SUSTAINABLE FLOOD MITIGATION:

RETURNING RIVERS TO THEIR NATURAL COURSE

by

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Community participation in flood planning has recently emerged as a successful approach to addressing and restricting the traditionally structural methods of flood control. Flooding, the most costly natural hazard worldwide, causes economic damages in spite of flood control efforts throughout the 20th century. To control flooding while allowing development, localities have traditionally used structural controls, such as levees and floodwalls, to physically separate floods from people. In light of the continued failure, high costs, and environmental degradation associated with structural flood controls, localities are now increasingly focusing on non-structural flood mitigation methods to reduce flood risks and losses. Furthermore, communities throughout the country are incorporating innovative flood projects that balance structural and non-structural flood mitigation in an attempt to better address environmental concerns.

This approach involves returning previously damaged rivers and floodplains to their natural state. This evolution from structural approaches to environmentally conscious flood planning is illustrated through a case study of Napa, California's model flood plan. Through an analysis of the flood plan and interviews with government representatives and project engineers, this case study illustrates how localities can design and implement flood plans to provide for environmentally sustainable flood mitigation. Building on a model of best management practices which incorporates the "living river" concept in the Napa River Flood Protection Project, this report suggests how other communities with severe river flooding can develop similar sustainable flood plans. Napa's flood project represents a paradigm shift in which local residents were the driving

force behind designing an environmentally sustainable and locally supported flood plan that would be carried out by the U.S. Army Corps of Engineers. The key lessons learned from Napa's flood project are that community involvement and consensus building among stakeholders are crucial to developing and implementing an environmentally sustainable flood management project.

I. INTRODUCTION

Floods are the most costly natural disasters worldwide (Hewitt 1997; Palm 1990) and make up 90% of all disasters in the United States (Federal Emergency Management Agency 1997). With the annual cost of flood damages in the United States estimated at $4 billion (Siegel 1996, 152), flood hazard mitigation policies are important to localities, states, and the federal government. Cities across the country have developed and utilized flood plans with various degrees of success at reducing flood loss and damage. In spite of these efforts, economic losses from natural disasters are still increasing (Mileti 1999, 24).

Traditional approaches to flood control involve structural methods, such as building floodwalls and levees, or straightening river channels. As is evident by the increasing economic losses from floods, these structural approaches are no longer successful. In addition, structural approaches are not environmentally sustainable. More sustainable, non-structural approaches are therefore necessary. Incorporating sustainable hazard mitigation, such as open space conservation, wetland protection, and river restoration, into flood plans can result in flood mitigation policies that reduce flood losses more effectively, while also maintaining environmental sustainability.

The purpose of this report is to analyze how the incorporation of sustainable flood mitigation approaches into local flood planning can address flood hazards in a more economically efficient and environmentally sound manner than does the structural flood control approach of river straightening. This report first provides a discussion of the flood problem and its relationship with urban development. Second, I discuss the problems related to the use of traditional, structural flood control adjustments. The next section discusses how non-structural flood mitigation decreases the risk of flood hazards and decreases the environmental and economic damages attributed to flood events. In connection with restoring the natural function of rivers and their floodplain, I provide a discussion of how rivers that have been artificially straightened or modified in the past have caused ecological degradation and increased flood potential and severity. Finally, given the significantly large probability of downstream flooding and environmental degradation resulting from channelizing or straightening rivers (U.S. Army Corps of Engineers 1995), I present the approach of returning rivers and floodplains to their natural functions as a new viable method of sustainable non-structural flood hazard mitigation. A case study analysis from a flood protection project for Napa, California is used to illustrate the use of environmental restoration for flood mitigation. This report focuses on how restoring rivers and their floodplains can mitigate flood risks and losses while also restoring and maintaining the quality of the natural environment along rivers. Furthermore, it will determine which environmental concepts and social and economic factors (community involvement, support and funding) enable the writing and implementation of such sustainable flood plans.

Whether they border vast rivers such as the Mississippi River, or relatively small urban rivers such as the Napa River in California, many cities need to utilize flood plans to protect the safety and well being of their residents. This report is therefore valuable for any locale that is threatened by river flooding. By guiding future flood mitigation projects and policies to address the question of sustainability, this report can improve flood plans and result in improved and more effective efforts to reduce flood loss and damage for communities throughout the United States.

II. THE FLOOD PROBLEM

Human settlement patterns have increased flood hazards because population growth increases development pressures in flood-prone areas (Blaikie 1994, 125). Flooding itself is a naturally occurring event that replenishes and sustains ecosystems and as such, is not a hazard. Humans place themselves in the path of floods thereby transforming a natural event into a hazard. In addition, settlement patterns and related infrastructure in and near floodplains also increase the frequency and extent of floods. Due to unsound settlement patterns, the United States experienced $30 billion in flood damages between 1993 and 1997 (Changnon 2000, 85) and 10 million U.S. households were estimated to be at risk of flooding in 1997 (Federal Emergency Management Agency 1997).

Floodplains are defined as areas with a 1.0% probability of being inundated in any giver year (Palm 1990, 12). This is described as a 100-year flood. Floodplains are important natural resources because of their natural characteristics. Floodplains provide flood storage by absorbing most of the runoff from heavy rains and overflow from rivers (Burby et al. 1999, 252). Floodplains are also important natural resources because they provide crucial habitats for animals, improve water quality by filtering out pollutants, and aid in the recharge of groundwater (Burby et al. 1999, 252).

Two major man-made causes of flooding are the encroachment of structures and human settlement onto floodplains and the increase in impervious surfaces. Encroachment and development in floodplains increase the flood hazard. Development on the floodplain decreases the surface area of permeable soil and increases the surface area of impervious surfaces. Consequently, increased volume and velocity of surface water runoff is inevitable with increased development within floodplains (Ortolano 1997).

The infiltration and storage capacity of the land surface and the prevalence of impervious surfaces are important aspects of flooding that are directly affected by development practices. The infiltration and storage capacity is the amount of water that can be absorbed and stored by the land. This capacity is determined by the amount of water already in the soil due to recent snowmelt or rainfall, and the type of surface of the land, such as soil, vegetation, buildings, or pavement. As a result of human activities that decrease infiltration capacity, such as building homes, paving roads or clearing forests, rainfall intensity can exceed the infiltration capacity and result in direct surface runoff, increasing the likelihood and intensity of flooding (Ward 1978). The replacement of permeable soils with the impervious surfaces of urban areas and roads in rural areas contributes to the volume and speed of direct runoff from a rainstorm (Ward 1978; Siegel 1996, 137; Blaikie 1994, 125). The scale at which urbanization is taking place is also of concern and contributes to the severity of the flood problem because more rapid urbanization means more drastic land-use changes, which increases surface water runoff (Ward 1978).

III. STRUCTURAL FLOOD MITIGATION

Federal and State governments have addressed the destructive impacts of flooding on human settlements by enacting flood control measures throughout the 20th century. In an attempt to decrease the economic and human life losses associated with the inevitable flooding of rivers and floodplains, governments provided the legal authorization and necessary funding for structurally altering the natural environment to prevent or control floods. This chapter discusses these structural flood control measures.

Government policies enacted to manage and control flooding have historically been structural measures that focus on engineering approaches to flood control (Gruntfest 2000, 406; May et al. 1996, 146; May and Williams 1986, 65). In a few states, such as Mississippi, Congress authorized surveys and enacted flood control measures as early as the mid-1800s (Leopold and Maddock, Jr. 1954, 98). At the national level, Congress passed the 1917 Flood Control Act to control the waters of the Mississippi and Sacramento Rivers.

In spite of the structural adjustments provided by the 1917 Flood Control Act, the Great Mississippi River Flood of 1927 further illustrated the need for more funding for flood control measures, as well as more appropriate flood management policies. The flood of 1927 resulted in the enactment of the Flood Control Act of 1928, which included channel improvements and levee construction along Mississippi River and its tributaries, and authorized the federal government to pay substantial costs for maintaining all levees along the Mississippi River (Cech 2003, 227).

In response to continued severe flooding along the Mississippi River, the 1936 Flood Control Act was passed, which expanded on the 1928 Flood Control Act. The 1936 Act, along with its subsequent amendments in 1944 and 1960, put the power to plan for flooding and implement flood control measures in the hands of the federal government, as opposed to state or local government (Arey 1972, 29). The Flood Control Act acknowledged the destructive nature of flooding rivers and called for structural improvements to rivers for the purpose of controlling floods (Pasterick 1998, 125; Flood Control Act 1936). Thus began the national effort to control flooding with structural works.

Structural flood mitigation involves the use of major public works such as levees, floodwalls, dams and reservoirs, and channelization to control floodwater. The function of these structural methods is to prevent damage by keeping floods away from people and buildings. Structural adjustments can accomplish this by reducing the peak flow of floods, reducing flood elevations, containing flood flows within the channel, or routing flood waters away from developments (Owen 1981, 44). The design and construction of structural flood controls is primarily the responsibility of the U.S. Army Corps of Engineers in conjunction with local planners and engineers. The Army Corps of Engineers is the nation's oldest water resource agency focusing on flood control (Cech 2003, 222).

There are many perceived benefits of structural flood controls. Structural flood mitigation can re-route flood paths away from human settlement and structures and are often successful at restricting small-scale flooding. They have proven effective at times and provide a degree of protection from floods (Pasterick 1998, 125). The U.S. Army

Corps of Engineers estimates that structural flood controls prevented $19 billion in damages during the Midwest flood of 1993 (Burby et al. 1999, 252).

In spite of the benefits of structural flood controls, there are far more drawbacks associated with their use, including failure, environmental degradation, increased downstream flooding, and the promotion of floodplain development. Structural flood controls often fail in the long run (Burby et al. 1988, 2). The high cost for structural works is significantly increased from maintenance for failure prevention or repair. The Jackson, Mississippi flood of 1979 illustrates the potential for failure of structural flood controls. The flood control structures in place in Jackson, in this case a levee system, failed because the flood volume exceeded the design limits of the levees (Platt 1982, 228). A similar failure of the levee system along the Sacramento River, which could potentially occur from a moderate 50-year flood, could result in property damages totaling an estimated $9.2 billion (Burby et al. 2001).

In addition to their high risk of failure and maintenance costs, structural flood controls are also unsustainable because of their detrimental impact on the natural environment. Structural flood controls often result in negative environmental impacts including the destruction of fish and wildlife habitat (Owen 1981, 59; Smith and Ward 1998, 206). Straightening river channels for flood control, for example, results in steeper slopes and higher flow velocities, which will ultimately increase soil erosion (MacBroom 2002, 380). Widening channels can also have adverse environmental impacts because it reduces flow velocities, which leads to shallow water depths and subsequent sediment deposition (MacBroom 2002, 380).

A third drawback of structural flood controls is the increased downstream flooding. Although they protect the immediate area where they are located, levees, floodwalls, and other structural works can increase downstream flooding because they increase the carrying capacity of river channels (Owen 1981, 58; Beatley 1998, 239; U.S. Army Corps of Engineers 1994, 3-14). Pima County, Arizona, for example, discovered the drawbacks of channelization[1] during the 1983 flood event. The constructed concrete channels of the Santa Cruz River provided flood control for the immediate area where it was in place, but resulted in severe downstream flooding because the flood control channels reduced the infiltration capacity and rapidly transported flood waters downstream (Wood et al. 1999, 77). Therefore, structural flood control measures are neither sustainable nor equitable because they threaten one community while protecting another.

A fourth drawback of structural works is that they tend to inadvertently encourage floodplain development. The encroachment onto floodplains and flood prone areas can be partially attributed to the false sense of security provided by structural works (Pasterick 1998, 125; Hewitt and Burton 1971, 96; Montz and Gruntfest 1986, 326). When people believe that structural adjustments have eliminated the flood risk, development and settlement in flood-prone areas continues, an increasingly large portion of the population is exposed to flood risks, densities increase, and the proportion of impervious surfaces increases. The sense of security afforded by structural flood controls is misleading because levees and other public works can fail in times of severe flooding.

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[1] Channelization involves straightening a river channel to remove meanders and make water flow faster, and sometimes includes concrete lining on the sides and bottom of the channel (Environmental Protection Agency 2003).

Another type of structural flood control involves modifying channels to straighten the course of the river. River straightening or realignment has been used for flood control because it increases the carrying capacity of the river by shortening the flow distance and thus increasing the velocity at which floodwaters pass through the river. River straightening has also been historically used for purposes other than flood control, such as improving river navigation. As illustrated in Table 1, a large number of rivers have been straightened as early attempts at flood control, such as the Napa River, the Chicago River, and the Kissimmee River. In spite of being previously straightened for flood control, rivers continue to flood, downstream flooding is increased, and in many cases environmental conditions are degraded (MacBroom 2002, 380; U.S. Army Corps of Engineers 1995).

In downstream areas where no channel improvements or flood control works are in place, the greater discharge caused by straightened river channels will increase flooding (U.S. Army Corps of Engineers 1995, 6-3). In past cases, straightening a naturally meandering river has caused channel degradation, bank erosion, and the incision of tributaries (U.S. Army Corps of Engineers 1994, 3-2). Artificially straightened rivers also tend to have a less consistent pattern of sediment routing, are less stable morphologically, and maintain less hydrological and biological diversity (Keller and Brookes 1983, 384). Sediment routing is important because an imbalance between sediment transport capacity and sediment supply changes the channel morphology and results in incised river channels (Bledsoe et al. 2002). Straightened river channels impact the overall stability of the river, resulting in increased sedimentation that has harmful effects on aquatic ecosystems (U.S. Army Corps of Engineers 1995, 6-4, 6-8).

Table 1. Straightened Rivers in the United States.

River	State
Napa River	CA
Kissimmee River	FL
Chicago River	IL
Missouri River	MO
Sabines River	TX
Cuyahoga River	OH
Waupaca River	WI
Smiths Fork River	WY
Alamosa River	CO
Mississippi River	MS
Petaluma River	CA
Duchesne River	UT
Provo River	UT
John Day River	OR
Los Angeles River	CA
Salmon River	ID
Willamette River	OR
East Two Rivers	MN
Jordan River	UT
Sammamish River	WA
Russian River	CA
Trinity River	TX
Truckee River	NV
Long Creek	MS
San Antonio River	TX
Red River	NM, TX, OK, AR, LA
Puerco River	NM
Twenty Mile Creek	MS

Source: Internet search by the author. Websites listed in Appendix A.

Another drawback to straightening rivers for flood control is that rivers frequently return to their natural meandering course over time (U.S. Army Corps of Engineers 1994, 3-11, 3-15). In the long-run, a river channel returning to a meandering course without appropriate flood control measures can worsen flood conditions. Flooding will occur where the river is meandering away from the artificially straightened path, increasing the costs of this structural flood control method.

The growing economic losses from flooding are another indicator of the failing structural flood controls and river straightening. Despite the billions of dollars spent by the United States on structural flood controls, flooding remains a hazard (May and Williams 1986, 65). The exclusive use of structural controls is an expensive and limited approach to flood mitigation (Burby, et al. 1988, 2; May and Williams 1986, 65). As flood costs increase with the population growth and development in flood-prone areas, these structural methods should not be utilized as the main approach to reduce flood disasters, but merely a supplement to more sustainable flood mitigation measures. The following chapter discusses how non-structural flood measures protect communities from severe flooding while protecting environmental quality, which structural measures fail to address.

IV. NON-STRUCTURAL FLOOD MITIGATION APPROACHES

Structural solutions for flood control have typically dominated flood mitigation policies, whereas more cost-efficient non-structural approaches, such as changing land-uses in flood-prone areas, have yet to receive better promotion and support at all levels of government (Changnon 2000, 99). Non-structural flood measures can be used to achieve sustainable flood mitigation. Traditional examples of non-structural flood measures include land-use management, development regulations, land acquisition, warning systems, and flood insurance. More recent approaches that are gaining momentum in the field of flood planning involve restoring wetlands and returning rivers to their natural paths.

A. Sustainability criteria for flood mitigation

Sustainable flood mitigation involves policies that aim to reduce flood losses, while promoting sustainable communities and environments that are resilient to future flooding (Mileti 1999). These policies typically involve non-structural measures to address issues such as overgrazing, deforestation, poor irrigation management, intensive farming, unplanned development, environmental degradation, increased industrial activity, changing land uses in flood prone areas, and lack of contact between developers and people working on disaster management and mitigation (Mileti 1999). Non-structural means of mitigating flood losses can be the cornerstone of sustainable development policies to address these concerns.

Mileti (1999, 31) describes six components that characterize sustainable hazard mitigation: environmental quality, quality of life, disaster resiliency, economic vitality, inter- and intra-generation equity, and participatory process. Addressing these components and incorporating them into local flood management projects can promote sustainable and flood-resilient communities.

The first component of sustainable flood mitigation involves maintaining and enhancing local environmental quality so that human activities, such as development, do not reduce the carrying capacity of ecosystems (Mileti 1999). With regards to flood hazards, this can be accomplished by linking flood mitigation efforts to the management and preservation of natural resources (Mileti 1999). For example, when development encroaches onto the floodplain, it destroys the natural functions of the floodplain, such as water infiltration, which would under natural circumstances mitigate the flood hazard. Flood mitigation projects that restore floodplains to their natural functions, therefore, would address the environmental quality component.

Maintaining and enhancing the quality of life of a community can be achieved by avoiding flood control techniques that create negative externalities, such as downstream flooding caused by channelization and the construction of levees, or taxpayers costs of financial assistance after floods (Mileti 1999). This component of sustainable flood mitigation encourages working relationships at the local, state, and federal level (Mileti 1999).

Mileti's next component of sustainable flood mitigation is creating and maintaining communities that are resilient to flooding and other natural disasters. An important step in achieving disaster resiliency is by educating the general public of their unique local environmental problems and flood risks (Mileti 1999). A community can be more resilient to flooding if residents are well informed about the connection between flood risks and environmental sustainability, and how this connection affects the community's safety from flooding. Therefore, community education and outreach is an important method of attaining disaster resiliency.

The fourth component of sustainable flood mitigation is for a sustainable local economy that is diversified and resilient to the economic impacts of flooding and its aftermath (Mileti 1999). Communities experiencing recurrent flooding suffer not only from the initial flood event, but also from the loss of business associated with road closure, decreased tourism, and overall economic hardships. A flood plan designed to not only mitigate flood loss, but also enhance economic vitality would meet this component of sustainable flood mitigation.

The focus on inter-generational and intra-generational equity follows the principle that costs incurred today should not be shifted to subsequent generations, nor should exposure to hazards be unevenly distributed (Mileti 1999). As such, sustainable flood plans aim to protect both the present and the future through a fair distribution of costs and benefits. A flood plan that endangers downstream communities would not meet this criterion of sustainable flood mitigation.

The final component of sustainable flood mitigation proposed by Mileti is the participatory process. The participatory process involves building consensus (although a full consensus may never be reached nor desired) among community members and stakeholders about flood mitigation approaches and desired results (Mileti 1999). This process should involve all stakeholders in the planning process, generates and distributes information, can advance new ideas, and develops a sense of community (Mileti 1999).

To achieve sustainable flood mitigation, the methods used to remedy flood hazards should incorporate these six components. The following section focuses on determining whether each specific non-structural approach includes these components, and assesses whether it should be encouraged for use by local flood control projects.

B. Traditional non-structural approaches

As presented in the chapter on structural flood mitigation, structural flood controls often cause environmental degradation, result in an unequal distribution of hazards between communities and generations, and rarely involve public participation. In contrast, non-structural measures can maintain environmental quality, provide long-term resiliency to floods, and improve the quality of life by keeping people away from the flood hazard. Non-structural measures can also promote local economic vitality by supporting commerce in areas previously at high-risk of flooding, promote equity among communities and generations, and allow for active public participation. Therefore, non-structural flood mitigation approaches are more sustainable than structural measures.

1. *Land-use management*

Communities can mitigate flood risks by enacting land-use controls and implementing land-use plans which steer development away from flood-prone lands (Owen 1981, 43). By doing so, land-use management policies can reduce a community's susceptibility to flood damages (Burby et al. 1988, 82). Land-use management is an important element of sustainable flood mitigation because developers and policy makers contribute to the effects of flooding by developing floodplains for settlement and agriculture, and building roads and bridges in flood prone areas (Ward 1978). A solution to this problem is to develop land-use management policies that conserve open spaces within floodplains, regulate deforestation and land cultivation, provide wetland protection and restoration, limit the amount of impervious surface by managing urban growth, restrict alterations and "improvements" to river channels, and improve the enforcement of such policies.

Conserving open space can have multiple benefits. Local land-use designations can allow for floodplains to be conserved as open space and prevent development in flood-prone areas. Open space can be conserved through land acquisition, discussed below. Floodplains that are maintained as open space can be used for recreation (such as bike paths and parks), habitat conservation, and a variety of other uses that support the objectives of flood mitigation. Communities at risk of flooding can incorporate open space conservation policies into land-use plans as a long-term non-structural flood mitigation measure.

Land-use management is also conducted through local zoning ordinances. Zoning ordinances that limit new development in flood prone areas strive to redistribute the population and constructed environment so that they are situated in areas with a minimum risk of flood losses (Mileti 1999). Zoning ordinances can also require minimum and maximum lot sizes. Requiring larger lot sizes in flood prone areas, and thus requiring a higher percentage of unbuilt area on lots, may prove beneficial at reducing the surface area covered with impervious surfaces, thus reducing water runoff and reducing the flood risk.

Land-use management is an effective flood mitigation tool because it can be put into effect immediately and is effective in the long-term (Siegel 1996, 156). Land-use management promotes sustainable flood mitigation because it protects the environment while also creating disaster resilient communities that protect against the loss of life and prevent future flood disasters. Localities practicing land-use management can become resilient to flood disasters by preventing development on flood hazard lands.

However, there are obstacles to the implementation of land-use management for flood mitigation. Land-use management is a political process, and planners merely recommend land-use plans for implementation at the local or state level. A land-use plan must gain support by local and state decision-makers in order to be approved and implemented. Urban growth policies may also hinder the process of sustainable flood mitigation. By striving to contain development within urban boundaries, urban containment policies may put pressure to develop flood-prone land (Burby 2001, 478). On the other hand, growth management policies that prevent development in flood prone areas can reduce the risk of flood damage (Berke 1998, 76). Despite difficulties in implementation, land-use management can be an effective tool at sustainable flood mitigation.

2. *Building standards*

Enforcing specific building standards in flood prone areas is a useful non-structural method of preventing flood damages. Building standards for flood hazards can include setback requirements from rivers or minimum floor elevation requirements to protect buildings from flood damage. For example, building standards are used in Pima County, Arizona to guard against flood losses within or near floodplains. A minimum building setback of fifty feet is required along any watercourse with a base flood peak discharge of two thousand cubic feet per second (cfs) or less (Pima County Code. Title 16). For all watercourses with base flood peak discharges between two thousand and ten thousand cfs, building setbacks are 100 feet (Pima County Code. Title 16). Watercourses with base flood peak discharges greater than ten thousand cfs require a building setback of 250 feet (Pima County Code. Title 16). When unusual conditions exist along a watercourse, the county engineer determines building setback requirements on a case-by-case basis. For example, the Santa Cruz River, Rillito Creek, Pantano Wash, Tanque Verde Creek, and the Canada del Oro Wash, the floodplain management ordinance requires a minimum building setback of 500 feet (Pima County Code. Title 16).

The benefits of building standards in flood mitigation tend to be overlooked. According to Burby et al. (1999) only 10% of local governments in the United States utilize programs to encourage individual property owners to reduce flood hazards by investing in building standard measures (Burby et al. 1999, 252). A weakness in the use of building standards as a tool for flood mitigation is that, like structural flood controls, they often encourage development in flood prone areas, thus increasing floodplain encroachment and potential flood risks (Olshansky and Kartez 1998, 194). Since building standards can encourage floodplain development, they do not build disaster resiliency and do not promote inter-generational equity, and thus fail to include some of the sustainability components proposed by Mileti. For this reason, incorporating building standards into local ordinances or as voluntary measures for individual property owners should not be used as the only method of sustainable flood mitigation. However, requiring buildings to be set back from major rivers or to be elevated above flood-prone lands promotes environmental quality because buildings do not tamper with the natural environment. This approach is therefore in part sustainable.

3. *Land acquisition and relocation of structures*

Land acquisition is another non-structural approach to flood mitigation that can prevent future development on flood-prone land. Land acquisition involves purchasing open space within floodplains by public or non-profit entities and may involve the relocation of buildings in flood-prone lands to avoid and limit development.

Floodplain management via land acquisition can preserve open space. Acquiring open space for flood mitigation is accomplished by mandatory dedications required by subdivision regulations, conservation easements, donations from private property owners, or the public or non-profit purchase of land from private property owners (Burby et al. 1988, 5). Cities and states can promote the purchase of open space in flood-prone lands to be used as parks, athletic fields, golf courses, or natural preserves, instead of allowing them to be developed with housing or other buildings that will increase the flood potential and place more people at risk (Owen 1981, 44).

The transfer or purchase of development rights can also be linked with land acquisition programs. Transferable Development Right programs work by separating the development potential of a parcel from the actual land, and selling that development potential to be used on another parcel (Juergensmeyer and Roberts 1998). Transferring development rights also often takes the form of conservation easements, in which the existing condition of the land is conserved and managed, thus preventing flood concerns associated with increased development. Through the purchase of development rights localities can prevent further development on flood-prone land.

Although more difficult to accomplish than purchasing land as open space, acquiring land to relocate buildings involves purchasing property and relocating people and buildings onto land less prone to flooding (Burby et al. 1988, 5). Tulsa, Oklahoma exemplifies the promise of relocation as a flood mitigation measure. In response to years of severe flooding, Tulsa's relocation program has moved 900 homes out of the Mingo Creek watershed since the 1980s and maintains the acquired land as open space (Beatley and Manning 1997, 100).

There are many benefits associated with land acquisition. Cities can preserve open space, protect water quality, allow groundwater to recharge, and provide areas for recreation, all while also reducing flood risks (Burby et al. 1988, 5). Land acquisition is a viable strategy at mitigating flood losses because it is permanent. However, a key drawback of this approach is that it can be very expensive (Siegel 1996, 157; Olshansky and Kartez 1998, 197).

Using land acquisition is a sustainable approach to flood mitigation because it restricts further development of floodplains, thus protecting environmental quality. With land acquisition, the harmful impacts of development are avoided. Land acquisition and relocation of structures away from flood-prone areas also prevents economic losses from floods and promote disaster resiliency. Land acquisition and relocation further promotes inter- and intra-generational equity because it enhances the ability of the present and future generations to maintain environmental quality and a high standard of living by becoming more resilient to flood disasters. In addition, land acquisition can also involve public participation through dedications, donations, and conservation easements.

4. *Warning systems*

Warning systems are useful tools to decrease the losses associated with flooding by alerting residents of potential floods, thereby allowing them time to safeguard their property or evacuate if necessary. Flood forecasting and warning systems can reduce economic losses by 40% (Siegel 1996, 152).

As with structural flood controls, warning systems may encourage floodplain development because people believe the flood hazard is significantly diminished by the presence of a warning system. Although warning systems are beneficial and can save lives and money, they do not decrease the risk of flooding, they merely alert the public of a flood so appropriate actions can be taken to reduce loss of life and building damages.

Warning systems do not destroy the natural environment and their presence can protect the quality of life and significantly reduce economic losses. However, they are not necessarily sustainable flood mitigation tool: they do not build disaster resilient communities because the flood hazard remains. Warning systems allow time for temporary structural adjustments to combat an imminent flood, but they do not address long-term flood hazards and future generations will still face the risk of flooding. For this reason, warning systems are not as sustainable as other non-structural methods of flood mitigation and are merely used as a tool to reduce the costs of property damages and the number of lives lost from floods.

5. *Flood insurance*

The National Flood Insurance Program (NFIP), established by the National Flood Insurance Act of 1968 and further strengthened by the Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994, provides insurance against damages from flooding. Because most homeowner's insurance policies do not cover flood damages, participation in NFIP is a crucial step that homeowners should take to protect their property. A community and individual homeowners may receive federal aid after a flood only if they participate in the NFIP and pay the insurance premiums. Premiums are determined according to floodplain regulations existing within the community. Therefore communities with more stringent floodplain ordinances and flood mitigation plans have lower flood insurance premiums. The 1997 average premium for a flood insurance policy under the NFIP was $300 per year for $100,000 worth of coverage (Federal Emergency Management Agency 1997).

The NFIP is a means of mitigating flood losses because it requires long-term floodplain management as a condition of eligibility for flood insurance (Platt 1998, 41). By discouraging additional development on floodplains or flood hazard areas, participation in the NFIP can reduce communities' future flood losses (Schad 1988, 37; Smith and Ward 1998, 305). Some states require participation in NFIP as part of their floodplain management policy (Smith and Ward 1998, 305). More than 18,500 communities throughout the United States participate in the NFIP (Federal Emergency Management Agency 1997). Designing a flood mitigation plan also reduces NFIP premiums and reduces flood risks. By providing the necessary funding, the Hazard

Mitigation Grant Program (HMGP), which is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, assists states and communities to design and implement long-term hazard mitigation plans (Kaplan 1996, 228).

The NFIP requirement for floodplain management provides a sustainable means of flood mitigation because it does not negatively impact the natural environment and promotes disaster resilient communities. However, by providing insurance against flood losses the insurance program itself may encourage development in flood-prone areas. By reducing financial risks and responsibilities from flood disasters, flood insurance can potentially reduce the impacts of sustainable approaches to flood mitigation.

C. New approaches to flood mitigation

The non-structural approaches to flood mitigation discussed in the previous section reduce flood-related damages while maintaining the quality of the natural environment. Given the better outcomes from non-structural approaches to flood mitigation, cities are re-evaluating past structural approaches (e.g. river straightening) and attempting to return rivers to their natural course and use a non-structural approach to address flood risks. Increasing the flood capacity of a river by modifying the natural channel (e.g. straightening or realignment) has come under increasing attack because it worsens channel stability and causes ecological problems (U.S. Army Corps of Engineers 1994, 3-1). In light of growing concern regarding the adverse environmental effects of structural approaches to flood mitigation, cities across the country have been adopting innovative flood projects.

With recent river and floodplain restoration efforts, communities are acknowledging the important relationship between the quality of the environment and flood risks. River restoration involves the correction of a previously disturbed, altered, or damaged river's physical, chemical, and biological characteristics (MacBroom 2002, 379). Correcting the effects of structural flood control modifications of rivers involves returning the river to its natural state. Addressing flood and ecological concerns, as well as aesthetics and recreation concerns, can be achieved through river and floodplain restoration. In their attempts to restore straightened rivers and degraded wetlands, localities may acquire floodplain lands to be maintained as open space or create urban river parks.

Localities undertaking restoration projects are not only experimenting with the potential of river and floodplain restoration as a means of flood mitigation, but also with the difficulty of processes involved in implementing such flood projects. Restoration projects have emerged throughout the country in the past decade. Examples include the current ongoing projects for the Kissimmee River Restoration Project in Florida, the Elwha River Restoration Project in Washington, the Bronx River Restoration Project in New York, and the Napa River Flood Protection Project in California, to name a few.

Restoration projects are based on an understanding of the adverse effects that past structural approaches have had on floodplains, ecosystems and communities. For instance, Napa, California's flood project determined that traditional structural flood controls, including river straightening and levees, degrade the natural environment. Similarly, other localities and regional agencies, such as the South Florida Water Management District for the Kissimmee River, have researched the negative effects of previous structural measures and have found ways to correct the environmental damages created by past structural flood control measures. Methods to “undo” previous structural flood control methods include the removal of levees, dechannelization, and returning rivers to their natural courses.

The Napa River and Kissimmee River projects are two examples of community efforts using river restoration to support sustainable flood mitigation. These communities show that the principles of flood control have evolved from structurally controlling nature, to promoting sustainable flood management and mitigation. The Kissimmee River Restoration Project (1997) is a response to the degradation to the Kissimmee River ecosystem as a result of previous flood controls implemented by the U.S. Army Corps of Engineers. Throughout its 15 year timeline, the Project will undo portions of the artificially straightened river, thus restoring 43 miles of the meandering river channel, 27,000 acres of lost floodplain wetlands, and lost fish and wildlife habitat. In response to the restoration project, aquatic vegetation along the Kissimmee River is returning, water quality has improved, the historic characteristics of the river’s hydrology are being reestablished, and flood control remains effective (South Florida Water Management District 2003). Figure 1 portrays the naturally meandering shape of the Kissimmee River in contrast to the straightened river channel that will be backfilled as part of the restoration project.

Figure 1. The straightened portion of the Kissimmee River, partially backfilled here, is a stark contrast to the naturally meandering course.

Source: U.S. Army Corps of Engineers Jacksonville District 2003.

The remainder of this report will discuss another river restoration project and provide an analysis of the flood mitigation approaches used to lessen flood risks and restore the river to its natural state. By presenting the negative effects of structural flood control and building on the lessons learned from the Napa flood and river restoration project, this research will provide an example of how the negative impacts of river straightening and structural controls can be addressed to allow for sustainable flood mitigation. In conjunction with other non-structural approaches to flood mitigation, this new sustainable approach to flood planning may prove useful for communities nationwide.

V. METHODOLOGY: The Napa River Flood Protection Project Case Study

An extensive review of the literature on the various approaches to flood control illustrates that traditional structural adjustments for flood control have serious drawbacks, including failing during flood events, high construction and maintenance costs, and severe environmental degradation. Accordingly, the use of environmentally sustainable non-structural approaches to flood mitigation has gradually taken precedence in the flood planning arena. Non-structural approaches, including floodplain management, zoning, and open space conservation, are on the forefront of contemporary flood mitigation techniques. A common theme in recent flood plans is the recognition that straightening and channelizing rivers with concrete is not a viable option for the long-term reduction of flood severity and frequency because of the subsequent environmental impacts.

Given that straightened or channelized rivers can increase flood risks and destroy natural resources, can restoring rivers to their natural state, thus restoring the natural function of the floodplain, decrease flood risks while also enhancing or maintaining the quality of the natural environment? Answers to this question can be applied to most localities with straightened or channelized rivers suffering from frequent or severe flooding. Assessing the potential of returning rivers to their natural courses and restoring the floodplain function is therefore an essential endeavor for flood planners and localities at risk of flooding. This report investigates such questions by reviewing the process and content of a flood plan that utilized floodplain restoration as a major element of its flood protection project.

A. The Napa River/Napa Creek Flood Protection Project criteria and methods

The innovative flood plan for the City of Napa, California is used as a case study for this report. The case study serves to provide an illustration of how a community reduced flooding in an environmentally sustainable manner. This case study was selected to illustrate how a community with a previously straightened river, and which is currently suffering from flooding, has developed a sustainable planning project to reduce flooding through environmental restoration. Napa, California is a nationally recognized community with such efforts (see list of awards below**.)** The case of Napa illustrates how innovative and sustainable approaches to flood mitigation can correct past structural mistakes of flood control, and current needs for improved flood mitigation.

Napa's flood project was selected because it is a model plan (Dacus 2003; Wadsworth 2003). The Project has received numerous awards, such as the 1998 American Institute of Architects Award, the 1998 American Society of Landscape Architects Award, and the 1999 Governor's Environmental and Economic Leadership Award from the California division of the Environmental Protection Agency. Kathleen McGinty, the 1998 Chair for the President's Council on Environmental Quality, praised Napa's flood project:

> In redefining its relationship with nature, Napa exemplifies a new model of environmental decision-making. They had the courage to break with convention…and in so doing, they helped inspire new thinking in other communities and within government agencies (Napa County Flood Control and Water Conservation District 2002).

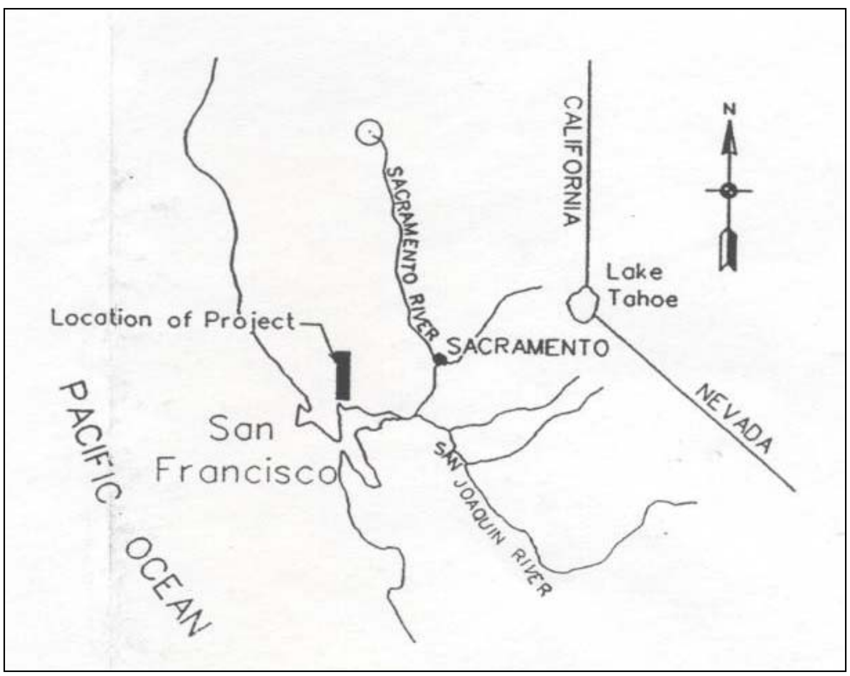
Furthermore, Napa's flood plan is being used to guide flood projects in other communities, such as Santa Clara County (Wadsworth 2003; Lander 2003). It is therefore a nationally recognized and respected flood project. Described as setting the standard for environmentally sensitive flood planning, Napa's flood project provides an ideal case study to illustrate how localities can move away from the traditional structural flood control approaches of river straightening and levee construction, and implement a flood plan that simultaneously protects a community and its natural environment.

This research is based on an in-depth analysis of the Napa River/Napa Creek Flood Protection Project. First, the written document for the flood plan, the Supplemental General Design Memorandum (GDM), prepared by the U.S. Army Corps of Engineers, is analyzed as primary data. The GDM provides detailed descriptions of the various relevant components of the Project. Second, face-to-face interviews were conducted with City of Napa Councilmember Jill Techel and Napa County Department of Public Works engineer Jon Lander. Questionnaires were conducted via e-mail with City of Napa Public Works Department engineer Graham Wadsworth and the federal project manager, Larry Dacus, with the U.S. Army Corps of Engineers. The non-profit organization Friends of the Napa River was also contacted for an interview, but to no avail. Friends of the Napa River was instrumental, if not the key player, in opposing the Army Corps of Engineers flood plan and in designing the final sustainable flood plan. The interviews utilized both open ended and closed ended questions. Appendix B presents the interview questions that were used to determine the main features of the flood plan and the role of community involvement in its design and implementation. Appendix C presents a summary of the responses, which clearly emphasize that public participation in the planning process is crucial to successfully devising an environmentally sustainable flood plan. These interviews are used to supplement the information obtained from the GDM and to gain better insight on the content of the plan and the process for implementing the plan.

B. Description of the study area

The Napa River drainage basin covers 426 square miles and is located approximately 40 miles Northeast of San Francisco, California (Figure 2). Characteristics of the Napa River include a meandering course, a large oxbow within the city limits, and the tidal marshlands of San Pablo Bay. Figure 3 shows the meandering path of the river as it travels south through the City of Napa. The Napa River supports various habitat types, including emergent marsh, riparian vegetation, oak upland, and grasslands. As shown in Figures 4 and 5, the Napa River supports a lush array of vegetation.

Figure 2. The study area of the Napa flood project in California.



Source: U.S. Army Corps of Engineers 1998.

Figure 3. An aerial view of the Napa River, looking south over downtown Napa at the oxbow.

Source: Napa Traffic Management Plan 2003.

Figure 4. Lush vegetation along the Napa River.

Photograph by Vanessa L. Bechtol 2003.

Figure 5. Vegetation along the oxbow bend of the Napa River.

Photograph by Vanessa L. Bechtol 2003.

During the past decade, Napa planners, engineers and policy-makers have focused on new approaches to flood planning. By removing structural controls and thus allowing a river to flow its natural course, local flood planners are utilizing a nascent approach to sustainable flood mitigation. In an unprecedented move, Napa integrated the "living river" strategy in their urban flood protection project. According to City of Napa project engineer John Lander, Napa is the first city to emphasize such consideration of the urban environment in a core urban flood project (Lander 2003). By removing dikes, acquiring flood-prone land and structures within the oxbow, and restoring tidal wetlands, the Project is allowing the Napa River to run its natural course and restore the wetlands to their natural function, thus further mitigating flood threats.

Adopted in October 1998, the Napa River Flood Protection Project is a community-wide effort at addressing the frequent flooding of Napa County by providing a 100-year level of flood protection. Through an organized community coalition, stakeholders and concerned citizens were able to provide input on the goals of the project and the process to develop and implement the project. The involvement of the community in the design and implementation of this project is key to its success, and is further discussed in the section Evidence of public support, on page 53.

Based on this case study, the "living river" objectives are discussed and presented as guidelines for other localities suffering from river flooding. This analysis will provide an illustration of how the environmental damages incurred through previous flood control techniques can be addressed and improved upon, while at the same time effectively reducing flood risks in an environmentally sustainable fashion.

VI. FINDINGS[2]

Napa County, California has undertaken an innovative, sustainable, non-structural effort at flood mitigation. The case study illustrates that sustainable flood mitigation is possible for communities willing to address the environmental concerns and priorities of their residents. This Chapter discusses the history of flooding along the Napa River, the chronology of flood mitigation planning efforts and regulatory context, and the evolution of the Napa River/Napa Creek Flood Protection Project. Discussion of the Project includes the strategy implemented, the applied structural and non-structural approaches to flood mitigation, local and federal agency responsibilities, and the participatory process used through the creation of a community coalition.

A. Flood history

The Napa River/Napa Creek Flood Protection Project comes in light of more than a century of severe flooding for Napa residents. Established in 1879, Napa's economic base was focused on access to the river, and therefore development primarily took place in the floodplain. Floodplain development has increased the flood hazard (Wadsworth 2003) and the area has been subject to flooding for more than a century.

In an early attempt to control the flooding of the Napa River and improve navigation, the Army Corps of Engineers straightened a portion of the river during the 1930s (Wadsworth 1998). Since the straightening of the Napa River, Napa has suffered 15 major floods (Wadsworth 1999). Although it is argued that the river straightening

[2] Unless specified otherwise, the findings are from the Napa River/Napa Creek Flood Protection Project Final Supplemental General Design Memorandum.

probably reduced flooding in this case, there is debate as to its impact on the downcutting[3] and incision of the Napa Creek and other creeks draining into the Napa River (Wadsworth 2003). Napa County engineer Jon Lander states that the straightening of the river south of the City (shown in Figure 6, looking east over Horseshoe Bend) has decreased riparian habitat, making the restoration of the marshland habitat necessary (Lander 2003). U.S. Army Corps of Engineers project manager Larry Dacus, on the other hand, believes that environmental impacts are minimal because of the short length of the straightening (Dacus 2003).

Figure 6. Napa River at Horseshoe Bend with tidal waters in marshland.

Source: http://www.dhigroup.com/ProjRef/Napa.gif 8/7/03.

[3] Downcutting is similar to channel incision and involves the cutting of the channel.

Major floods have been recorded on the Napa River since 1862, with the most recent and severe occurring in the years 1940, 1942, 1943, 1955, 1962, 1963, 1965, 1967, 1973, 1978, 1982, 1983, 1986, 1995, and 1997. Figures 7 and 8 illustrate the devastating floods of 1940 and 1986. Napa suffered from its largest flood in February 1986, which is estimated to be a 50-year flood event and has a 2% chance of occurring in any given year (U.S. Army Corps of Engineers and Napa County Flood Control and Water Conservation District 1997; Napa County Flood Control and Water Conservation District 2002). Compared to the annual average rainfall of 36 inches, the 1986 flood event was caused by 20 inches of rainfall in a 48 hour period (Wadsworth 1998). Severe flooding also occurred in January and March 1995 and January 1997, with additional minor flooding in subsequent years (Wadsworth 1998). The 1986 flood caused $100 million in total damages, including the complete destruction of 250 homes, damages to 2,500 homes, 27 injuries and 3 deaths (Wadsworth 1999). The January and March 1995 floods resulted in property damages estimated at $5.5 million and $10.8, respectively.

Figure 7. Napa flood of 1940, looking north on Main St.

Source: Napa County Flood Control and Water Conservation District 8/7/03.

Figure 8. Napa flood of 1986.

Source: <gbgm-umc.org/photos/ usa/861447m.stm>. 8/7/03.

B. <u>History of flood mitigation planning efforts and regulatory framework</u>

In response to the floods of 1940 and 1955, Congress authorized a major flood project for Napa County, to be produced by the U.S. Army Corps of Engineers. The 1965 project proposal and a 1975 General Design Memorandum (1975 GDM) submitted by the U.S. Army Corps of Engineers did not receive a warm welcome by Napa County residents. The 1975 GDM was an alternate to the initially proposed 1965 plan, which included channel enlargement, channel dredging, levees, and floodwalls along 11 miles of the Napa River. The major changes from the 1965 and 1975 proposals are that the 1975 GDM eliminated the high channel walls and some levees that were not deemed economically feasible, aesthetics criteria were included, and it proposed to acquire and create 577 acres of wildlife habitat as environmental mitigation. Despite the creation of wildlife habitat, the 1975 GDM was rejected in subsequent referendum elections in 1976 and 1977 because residents were displeased with the plan's failure to address environmental impacts. The flood project proposal was thus shelved and not reactivated for another decade.

The 1973 Flood Disaster Protection Act (Public Law 93-234) requires flood prone communities to participate in the National Flood Insurance Program (NFIP). The City of Napa began participating in the NFIP in 1979. The City's adoption of the Floodplain Management Ordinance was a requirement to participate in the NFIP and provided reduced flood insurance rates to policyholders (Wadsworth 2003). NFIP further requires that all new residential and non-residential structures have their first floor elevated to the 100-year flood level. Napa's Floodplain Management Ordinance requires an additional foot above the 100-year flood elevation.

While neither city nor county policy changes have been the primary focus of flood management projects, Napa does utilize various policy approaches to mitigating flood hazards. The City and County both have Floodplain Ordinances in effect, but they are only applicable, and therefore effective, for development after their adoption in 1979, which excludes many structures. The City of Napa's Municipal Code, Chapter 17.62 (updated in 1998), sets forth provisions for new developments located in the floodplain or any other designated flood hazard area. The Floodplain Management Ordinance restricts activities that result in an increase in flood heights or velocities, requires new construction to be protected against flood damage, regulates the alteration of natural floodplains, stream channels, and natural protective barriers that accommodate flood waters, controls all filling, grading or dredging operations that might increase flood damage, and regulates the construction of barriers that unnaturally divert floodwaters or increase flood hazards elsewhere (Ord. No. O98-006, Repealed & Reenacted, 04/21/1998).

Title 16, Chapter 16.04 (1995) of Napa County Code sets forth the Floodplain Management regulations for the County, which are similar to the City's Code. The provisions outlined in this ordinance include flood loss reduction, preservation and development restrictions for riparian areas, identification of special flood hazard areas, residential and non-residential construction restrictions, and the issuance of floodplain permits (Ord. 1095 § 1 (part), 1995). The flood loss reduction provisions within the Floodplain Management ordinance restrict and prohibit land uses and activities that may increase erosion or flood height and velocities, control the alteration of natural floodplains, stream channels, and natural protective barriers that help accommodate floodwaters, control all filling, grading or dredging operations that might increase flood damage, and regulate the construction of barriers that unnaturally divert floodwaters or increase flood hazards elsewhere (Ord. 1095 § 1 (part), 1995). While such policies can be effective at mitigating flood losses, Napa's continual struggle with flooding illustrated the need for additional flood mitigation measures. Thus came the innovative flood project finally approved in 1998.

The devastating flood of 1986 triggered the need to develop and implement a major flood protection project for the Napa River. After a thorough revision of their 1975 GDM, the U.S. Army Corps of Engineers submitted a revised proposal in 1995, referred to as the Updated 1975 GDM, only to be deemed unacceptable by residents again due the lack of environmental sensitivity. It is this Updated 1975 GDM that lead to the formulation of the current flood project for the Napa River.

C. The Napa River/Napa Creek Flood Protection Project

In 1998 Napa County voters approved The Napa River/Napa Creek Flood Protection Project (Project), which is a revision of the Updated 1975 GDM that was opposed by voters. Unlike the Updated 1975 GDM, this Project focuses on the adoption of "living river" principles, an emphasis on non-structural elements, sharing responsibilities between local and federal agencies, and strong public support. The Project also includes flood mitigation measures for the Napa Creek, a tributary to the Napa River, which passes through downtown Napa. Other major differences between the Updated 1975 GDM and the final approved Project include the use of biotechnical bank stabilization[4] and marsh plain and floodplain terraces[5] instead of channel excavation and realignment. Covering a 6.9 mile expanse along the Napa River within the city limits, the Napa River/Napa Creek Flood Protection Project also includes lowering and removing dikes, a dry by-pass channel, levees and floodwalls, bridge relocations, building demolition, and recreation trails.

1. *The living river strategy*

The community-devised "living river" strategy is the basis of Napa's Project innovation. The main objective of the "living river" strategy is to "maintain or enhance the Napa River's natural processes and characteristics by integrating principles of fluvial geomorphology with river engineering and riparian wetland ecology" (U.S. Army Corps of Engineers 1998, 5-1). Developed by the community, the "living river" objectives are based on scientific principles that have not previously guided urban flood projects (Lander 2003). The "living river" objectives, outlined in Table 2 and presented in their entirety in Appendix D, were used to guide the flood mitigation project to ensure flood protection without environmental degradation. While the community agreed that flood protection was the central goal of the Project, it also accepted that to be successful the Project needed to allow the river to sustain wildlife and bring "new vitality to the neglected Riverfront areas" (Napa County Flood Control and Water Conservation District 2002, 7). According to Friends of the Napa River, "a 'living' river system functions properly when it conveys variable flows and stores water in the floodplain, balances input

[4] Biotechnical bank stabilization optimizes habitat development by incorporating bioengineering techniques to stabilize banks and control erosion (U.S. Army Corps of Engineers and Napa County Flood Control and Water Conservation District 1997).
[5] Marsh plain and floodplain terraces are discussed on page 50.

with sediment transport, provides good quality fish and wildlife habitat, maintains good water quality and quantity and provides recreation and aesthetic values" (Rippey 2000, 1).

Table 2. Living river objectives addressing geomorphic stability.

OBJECTIVE
Maintain natural slope of river (river should not be altered by straightening or dredging)
Maintain natural width
Maintain natural width/depth ratio
Maintain and restore connection of river to its floodplain (accommodating natural meandering)
Provide setbacks to allow natural meandering
Maintain channel features such as mudflats, shallows sandbars and a naturally uneven bottom

Source: Rippey 2000.

Maintaining the natural course of the river by avoiding straightening and dredging is a major component of the "living river" objectives. This emphasis on geomorphic stability is evident not only in the limited amount of channel modification provided for in the Project design, but also in the construction of a dry by-pass channel, as opposed to an alternatively proposed wet by-pass channel. The dry by-pass channel is discussed in the following section.

Creating and maintaining geomorphic stability is also addressed by maintaining the natural width of the river, maintaining the natural width-depth ratio, restoring the connections between the river and the floodplain, allowing natural meandering and maintaining other natural channel features such as mudflats, shallow sandbars, and a naturally uneven bottom. This aspect of the "living river" strategy illustrates the trend towards returning rivers to their natural meandering course instead of artificially straightening rivers. This “living river” strategy and the public participation described below make Napa’s project unique and innovative.

2. *Structural and non-structural elements*

The end-result of the community participation and the use of the “living river” objectives is a flood project that can reduce flood risks while maintaining environmental quality, and be supported by the community. Major components of the Project include a combination of structural and non-structural elements.

The structural elements include the reconstruction of several bridges that hinder flood conveyance and construction of the oxbow dry by-pass channel. Although there are a few structural approaches to flood control used in the Project (such as the construction of levees and floodwalls in a few locations), the bridge re-construction and dry by-pass channel are used to protect the environment and support sustainable flood mitigation approaches (as discussed below), and are not necessarily associated with the negative effects of structural flood mitigation as mentioned in Chapter 3.

The re-construction of the Third Street Bridge (which has been completed) and the Maxwell Bridge (which will be completed in November 2005) improve flood conveyance and provide increased elevation of roads from potential floodwaters. In addition, the Maxwell Bridge reconstruction is necessary to accommodate the floodplain and marshland terraces created in the southern portion of the project area. The construction of the dry by-pass channel will require the First Street Bridge to be torn down. The 140-year old First Street Bridge is recognized as the third oldest stone bridge in California (Courtney 2003). Although this was known when the Project was supported and approved by county voters in 1998, a few residents are now opposing the Project's decision to remove the historic bridge. Saving the bridge would require alterations to the design of the dry by-pass channel. Such changes will decrease flood conveyance, therefore altering the effectiveness of the dry by-pass channel. As such, the historic First Street Bridge will need to be removed.

Although straightening the river was not considered as a primary means of flood control for the Napa River, the U.S. Army Corps of Engineers proposed that a portion of the river at the oxbow be excavated to provide a wet by-pass flood channel. Local decision-makers and residents deemed this alternative unacceptable because of the environmental consequences of straightening even such a small length of the river. A dry by-pass channel[6] was therefore substituted in its place. This channel serves as a route for floodwaters bypassing the oxbow that inevitably floods with heavy rainfall.
By purchasing property within the river's oxbow the Project provides the necessary space for the construction of the dry by-pass channel. Creating a dry by-pass allows floodwaters to pass through downtown and by-pass the oxbow without decreasing the already low summer flows in the oxbow reach of the river. Because of the raised bed, the dry by-pass will carry flood flows only when the river reaches flood levels, thus mitigating the adverse impacts to water quality and riparian habitat that would accompany a wet by-pass channel and lower summer water flows in the oxbow. These efforts will help minimize the loss of existing habitat and protect fish and wildlife from threats of poor water quality.

[6] The dry by-pass channel is the local term for a raised bed oxbow cutoff channel.

Figure 9 presents an aerial view (looking east) of the oxbow before the construction of the dry by-pass channel. Figure 10, a view from the opposite side of the oxbow and looking west, portrays an artist's rendering of the completed dry by-pass channel at the oxbow. The center of the diagram is where the dry by-pass is being constructed.

Figure 9. The Napa River at the oxbow in downtown Napa, before construction of the dry by-pass channel.

Source: Napa County Flood Control and Water Conservation District 2003.

Figure 10. An artist's rendering of the completed oxbow dry by-pass channel.

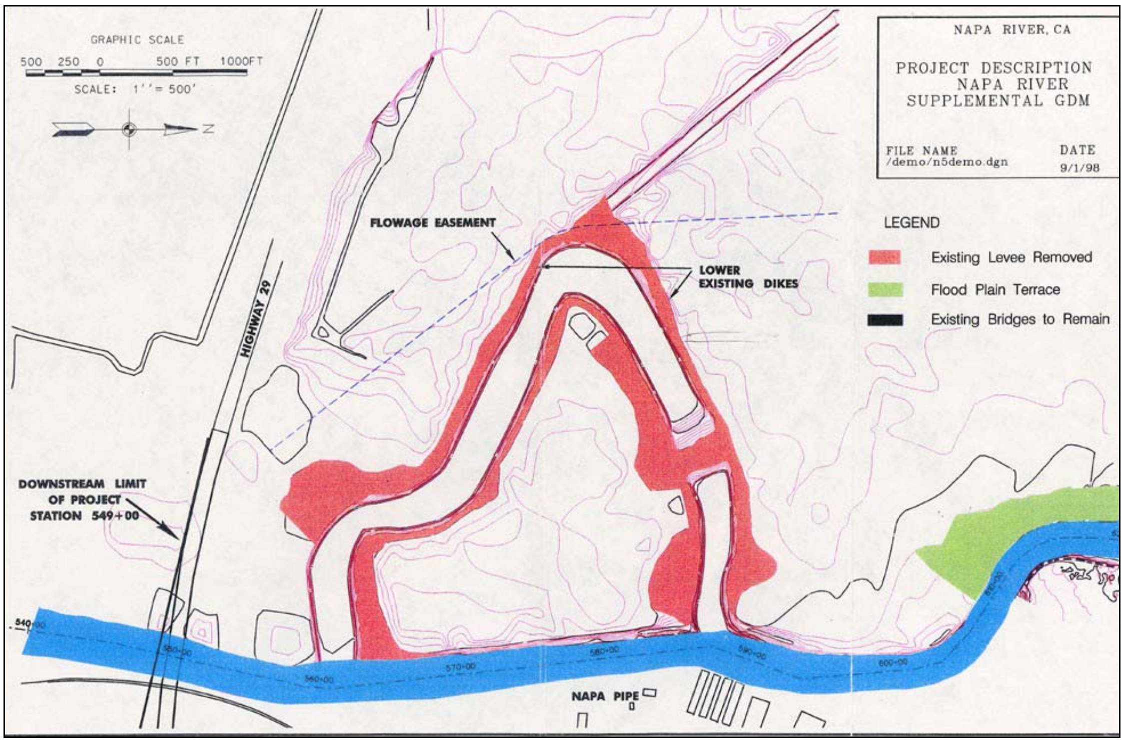
Source: Napa County Flood Control and Water Conservation District 2003.

While the Project does not focus flood control efforts on a system of levees or floodwalls, some levees and floodwalls are necessary at isolated points along the River and Creek to provide 100-year level flood protection. Because the levees and floodwalls will prevent floodwaters from flowing through the overbank floodplain and will consequently pass the water through the City more quickly, there is a potential increase in the peak discharge downstream of the Project. Because downstream flooding is a common problem associated with levees and floodwalls, the U.S. Army Corps of Engineers project engineers investigated this concern and concluded that the increase in downstream discharge will be insignificant.

The importance of non-structural mitigation, as opposed to structural mitigation, is apparent by the fact that 32% of the capital costs are for land acquisition, while only 9% are dedicated to levees and floodwalls (U.S. Army Corps of Engineers 1997). In response to a survey question about the main feature of the Project, Project engineers from the U.S. Army Corps of Engineers and the City of Napa responded that the marsh plain and floodplain terraces and the subsequent floodplain restoration are the main features of the Project (Dacus 2003; Wadsworth 2003). This further illustrates the growing emphasis of non-structural flood mitigation elements in the flood protection project. In contrast, project engineer from the County of Napa claims that most of the flood protection will come with the completion of the dry bypass channel at the oxbow (Lander 2003). While this may indicate the existing need for some structural efforts in flood control, the significance of environmental restoration in flood planning remains evident by the emphasis on the excavation of marsh plain and floodplain terraces.

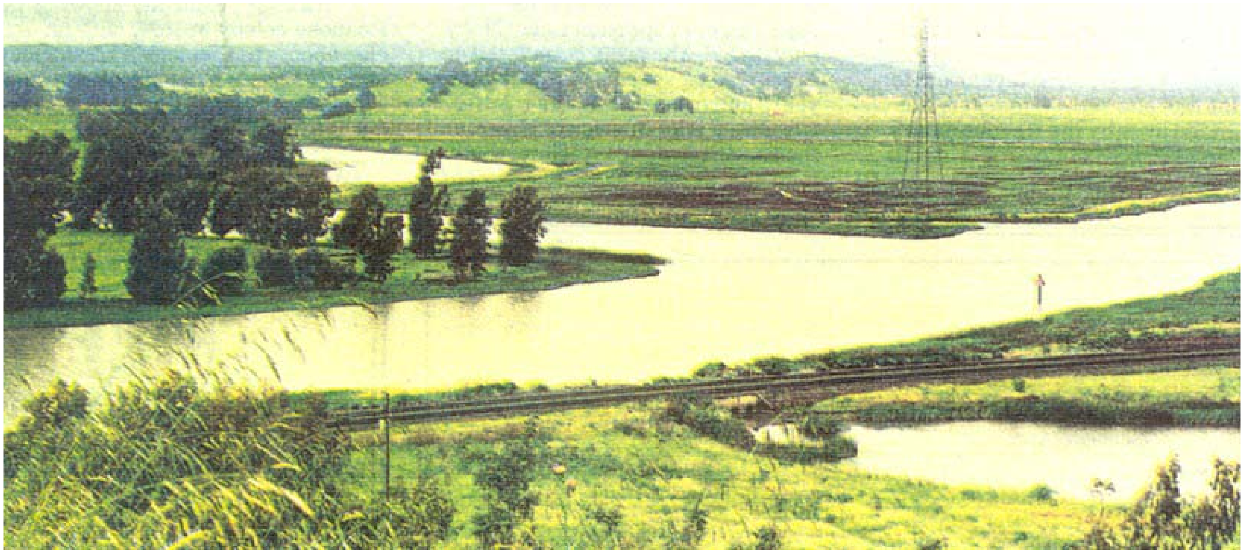
While providing more room for a river to take its course is not necessarily unique to Napa, the Project's approach of setting back or removing levees and dikes is receiving National attention and awards (Wadsworth 2003). These awards are mentioned in Chapter 5. The map portrayed in Figure 11 illustrates the stretch of the river along Horseshoe Bend where existing levees will be removed. The removal and setback of dikes and levees allow the Napa River to take its natural course and return it to its natural historic state, thus restoring and creating 600 acres of wetland and marshland habitat (Napa County Flood Control and Water Conservation District 2002). The restoration of wetlands by removing levees near Horseshoe Bend is apparent in Figure 13. Prior to their removal, the levees prevented tidal cycles from inundating the wetlands, as the 1998 photograph illustrates in Figure 12.

Figure 11. Napa River at Horseshoe Bend, where levees were removed.



Source: U.S. Army Corps of Engineers Sacramento District 2003.

Figure12. Levees blocked the wetlands from tidal action in 1998, before the removal of levees.



Source: Napa County Flood Control and Water Conservation District 2003.

Figure 13. In 2002 the wetlands are reborn with the removal of levees.

Source: Napa County Flood Control and Water Conservation District 2003.

Wetland (or marsh plain) and floodplain terraces constructed for flood conveyance will also restore habitat in the wetlands and floodplain. Wetland terraces are excavated at the mean tide level and floodplain terraces at the 2-year flood level (Dacus

2003). The wetland terraces (shown during low-tide in Figure 14) submerge twice daily during high tides, thus creating wetland habitat (U.S. Army Corps of Engineers and the Napa County Flood Control and Water Conservation District 1997). The river channel will be widened just above the low-tide level to create 108 acres of tidal marshland and wetlands, and their associated riparian forests. The floodplain terraces are slightly elevated from the wetland terraces and will be inundated every few years (U.S. Army Corps of Engineers and the Napa County Flood Control and Water Conservation District 1997). During dry periods the floodplain terraces can be utilized for recreation and bird watching. Overall, the Project creates, enhances or restores more than 400 acres tidal marshland and 150 acres of seasonal wetland (Napa County Flood Control and Water Conservation District 2003). Table 3 illustrates the acres gained and lost from the excavation of wetland terraces. Note that in addition to the creation of 108 acres of, 36 acres are destroyed, resulting in a net gain of 72 acres of tidal marshland and wetland habitat.

Table 3. Habitat types lost and created

Habitat Type	Acres Lost	Acres Created	Net Gain or Loss
Riparian forest	5.03	4.58	-.45
Low-value woodlands	11.24	0.00	-11.24
High-value woodlands	0.99	4.87	3.88
Emergent marsh	7.32	65.05	57.73
Seasonal wetlands	9.18	27.27	18.09
Tidal mudflats	0.00	3.56	3.56
Shaded riverine aquatic cover	0.31	0.99	0.68
Riparian scrub-shrub	2.03	1.96	-0.07
Totals	**36.10**	**108.28**	**72.18**

Figure 14. Marsh plain terracing during low tide, November 13, 2002.

Source: Napa County Flood Control and Water Conservation District 2003.

3. *Local and federal Project responsibilities*

Although the Project is for the Napa River within the limits of the City of Napa, the local sponsor of the Project is the Napa County Flood Control and Water Conservation District. The U.S. Army Corps of Engineers, Napa County and the City of Napa share responsibility for the Project. The responsibilities of the U.S. Army Corps of Engineers include building the railroad bridges, excavating floodplain and marshland terraces, excavating for the dry by-pass channel at the oxbow, and building levees and floodwalls (Wadsworth 2003). The County of Napa responsibilities include acquiring lands, relocating residents, businesses and utilities, and finding soil disposal sites (Wadsworth 2003). The City of Napa is responsible for administering the design and the construction of the four replacement bridges, as well as designing and promoting a major traffic management plan (Wadsworth 2003). The traffic management plan was implemented in conjunction with the necessary construction plans (such as bridge reconstruction and construction of the dry by-pass channel) and according to City Councilmember Jill Techel, was effectively designed and is working extremely well (Techel 2003).

D. Evidence of public support

Public participation is vital in designing successful plans that effectively address the concerns of a community. Furthermore, public participation can build the necessary support to implement and fund a community plan. Although consensus building is crucial to preparing a plan that meets the needs of all residents and stakeholders, there need not be a consensus of opinion on every component addressed by the plan, merely a consensus for the plan as a whole (Kelly and Becker 2000). Public participation in the Napa River Flood Protection project was crucial in writing and implementing a well supported and funded flood plan (Dacus 2003; Wadsworth 2003; Lander 2003).

1. *The Coalition*

Acknowledging the need for community support for the flood plan, the community coalition Citizens for Napa River Flood Management (Coalition) was created in 1996 (Lander 2003). Table 4 illustrates the broad scope of participation in the coalition. Despite the diversity of the Coalition, comprised of more than 400 representatives from business, agriculture, ecology, environmental groups, and government, all interest groups and politicians worked towards a common outcome (Wadsworth 2003). Interviews with Project engineers from the U.S. Army Corps of Engineers, Napa County and the City of Napa indicate that public involvement and consensus building within the Coalition was key to getting the Project approved (Dacus 2003; Lander 2003; Wadsworth 2003). After years of inaction due to disagreement on the appropriate flood management measures to take, the Coalition resulted in groups and individuals with a long history of feuding expressing their support for the "living river" strategy of flood management (Wheeler 1998).

Table 4. Participants in the Coalition for the Napa Flood Protection Project.

CITIZENS FOR NAPA RIVER FLOOD MANAGEMENT
Friends of the Napa River
Napa County Resource Conservation District
U.S. Army Corps of Engineers
Napa County Flood Control & Water Conservation District
California Department of Fish and Game
Napa County Farm Bureau
Napa Chamber of Commerce
Napa Valley Grape Growers Associations
Suscol Council
American Center for Wine, Food & Arts
Napa Valley Conference & Visitors Bureau
Napa Valley Economic Development Corporation
Napa Downtown Merchants
Napa Valley Expo
Napa County Landmarks
Napa Valley Vintners Association
Sierra Club
Flood Plain Business Coalition
Napa County Land Trust
Napa-Solano Building Trades Council
California Lands Commission
Napa Valley Fisherman's Associations

Source: Napa County Flood Control & Water Conservation District 2002.

The Coalition was formed in 1996 and went through 7,000 person hours of public meetings (Wadsworth 1998) until the approval of the project in 1998. The Coalition process involved numerous public meetings in which facilitators aided the community in coming up with ideas for the Project, making compromises when necessary, and moving as a group toward the design, education and funding mechanism of the final Project (Wadsworth 2003). The Coalition meetings were held monthly and were facilitated by representatives from the non-profit organization Friends of the Napa River (FONR), although FONR was an equal participant with all other stakeholders (Krevet 2003). The input provided by citizens and agency representatives of the Coalition resulted in the use of the "living river" strategy in the flood plan and pulled the focus away from building higher levees and the channelization of rivers. This new trend in moving away from traditional structural approaches to flood mitigation was supported and advocated at community meetings by long-time flood management expert Luna Leopold of the University of California at Berkeley (Wadsworth 2003).

The role of the U.S. Army Corps of Engineers was also crucial in the success of the Coalition and allowing community concern and input to be listened to. Project manager Larry Dacus explains this role:

> "In the past the Corps has often gone off by themselves and developed a plan and then told the community to take it or leave it. The Coalition Process…with the Corps as an equal participant allowed the community to feel as if they owned the project. We are now constructing 'their' project" (Dacus 2003).

The fact that the community feels that it is "their" project is an important aspect of successful community planning. The Coalition process enabled the Corps to be an equal participant rather than an outsider imposing their ideas upon a community.

Another characteristic of the Coalition that made it successful is the leadership by people passionate about preserving the natural beauty of the river while also providing flood control. Moira Johnston Block and Karen Rippey are two residents who shaped the Coalition into a group of concerned citizens and agency representatives that were able to make compromises and reach the consensus that was critical in getting the final flood project approved by the community (Daily and Ellison 2002).

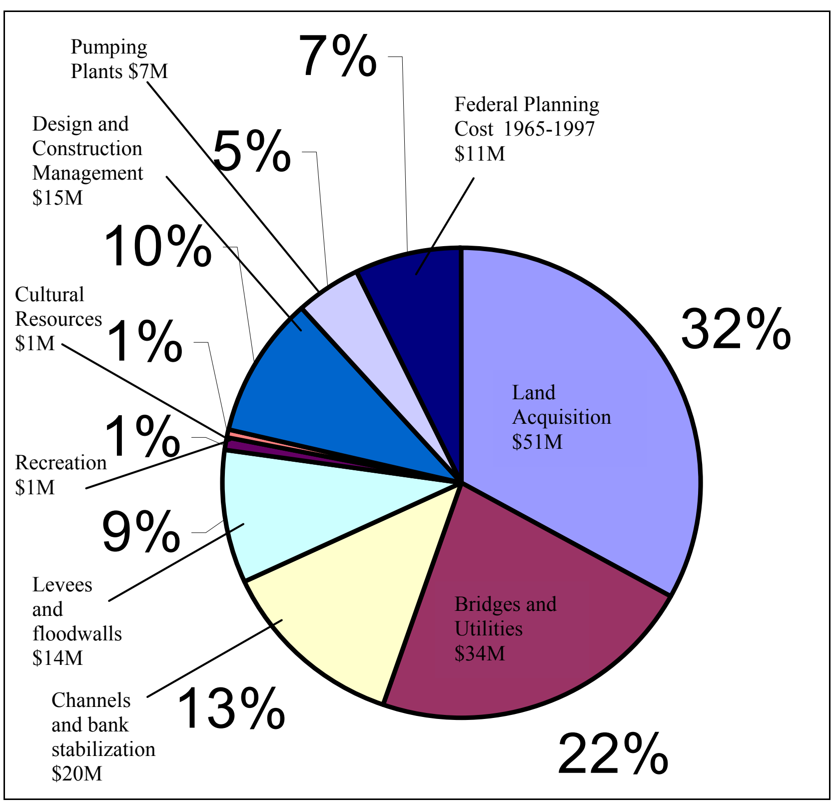
The participants in the Coalition had various reasons for pushing the development and approval of the Project. From an economic standpoint, businesses could not afford to rebuild after flooding year after year and were eager for a flood protection project (Wadsworth 2003). Further, the considerable media attention given to the numerous flood events drove away tourists (Wadsworth 2003). Environmental groups pushed for the Project as a means to restore and improve habitat (Wadsworth 2003). Minimizing environmental impacts during construction was the main concern of State and Federal permit agencies involved in the coalition, such as the California Department of Game and Fish and the California Regional Water Quality Board (Wadsworth 2003). Policy makers and the general public, on the other hand, wanted to stop flooding with a cost effective and fundable flood project (Wadsworth 2003).

2. *Costs and funding*

After more than a century of devastating flood events and millions of dollars in damage throughout Napa County, voters approved a 1998 sales tax increase of ½ cent for 20 years to fund the Napa River Flood Protection Project. The local support for the Project is evident in the fact that the measure passed with 68% voter approval (a supermajority vote, two-thirds of the vote, was required) (Daily and Ellison 2002). Campaigns for the tax increase were significant. The U.S. Army Corps of Engineers and Napa County Flood Control and Water Conservation District spent $450,000 and local wineries spent $400,000 in campaigning for voter approval of the county-wide tax increase necessary to fund the Project (Wadsworth 1998).

The total capital cost of the Project is $155.5 million and the estimated cost for construction over a 20-year period is $238 million. Figure 15 depicts a breakdown of the various capital costs for the Project. Although the price tag for the project is high, it will save $20.9 million a year in avoided property damages. The greatest costs, for land acquisition and infrastructure, are anticipated costs that are common elements of any major public project.

Figure 15. Costs of the Napa River Flood Protection Project



The federal agency (the U.S. Army Corps of Engineers) and the local non-federal sponsor (the Napa County Flood Control and Water Conservation District) are each paying for 50% of the total Project costs. The sales tax increase is expected to raise $8-$10 million per year, and will fund the 50% of the total Project costs that Napa County Flood Control and Water Conservation District is responsible for.

In addition to revenues from the tax increase, other sources have granted funds for the Project. The Governor's Office of Emergency Services awarded $7 million in FEMA Hazard Mitigation Grant Program funds for the City of Napa to acquire land and seven homes along Napa Creek that will be demolished for the commencement of the project and for the construction of drainage improvements (Napa County Flood Control and Water Conservation District 2002). The Napa County Flood Control and Water Conservation District has been allocated approximately $35 million from the State Revolving Loan Fund and $15 million from the State Subvention Fund to cover the local costs of the Project (Napa County Flood Control and Water Conservation District 2002). Finally, the CalFed Bay-Delta Program and Coastal Conservancy has provided funding for the purpose of removing levees and acquiring lands (Napa County Flood Control and Water Conservation District 2002).

E. Summary of findings

The Napa River Flood Protection Project illustrates that Napa's Project meets Mileti's six components of sustainable hazard mitigation. Promotion of the plan before its adoption implicitly used the platform of non-structural, sustainable flood mitigation: "The project represents a much needed departure from past flood control efforts" (U.S.

Army Corps of Engineers and the Napa County Flood Control and Water Conservation District 1997, 23). The first component of sustainable flood mitigation, environmental quality, is unquestionably addressed through the use of the "living river" strategy and the restoration of the floodplain. The second and third components, which involve maintaining and enhancing the quality of life and creating resiliency to disasters through public awareness, are both achieved through the use of the Coalition and the Project's ability to provide 100-year level flood protection. The sustainable hazard mitigation component requiring a participatory process is also achieved through the Coalition. Inter-generational and intra-generational equity is achieved because there is not an unequal distribution of exposure to hazards.

In addition to improving environmental conditions throughout Napa County, the Project also addresses the concern of economic vitality. This is accomplished by not only protecting current businesses from floods, but also by using the restoration and recreation elements of the Project to attract new business. Three new hotels are already in the works in the vicinity of the oxbow and dry bypass channel (Techel 2003). Development plans for these hotels are also requiring public access walkways to provide connectivity between the businesses and the recreational trails provided by the Project (Techel 2003). An additional example of the economic vitality is that the old Opera House has been renovated and had is grand opening in Summer 2003.

The findings also illustrate how flood management can be improved when it is based on the concept of returning rivers to their natural state. They show how a broad community coalition can support such an innovative approach to flood planning. Utilizing a set of geomorphically based criteria for flood control efforts, the Coalition implemented the “living river” strategy and created a plan for sustainable flood mitigation. Like many community planning projects, incorporating sustainable flood mitigation into flood planning is best achieved through consensus building. With the numerous stakeholders involved, designing a sustainable flood plan that addresses flood and environmental concerns has proven to be a challenging, but attainable, goal.

Napa, California’s flood project is becoming a guidebook for other cities such as the City of St. Helena, California, and Santa Clara County, California (Dickson 2003; Lander 2003; Wadsworth 2003). The application of Napa’s model flood plan and approach in other communities, however, may come with obstacles. Because the Project was so land intensive, it was extremely expensive (Dacus 2003; Lander 2003). Other communities may not be as willing as Napa was to approve such expensive projects or tax increases. Nonetheless, elements of Napa’s Project are being considered elsewhere. Santa Clara County, California, for example, is using ideas devised for Napa’s Project and general concepts of sustainability to redesign its flood plan (Lander 2003). As Napa created the Coalition to address environmental impacts of a proposed flood project, the Guadalupe River Park and Flood Protection Project in Santa Clara County was halted in 1997 to form a Collaborative to re-examine the adverse environmental impacts of the flood project (Guadalupe River Park and Flood Protection Project 2003). Upon approval by the Guadalupe River Flood Control Project Collaborative and the U.S. Army Corps of Engineers, the Guadalupe River Park and Flood Protection Project resumed in 2002 (Guadalupe River Park and Flood Protection Project 2003). The Project provides flood protection to downtown San Jose, protects and improves the river’s water quality, preserves and enhances the river's habitat, fish, and wildlife, and provides open space for recreation (Guadalupe River Park and Flood Protection Project 2003).

St. Helena, CA, is also using Napa's flood Project to encourage the community to become more involved in designing and implementing a sustainable flood plan for the portion of the Napa River running through the St. Helena. The Friends of the Napa River modified St. Helena's proposed project, adding eight additional acres of open space and flood storage, preventing further development adjacent to the Napa River (Dickson 2003). If implemented, this plan will benefit the environment as demonstrated in the Napa Project (Dickson 2003).

VII. POLICY RECOMMENDATIONS AND CONCLUSIONS

This report provides a general illustration of the impacts of relying on river straightening and modification for flood control, the continued flooding of artificially modified rivers, and the emerging flood mitigation approach of returning rivers to nature. After years of attempting to dominate nature and control flooding, communities and flood project managers are acknowledging the benefits of allowing rivers to run their natural course. The removal of structural adjustments that have previously straightened and confined the floodwaters of rivers is a recommended approach to sustainable flood mitigation that can reduce flood risks and enhance and preserve the quality of the natural environment. As illustrated by the innovative flood plan for the Napa River, restoring floodplains can mitigate flood risks by increasing the flood storage capacity, and is acceptable to and can be supported by communities concerned with flood risks and environment sustainability. Furthermore, environmentally focused flood projects are receiving increased local support (as illustrated in Napa), which is often critical to approve a flood control project and allocate the necessary funds to implement it.

River and wetland restoration, as opposed to structural flood mitigation, are approaches to flood mitigation that are on the forefront of innovative, modern flood planning. This report has described the potential of river and wetland restoration as a nascent approach to maintaining environmental sustainability while providing flood protection. This recently recognized approach to flood planning illustrates the positive role that sustainability can play in decreasing the environmental and economic damages associated with flood hazards. As communities are borrowing from the Napa Project, many more communities in the United States can benefit from the lessons learned from this analysis.

A caveat of using the Napa River/Napa Creek Flood Protection Project as a case study, however, is that it has not been completed in its entirety yet. Although some aspects of the project have been completed, it is difficult to determine the overall effectiveness of the flood project. Furthermore, as with any flood plan, it will require years to assess its environmental outcomes and its effectiveness at reducing flood risks. Assessment of the outcomes of this project in five to ten years will indicate whether returning floodplains to their natural functions is an effective flood mitigation approach.

Nonetheless, the findings of this report support various policy recommendations. One policy goal might be to discourage or limit the U.S. Corps of Army Engineers' ability to straighten rivers as a means of flood control. Although Environmental Impact Statements are a requirement under the National Environmental Policy Act of 1969 and require the analysis of environmental impacts to all federally funded projects, a new federal or state policy specifically regulating the straightening or channelization of rivers can help decrease the environmentally detrimental artificial modifications that the U.S. Corps of Army Engineers has imposed upon America's rivers.

This report also identified the need for the U.S. Army Corps of Engineers to maintain a database of the rivers they have straightened. This data can provide insight on the scope of the problem and allow for flood planners to pinpoint the rivers and their communities that may benefit from returning their straightened rivers to their natural course. A more complete list of the straightened rivers in the U.S. will aid more intensive research on the negative impact of river straightening on environmental sustainability, and may ultimately guide future policy on regulating river straightening practices.

Using financial incentives to encourage sustainable flood mitigation may also support the growing flood management (versus flood control) approach. For example, federal funds could be specifically allocated for the design and implementation of sustainable flood mitigation approaches discussed herein, thereby improving flood management throughout the United States. In conjunction with existing local floodplain management ordinances, additional state and federal funding to support the shift towards sustainable flood mitigation could be used for updating Comprehensive Plans. The Comprehensive Plan could be the basis from which sustainable flood projects are developed. Comprehensive Plans can be updated to promote wise land use that does not increase flood risks, and more explicitly promote sustainable flood mitigation approaches.

Finally, as emphasized with Napa's flood project, community participation is key to successful and innovative sustainable flood mitigation. As such, policy changes at the local and state level could require and encourage increased public participation in the flood planning process. Encouraging participation from multiple stakeholders and citizens representative of the entire community can foster an increase in public participation, thus resulting in a locally driven and acceptable flood project.

The case study flood project in Napa owes its success to the impressive community involvement in the planing process. From its disapproval of the numerous past flood projects drafted by the U.S. Army Corps of Engineers, to its leading role in the design, approval, and implementation of the Napa River/Napa Creek Flood Protection

Project, the community was the driving force in creating this model flood plan. The community coalition process illustrates that communities need not remain passive while waiting for the U.S. Army Corps of Engineers to design a flood plan. By taking charge and actively pursuing a locally designed and supported flood plan, Napa residents and activities shifted the flood control paradigm in which the U.S. Army Corps of Engineers has typically controlled. Napa positively represents a flood project by the community, for the community, and is evidence that a community can force changes to flood control.

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APPENDIX A

Sources for list of straightened rivers in Table 1.

River Name	Date accessed	Website
Alamosa River	4/13/03	http://www.epa.gov/ecocommunity;/states/colorado2.htm
Chicago River	4/11/03	http://www.chipublib.org/004chicago/timeline/riverstrght.html
Chicago River	4/13/03	http://www.inficad.com/~ksup/chiriver.html
Cuyahoga River	4/11/03	http://web.ulib.csuohio.edu/SpecColl/croe/conscuy.html
Duchesne River	4/13/03	http://digital.library.okstate.edu/Kappler/Vol3/HTML_files/SES0429.html#sec23
East Two Rivers	4/11/03	http://www.mvp.usace.army.mil/navigation/default.asp?pageid=107
IL various streams	4/11/03	http://dnr.state.il.us/orep/inrin/ctap/sumrepo/chap3/chap3t.htm
John Day River	4/13/03	http://www.nwppc.org/fw/stories/johnday.htm
Jordan River	4/13/03	http://www.epa.gov/ecocommunity;/case3/jordan.htm
Kissimmee River	3/4/03	http://glacier.sfwmd.gov/org/erd/krr/pastpres/krrchanl.html
Long Creek		Army Corps of Engineers. "Channel Stability Assessment for Flood Control Projects." Engineers Manual. EM 1110-2-1418. 31 October 1994.
Los Angeles River	4/11/03	http://www.enn.com/features/1999/12/121499/rivermanage_7412.asp
Mississippi River	4/13/03	http://www.cesa10.k12.wi.us/Ecosystems/water/Mississippi/
Mississippi River	4/13/03	http://news.mpr.org/features/200007/04_losurem_sturgeon/index.shtml
Missouri River	4/11/03	http://www.npwrc.usgs.gov/resource/2000/cwmiss/cwmiss.htm
Missouri River	4/13/03	http://news.mpr.org/features/200007/04_losurem_sturgeon/index.shtml
Napa River	2/12/03	http://www.cityofnapa.org/Menu/MnuWeather.htm
Peteluma River	4/13/03	http://www.metroactive.com/papers/sonoma/06.15.00/river-0024.html
Provo River	4/13/03	http://www.flyfishrivers.com/Provoriver/Middleprovo.html
Provo River	4/13/03	http://www.mitigationcommission.gov/prrp/pdf/fact_factsheet.pdf
Puerco River		Army Corps of Engineers. "Channel Stability Assessment for Flood Control Projects." Engineers Manual. EM 1110-2-1418. 31 October 1994.
Red River		Army Corps of Engineers. "Channel Stability Assessment for Flood Control Projects." Engineers Manual. EM 1110-2-1418. 31 October 1994.
Rio Grande	4/30/03	http://www.usbr.gov/stewardship/index.htm
Russian River	4/30/03	http://www.epa.gov/owow/watershed/Proceed/marcus.html
Sabine River	4/11/03	http://www.tsha.utexas.edu/handbook/online/articles/view/SS/rns3.html
Salmon River	4/13/03	http://www.efw.bpa.gov/Environment/EW/PROPOSALS/AIWP/1999/9009.pdf
Salmon River	4/13/03	http://www.cbfwa.org/2001/projects/199901900.htm
Sammamish River	4/11/03	http://open-spaces.com/article-v3n4-rivers.php
Smiths Fork River	4/13/03	http://cc.usu.edu/~goodwin/prjsf.html
Trinity River	4/30/03	http://www.uscities.com/o-w/tx/dallas.htm
Trinity River		http://www.eswr.com/c101602.htm
Truckee River		Gregory, Daniel. "Response of a meandering river to artificial modification." In River Meandering Ed. Charles M. Elliott. 1983.
Twenty Mile Creek		Army Corps of Engineers. "Channel Stability Assessment for Flood Control Projects." Engineers Manual. EM 1110-2-1418. 31 October 1994.
Waupaca River	4/11/03	http://www.mainstreet-marketplace.com/Pages/historic_photos_set_9123.htm
Willamette River	4/11/03	http://www.4j.lane.edu/partners/eweb/ttr/globe/downloads/willamette_facts.PDF

APPENDIX B

NAPA RIVER FLOOD PROTECTION PROJECT - Interview Questionnaire

Flood Plan

1. Main feature of the project: the new bridges? Dry bypass channel? Or floodplain/wetland restoration?
2. What measures are in place to avoid development in flood prone areas?
    - What measures are in place to mitigate/modify presence of existing structures?
    - Are these policies effective to reduce impact of flooding?
3. Has the presence of levees, buildings/development, and lack of wetland/floodplain function, caused or worsened flooding?
4. Did any other cities' flood plans guide this one?
5. Why is this Napa flood project's general method used here and not elsewhere? Or is it used elsewhere? How site specific is this plan approach?
6. Role of "living river" strategy and objectives in guiding the Plan:

Process

1. Levels of government involved in planning and funding – mostly federal (Corps) or local sponsor (FCD)? Private/Non-profit?
2. What made this plan work/approval? The process? Content? Consensus building? Public pressure- is that why it was developed? Why it was approved?
3. Where did conflict arise? Which topics and by whom?
4. Why did these different stakeholders push for or against the plan?
    - Wealthy
    - Business
    - Agriculture sector
    - Industry
    - Policy-makers
    - General public
    - Green/environmental groups
5. How involved was the community/general public? Was their participation key to the success of the project, or just another element/requirement?

River Straightening

1. Why/when was the Napa River straightened? By the Corps?
2. Did river straightening worsen flooding? Dates/how/why? Did straightening cause environmental concerns?
3. How can straightening be undone for Napa River? In general?
    a. What is specific to Napa?
    b. Applicable elsewhere?

APPENDIX C

Summary of responses to interview questions and survey questionnaire.

Interview Question	Larry Dacus	Graham Wadsworth	Jon Lander
Main feature of the Project:	Marshland and floodplain terraces excavated in the overbank	Flood plain restoration and the dry bypass	Biggest cost was land acquisition
Have levees, development, or lack of floodplain function worsened floods?	No, in his opinion.	Yes – building in the floodplain put development at risk of natural floods	N/A
Did other flood plans guide this one?	No, this is considered a model for other flood plans	Not specific projects; trend around nation toward moving people out of floodplain instead of building deeper rivers and higher levees; Project is being used as a model by Corps for restoring floodplain; but expensive to purchase properties, so might not be appropriate for all communities	Napa is first with this deep consideration of urban environment in a flood project; geomorphic principles used were from other studies but it was new to apply these concepts to a core urban flood project
Why is this method not used elsewhere?	It is land intensive and is therefore expensive	It is expensive	Similar ideas are being used in Santa Clara flood project; their plan was redesigned to be similar to Napa's
Role of the living river strategy:	It's not in the form that can help designers and environmentalists develop specific alternatives; guidance was to provide flood protection in the least environmentally damaging manner and if possible also provide restoration	Allowed consensus across disparate groups	Guided the Coalition's goals
Coalition information:	Community very involved; their participation was key for local financial support	400 people involved; public was key	N/A
County Flood Control District responsibilities	N/A	Acquiring lands, relocating residents and businesses, relocating utilities, and finding soil disposal sites	N/A
City of Napa responsibilities	N/A	Administer the design and construction of 4 bridge replacements	N/A
Army Corps of Engineers responsibilities	N/A	Build Rail Road bridges, excavate terraces and dry by-pass, and build levees and floodwalls	N/A

What made this plan get approved?	Consensus building	Content was important, but consensus really moved it forward; all were working towards a common solution	Coalition
Where did conflict arise?	How best to include environmental restoration	N/A	Funding mechanisms; environmentalists posed first challenge
Who pushed for the Project and why?	N/A	Businesses: couldn't afford to rebuild after floods and media attention drove away tourists Environmental groups: improve habitat Permit agencies: minimize environmental impacts during construction Policymakers/public: stop flooding and have a plan that could be funded	N/A
When, where, and why was the river straightened?	1940s; for navigation; by Corps	1930s by Corps, south of the City	At Napa Pipe
Did straightening worsen flooding or have environmental impacts?	No, didn't worsen flooding; such a small length that any environmental impacts were minimal	Probably reduced flooding; debate on affect on creeks being downcut or incised	Doesn't think it affected flooding; it did decrease riparian habitat, which is why marshland habitat of current project is necessary
How can river straightening be undone?	It can't with out eliminating navigation	River straightening can increase velocities and erosion; Napa Project avoided straightening the Napa River and Creek	Dry by-pass channel addresses impact of straightening; by having it dry and not wet and at an incline, there is not a loss to habitat
Dry By-pass information	N/A	N/A	+200 parcels purchased for construction of dry by-pass; will be finished by end of 2006; most flood protection will be finished with completion of by-pass channel

APPENDIX D

Napa River - Living River Objectives (Source: Karen Rippey 2000).

NO.	OBJECTIVES	APPLICABLE
1.	Maintain or restore the river to a state of geomorphic equilibrium.	Geomorphic stability
2.	Maintain the natural slope of the River. The slope of the River should not be altered significantly by dredging or straightening.	Geomorphic stability
3.	Maintain the natural width of the River.	Geomorphic stability
4.	Maintain the natural width/depth ratio of the River.	Geomorphic stability
5.	To the maximum degree possible, maintain or restore the connection of the River to its floodplain. This should be of sufficient width to accommodate river meandering caused by naturally occurring flows	Geomorphic stability
6.	Provide sufficient setbacks to allow natural meandering processes.	Geomorphic stability
7.	Maintain channel features such as mudflats, shallows, a naturally uneven bottom configuration, and sandbars.	Geomorphic stability
8.	Restore the river to a state of sediment transport equilibrium as follows: a. Upstream of Trancas (riverine): • The amount of sediment entering and leaving the system should be equal. • Restore the natural relationship between the floodplain, riparian edge and River. b. Downstream of Trancas (estuarine) • Re-establish natural deposition rates. This will require adequate flow and channel geometry, providing appropriate velocity, slope, width, and depth to transport the sediment load. The project should not increase the sediment load or alter the settling capacities of the sediment such that there is an increase sediment deposition South of Third Street.	Sediment transport
9.	Quantify the overall sediment load to the system. Long-term watershed management measures should be determined to reduce the sediment load to the system to re-establish equilibrium.	Sediment transport
10.	Design a project that re-establishes a system in equilibrium and decreases upstream erosion rates, rather than relying on maintenance dredging to maintain the channel capacity.	Sediment transport
11.	Design a project that minimizes the need for erosion control measures such as rock rip-rap or other hard structure/materials.	Sediment transport
12.	Maintain seasonal flows of sufficient magnitude and duration to sustain channel morphology within a floodplain and sustain estuarine system components.	Flow and velocity
13.	Maintain adequate flows and velocities for sediment transport.	Flow and velocity
14.	Maintain velocities in the ranges that might be expected in a natural system.	Flow and velocity

NO.	OBJECTIVES	APPLICABLE
15.	Identify measures throughout the watershed to increase infiltration and decrease stormwater runoff.	Flow and velocity
16.	Preserve the size and seasonally varying location of the null/entrapment zone and its ecological characteristics.	Dynamics of the null/entrapment zone
17.	Tidally influenced waters (South of Trancas) Minimum, at all times: 5.0 mg/L	Dissolved oxygen
18.	Cold water Fishery (North of Trancas) Minimum, at all times: 7.0mg/L	Dissolved oxygen
19.	All waters Minimum (three month median): 6.8-7.2 mg/l[5] (summer, 80% of saturation)	Dissolved oxygen
20.	Maintain or restore the river to a state of geomorphic equilibrium. This should eliminate the need for extensive ongoing maintenance dredging.	Dissolved oxygen
21.	Maintain or restore a riparian zone to provide shade for the River in order to reduce temperatures.	Dissolved oxygen
22.	Maintain or restore adequate low flows.	Dissolved oxygen
23.	Maintain adequate water velocity during low flow months.	Dissolved oxygen
24.	Maintain adequate circulation patterns.	Dissolved oxygen
25.	Maintain and decrease nutrient loading. Nutrients should not increase through discharge of dredge material or sediment resuspension; such that increased primary production occurs.	Dissolved oxygen
26.	Maintain water temperatures appropriate to the needs of the local biota.	Dissolved oxygen
27.	Water quality factors should not increase the total dissolve solids or salinity so as to adversely affect the location the entrapment zone, or beneficial uses of the River, particularly fish migration and estuarine habitat.	Salinity
28.	The project should not have any the following effects on salinity (seasonally or in worst case conditions such as summer low-flow or droughts): 1. Compress or alter the location of the null/entrapment zone; 2. Steepen the salinity gradient; 3. Alter the average salinity concentrations (seasonal); or 3. Alter the location of the seasonally varying upstream extent of salinity. 4.	Salinity
29.	The natural river/creek water temperature should be maintained.	Temperature
30.	Velocity, circulation patterns, and mass flow should not be altered in a manner that causes an increase in temperature.	Temperature
31.	Avoid increases in turbidity from dredging or other project activities that can cause an increase in water temperature.	Temperature

NO.	OBJECTIVES	APPLICABLE
32.	Avoid creating thermal barriers to migration or movement by project activities (e.g., dredging).	Temperature
33.	Increases from normal background light penetration or turbidity should not be greater than 10% in areas where normal turbidity is greater than 50 NTU.	Turbidity
34.	The flood control project should not: • Increases sedimentation rates in the lower River (below Trancas), • Increase bank and bed erosion upstream or in the tributaries, • Cause resuspension of sediments from dredging, • Increase algae growth.	Turbidity
35.	All waters should be maintained free of toxic substances in concentrations that are lethal to or produce other detrimental responses in aquatic organisms. Detrimental responses include decreased growth rate and decreased reproductive success of resident or indicator species (See San Francisco Bay Regional Water Quality Control Board, Basin Plan for specific numeric limits).	Toxicity
36.	The project should not result in the release or discharge nitrates and phosphates in concentrations that promote aquatic growths to the extent that such growths cause a nuisance or adversely affect beneficial uses.	Nutrients/Algae Blooms
37.	A recommended maximum level for nitrate is 0.3 mg/l.	Nutrients/Algae Blooms
38.	The project should not result in a wide, shallow low-flow channel (this would result in increased water temperatures, causing increased plant growth).	Nutrients/Algae Blooms
39.	The vegetable transition zones should exist from the low water level to the upper floodplain. Each zone should be of sufficient width to sustain habitat complexity and ecosystem function. There are no set widths. Specific widths will vary with topography and bank slope. To create a self-sustaining river system, widths should be set by studying and mimicking natural conditions to the greatest extent feasible.	Vegetation
40.	Design a project that minimizes the need for erosion control measures such as rock rip-rap or other hard structures/materials.	Vegetation
41.	From saltwater to freshwater, the vegetation should exist in a linear uninterrupted continuum. This continuum should have the successional variation, diversity and structure to provide cover and habitat for a natural variety of aquatic and terrestrial life.	Vegetation
42.	No physical or water quality barriers to migration.	Vegetation
43.	Post-project conditions should include: • geomorphic features (e.g., meanders) that will foster development of varying water depths over mudflats, sand bars, pools; • graduation of depth from bank to bank; • presence of pools, low flow channels, mudflats, and sand bars, • banks at a slope and with appropriate substrate to support vegetation; • minimal maintenance dredging or other disturbances that eliminate structural complexity. •	Vegetation

NO.	OBJECTIVES	APPLICABLE
44.	Maintain seasonal flows in the Napa River and its tributaries that permit upstream migration, summer residence, and out migration of steelhead.	Vegetation
45.	Restore or maintain riparian and wetland habitat. Re-establish a linear continuum of vegetation and a buffer of sufficient width to protect plants and animals from human disturbance.	Wildlife
46.	Maintain mudflats and shallow areas.	Wildlife
47.	Restore or maintain a riparian corridor that is predominantly undisturbed by human activity. Minimal disturbance can be achieved by creating a trail system that is not located directly along the River banks in most places. Rather, the trail should be located a distance away from the River, with discrete access points viewing, fishing, etc. (Exceptions to this would be within the City Downtown area where parks, trails could be located as enhancements to that area).	Wildlife
48.	No physical or water quality barriers to migration	Aquatic species habitat
49.	The project should provide for a graduation of depth from the bank to bank.	Aquatic species habitat
50.	Maintain existing riffle:run:pool ratios in the upstream areas, and try to replicate this in the downstream areas. Maintain a low flow channel and gravel bars.	Aquatic species habitat
51.	Maintain geomorphic features (e.g., meanders) that foster continued development of varying water depths, pools, etc.	Aquatic species habitat
52.	Provide for sufficient cover for various fish life stages, particularly nursery habitat for steelhead and contiguous bank escape cover for out migrating steelhead smolts (wooden snags, rootwads, large rocks and submerged vegetation).	Aquatic species habitat
53.	Ensure conditions that create clean, well rounded gravel for spawning.	Aquatic species habitat
54.	Embeddedness less than 25%.	Aquatic species habitat