites, cells can be terraced into the landscape.

Vertical slopes, or slopes of the shorelines of ponds should be graded between the ratios of 3:1 to 5:1 to provide access for wildlife and limit erosion. This also provides opportunities for water levels to gradually drop and rise.

The varied slopes add habitat value for a variety of different plants. Marginal trenches can be used to prevent plants colonizing the open water areas in a wetland (France, 2003).

Islands

Islands are another important aspect of wetland design. Their existence promotes water storage by increasing the flow travel time. Islands more than half an acre in size, provide sanctuary for wildlife from humans and predators. Low and irregular islands make ideal water fowl habitats because their shape increases edge habitat.

Islands reduce the distance that waves travel, which decreases the opportunity for solids to become re-suspended in the water and for transport of solids downstream (France, 2003).

DESIGN AND CONSTRUCTION GUIDLINES

Buffer Zones

Buffer zones provide a natural transition zone. Riparian habitats in this zone provide nesting habitat for birds and shade they provide helps regulate wetland temperature. When planting these buffer zones, it is important to consider and design natural corridors which connect the wetland habitats to the rest of the landscape. Corridors will allow for populations to intermix and travel to and from the wetland (EPA, 2000). When possible, these zones should be at least 3oo feet wide to provide adequate habitat.

These buffer zones also provide safety zones which can store additional storm water during a major flooding event (France, 2003).

HABITATS

The design features of this wetland will provide habitats for many different species. Even though the wetland will cut into the existing riparian corridor, it will provide riparian habitat along its edges and new habitats for many species.

Figure 3.3: Waterfowl in a wetland
Source: www.sierraclubcalifornia.org/wetlands.html

Design Features

Here are some of the design features and the species which will use them. Taken from the Wildlife Habitat Enhancement and Management Plan for West Davis Pond, 1989.

Small Islands will provide habitat for shorebirds and waterfowl for nesting and resting.

Permanently flooded channels will provide habitat for waterfowl, warm water fish, frogs, and crustaceans.

Mudflats and seasonal wetlands will provide seasonal habitat for fish and crustaceans and will provide sources for feeding of waterfowl.

Shoreline riparian and wetland planting will provide wildlife cover and waterfowl food production.

Basin slopes will provide foraging habitats for waterfowl and songbirds. Will also provide nesting habitats for ground squirrels and burrowing owls.

Native planting will act as wildlife cover, songbird feeding habitat, and roosting habitat.

SITE ANALYSIS

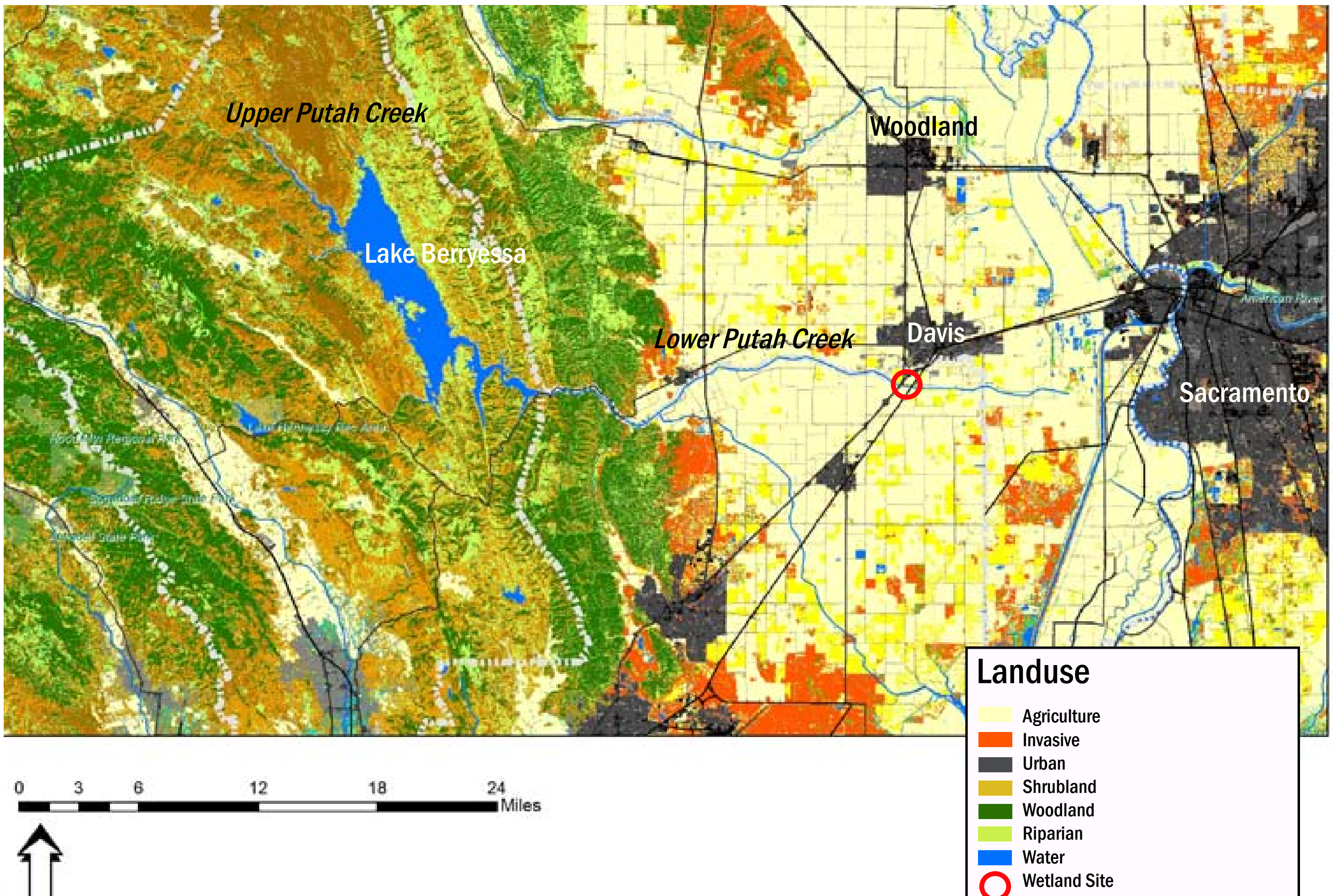
On my first visit to the site, I instantly fell in love with it; I also instantly knew why. It is an in between sort of place, the kind of place that organically evolved over time. Nobody really planned it or had a grand notion of what it must be. It represents the convergence between human activities and nature. The two elements together extenuate each other's beauty.

The first time I came to the site, I entered through the west end. The highway bridges welcomed me in as gates. The place has a magical feel. Walking into it is like discovering Terabithia; a secret and wonderful sort of world.

Figure 4.1: West Entrance

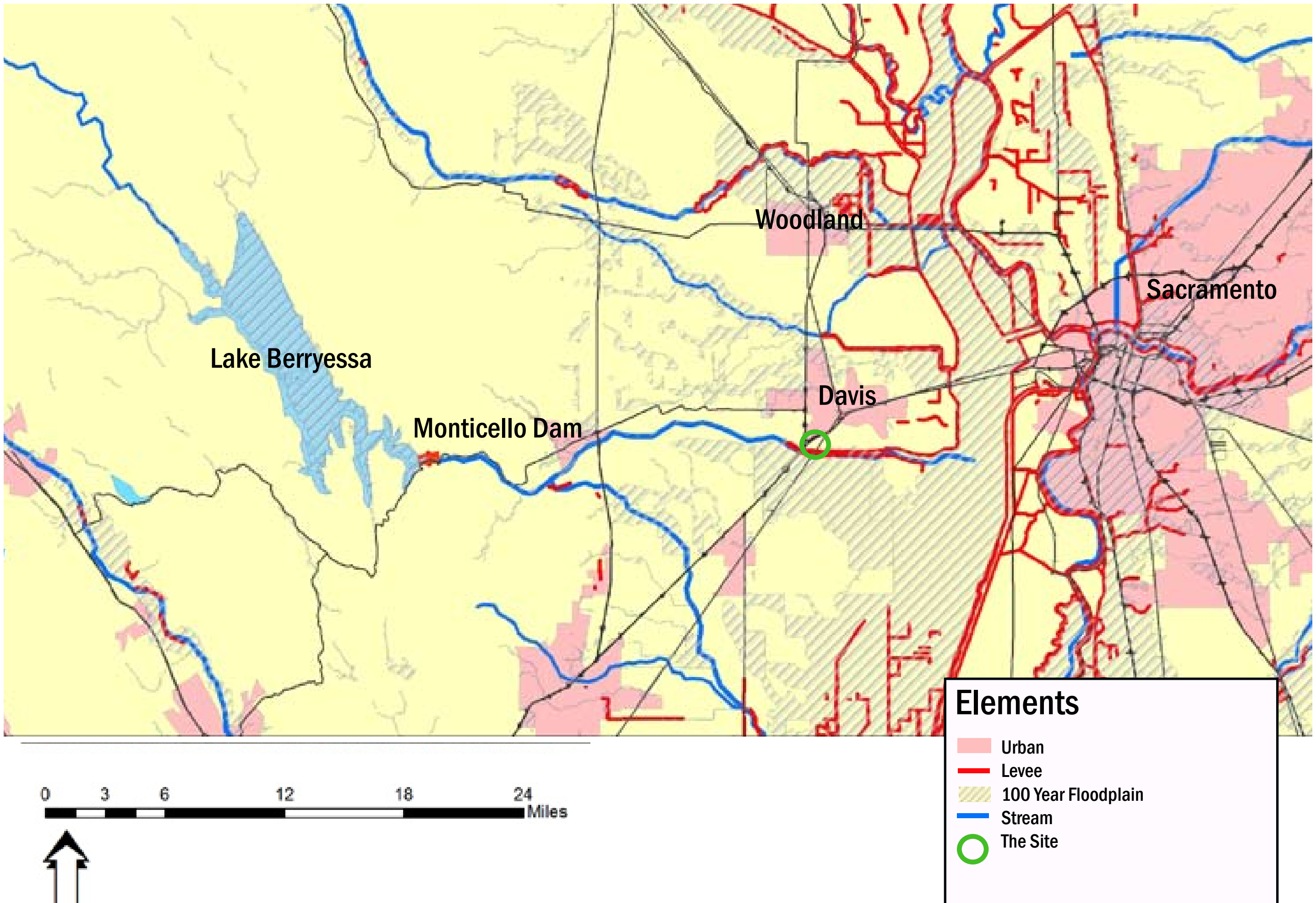
CONTEXT

Figure 4.2: Landuse Map



CONTEXT

Figure 4.3: Hydrology Map



CONTEXT

Context-Landuse Map

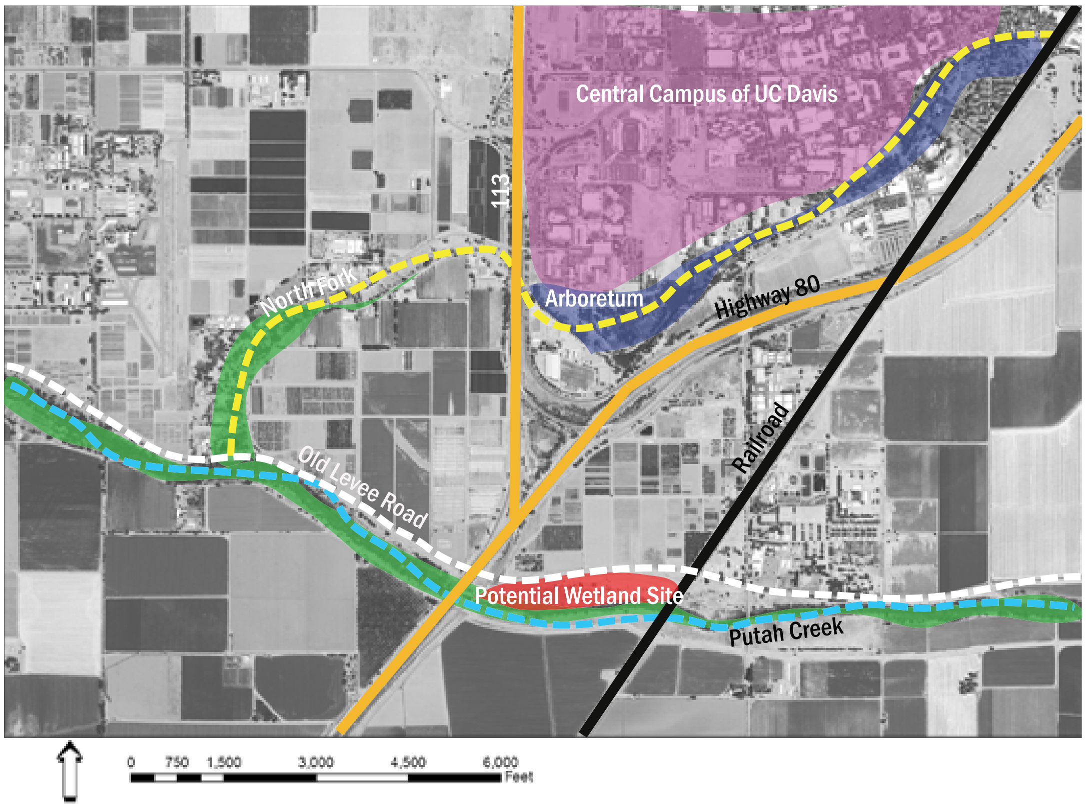
The map on page 27 shows the context of the site. It sits on the banks of Putah Creek near the UC Davis campus. Its located in the Central Valley of California. The map shows Lake Berryessa as well as surrounding cities, roads, and vegetation types. It also shows that the site is surrounded by agricultural land. The surrounding mountains contain chaparral, various types of woodland vegetation, riparian vegetation, and extensive invasive vegetation.

Regional Hydrology Map

The map on page 28 shows the regional hydrology of the site. In red are the levees and dams. The map depicts levees along Putah Creek and the Yolo Bypass. It also shows areas that are in the 100 year floodplain.

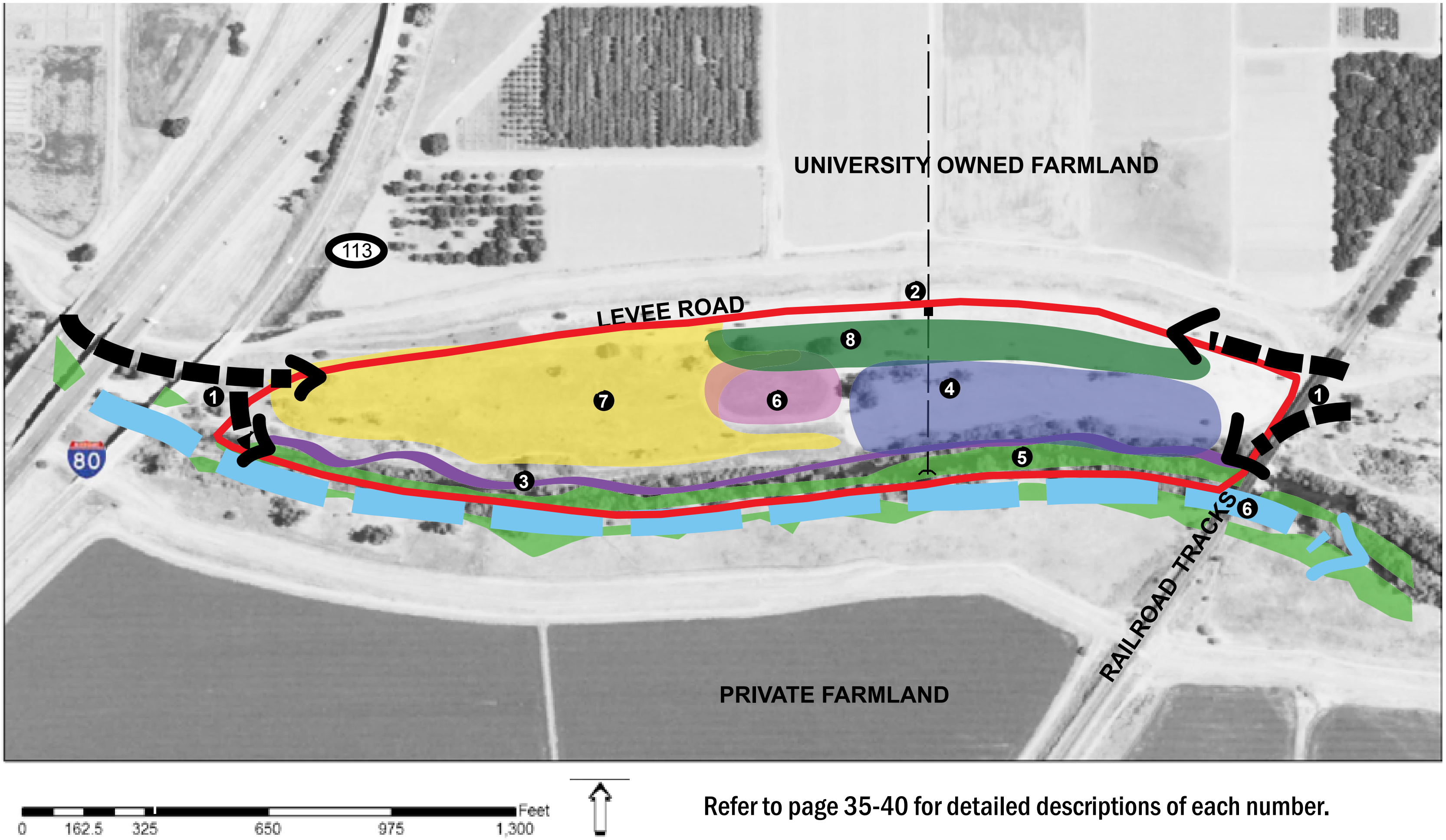
The map shows the site as part of a larger water system and how the site relates to its regional watersheds.

Figure 4.4: THE SITE IN RELATION TO THE ARBORETUM



This map shows the the location of the potential wetland site in relation to the campus, the arboretum waterway, the levee, and surrounding roads.

Figure 4.5: SITE CLOSEUP



Refer to page 35-40 for detailed descriptions of each number.

SITE DESCRIPTIONS

This site is a remnant, defined by what is around it. A hodge-podge of uses and purposes have evolved here over time. Its sense of place and identity evolved over time, piece by piece, and not usually by intentional design. These elements came together to create the site as we see it today.

#1 Entrances

The site itself is off the beaten path. Locating it can be fairly difficult. There are two ways to enter.

One way is by traveling on the old levee road along the former Putah Creek channel. Once reaching the gate of the Putah Creek Preserve, walk or bike 2/3 of a mile on the levee towards the convergence of highway 113 and I80. Once reaching the highway bridge, the road dips down into the site.

Another method of entering the site is by driving down Old Davis Road, past the Wastewater Treatment Plant and making a right at the Levee Road. From there, just walk down the footpath towards the West.

Figure 4.6: The West Entrance.

SITE DESCRIPTIONS

#2 Pipework

Top: Figure 4.7: Outflow pipe into Putah Creek

Figure 4.8: The Check Gate valve box

On my first site visit, the primary thing I needed to do was look for the arboretum water outflow pipe. Not surprisingly, this pipe was fairly hard to find. I actually found it pretty quickly, but the opening itself was submerged underwater to the extent that I could not see the water leaving the pipe. I expected the pipe to be more visible and noisy, so I continued to look for it even after I found it. The outflow is underneath a metal mesh surrounded by riparian trees and shrubs.

When walking in a straight line from the outflow pipe to the levee, I could see a concrete box on top of the levee. This is a check gauge valve for the Arboretum Waterway discharge pipes. It keeps debris out of the   pipe during low flow, and can also be used to restrict flow. Looking through the mesh on the gauge, one can see the water flowing through the pipe.

SITE DESCRIPTIONS

#3 Pathways

Figure 4.9: Visitor walking on path.

Formal and informal pathways weave through the site. After the rain, the pathways become very muddy. It appears that horses regularly use these paths because the hoof prints they leave behind dot the trails.

Many visitors take a hike and bring friends, family members, or pets with them. Some of the visitors remain on the levee road and do not pass under the bridge or walk through the riparian preserve. I have not encountered anyone sitting or observing the site.

#4 Wetland Potential

This area borders a terrace to the north. It contains potholes which sometimes fill with water during the winter. This is a good potential area for the wetland because of its natural contours and location in proximity to the check gate valve.

Figure 4.10: Site near the East end, with potential for wetland construction.

SITE DESCRIPTIONS

#5 Remnant

This is the riparian habitat growing along the creek. It is very thin in some areas and wider in other areas. The trees in this area shade the creek.

#6 Illegal Activities

Graffiti adds color and interest to the concrete bridges and rusty rail road bridge. It is most prevalent on the east side of the site underneath the railroad bridge. Here, people have climbed onto the bridge platforms built in the stream and have drawn elaborate graffiti on the bridge's poles. Discarded spray cans and beer cans litter the area. The graffiti itself however, adds an ever-changing point of interest to the site. It is quite enjoyable to sit on the bridge platforms with legs dangling down from the edge while enjoying the the shade and the breeze and gazing at the intricate artwork.

Figure 4.11: Graffiti under the railroad bridge.

SITE DESCRIPTIONS

#7 Restoration Efforts

Efforts to maintain the site and provide habitat for wildlife are apparent on site. The yellow area has been seeded with native grasses. Young eucalyptus trees lie in piles along the site showing the efforts of management to eradicate them. Bird boxes also hang from many of the trees.

Left: Figure 4.12: Native grasses area
Top: Figure 4.13: A bird box

SITE DESCRIPTIONS

#8 Oak Planting

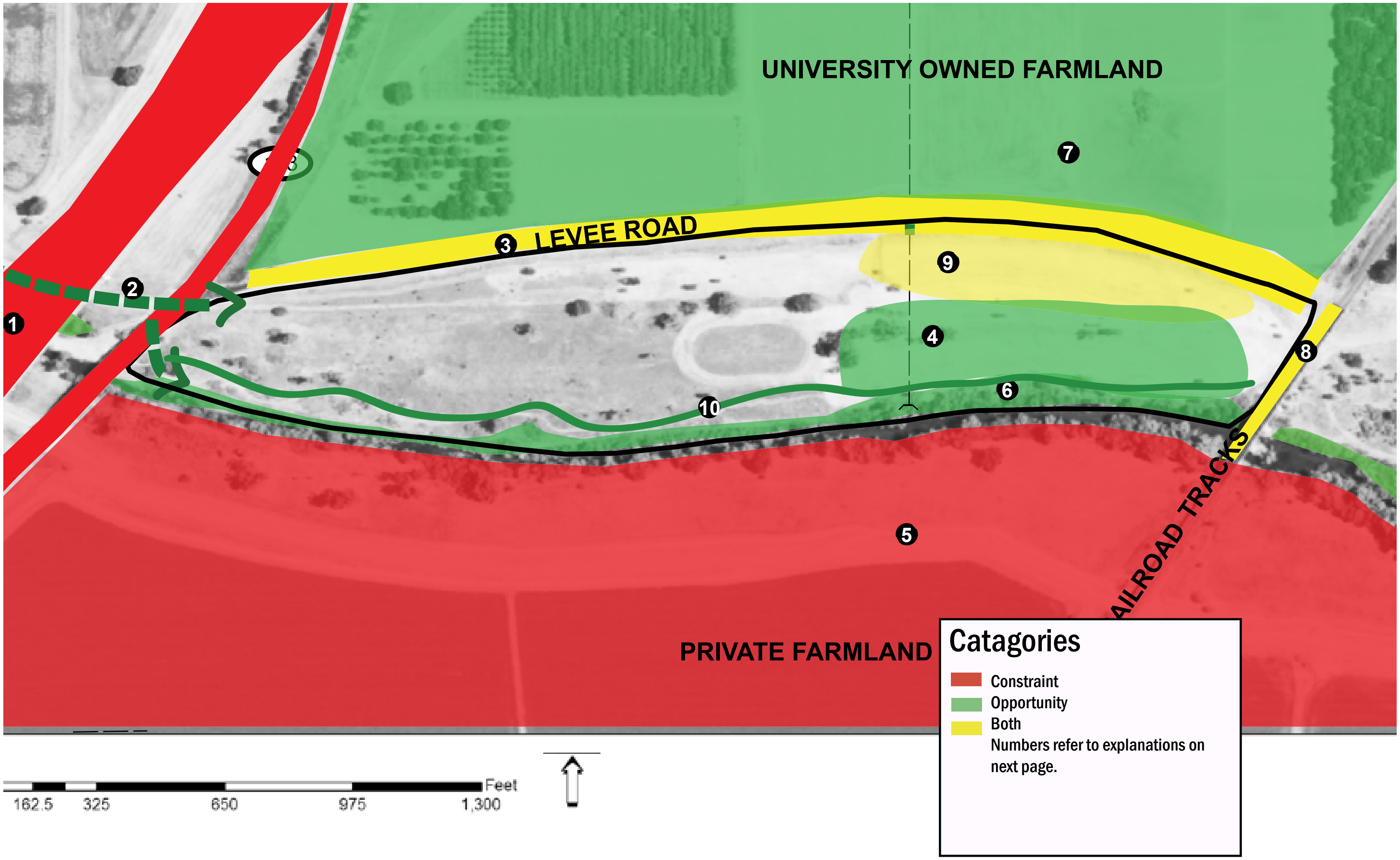
This upper terrace has been planted with oak seedlings according to Andrew Fulks, Manager of the Putah Creek Preserve. They can provide shade for the the potential wetland and will provide valuable habitat for birds, mammals, and insects.

Overall

Over time, the site has been shaped by the urban infrastructure surrounding it, by the native remnants of historical ecosystems, by the river running through it, by human restoration efforts, and by visitor activities (whether legal or not). All these factors came together to create the site as we see it today. It is a tranquil place not frequented by many visitors and a good place to visit for a nice walk along the creek.

Figure 4.14: Putah Creek, the riparian corridor, and the railroad bridge. This shows the relationship between infrastructure and nature.

Figure 4.15: OPPORTUNITIES AND CONSTRAINTS



SITE ANALYSIS
OPPORTUNITIES AND CONSTRAINTS DESCRIPTIONS

#1 Highway

The bridge is a constraint on the site because it adds noise, air, and visual pollution. Cars driving by sometimes drop garbage from windows.

#2 Underpass

The underpass is an opportunity because it allows wildlife to pass underneath the highway. The bridges frame the site and provide an interesting entrance.

#3 Levee Road

Levee road is an opportunity because it connects the site to the rest of Davis. Service vehicles and visitors can use this road to get to the wetland or for maintenance purposes.

The Levee road is a constraint because it restricts the types of structures which can be built in the area. The levee also acts as a wall, separating the site from its surroundings.

#4 Lower Terrace

This area is near the check gate valve, it has natural topographical variations and borders the creek. It is an appropriate location to construct a wetland.

#5 Private Farmland

The south side of the bank is privately owned, so it is out of limits when it comes to design and usage.

#6 Remnant

The riparian remnant is a corridor for wildlife. It also shades the river, which creates niches for aquatic wildlife. The Wetland will add riparian areas to this corridor.

#7 UCD Farmland

This farmland is already owned by the university, so this gives the opportunity to design elements that include the farmland.

OPPORTUNITIES AND CONSTRAINTS DESCRIPTIONS

#8 Railroad Bridge

A constraint because it is noisy and rusty. People who leave graffiti on this site also tend to leave garbage (particularly spray and soda bottles).

An opportunity because the areas underneath it are points of interest on site.

#9 Oak Planting Area

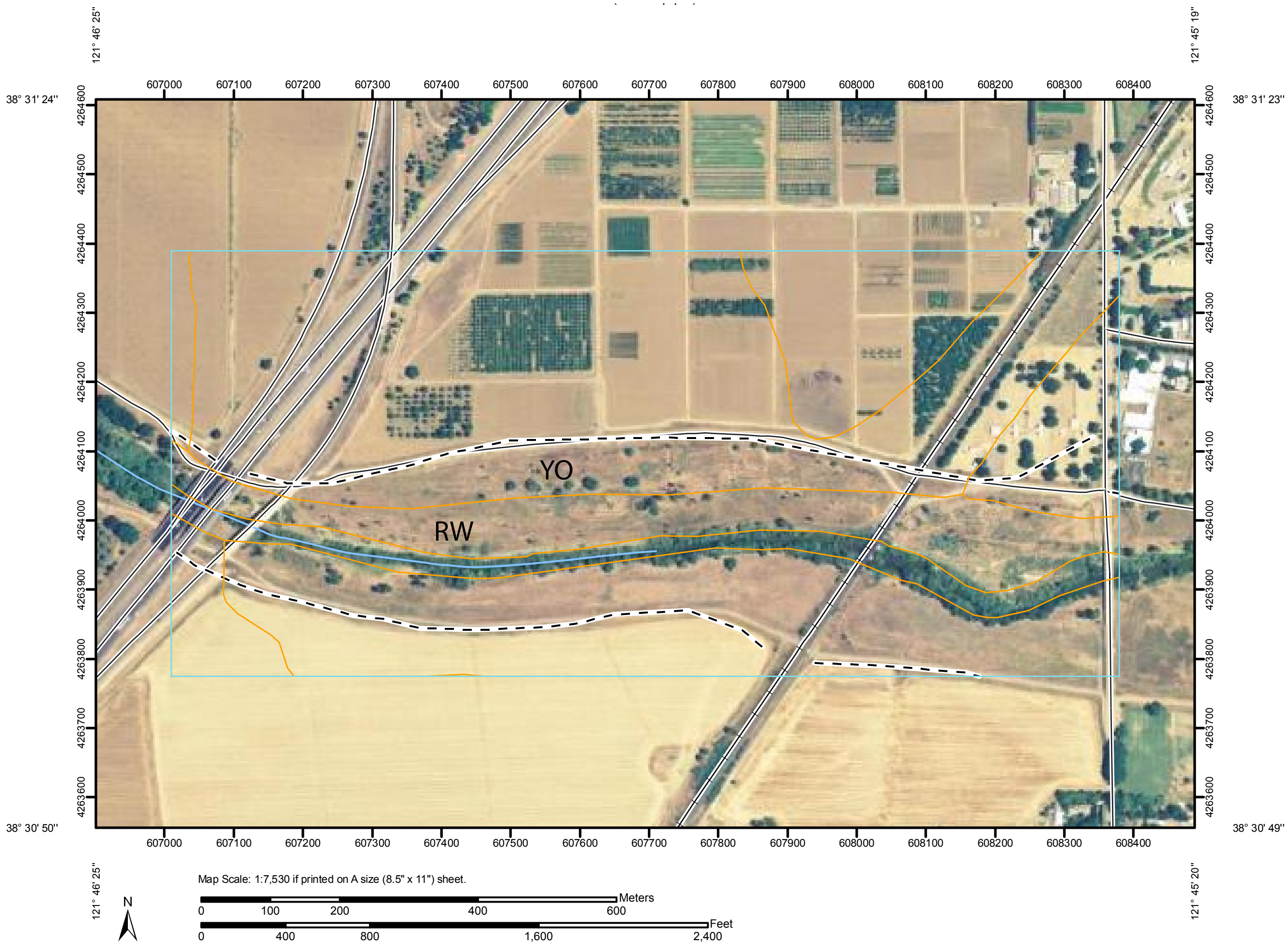
Mostly an opportunity because it will add a riparian buffer zone around the wetland which will increase wildlife habitat. The trees can provide shade for some of the pools.

It is a slight constraint because the wetlands cannot be build here due to oak plantings.

#10 Trails

Already existing trails can be used in the design to get visitors to the site.

Figure 4.16: SOILS



USDA Natural Resources Conservation Service

Web Soil Survey
National Cooperative Soil Survey

5/13/2010
Page 1 of 3

SOILS AND WATER

RW-Riverwash

The wetland site is mostly located on this type of soil. Riverwash is classified as "Excessively Drained" which means that water is removed from the soil very rapidly. The parent soil is sandy or gravely alluvium. This type of soil is also frequently flooded (USDA, 2010).

YO-Yolo Loam

The north part of the site is located on this type of soil. It is classified as "Well Drained" meaning that water is removed from the soil fairly quickly, but not rapidly. The parent soil is alluvium derived from sedimentary rock (USDA, 2010).

Flooding

According to Andrew Fulks, the site floods occasionally even though the Monticello Dam and Solano Diversion Dam have prevented Lower Putah Creek from flooding as it would historically.

When the site does flood, the wetland design must accommodate the extra water and drain it back into the river.

Accomidation for Soils

Since the site contains well drained soils, it will most likely be necessary to line the pools with 16-20in of clay. This will prevent major leakage of contaminated water into the water table.

DESIGN INTENT

As landscape designers we are inclined to give our landscapes some kind of great purpose. We want to design them and make them more useful in one way or another. However, as designers, it is also important to know when our expertise is not needed and recognize that sometimes organic growth is more appropriate than purposeful design.

Even though I aim to instal a wetland on this unnamed site, I want it to keep its character because, as populations grow and cities expand, every scrap of space becomes utilized for a defined purpose. Even in a public park, visitors are instructed on where to eat, to sit, to play, and to walk, by the layout of the park and placement of structures. However, I see importance in leaving some of these patches of remnant space as is, or only making minor changes. People need spaces that are not necessarily free of restrictions, but that retain the feeling of being free of restrictions. This site certainly portrays an air of tranquility and freedom seldom found in intensely designed landscapes.

DESIGN PROCESS

I assessed the site by doing research and conducting a site analysis. Then, I created several concepts for the potential wetland. Initially, I intended to design a single large pond on site, however, due to the shape and size of the site, I was advised to design a series of smaller ponds . This is to control water residence time by pooling the water and thus, slowing it down. Smaller pools are also easier for maintenance

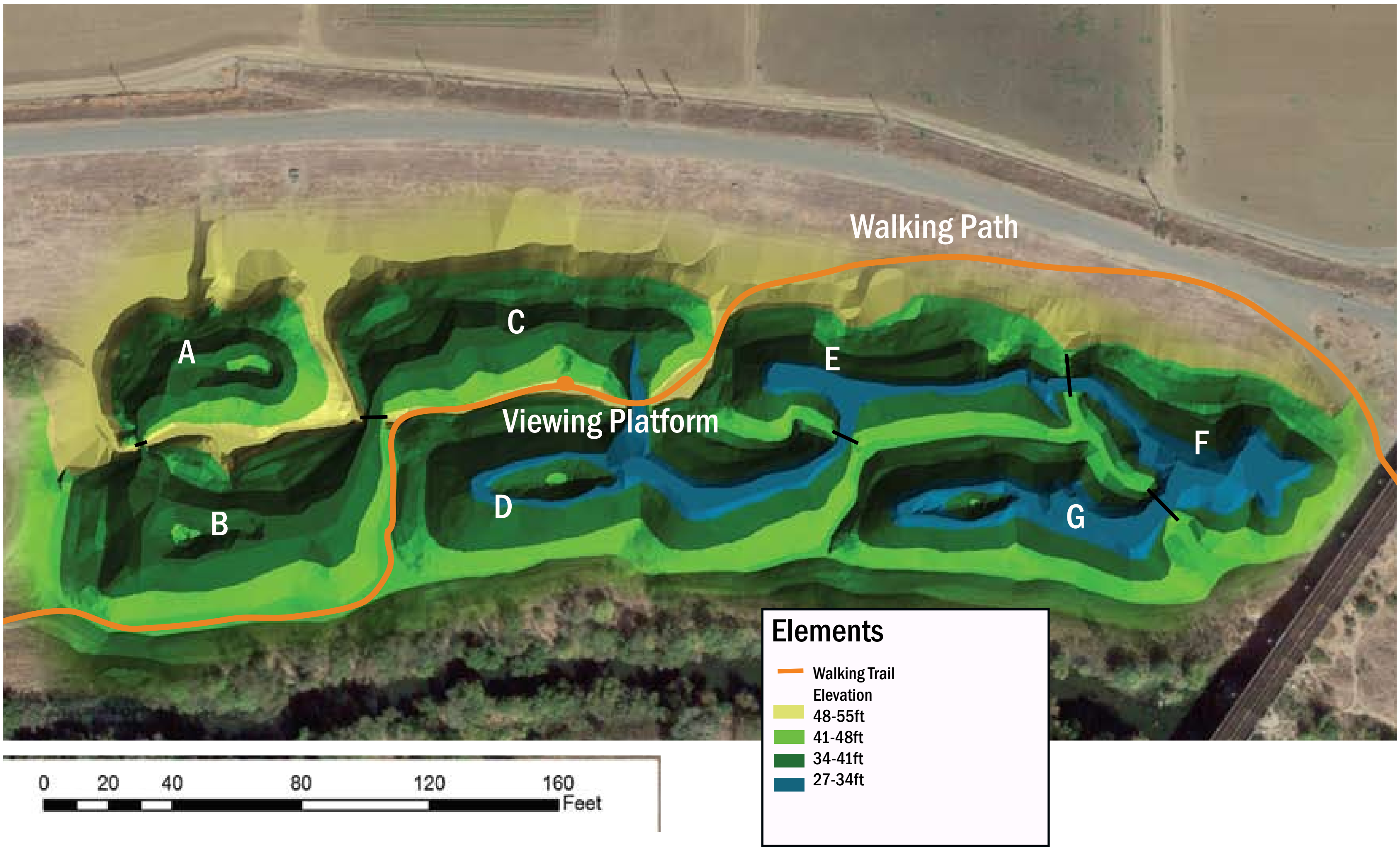
I started designing the ponds by drawing their outlines. Then, graded them in AutoCAD and moved the file into ArcGIS. Throughout the grading process, I made several changes in my design. Initially, the ponds drained from north to south, but I changed them to drain from west to east (in the direction of Putah Creek's flow).

In ArcGIS, I created a model of the wetland and realized that my slopes are extremely steep. So, I regraded them, this lowers their water residence time, but should render them more functional.

The final design includes a model, two sections, and some illustrative perspectives. I added a pathway and a viewing platform for visitors and staff.

The design itself is intended to give a conceptual representation of what this wetland would look like. Due to some missing data, I could not gauge how much water the wetland will actually need to hold. So, some further research is defiantly needed to ensure the success of the wetland.

Figure 5.1: MASTER PLAN



DESIGN EXPLANATION

The design features a series of ponds which range from .5 acre to 1.5 acre in size. Water flow in between them can be regulated using mechanical weirs, which allow fish to dwell in the wetland. The wetlands also feature perches and islands which act as habitat for wildlife but also help increase the surface area of the wetlands to facilitate filtration.

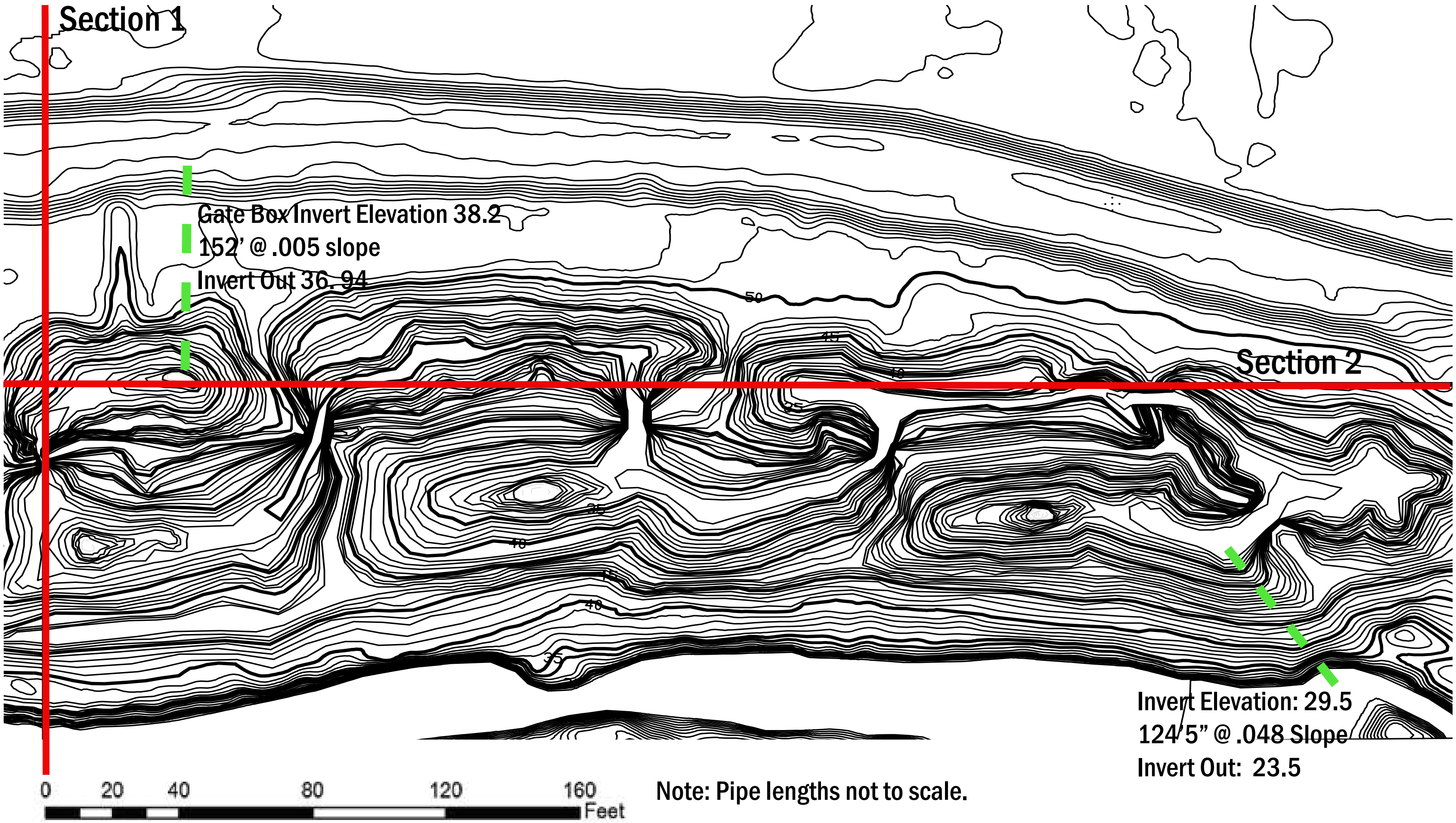
The entire area of the wetlands measures up to approximately 8 acres. This should be appropriate for holding the runoff from central campus because according to France, the wetland should be 2-4 percent of the size of the watershed. In this case, Central Campus acts as the watershed. In actuality, it is not a watershed but an uban drainage basin. It's area is approximately 360 acres. 2-4 percent of this equals 7.2-14.4 acres.

The model (pages 54, 55) and topography (Page 50) accurately show the steepness of the bank slopes. These slopes may be a bit steep for constructed wetlands and the depths of the pools may be steeper than customary. This represents a compromise between space availability, water volume, and wetland functionality. It shows that more pools may need to be added if shallower, more gradual pools are desired.

The ponds drain from west to east because this is how flood waters drain away from the site.

For this wetland to be as efficient as possible, the campus needs to regulate and monitor the amounts of water flowing from the Arboretum Waterway and into Putah Creek. Otherwise, we do not know how much water we are working with.

Figure 5.2: GRADING PLAN



Note: Pipe lengths not to scale.

DESIGN SECTIONS

Figure 5.3: Section 1

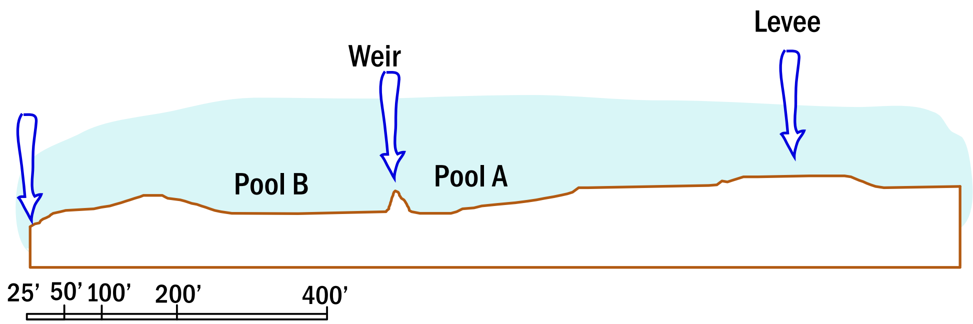


Figure 5.4: Section 2

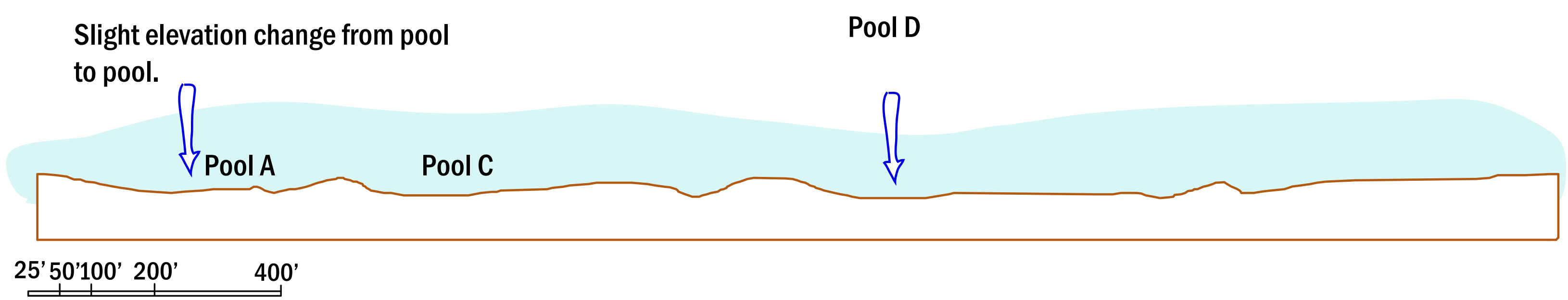
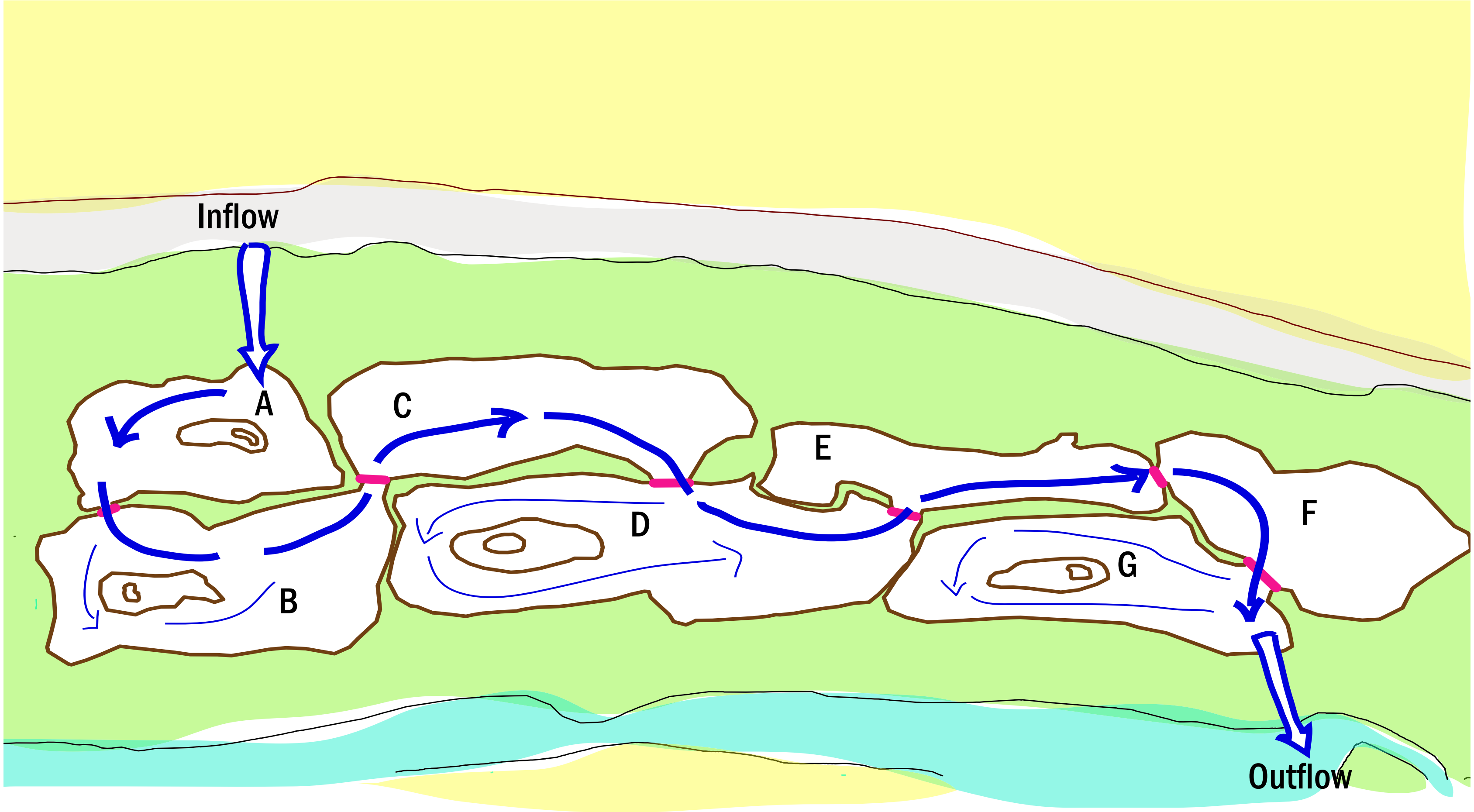


Figure 5.5: FLOW DIAGRAM



FLOW DIAGRAM

Explanation

The flow diagram shows the direction in which water will move through the wetland. The wider arrows show the major flow while the thinner arrows show minor flows. The pools are separated by weirs, so they will fill up to a certain, controlled height before water moves on to the next pool.

MODEL

I took the topographical map I created into ArcScene where it can be viewed as a movable model. Here are four different views of the ponds. They are empty, but this gives an idea what the slopes and other features look like together. The gray shapes separating the pools represent the mechanical weirs which will separate the wetlands.

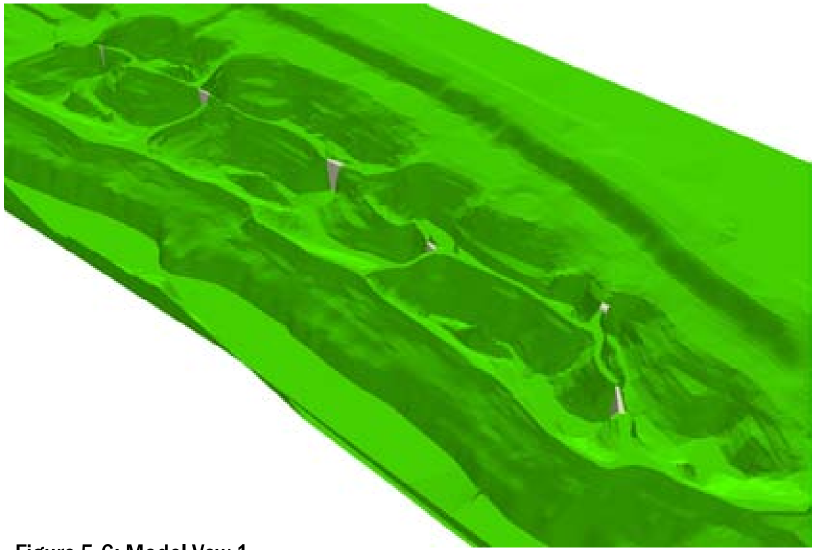


Figure 5.6: Model Vew 1

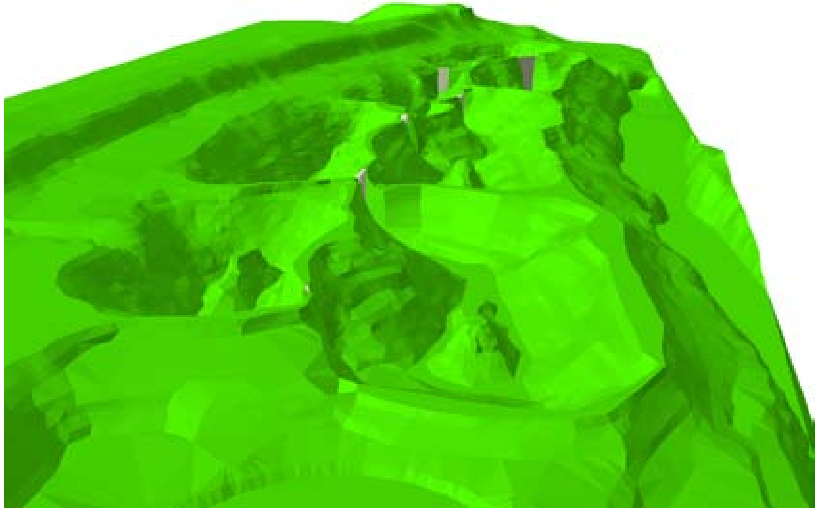


Figure 5.7: Model Vew 2

MODEL

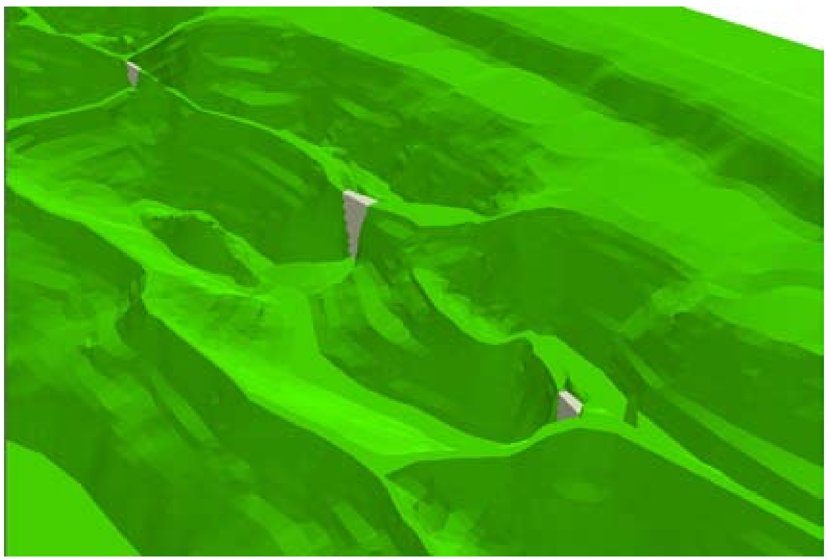


Figure 5.8: Model Vew 3

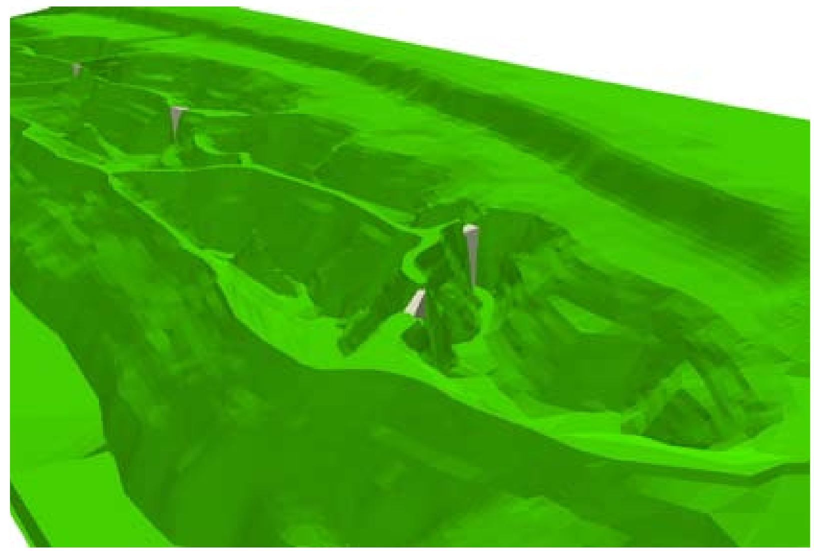


Figure 5.9: Model Vew 4

Figure 5.10: What the wetlands might look like in the winter.

PERSPECTIVE

Figure 5.11: What wetlands might look like in the summer.

VOLUME

Calculations

When it comes to the water holding capacity and retention time of the wetlands I had no concrete number to work with. So, I used the average daily flow measurements of water coming into the arboretum from the Waste Water Treatment plant. I calculated how long the ponds will hold water (before they fill) for the mean amount, the low amount, and the high amount of flow. I did this to figure out how wetland water holding capacity will change with changes in water flow rate.

I made the assumption that ponds start empty and that if the pools are full, the water will be displaced at a rate similar to the infil rate.

First I found the volume of each pond in cubic feet, then, I converted the number into gallons. After this, I divided the volume (in gallons) by the amount of daily flow.

		Water Detention time (per day)		
pool	volume (gallons)	At mean flow- 1.57 million gallons	At High flow- 2.41 million gallons	At low flow- 0.94 million gallons
A	1270022	0.8	0.53	1.35
B	2137447	1.36	0.89	2.27
C	2002852	1.28	0.83	2.13
D	3011747	1.92	1.5	3.2
E	1836826	1.17	0.76	1.95
F	2014551	1.28	0.84	2.14
G	2018665	1.29	0.84	2.15
total	14292110	9.1	6.19	15.19

Figure 5.12: The table above shows the volume and detention time of each pond and for all of the ponds together.

DESIGN
PLANTING

The different elements of the wetland will be seeded and planted according to their slopes and frequency of flooding. Several different planting zones exist. Flood tolerant species are planted on slopes and banks in lower elevations and on basin floors. While drought tolerant plants will be placed on basin rims and higher contours. Mudflats are seeded with a plant mix specialized for waterfowl food.

Ponds E, F, and G will not have any tree cover while ponds A, B, C, and D will be shaded by riparian trees (refer to page 48 for pool ID). The trees near the pools will provide habitat for birds to nest while the pools themselves will provide foraging habitat. The pools that are not shaded will provide habitats for waterfowl.

Another reason for this tree planting scheme is the railroad bridge, it is better to avoid planting trees near such infrestructure.

Some plants to use on basin floors and mudflats are rushes, sedges, and tules. Some plants to place in higher elevations are wild rye, barley, rescue, and purple needle grass. The riparian areas include cottonwoods, box elders, willows, , buckeye, elderberry, and wild grape.

For more detailed plant selection and guidelines refer to:

Calflora, "Information on Wild California Plants for Conservation, Education, and Appreciation". <http://www.calflora.org/>

A good source for detailed information about California native species and their habitats.

West Davis Ponds Report. 1989. Wildlife Habitat Enhancement Plan for the West Davis Pond.

A good source for guidelines, management plans and planting lists.

HUMAN INTERACTION

Pathways

Visitors will be able to interact with the site by walking through the pathway provided. There may be a need to construct fences to protect and screen the wildlife from people. The pathways are also needed for maintenance purposes.

Viewing Platform

A viewing platform will be a good addition to the wetland because it will allow people to stand and observe the wildlife in the wetland. It can include benches, but must include a wooden barrier to hide people's legs from the wildlife.

Figure 5.13: The viewing platform might look something like this one, but instead of mesh in between the wooden poles, I recommend using wooden panels. Source: http://sciblogs.co.nz/science-life/2009/10/29/orokonui-ecosanctuary-to-open/

CONCLUSION

A constructed wetland in the Putah Creek Riparian Preserve is a viable and plausible solution to the problem of low water quality leaving the Arboretum Waterway. Sometimes the water quality in the Waterway is so low, that dissolved oxygen levels kill resident fish in the Arboretum. Building a wetland will help to protect wildlife and ecosystems in and along the creek. Wildlife on site will also benefit from added habitats. The wetland will give the university another great opportunity to act as a steward to nature.

To make a constructed wetland functional, many different elements must come together. The biggest challenge in the process of creating the thesis was gathering information.

The first step the University must take in the case of wetland construction in the Putah Creek Riparian Preserve, is to monitor water volume leaving the Arboretum Waterway. The volume of flow can drastically change the number, depths, and placement of pools for this wetland.

The wetland will not solve water quality problems in the Arboretum itself, but will prevent the arboretum water from harming and stressing habitats in and along the creek.

This thesis is aimed at raising awareness for the issue at stake and to help open a door for a new possibility in the Putah Creek Riparian Preserve.

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Picture Sources

All photographs taken Ella Ver, unless otherwise noted on the page.

Maps and other imagry created with the aid of AutoCAD, ESRI, and Adobe Master Collection.