URBAN WATERS

flood resistant design for west sacramento

UC Davis Landscape Architecture
Senior Project by
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flood resistant design for west sacramento

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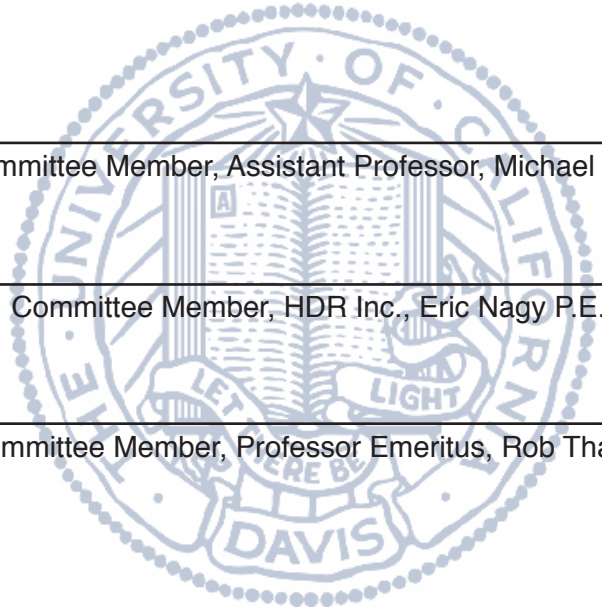

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ABSTRACT

For the many cities that are located along or close to rivers, there has been a general ignorance for the concern of the potential flooding that could destroy them, and only recent events such as the flooding of New Orleans has brought attention to the safety of floodplain cities. One such city that is at risk of being heavily damaged during a extreme flood event is the City of West Sacramento, along the Sacramento River in California. Billions of dollars worth of damages and potential loss of many lives would be the end result if the levee reach system were to breach. To find a balance within the urban systems of developing amongst the strong natural systems, this project is an attempt to develop flood resistant urban design for the City of West Sacramento. This project will analyze the different systematic layers of census, land use, natural systems, emergency services, evacuation routes, hazardous material locations, and evacuation centers that comprise the city and evaluate the weaknesses and vulnerability of those systems. A final master plan will create conceptual design guidelines that would integrate urban and natural spaces together to mitigate floodwaters and reduce the high social and economical damages that would be incurred within West Sacramento.

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Dedicated to Joyce Chin, a wonderful aunt who has always been there to support my education and take me to the corners of the earth that I could never go myself

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Water. An essential and necessary resource that has been a strong factor in shaping the course of human settlements and their locations along the water streams and rivers environment (Hough, 2004, p. 5). Rivers and human evolution became intertwined together when floodplains allowed fertile grounds to become plowed and harvested agricultural fields, allowing humans to create settlements and develop centers of commerce and transportation (Kersting, 2007, p. 1). However, the draw of human development along the river's edge spurred a dangerous side of the river as the river's natural geomorphology and flooding battled the urban systems (Kersting, 2007, p. 1). Soon, humanity developed a false sense of dominance over rivers with a series of flood control devices such as levees, bypasses, or other flood infrastructure. These flood control projects allowed cities to exist and prosper along rivers (Langenbach, 2007, p. 77).

One such test was the 2005 Hurricane Katrina flooding of New Orleans that cost the city billions in damages due to breached levees, and hundreds of lost lives (NOAA, 2007, p. 6). Due to the recent flooding disasters, there has been a call within landscape architecture, urban design, flood engineering, and architecture to find landscapes that can "react and adapt to repeated flood events while improving the quality and appearance of the new environments" (Girots, 2008). Solutions that can design flexible flood resistant networks that are comprised of differently layers to decrease vulnerable areas in cities and strengthen the overall urban fabric of the city. My project will identify West Sacramento as an ideal project city for a flood resistant urban network that will consist of different systematic layers working together to mitigate flood waters. The master plan and design guidelines will be based upon another systematic GIS analysis of the city's infrastructure to design accordingly.

One such city with a high potential of flooding is the City of West Sacramento, California. West Sacramento is located in Yolo County on the western banks of the Sacramento River, directly the river across from California's capital, Sacramento. West Sacramento became a separate city in 1987, and today houses 31,615 people (2000 U.S. Census Bureau) and is the site of the economically vital Port of Sacramento (City of West Sacramento, 2007). The Port is an economically vital industry to the city allowing domestic and international ships to drop off their cargo after the 22-mile Deep Ship Channel journey that originates in the Sacramento Delta (Nagy, Interview, 2008).

West Sacramento's geographic location quickly puts the city at high risk of flooding due to the Sacramento River's 100-year flood plain event. West Sacramento, like many Sacramento Valley cities are protected by a series of levees that bind it, creating physical boundaries that limit the growth inside a safety zone that the levees provide. However, population forecasts are projecting a California state wide to 17.6 million people by 2050 and the population within West Sacramento to grow by 80% to 57,730 in 2015 (Yolo County, 2007, p. 2). New commercial centers and housing developments are necessary to keep up and accommodate for the growing job market and population. With additional developments being added and suburban sprawl consuming vital agricultural land, a new design philosophy is necessary to invest and create fortified developments that will protect the social and economical assets of West Sacramento.

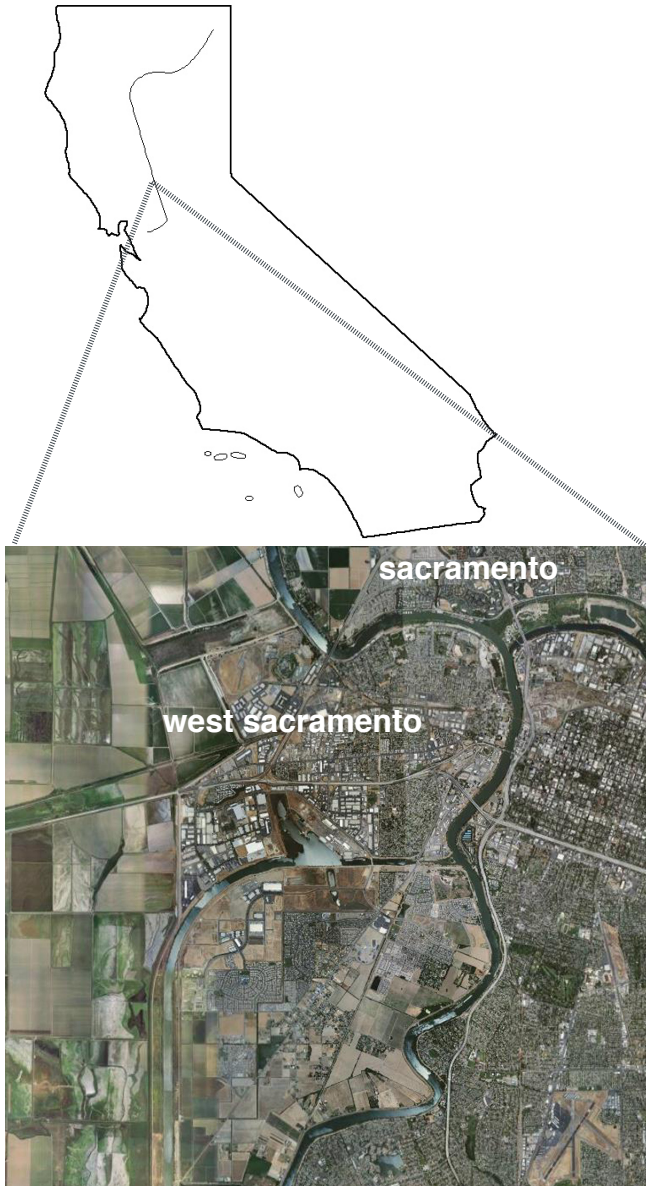


fig. 1
Context Map

Flooding is a natural process of rivers that occurs when the volume of the water stream exceeds the channel (Environment Canada, 2004, p. 1). Snowmelt, precipitation, climate, coastal storms, urban runoff, or storm variables such as intensity, duration, run-off; each can affect the volume of water that is placed into a water channel (Environment Canada, 2004, p. 1). To predict if a water stream is going to flood into a large basin such as the Sacramento Valley, it is necessary to rely on magnitude and frequency methods to calculate the probability of the recurrence of the large flows based on historical records in increments of 2-year, 10-year, 50-year, 100-year, or etc. (Marsh, 1997, p. 188). Although these storms or floods may only happen every 100or 200-years, these storms or floods may happen in consecutive years (Marsh, 1998, p. 188).

Floodplains are created when the natural geomorphology and water shape the valleys and topography, which in turn influences how the water flows across the floodplain (Marsh, 1997, p. 191). The Sacramento Valley originally had a large expanse of floodplains and allowed for floodwaters to flood freely across itself. However, the development of levees along the river constricted river growth and reduced the flood capacity of the Sacramento River (Marsh, 1998, p. 191). An added benefit to accepting floodwaters is that floodplains are extremely important in maintaining hydrologic connectivity and interaction with the water that allowed ecosystems to flourish and support high bio-diversity (DWR, 2007, p. D-1). When floodplains are developed and levees built on the waters' edge, the flood capacity is lowered, natural ecologies are lost, and the potential structures that will be flooded and destroyed due to water damage (DWR, 2007, p. D-1).

Currently, there are extraneous factors that are projecting different flooding scenarios that have not been previously modeled such as climate change and the resulting rising sea levels. With a warming global climate melting glaciers and ice sheets, the projected sea rise is about 39 inches within the next 50 years (Borenstein, 2007, p. 1). A 100-year floodplains event is projected to expand from 10,000 to 20,000 square kilometers because coastal storms may be more intense with larger precipitation and runoff amounts causing river surges that could breach or topple levees (UCSUSA, 2005, p. 2).

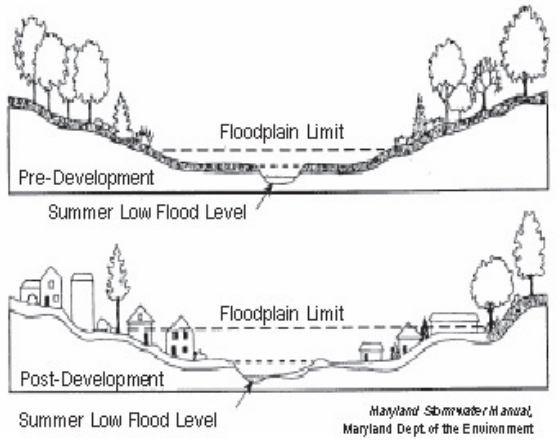


fig. 1
Floodplains
(Maryland DOE, 2006)

Site Analysis

Before a master plan can be initiated, an in-depth site analysis of West Sacramento is requited to map all of the different systems that are compose West Sacramento such as: the natural, social, economical, and physical systems.

System Layers

1. Water Systems
2. Flood Depths & Land-Structure Damage
3. Flood Control Systems and Flood Hazards
4. Census by Block
5. Land Use
6. Evacuation Routes
7. Post Evacuation Shelters
8. Emergency Services
9. Hazardous-Materials (Haz-Mat) Locations

Each system is inter-connected with each other making it necessary to compare and contrast each map to find vulnerable and resilient areas of the city. ArcGIS (Geographic Information System) was used to gather metadata (provided by the City of West Sacramento) to create the overlays for the vulnerability/resiliency maps. By overlaying the different systems it would be possible to identify the points of weaknesses within existing infrastructure and identify areas of least resiliency that will determine which areas are suitable for developements and which areas are not.

West Sacramento is located in between several water bodies that are a part of the greater Sacramento River valley. The main body of water is the Sacramento River (including North, Middle, and South Forks) which is sourced from Mount Shasta. Immediately north of West Sacramento, the American River enters the Sacramento River and further north and to the west of the city, the Yolo Bypass serves as a flood relief device for the Sacramento Valley and greater Sacramento Metropolitan area. Although not a natural system, the Deep Ship Channel is a 22-mile canal that originates from the mouth of the Sacramento Delta that is used by freight ships to bring goods into the Port of Sacramento (Nagy, Interview, 2008). Identification of water locations and flows are important to where the variable water heights during a storm event could possibly topple or breach levees.

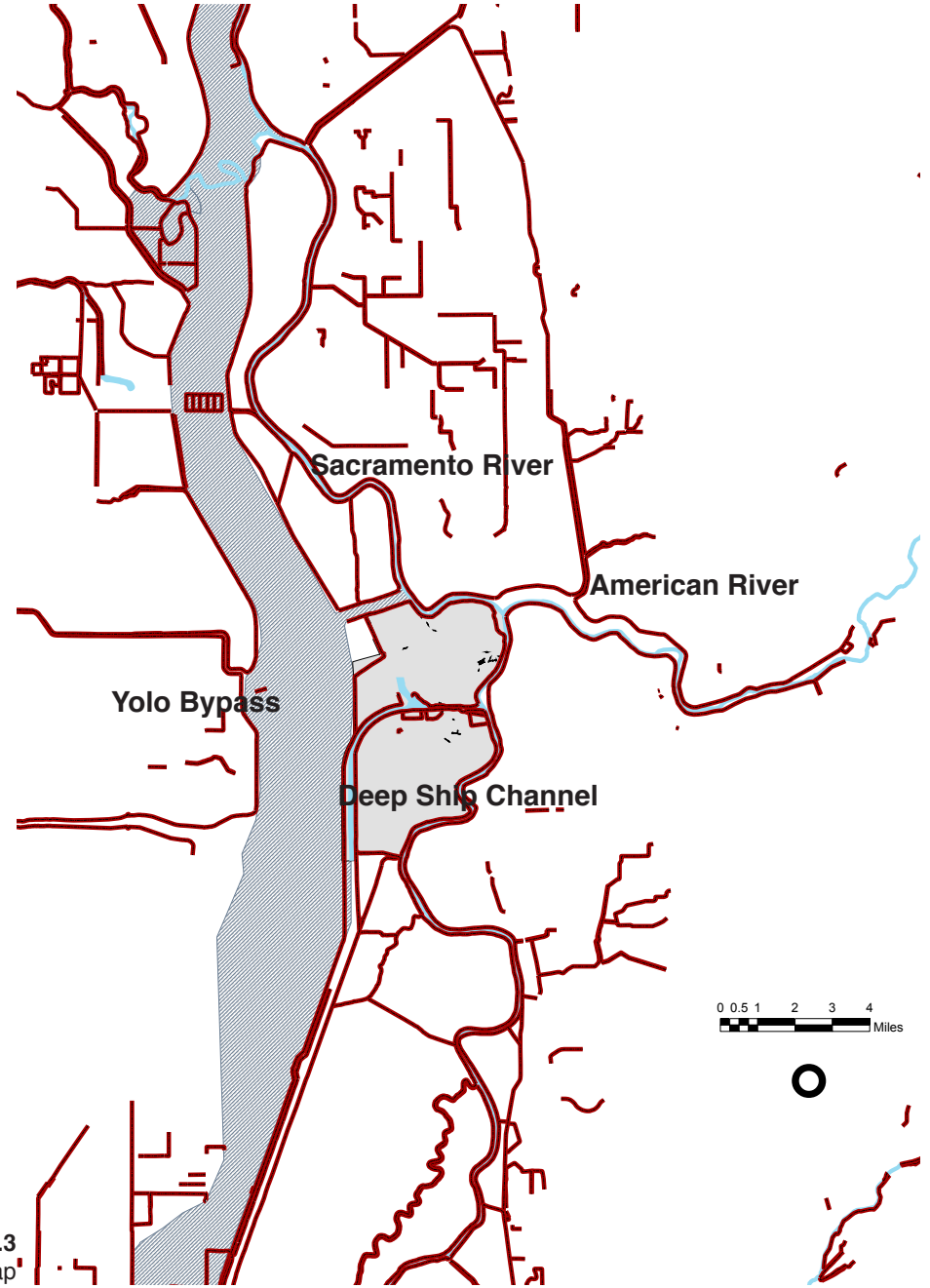


fig.3
Regional Watershed Map

There are several flood control devices used by West Sacramento to protect against floodwaters including a levee system and the Yolo Bypass [fig.4]. The resiliency of these devices and the accurate protection to West Sacramento is questionable and has been undergoing retrofits to better protect West Sacramento (Cermak, 2007, p. 6). The Sacramento Valley has 1,000 miles of reach levees, which over time have slowly degraded due to either maintenance ignorance or poor development materials (DWR, 2007, p. 26). These regional levees provide small amount of relief but actually constrict water flows, which disturb natural habitat, lowers the flood capacity of a river, and creates dangerous downstream conditions at the urban bottlenecks (DWR, 2007, p. 26). An example of the vulnerability of the regional levee system happened during the large flood event of 1997 where 30 levees were breached and 300 square miles were impacted. The damage to the land totaled more than $2 billion in damages, displaced hundreds of people from their homes, and caused nine deaths (DWR, 2007, p. 1).

West Sacramento's levee system houses a 9-reach, 30-mile levee system that binds the city protecting it from Sacramento River in the East, the Deep Ship Channel in the interior, and the Yolo Bypass in the west (Nagy, Interview, 2008). The current levee reach system of West Sacramento is built only to a 100-year flood protection against storms that may happen 1% of any given year but any larger flood would topple the levees (DWR, 2007, p. 15). Although there are currently levee-upgrading projects commissioned

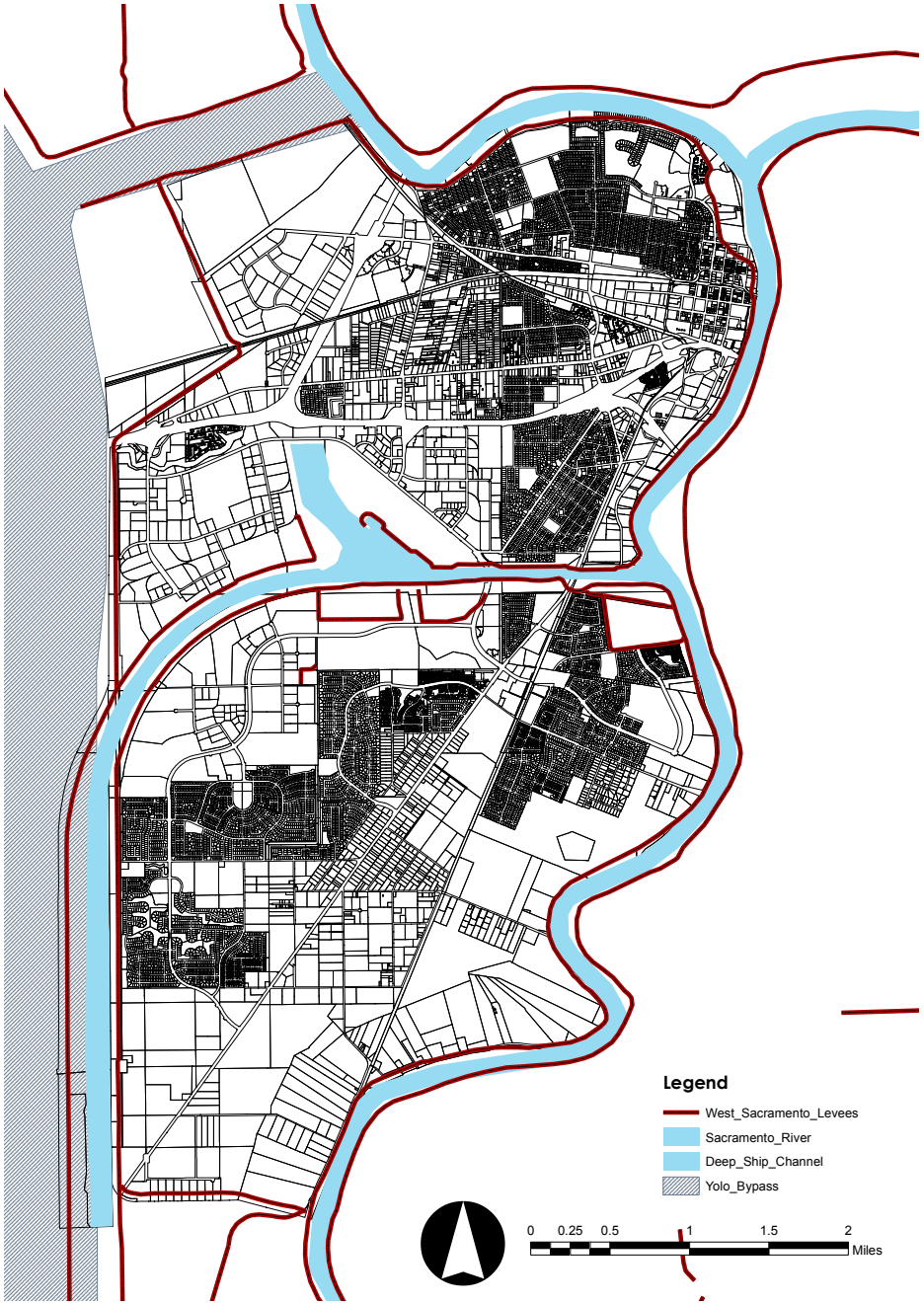


fig. 4
Levee and Water System Locations

to bring levees up to the 200-year flood protection, the levees should be established at 500-year flood protection and re-constructed to replace poor soils originally used in the construction of the levees to prevent toppling or breaching (DWR, 2007, p. 17). Without these changes, the levee condition and protection level is poor for West Sacramento posing dangerous flood hazards for the city if a large flood event were to occur in the near future.

Although the levee reach system provides coverage for the city, the Yolo Bypass provides a greater depth of primary flood control not only to West Sacramento, but to the surrounding metropolitan areas in the Sacramento Valley. The Yolo Bypass has a maximum flow rate of 500,000 cubic feet per second (cfs) and holds the majority of flood waters while the Sacramento River holds only 1/5 of the flood (Nagy, Interview, 2008). Due to the high yield of flood waters contained in the Yolo Bypass, the Bypass doubles as flood control and also poses a dangerous threat to West Sacramento. Due to the width of the Yolo Bypass, wind speeds that flow across the water pick up energy and create waves that will create a large amount of erosion activity along the western reaches of the West Sacramento levees (Nagy, Interview, 2008). This erosion could force a levee failure causing a devastating flood within the city, especially in the northern part of the city. During a southern levee reach break, the Ship Channel could mitigate the impact of floodwaters by acting like a drain and sending the waters south towards the Delta (Nagy, Interview, 2008).

Erosion from the Sacramento River slowly eats away at the levees making the structural integrity weakened and leaving them vulnerable to breaching. The strongest erosion point is located at #2 in the Hazard Map due to the large amounts of energy coming down from the Sacramento River, the water cuts away causing deep holes of erosion making the area behind the levee very susceptible to flooding (Nagy, Interview 2008).

A secondary flooding threat to the internal infrastructure of West Sacramento is the Deep Ship Channel. The Ship Channel is 22 miles long and connects with the Sacramento River and further down south on the mouth of the Sacramento River. Because water is regulated by the level of the Sacramento River, a high surge from the north would push water 22 miles south along the Sacramento River and then back into the Ship Channel 22 miles north to West Sacramento causing a relative danger to the Port of West Sacramento; a phenomenon called “backflow” (Nagy, Interview, 2008).

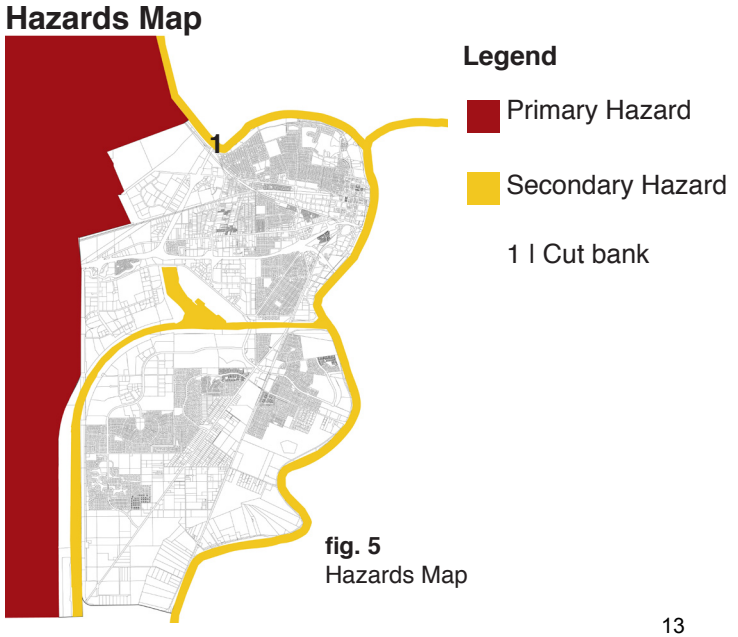


fig. 5
Hazards Map

Potential flood waters within the City of West Sacramento would be devastating and destroy a large amount of the social and economical infrastructure that would already exist within the city. The ArcGIS map [fig.6] describes the flood depths of a 100-year flood event, with different zones of flooding: 0-1 ft., 1-5 ft., 5-10 ft., and 10+ ft within West Sacramento. In a theoretical flood, this map shows the extent of the flood waters by area. These flood depths are important in mapping the vulnerability of the social and economical infrastructure of the city, and the depth of flooding is a direct correlation with the loss of life and structural damages (DWR, 2007, p. 20).

Damage estimates to a city can be measured based on the monetary lands and structure value based on land use type--either, residential, commercial, or industrial. Although human lives are hard to put into an economic projection of monetary damages, they do weight on damages that are incurred thus making the estimates low). Land damage figures are based upon a number of factors such as site vacancy or development, cost of re-development, and cost of flood insurance (Cermak, 2007, p.24). The City of West Sacramento and the West Sacramento Area Flood Control Agency (WSAFCA) have developed a minimum 10% damage factor to each parcel of land and applied it to the current land values associated with each land use to finalize theoretical land damage in $/acre (Cermak, 2007, p.24).

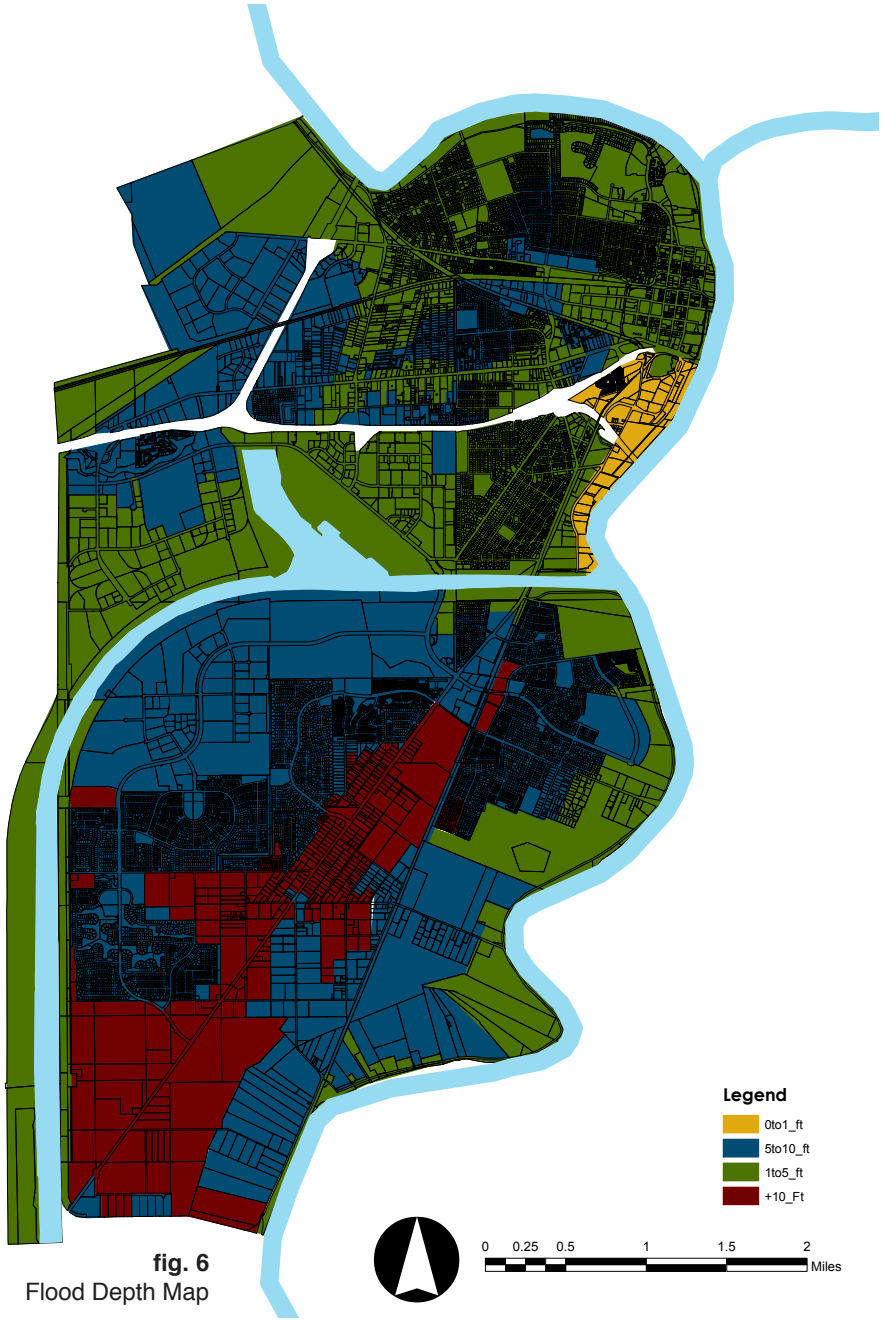


fig. 6
Flood Depth Map

Land Use	Relative Land Damage ($/Acre)
Single Family -Residential	25,100
Multi-Family Residential	27,800
Commercial	55,400
Industrial	23,300
Vacant	12,100
Residential - Mobile Home	25,100

fig. 7 Relative Land Damage

To estimate the amount of structural and content damage, each land use type has a different monetary factor relative to the replacement cost of the structure and the contents within it (Cermak, 2007, p. 26).

Land Use	Relative Structure Damage ($/sft.)
Residential	60
Residential-Mobile	30
Commercial	70
Industrial	50

fig. 8 Land Use Structure Damage

LandUse	Flood Depth Zones			
	0-1 ft.	1-5 ft.	5-10 ft.	10+ ft.
Residential	15%	33%	70%	79%
Commercial	20%	72%	125%	146%
Industrial	59%	74%	105%	136%

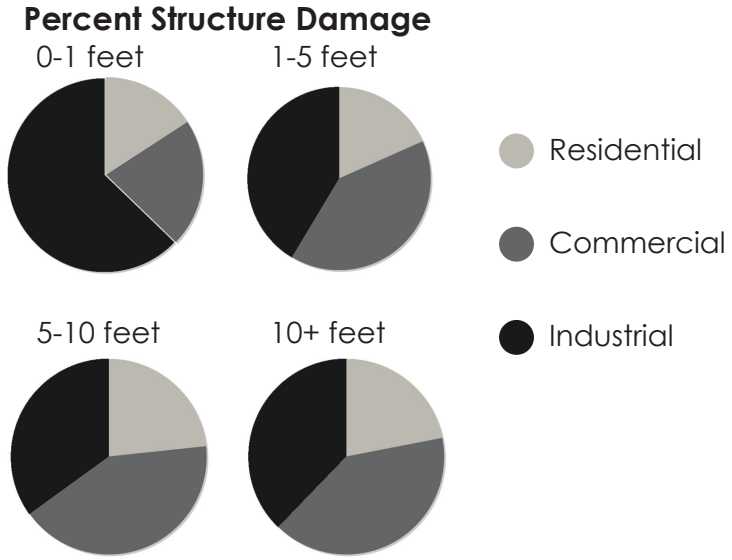


fig. 9 Percent Structure Damage

Using this data in correlation with the flood depth zones, total values of land and structural damage were compiled [fig. 8]. Each flood zone has different monetary values based on the variety of land use types and the density of the housing in the different areas. However, due to most of West Sacramento being within the 1-5' and the 5-10' zones most of the land and structural damage is focused here. Combined totals of damage amount to $1.75 billion, while land damage is $238 million, with an overall total damage of almost $2 billion. These totals are only an estimate of the potential damages, and they could possibly be under-estimated. After a flood, communities are destroyed far beyond the replacement cost of structures and land damages. People are often relocated and eventually get disconnected from their residential and business communities severing the economical health that once existed and creating larger social and financial damages that cannot be estimated (DWR, 2007, p. 5).

Flood Depth	Number Parcels	Parcel Area (Ac.)	Land Damage $	Building Footprint (Sf).	Structure Damage $
0-1'	130	209.1	3,601,527	492,045	14,093,540
1-5'	5,815	4,647.60	113,158,528	21,116,715	721,683,083
5-10'	8,778	5,114.10	100,198,123	19,919,023	977,782,386
10-15'	674	1,753.20	20,805,469	602,622	36,559,089
Summary	15397	11724	237,763,647	42,130,405	1,750,118,098

fig. 10 Total Flood Damages

Land use of West Sacramento is separated into four main categories: residential, commercial, industrial, and agricultural. Land use is important to understand how the city allocates its resources in terms of the distribution of residents, industrial, commercial, and open space. The analysis of West Sacramento finds that most of the commercial retail and resources are located in the center of the city creating a disparity of resources in times of a flood. Industrial sites are bordering the Ship Channel and the Sacramento River that are first to encounter flood waters thus absorbing a lot of the city's economic damage. Residential areas are at a higher density in the North West Sacramento and become sprawled suburban low-density housing while mixed agriculture land use occurs in South West Sacramento. In the southern regions of West Sacramento, there is a growing trend of turning agricultural lands into suburban developments, especially land within the dangerous 10+ ft. flood depth zone, creating a dangerous disposition for those residents.

Land Use Key

HSC-Highway Service Commercial	LR-Light Residential
NC-Neighborhood Commercial	MR-Mixed-Use
WRC-Water River Commercial	HR-High Residential
CBD-Central Business District	MCI-Mixed Commercial/Industrial
HI-Heavy Industrial	BP-Business Park
LI-Light Industrial	O-Office
WRI- Water River Industrial	RMU-River Mixed Use
RE-Rural Estates	AG-Agricultural
RP-Rec.&Parks	OS-Open Space

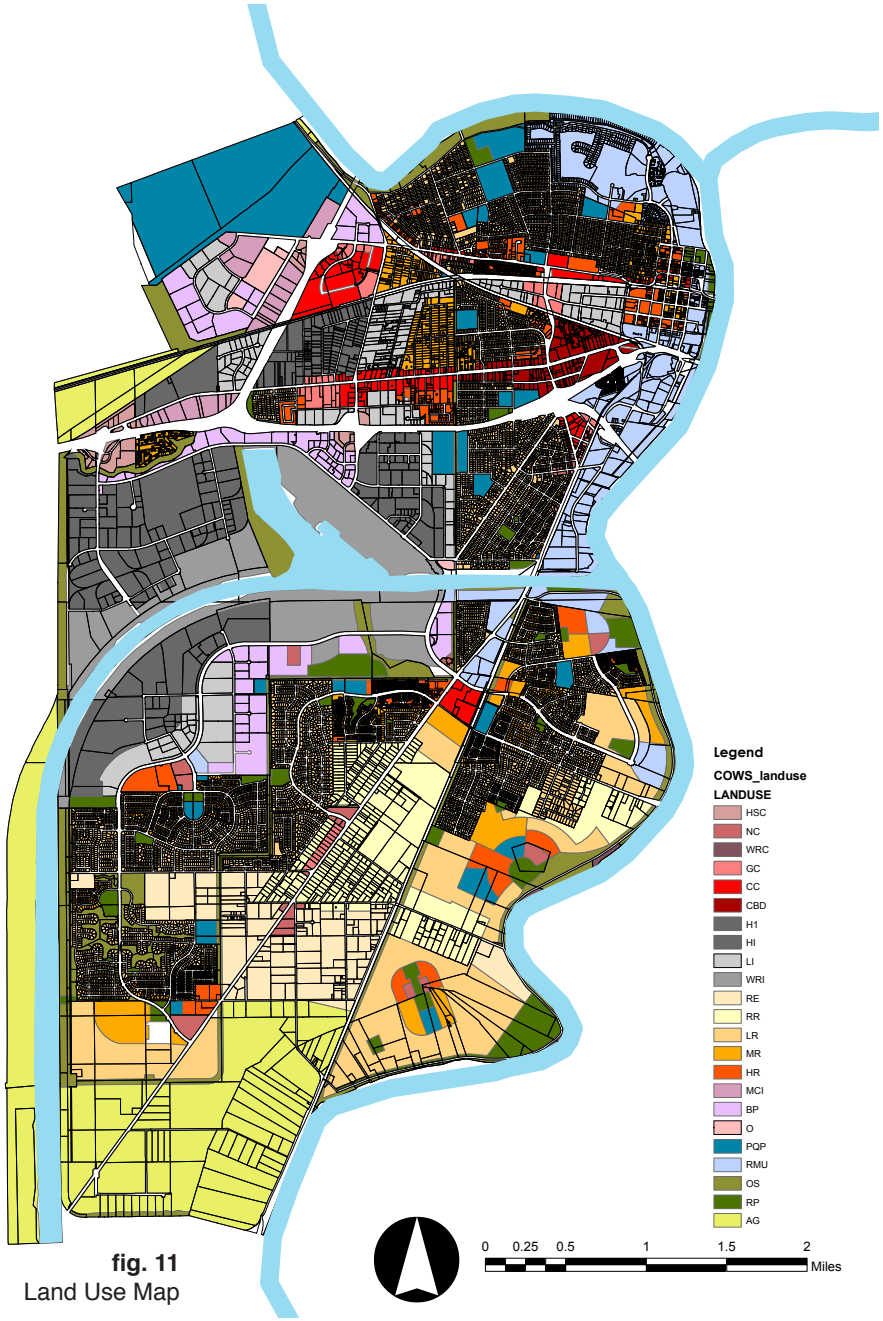


fig. 11
Land Use Map

Census mapping was based upon the United States Census 2000 Blocks of West Sacramento[1]. The basis of mapping census block information was to correlate the density of people in West Sacramento and the vulnerability of lives to the location of emergency services, evacuation routes, shelters, and most importantly flood depth zones. The GIS map for census blocks were able to identify that in general, most of the citizens of West Sacramento live within the 1-5 feet flood zones, highest populations were centered towards the center core of West Sacramento. The southern portion of the city holds less density due to the lower density of housing that it supports; however, more developments are being constructed and could raise the population count in the short term future and the area contains the deepest flood depths.

With the direct connection with the loss of life and flood depths, the higher density areas that lie in the 5-10 feet flood zones are in high danger. Although population counts are smaller in the southern region, the flood depths are within the 10+ foot flood zone creating a dangerous position of the residents living there. Intervention and resources are needed to protect the higher density of citizens.

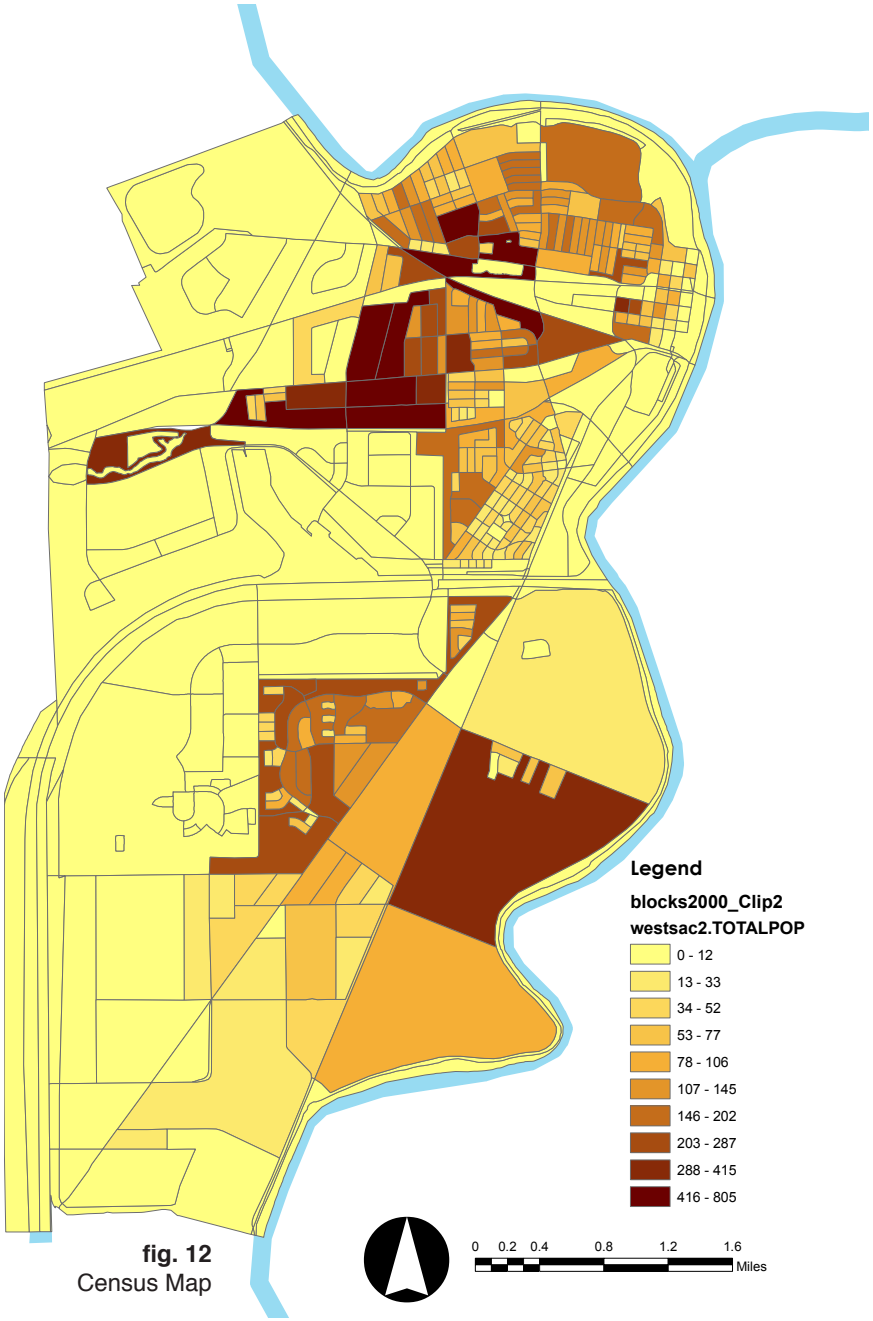


fig. 12
Census Map

1. Census data has changed since 2000; however, this is the most recent block data available for West Sacramento. Numbers represented may be lower than current census data due to recent housing developments.

The City of West Sacramento does have an evacuation plan during times of flooding that is correlated with a “Slow Rise” of the river height and levee conditions, which gives advanced warning to residents of West Sacramento (Chow, 2007). Currently, the evacuation routes planned for West Sacramento are divided into two categories: main evacuation route and feeder evacuation routes (Chow, 2007). The main evacuation route is I-80/Business-50 providing the only east/west outside access creating a constricted evacuation plan that could prove to be dangerous during a rapid flood rise or a levee failure. The feeder evacuation routes are a series of collector streets within the city that direct movement to I-80/Business-50.

These evacuation routes are overlaid with flood depths, population density, and land use to predict the movement of people and which areas are most vulnerable to be isolated from evacuation routes. The areas located furthest away from the primary and secondary routes are in the most danger due to the long distance and the potential isolation of the feeder routes to be cut off by flood waters. The GIS maps show there is a need for another evacuation route and a number of feeder routes for the southern portion of West Sacramento. In a flood event in the city’s southern sector, there would be a logjam of evacuees fleeing north. If the sole feeder route to the north was cut, residents would be stranded. Overall, roads can be compromised with water, either by being too deep to cross or eroded away preventing any escape from an area. Alternate routes and transportation methods need to be explored to effectively move mass amounts of people to different parts of the city or out of the city.

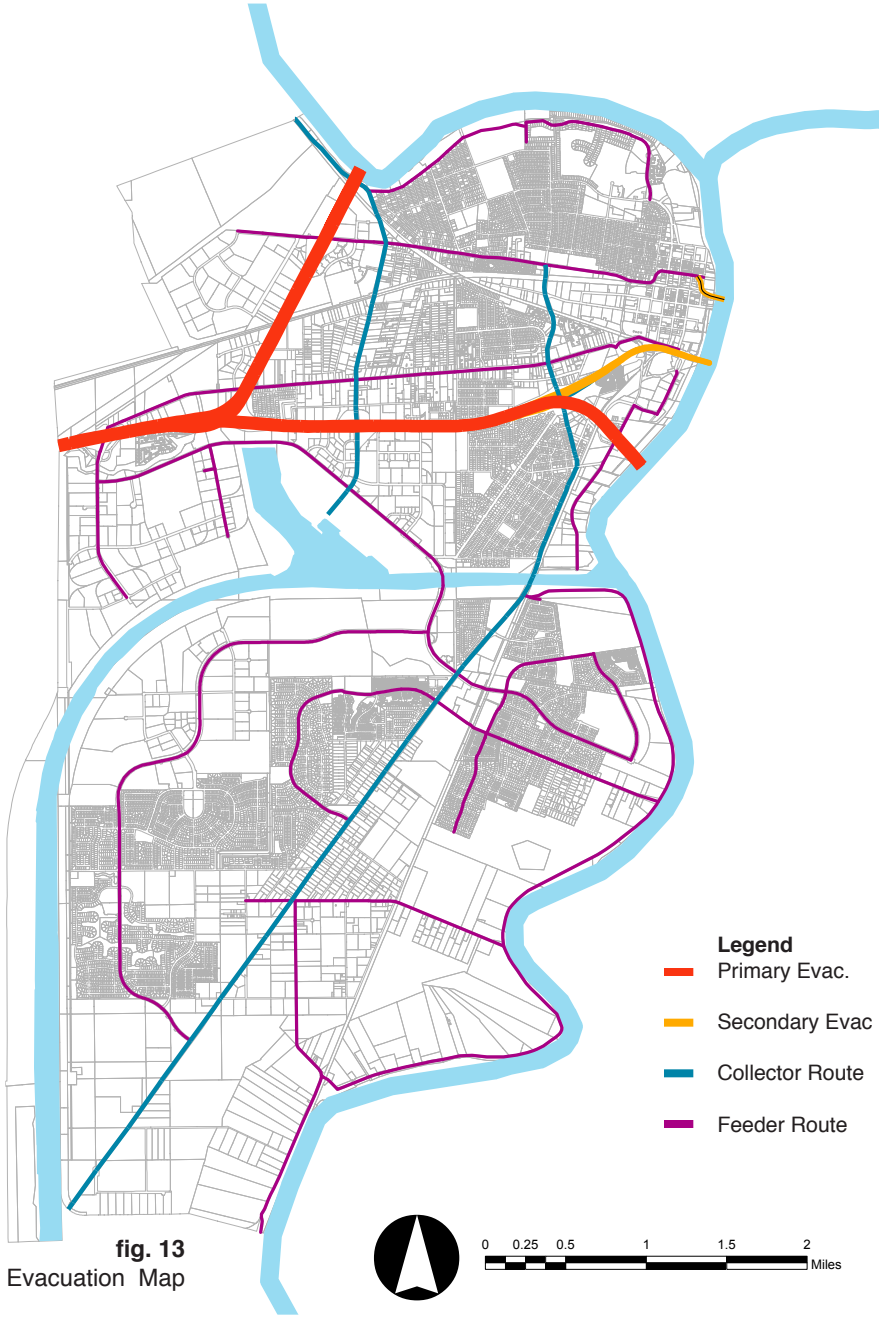


fig. 13
Evacuation Map

West Sacramento emergency services are composed of fire, police, and the Emergency Services Division. The Emergency Services Division is responsible to respond to fires, rescue, hazardous materials, medical and other public services (City of West Sacramento EIR, 2006, p. 1). Currently, there is one police station, five fire stations and the nearest hospital is located across the river in Sacramento. The lack of a major medical facility in West Sacramento limits the triage facilities that may be required to provide fast and immediate medical response. In a dire flood, emergency services would be inundated and unable to respond to the vast majority of calls, resulting in a response time, from low to improbable.

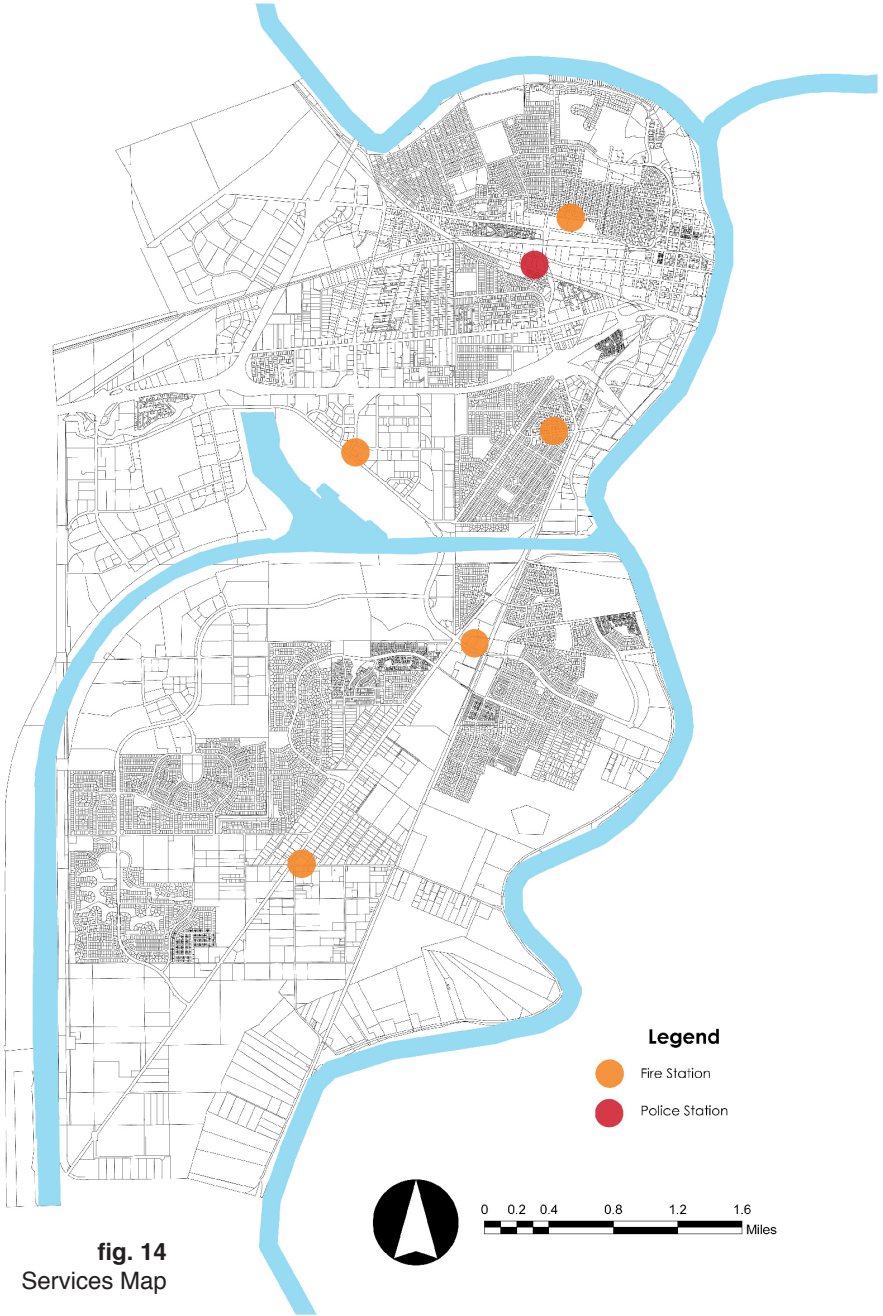


fig. 14
Services Map

The identification of post-evacuation shelters prepares capacity to house mass amounts of people from affected areas after flood waters have receded. Schools and civic and religious centers can act as places of refuge and are usually located around residential and communities. Post-evacuation shelters can be responsible for providing the basics of living: food, water, shelter, and medical support if needed.

Most of the post-evacuation shelters are located in the denser area of West Sacramento's northern part and a few are scattered in the southern sector. With partial flooding of different parts of the city, people would move from an area to one of these post-evacuation shelters. Instead of having scattered or locations within deep flood zones, shelters should be fortified and localized and accessible to each neighborhood.

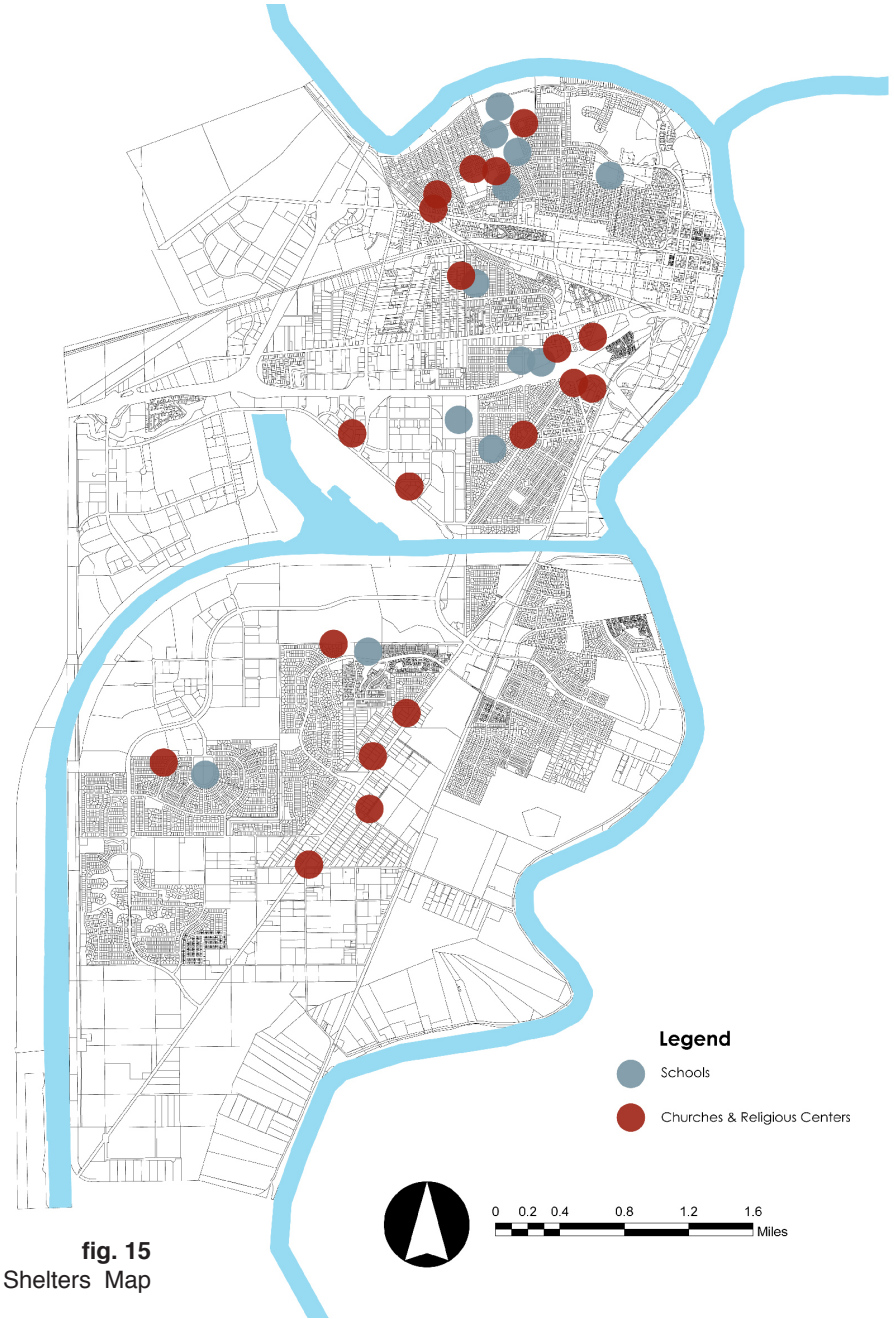


fig. 15
Shelters Map

The possible contamination of floodwaters from industrial or commercial sources can prove to be dangerous to public health and /or environment due to their quantity, concentration, or chemical properties (COW EIR, 2006, p. 2). Hazardous materials are the "raw or unused materials that are part of the manufacturing step," "which could pose a serious threat to human health and safety or the environment if released because of its quantity, concentration, or physical or chemical characteristics" (COW EIR, 2006, p. 2) These materials can include pesticides, chemicals, mechanical lubricants, and waste oil (COW EIR, 2006, p. 2).

During an event when a flood inundates industrial or business sites with floodwaters, there is a possibility of the contamination of water with these hazardous materials. Waters that are contaminated would spread throughout the immediate area and eventually the city causing a public health threat. With most of the haz-mat areas located within the central industrial area of West Sacramento, the immediate residential areas would be affected with dangerous amounts of toxins and would need to be evacuated as soon as possible and have a response team allocated to the area.

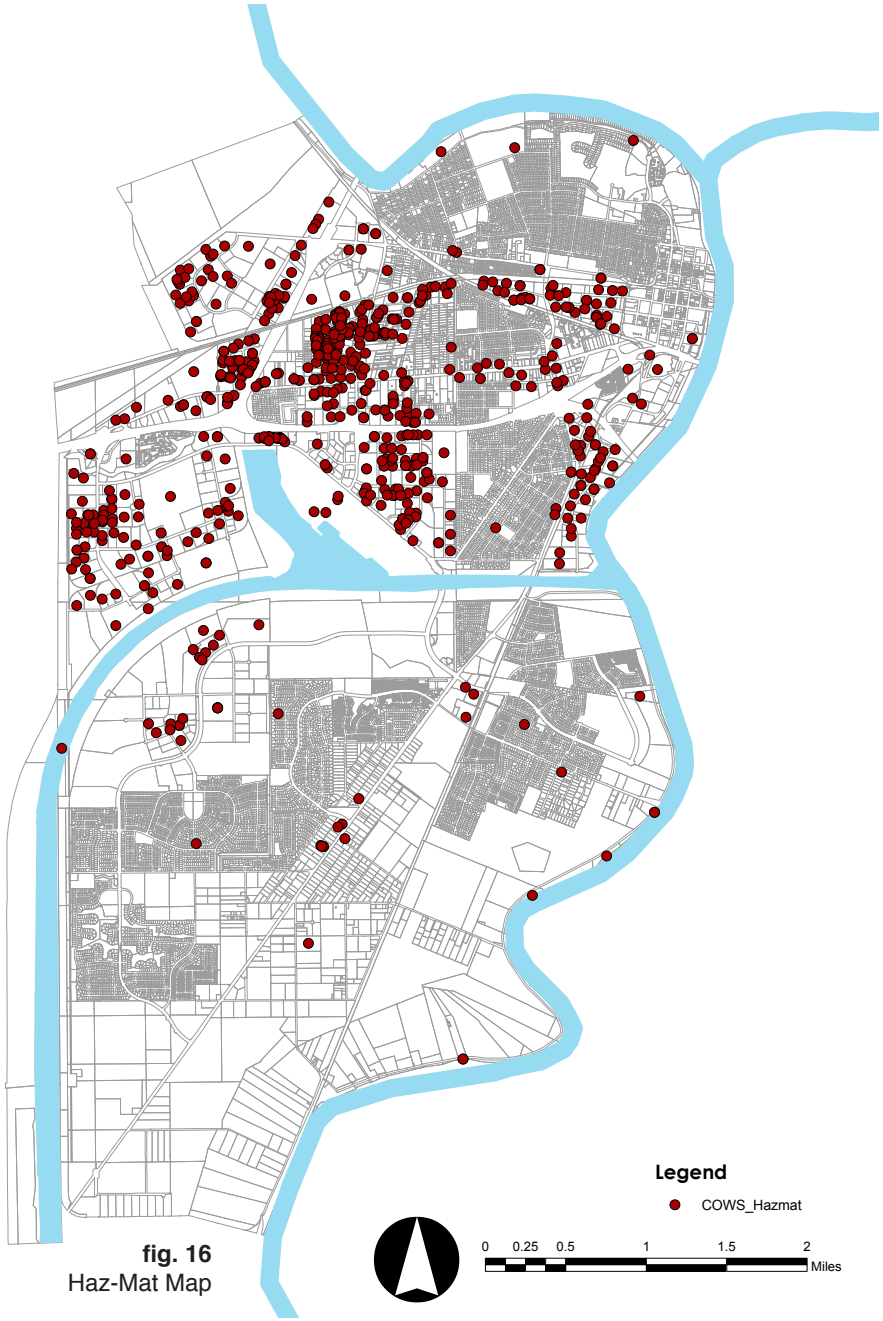


fig. 16
Haz-Mat Map

Overall, there is a strong relationship between flood depths and the other corresponding system layers. Flood depths affect how each system would react to a disturbance during different flood depths. West Sacramento's systems are fairly weak due to low levee standards, high hazard areas, a lack of fortified evacuation routes or disaster infrastructure, isolated resources, and high social and economic flood damages.

However, for a flood resistant network to be put into place, sites have to be rated to logically find vulnerable sites to the safest one to plan out how the elements of the master plan are going to interact together, A vulnerability matrix was created to rate the vulnerability of each area within the city on a scale of minimum, moderate, and high. Most aspects of the site analysis are made in comparison of the flood damages/depths due to the strong relation floodwater depths have with every with other systems. Coupled with the vulnerability matrix, all the systes will be overlayed to find areas within West Sacramento became apparent to either develop, revise the land use patterns, or use a series of cut or fill options to fortify or make an area more vulnerable.

As a general note, flood damages are based upon the depths provided by the flood depth map and the percent damage figures provided by the City of West Sacramento (COW) and the WSAFCA. Land use was also included within flood damage percentage due to the relation of percent damage of structure to it's land use category and $/square foot allotted by the COW and WSAFC. The most vulnerable land use categories are industrial and commercial centers due to the economic interests invested. Although residential areas are of lesser economic value, the residential areas rank higher socially. Emergency services are currently already distributed into appropriate fire districts and the vulnerability of the emergency service infrastructure is the generally the lack of fortified positions, sub-police stations, and triage centers to treat or hospitalize evacuees.

Vulnerability Rating			
	Degree of Vulnerability		
	Minimum	**Medium**	**High**
Flood Depths	Flood depths are 0-1 feet	Flood depths are 1-5 feet	Flood depths are 5 feet or greater
Strucuture Damage (in relation to use)	0- 50% damage to structure	50-100% damage to structure	More than 100% damage to structure
Evacuation Routes	Primary route within 0-1 miles	Primary route is 1-2 miles away	Primary route is 2+ miles away
Haz-Mat	no concentration of haz-materials	low concentration of	High concentration of haz-materials
Flood hazards	Located in neither of the immediate area of primary or secondary flood hazard area	Located within immediate area of a Secondary Hazard area	Located within immediate area of a Primary Hazard area

fig. 17 Vulnerability Rating

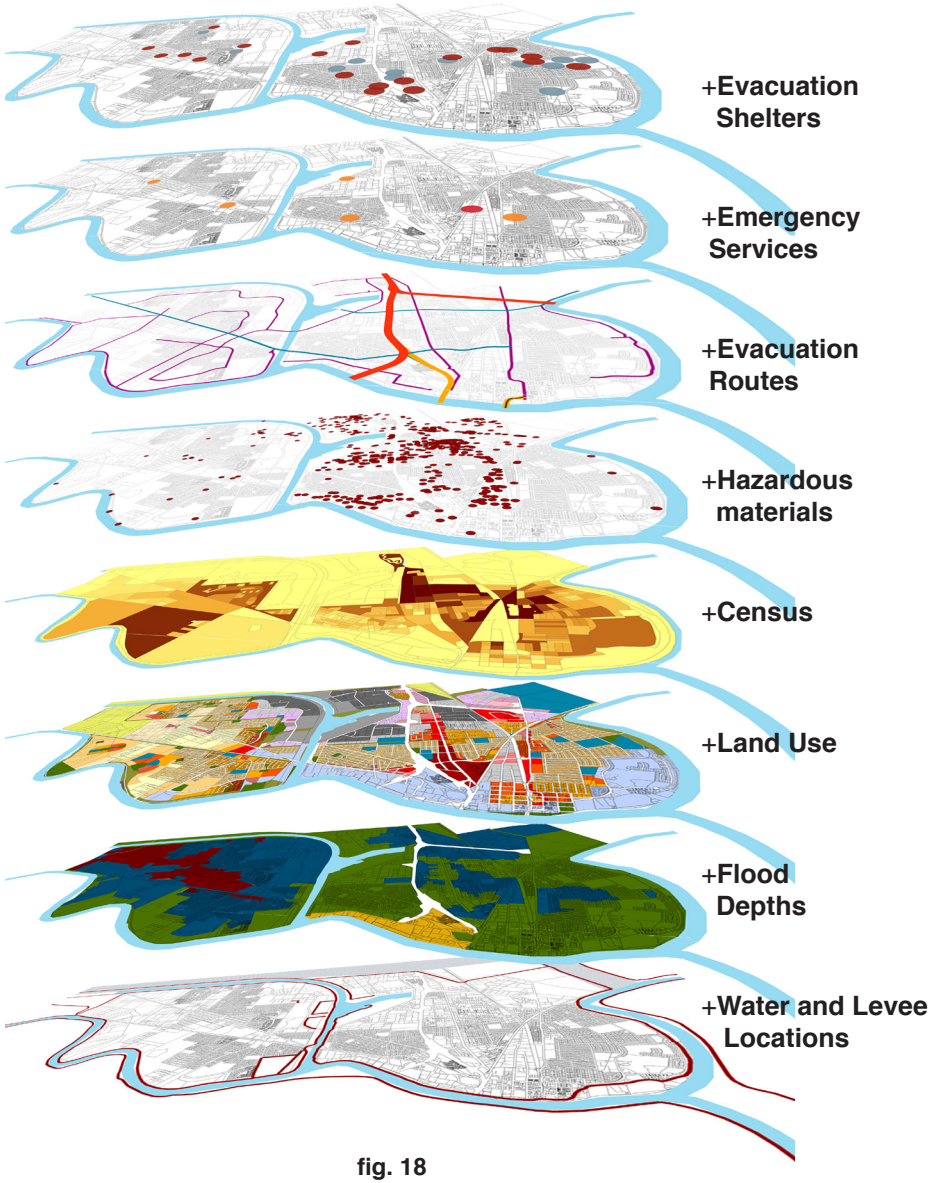


fig. 18
Overlays

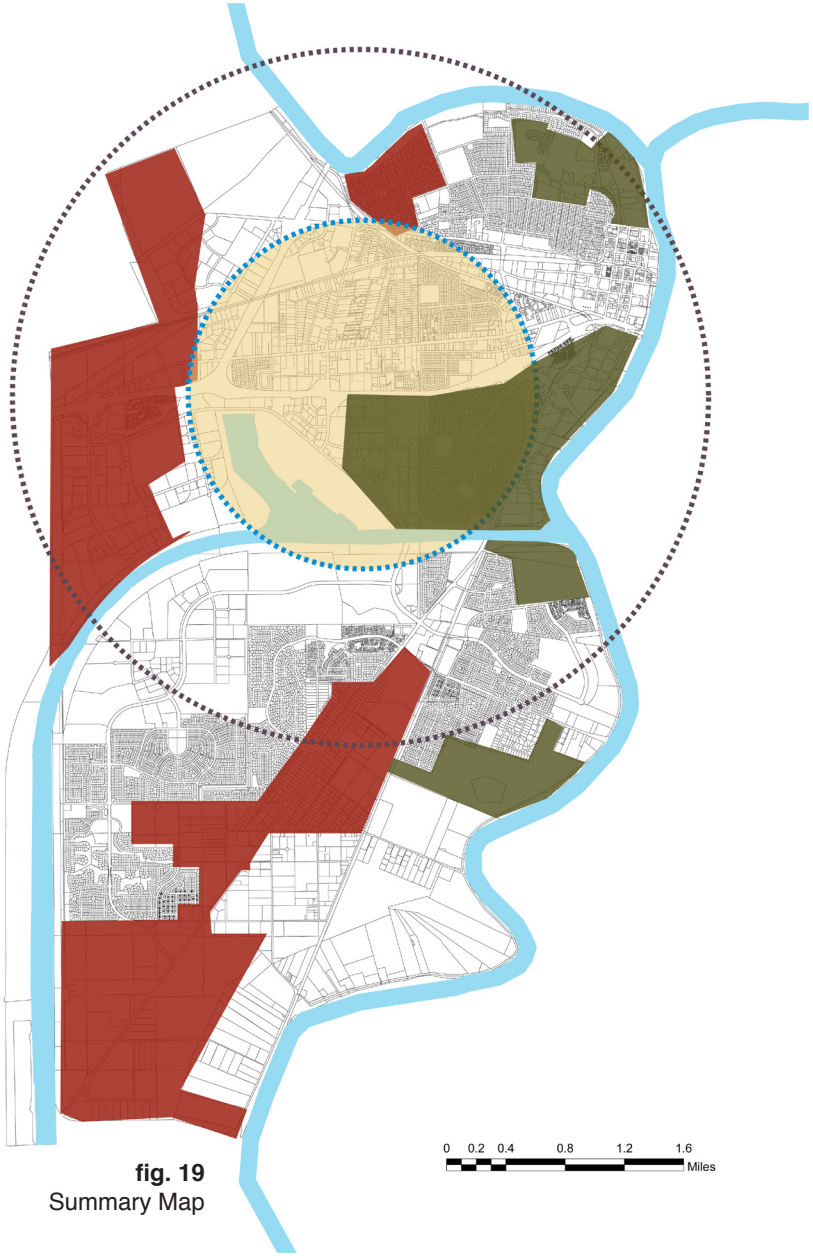


fig. 19
Summary Map

Legend

- 2 mile radius to evacuation
- 1 mile radius to evacutation
- High concentration of haz-mat

High Vulnerable Areas (RED): The most vulnerable areas are located within the 10+ foot and 5-10 feet flood depth zones, adjacent to the Yolo Bypass, and located within the cut banks of the Sacramento River. Due to the high hazard levels. these areas have to be avoided or made into alternative land uses to prevent high structure and land damages and loss of life. Areas with in **YELLOW,** are high haz-mat areas that would be affected during a flood making contamination a serious threat. In addition, areas at high vulnerability lie outside the 2 mile radius from the I-80 evacuation route **(PURPLE LINE)**.

Moderate Vulnerable Areas (CLEAR): Moderate areas are located mostly within the 1-5 feet zones are suitable for moderate intensity uses such as medium density residential, open space, and commercial uses. Buildings will have to maintain building codes to compensate for flood waters. Moderate areas are within 1-2 miles of the evacuation route and there is a low concentration of hazardous materials.

Minimum Vulnerable Areas (GREEN): These areas consist of the eastern side of West Sacramento where the flood depth levels are minimal at 0-1 feet and 1-5 feet. These areas are suitable for urban development and should have fill soils to create a larger surface area for development and decrease flood depths of the urban areas to 0-1 feet minimum. Although most of these green sites are located outside of 1 mile of the evacuation routes, the ground level outweighs the radius in favor of appropriate for development and fortification. In addition, these sites are away from any primary hazards and will most likely hold up during a flood event.

Master Plan

Floods are dynamic systems that require a flexible design approach that can deal with the changing variables of water depth, frequency, and water residency. The flood resistant master plan for West Sacramento will require working with existing structural infrastructure such as the levee reach system and the Yolo Bypass, but will create different pockets of resilient development that will contain landscape architectural and urban design elements to absorb and disperse the flood waters out of the city to mitigate the damages of the water. The integration of conventional flood control and a new technique of utilizing the urban spaces and that can disperse and facilitate flood-waters will be the ideal conceptual plan for West Sacramento. Each element that is a part of the design can work as an independent system; however, during a flood event, these systems come together to form a unified network that work together to mitigate flood waters.

A list of guidelines are ncessary to guide the development and changes within the City of West Sacramento that deal with the creation of fortifying and creating more vulnerable areas, urban centers, setback levees, patchwork of open space, and a transportation system. These guidelines can be used as a systematic transition from conventional development standards to a flood resistant network. Although all attempts are made to preserve existing elements within the city, this is a best case scenario centered at mitigating flood waters.

Fortifying & Vulnerability

The most obvious urban solution to flooding is to create higher grades where areas will become less prone to flooding and to use the city's most vulnerable sites for flood ponding. The most vulnerable areas of West Sacramento will be re-graded and cut to lower the ground elevation to allow the water that breached the city to pool and drain away. These areas need to will be re-zoned as either open space, rural density housing, agricultural areas, or other low-intensity uses. Protecting urban or industrial areas and reducing the protection of lower lying and lower intensity uses will. This allows these areas to be used for two functions, minimizing the risk to the number of human lives and the magnitude of monetary damages. Ground and structural controls will be removed from these more vulnerable locations and relocated to raise the ground grade of the fortified areas. Due to the vulnerable areas as the highest risk for damage, the re-allocation of resources and control structures to fortified areas makes the most economic sense.

For example, a flood breaks out within the southern levee reaches of West Sacramento. The newly cut agricultural land would provide relief to the immediate area as a detention and drainage for the southern reach. With the removal of suburban homes, structural damage and loss of life would be kept at a minimum.

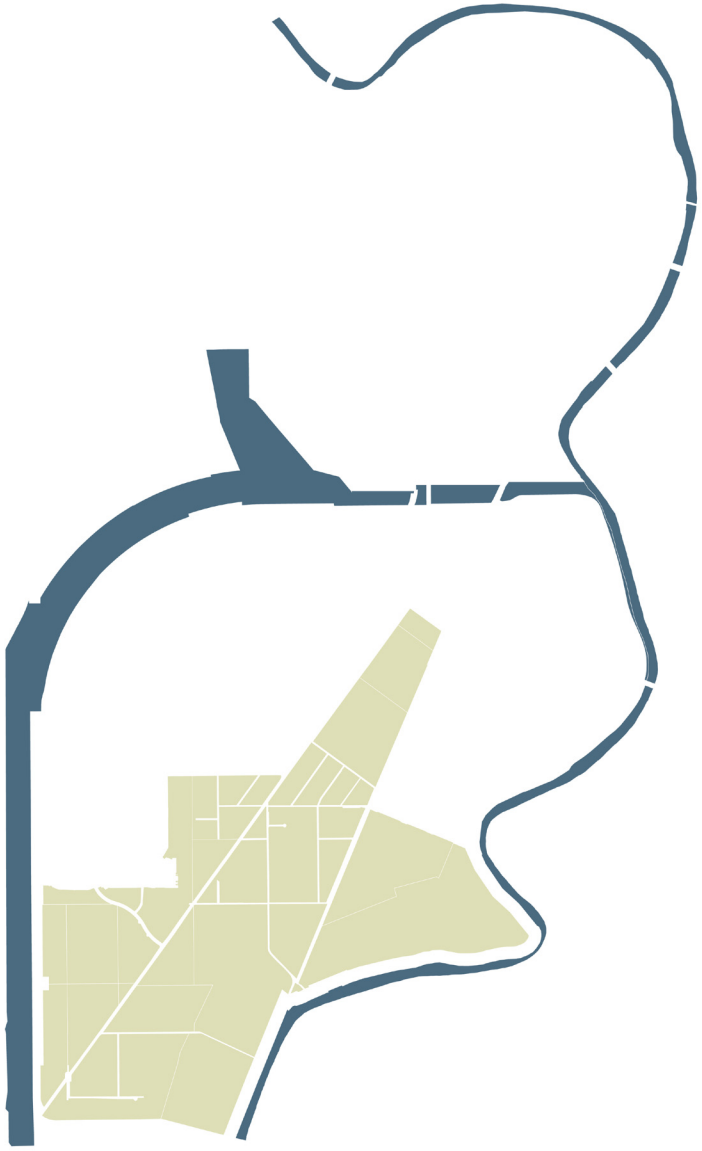


fig. 20
Fortifications Map

Urban Centers

Fortified urban centers create coverage areas or districts that will be responsible for being neighborhood control centers in times of emergency. These urban centers will be able to coordinate local response efforts and provide localized resources for citizens instead of locating all the resources for the city in one or two core locations; resources will be distributed evenly in each center throughout the city. Although each center can operate autonomously, they will be connected with each other to function together to maximize the protection of the entire city. These urban centers can develop in their own fashion creating strong urban social and cultural lifestyle destinations filled with restaurants, shops, mixed-use facilities, and hubs of transportation.

fig. 21
Urban Centers Map

Northern Center
Using existing grided conditions, this urban center takes advantage of a nearby golf course for immediate flood relief. Surrounding residential aras, make this northern center a good choice as a command center for this district. Grade also makes this spot a canadite for fill soils that will be added from agricultural lands.

The Triange
Already planned to under go re-development into mixed use, this is an accentuation of the plan to incorporate a more flood resistant infrastrucuture. Due to the existing high ground, this site was an obvious choice.

Southern Center
This urban center is an extension of the triangle in the southern reach. This site was chosen due to the potential of adding fill soils to the already higher ground to provide fortified conditions for development and its proximity to pre-existing residential areas to act as a district command center.

Linear Center
This urban center is in a linear pattern to be built upon a levee that will help protect the surrounding suburban developments from being flooded if the adjacent agricultural fields fill up to capacity. This urban center will provide flood services, resources, and coverage to the suburban homes it protects

fig. 21.1
Urban Centers Map

Levee Setbacks & Changes

Along the Sacramento River, except for the Triangle Re-development area and other fortified urban centers, the levees will be replaced and rebuilt with a setback of 300 feet from their current position. Setbacks will increase natural habitat along the river and dramatically increase the flood capacity of the river, also reducing the flood hazard for the river.

The relocation of levees 300 feet from their current position will free large parcels of land that can be seasonally used as open space elements for West Sacramento. During non-flooding stages of the Sacramento River, these setback open spaces can l host city recreational areas that for a variety of activities such as boating, fishing, and camp sites. A warning system with alarms and flashing lights will be able to warn users of any flash flooding or rising water depths in advance to give ample time for evacuation. A wide array of stairs and ramps will lead up and over the levees. In addition some areas can be set aside as natural preserves with the re-vegetation o to provide source corridors for riparian species.

According to the WSAFCA, levee upgrades are continuing to improve the levee system for a 200-year flood protection. To protect against wind/water erosion along the Yolo Bypass, a series of riparian trees and shrubs along a bench on the toe of the levee will act as energy dispersion devices and will help prevent erosion. Natural elements along levee reaches will establish more riparian corridor habitat while enhancing the visual aesthetics of levees. Careful consideration needs ensure that the riparian habitat does not interfere with the maintenance and integrity of the levees.

fig. 22
Setback Levee Map

fig. 23
Setback Perspective

Perspective of the setback levees and open space along the Sacramento River

Patchwork of Urban and Open Spaces

The “quilting” of urban and open spaces together will create a flexible urban fabric that will allow the urban system to survive, based upon the open space’s ability to offer stability and protection to the city. A series of these open space patches create “green rivers” throughout the urban fabric, allowing water that has inundated the city to be stored, infiltrated, and drained out of the city to an exit point (Ship Channel, Sacramento River, Bypass). Densification of the urban centers will allow for the allocation of city and home parcels to use reclaimed land for open space.

Open spaces can be created below the grade of the urban spaces to allow for the detention of water to occur. These open space elements are used passive or intensive use, or ideally a combination of the two. Passive uses can be a source and corridor landscape ecological network for West Sacramento. Intensive uses can include recreational activities such as: greenways, softball/baseball, soccer, football, jogging, and other recreational activities. For intensive use spaces, a system of alarms warns users of potential flooding and to evacuate the area. A wide accessibility of ramps and stairs will provide users plenty of emergency exits outside of the sites.

fig. 24
Open Space Map

Transportation

A monorail transportation system will be installed to facilitate public transportation around the city to connect each urban center. During floods, when the road system can be congested or even knocked out or, the monorail that is elevated from the ground by twenty feet, provides reliable means of evacuation. The monorail system will be tied to each fortified urban center to give evacuees public transportation out of their flooded neighborhoods throughout the city possible. The monorail system will double as a regional public transportation system throughout the City of Davis, West Sacramento, and the Sacramento Metropolitian Area. Connections outside of West Sacramento are vital for worst case scenarios when the entire city is flooded. When West Sacramento and the City of Sacramento are both adversely affected and inundated, the connections to the City of Davis are paramount. In addition, a southern bridge that crosses into Sacramento is alos required to improve evacuation movement and options, especially for the southern section of West Sacramento.

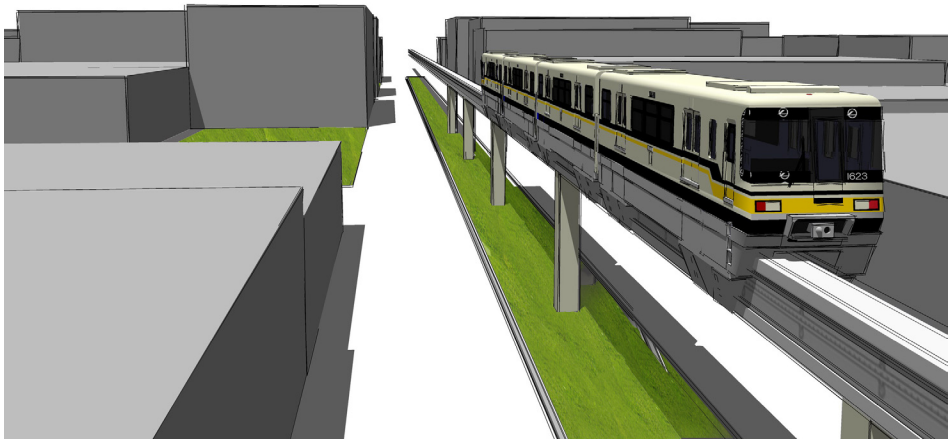


fig. 25
Monorail Perspective

Perspecitve of the monorail in the urban center.

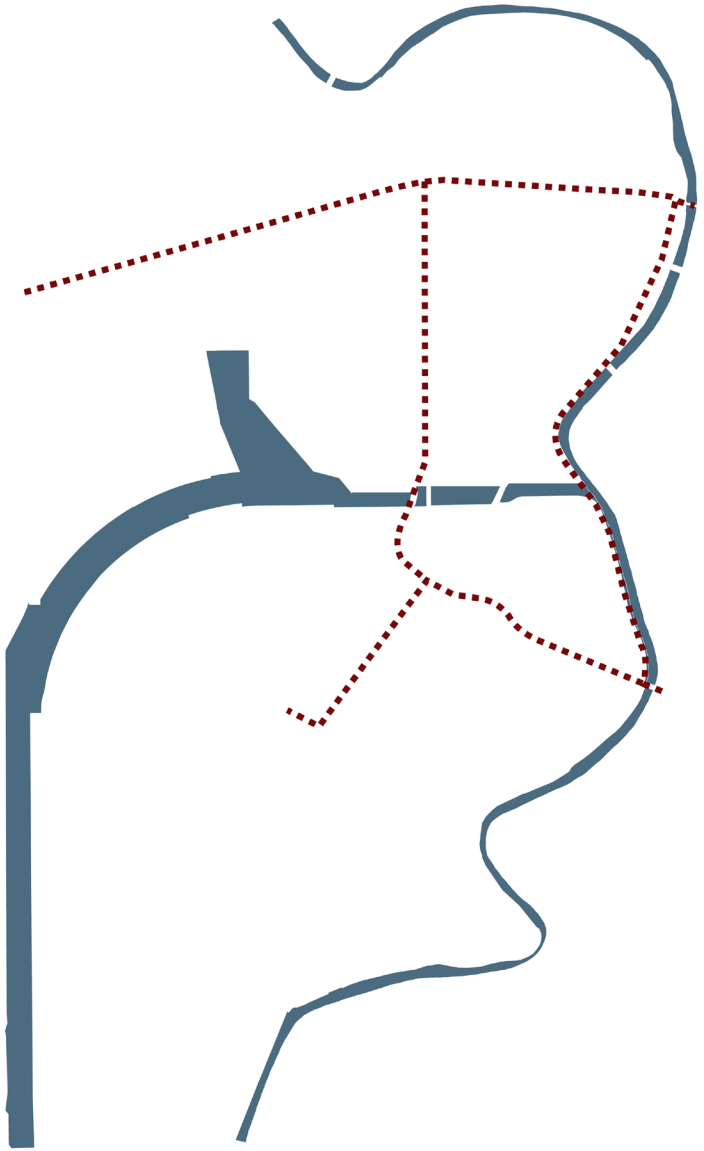
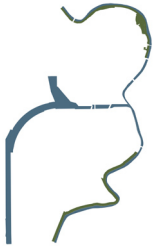


fig. 26
Monorail Map

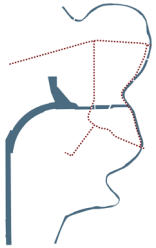
Fortification
+ cut elevation
low intensity uses
agricultural land
flood storage



Setback levees
+ open space
riparian habitat
200 yr. levees
increased flood capacity

Patchwork
+ open space
flood detention
flood drainage

Urban centers
+ emergency districts
fortified and increased elevation
high density, transit oriented design
district emergency services
post-evacuation shelters



Monorail
+ transit oriented
services urban centers
public regional transportation
emergency evacuation

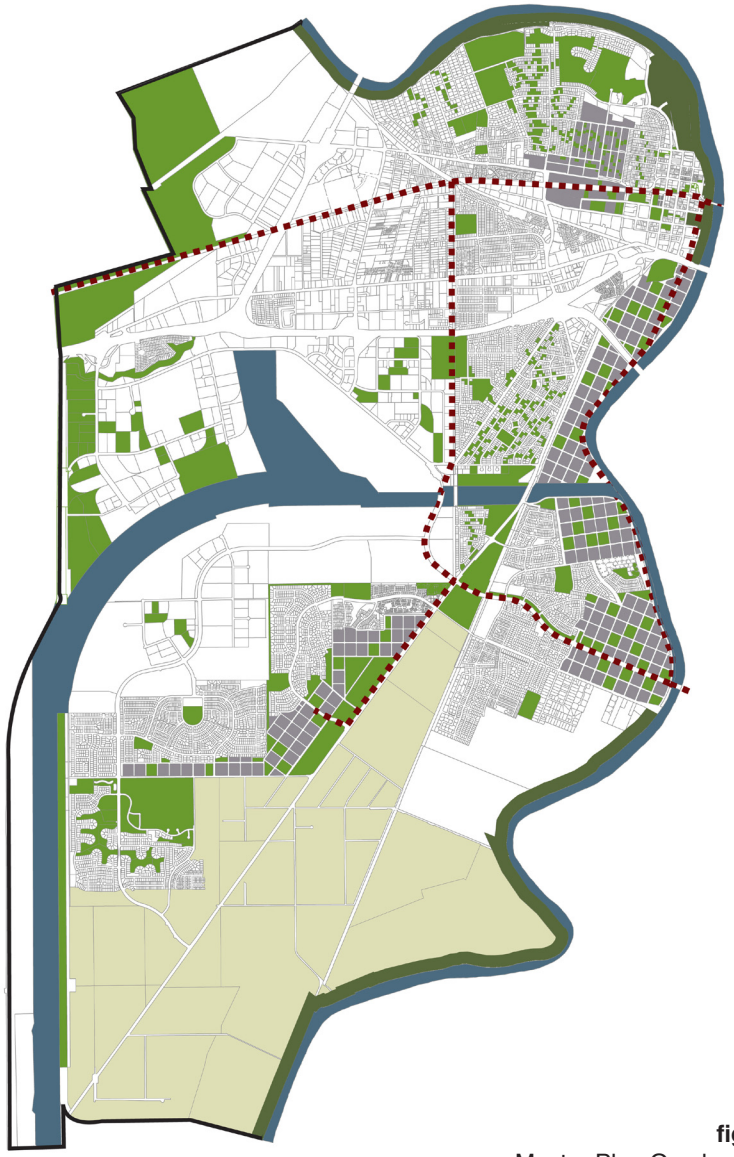


fig. 27
Master Plan Overlay Map

Urban Guidelines

The urban centers that reside within the master plan, need to be designed with certain guidelines to ensure the resiliency of the urban centers. These guidelines are made to make the city resistant against floodwaters, not floodproof. The urban strucutures are made to work with the natural system to be flexible and work with floodwaters requiring minor repairs to the urban infrastructure after a flood.

Architectural Elements

Changes to building codes need to be updated and written in order to require architectural design and building construction that provide for high flood waters. For instance, all single-family houses, multi-unit, and multi-story buildings will be required to only use the first floor (ground level) for storage or parking garages. By elevating the living spaces from the ground level to the second floor all residents will be placed above the 10-foot flood level. Additional homes can even be built upon stilts, raising the building out of flood drastically reducing any damage to the home's structure, contents, and in habitants. Building materials will have to perform to a variety of flood variables. Building materials should be resistant to a variety of durations, especially long periods of time, and be resistant to corosion (Ashley, p. 278)

Urban buildings that established inside the fortified urban centers and have potentially a new flood depth of 0-1 feet, will be required to have a water board of 3 feet minimum to protect bottom floor businesses. By floodproofing homes, the number magnitude of homes, contents, and lives that are at peril will significantly reduced and the subsequent structural damage and replacement costs will also be reduced lowering the economical damage to the city and preventing its citizens from being displaced from their homes.

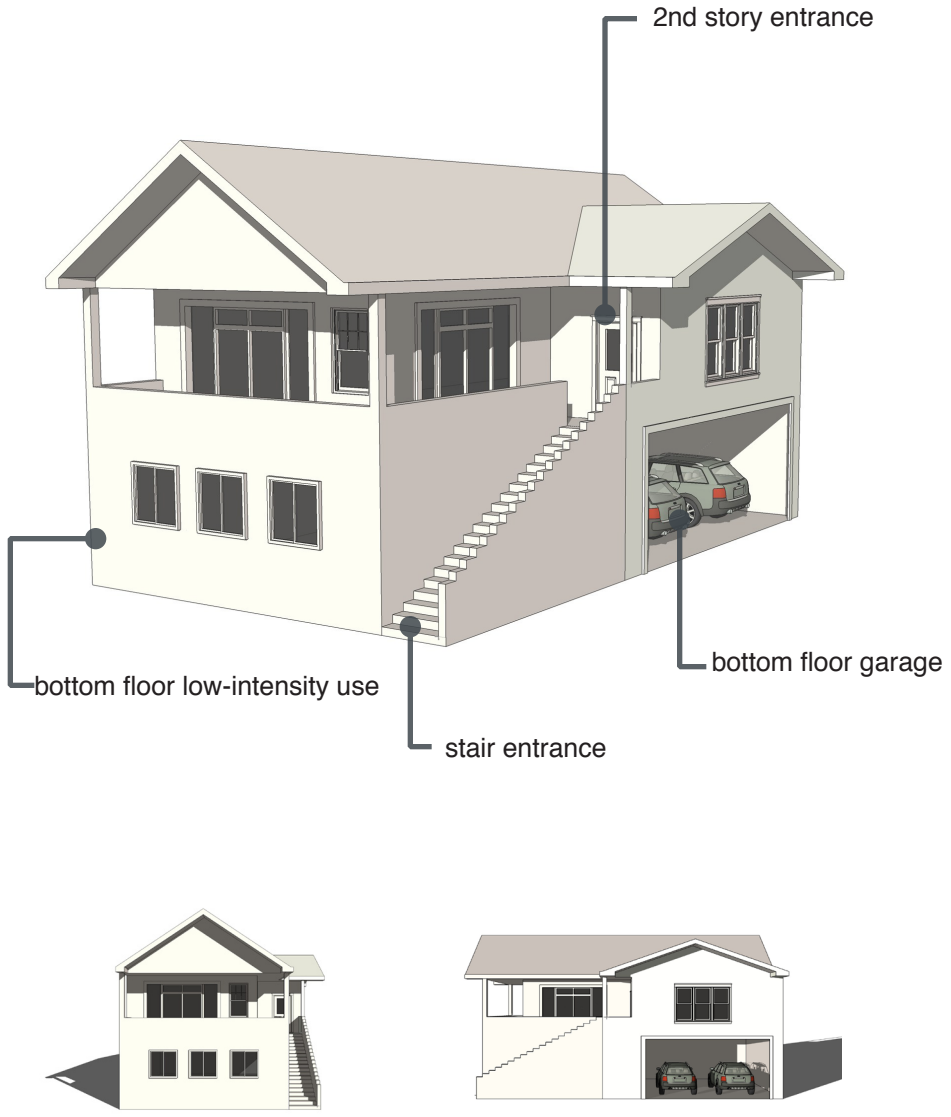


fig. 28
Architectural Perspectives

Raised Grade

Land exhumed from lowering the vulnerable areas will be transferred to the urban centers to maximize the grade and minimize the flood depths. Due to the location of the urban sites within the 1-5 feet depth zone, additional fill of 4 feet would reduce the flood threat of the urban centers to the 0-1 feet depth zone. Soils analysis will have to be conducted and amended if necessary to maximize drainage.

Re-location of essential Resources & Services

Each urban center will allocate all emergency services, triage centers, and response teams within the fortified areas of West Sacramento. The allocation of these emergency services in higher ground will prevent the emergency teams from being compromised, allowing them to access their corresponding districts. Each urban center will act as a base of operations for the emergency periods, coordinating the response efforts of their district and also helping other urban centers if need be.

In addition to the re-distribution of emergency services, essential resources such as grocery stores, gas stations need to be moved to the urban centers. The current land use of West Sacramento has only a few core areas of retail isolating the resources from being readily and equally available to West Sacramento residents. By creating new urban centers and allocating an equal number of retail and resource commercial stores could equally distributing and fortifying the resources amongst the centers to make each center self-sustaining.

Re-location of schools, community centers, & religious centers

The centralization of the schools, community centers, and religious centers in the fortified zone will create orderly evacuation routes and plans of action for each urban district. In addition, centralized location will proved equal access for residents surrounding the urban centers. Within the fortified centers, the vulnerability of these locations will be limited, making them secure locations during emergencies.

Urban Structure

The general layout of each urban center will be transit-oriented, with a central monorail and a regional bus hub to provide easy access to the monorail station. The monorail network will establish central stations within each urban center and with regional connections with Sacramento and the City of Davis. Radiating away from the station will be mixed-use buildings with retail, commercial, and residential uses. Continuing out will be office spaces, businesses, and high density residential properties. The compact development plan will become more sustainable for West Sacramento in the long run by decreasing car trips, increasing public transportation, and increasing pedestrian activity within the

urban centers due to the higher density of resources

Each urban center is built upon a strong grid of streets and alleys to mimic canals during times of flooding to the streets maximize the drainage of floodwaters away from the urban patches to the open space or higher level drainage spaces. The orientation of the streets is perpendicular to the drainage source such as the open space, Sacramento River, or Ship Channel. In addition, the patchwork of open space will accent non-structural flood control and detention.

Integration of Aesthetics, Urban Space, and Flood Technology

With the availability of stronger and better flood control structures, there is a necessity to integrate aesthetics and highlight new urban spaces that the flood structures once intruded upon (Langenbach, 2007, p.79). One of the finest examples of integrating technology and urban solutions was the Bangladesh “Ghat,” hard structured steps that lead down to the river allowing for different heights of interaction with the river as it rose and fell (Hough, 2004, p.57). These “Ghats,” were used for river commerce, entertainment, and recreational boating. A similar idea will be used for the urban centers that have a direct interface with the Sacramento River. Steps will cascade down directly to the river allowing for a variety of uses such as fishing, boating, entertainment, relaxation, or for stroll down to the river; demonstrating for a stronger connection between people and the river instead of hiding the relationship behind an earthen levee.

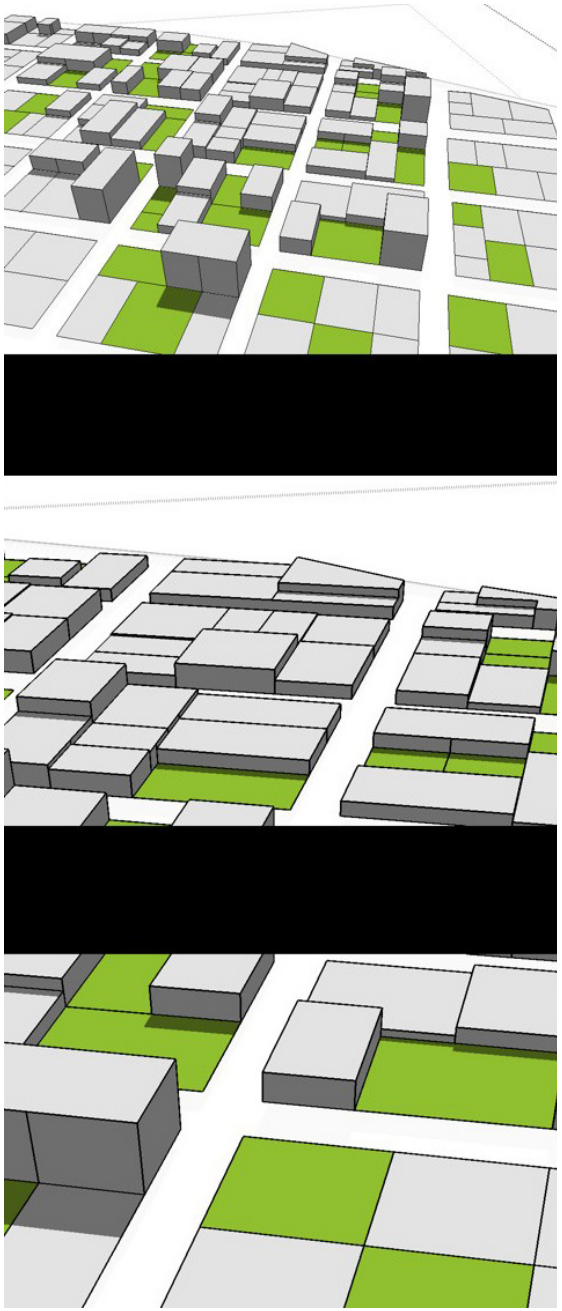


fig. 29
Patchwork

These aerials provide a view of the patchwork of open and urban spaces in an integrated urban fabric.

fig. 30
Ghat Perspective

Perspective of the functional use of a levee and the double use as an aesthetic open space element.

Conclusion

Although this project is a best-case scenario for West Sacramento, large amounts of money and land reclamations will be necessary from private and public sources to implement the plan. However, prevention is the biggest motivator for any city to consider and would economically make sense to invest in the protection than deal with a total disaster. There are little examples of cities in the world that have taken such large steps for protection; however, this plan for West Sacramento can be modified and evolve to adjust to different city conditions making it a flexible design. With global climate change and variable environmental conditions, cities have to step away from conventional thinking of ignoring the surrounding water systems. This design is a new movement to make urban footprints, systems, and people responsive and the ability to evolve with the rivers.

Ashley, R., Garvin, S., Pasche, E., Vassilopoulos, A., Zevenberger., C. (). (2007). *Advances in Urban Flood Management*. New York: Taylor & Francis

Borenstein. S. (2007). *Rising Seal Levels to Flood U.S. Historical Sites*. Live Science. Retrived May 10, 2008, from http://www.livescience.com/environment/070923_ap_sea_history.html

Cermak, R. (2007). *Engineer's Report: West Sacramento Area Flood Control Agency*. West Sacramento, California: City of West Sacramento.

Chow, W. (2007). *West Sacramento Flood Protection: Public Workshop*. West Sacramento, CA: WSAFCA.

City of West Sacramento Environmental Impact Report (COW EIR). (2006). *Hazards and Hazardous Materials*. West Sacramento, CA: City of West Sacramento.

Department of Water Resources (DWR). (2007). *A California Challenge-.Flooding in the Central Valley.* California: California Department of Water Resources.

Environment Canada. (2004). *Flooding Events in Canada*. Retrieved May 8, 2008, from http://www.ec.gc.ca/water/en/manage/floodgen/e_bc.htm

Girot, C. (2007). Topos. New Landscape Topology For Flood Control. Denmark: Callwey

Hough, M. (2004). *Cities and Natural Processes*. New York: Routledge.

Kersting, N. (2007). *Changes in Flood Management Strategies Over Time.* UNESCO-Institute for Water Education. May 14, 2008, from http://www.unesco-ihe.org/floods/report6.htm

Langenbach, H. (2007). Topos. *Flood Management: Determining the Risks*, 77-82. Denmark: Callwey

Marsh. W. (1998). *Landscape Planning and Environmental Applications*. New York: Wiley & Sons.

Maryland Deoartment of the Environment. (2006) *Stormwater Management*. Retrieved May 20, 2008, from, http://www.cbf.org/citizenguides/cbf_stormwater_site/p6_stormwater_diagram.jpg

Nagy, E. (2008). Personal Interview. Sacramento, CA.

Union of Concerned Scientists, United States (UCSUSA). (2005). *Early Warning Signs of Global Warming*. Retrieved May 17, 2008, from http://www.ucsusa.org/global_warming/science/early-warning-signs-of-globalwarming-sealevel-rise-and-coastal-flooding.html