Alterations of Freshwater Flows: Implications for Coastal Zone Management

by

Marguerite E. O'Neill

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Submitted to the Department of Ocean Engineering
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Abstract  
The pattern of freshwater flows into and through coastal areas is critical to the health of coastal ecosystems. These flows have been altered, often on a large scale, by projects such as dams, diversions, irrigation systems, and channelization designed to fulfill a range of human objectives. But changes in freshwater flows, either through a reduction in quantity, due to diversion, or through an alteration in flow speed, timing, or location of input can severely damage the receiving coastal ecosystem. These damages are felt in terms of market economics via the loss of commercial and sport fisheries, lost shellfishing, lost recreation, lost wetlands and consequently diminished natural storm protection systems, to name just a few. Despite solid technical evidence documenting these linkages, the topic of freshwater flows is largely absent from the efforts to manage coastal areas for sustainability. This topic has been tackled only in a case-by-case manner when freshwater manipulations have caused a particular ecosystem severe damage. The measures required to restore the degraded areas and reverse alterations now are increasingly costly and extremely difficult to implement because they involve altering economic systems highly dependent on the existing, altered flow patterns. But because the majority of the largest alterations – dams, channels and levees – are productions of consolidated government agencies, and not of myriad private entities, prevention of new projects is, theoretically, readily accomplished. Therefore as coastal management expands to encompass entire drainage basins, questions of freshwater inflow must be addressed. Watershed management needs to account for water quantity and not just water quality, for with inadequate quantity, quality cannot be attained.  

Thesis Supervisor: Judith T. Kildow  
Title: Associate Professor of Ocean Policy
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Dedicated to the memory of Leo, feline companion. 1975 - 1994.
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Chapter 1

Introduction

The coasts of the world are imperiled. The waters are polluted by chemicals, bacteria, garbage and sewage. The beaches and shorelines in many places are rapidly eroding. Fish and shellfish populations are at historical lows, and in many places such resources are no longer fit for human consumption. Wetlands are being lost at an incredible rate, along with the vegetative and animal species that reside there. Increasing numbers of marine, estuarine and riverine species are endangered; genetic diversity is decreasing. Alterations in conditions are allowing exotic species to displace native breeds.

These changes are effects of humankind's explosion in development and industrialization and, consequently, natural resource consumption of the past hundred years. Some of these changes are partially attributable to natural phenomena, such as population dynamics, sea level rise, climate variability, storms. But the impacts of human settlement and development have accelerated these processes and exacerbated the effects of these natural changes. Thus the incremental changes wrought by both natural and anthropogenic influences have accumulated to produce catastrophic results, namely, serious damage to coastal systems. And these environmental crises are important not only in terms of ecological parameters, but also in terms of the ultimate impacts on human activities dependent on these resources.

This crisis on the coast has been recognized in the United States since the mid-1960's; at that time the primary concerns were dredging and filling operations and the loss of wetlands. Starting at that time, the health of the nation's coasts has been addressed in legislative efforts at all levels - from local, to state and up to federal authorities - and the legislative remedies have evolved as technical understanding of the variety of problems evolved. From these initial efforts targeting dredge and fill, coastal protection efforts have expanded to consider the questions of industrial and sewage discharges, oil pollution, pollution from ships, nuclear wastes and garbage
disposal. The 1990 Reauthorization of the federal Coastal Zone Management Act even includes a mandate to the states to address non-point source pollution. But despite these legislative efforts, problems on the coast still exist.

This failure is largely attributable to a shortsightedness in problem assessment and solution scope. The coast exists at the juncture of land, air and water. As such, it is subject to a variety of influences from both landside, seaside and above. But efforts to manage the coast fail to comprehend the full extent of influence. The Coastal Zone Management Act defines the coastal zone as “the coastal waters (including the lands therein and thereunder) and the adjacent shorelands (including the waters therein and thereunder), strongly influenced by each other and in proximity to the shorelines of the several coastal states, and includes islands, transitional and intertidal areas, salt marshes, wetlands, and beaches. The zone extends ... seaward to the outer limit of the outer limit of State title and ownership under the Submerged Lands Act” or other applicable acts.\(^1\) “The zone extends inland from the shorelines only to the extent necessary to control shorelands, the uses of which have a direct and significant impact on the coastal waters.”\(^2\)

Individual states are required to identify the boundaries of their territory subject to the coastal zone management program, but given the restrictive federal definition, few states have included entire drainage basins in their program jurisdiction. Most define the landward boundary in the immediacy of the shoreline. The program authorization restricts the seaward boundary to lie at the Submerged Lands Act’s three mile territorial state limit\(^3\), and no formal upward boundaries exist.

The scope of airborne influence surpasses that of the other two realms; the sources can be thousands of kilometers removed from the impacted region. Practical management of such pollution is therefore often impossible for the various state authorities; indeed, aerial fallout is often an international problem. This leaves two realms – land and water – to coastal managers. Early attempts to address coastal environmental deterioration focused on the visible, the point sources: sewage outlets, dredge and fill operations, industrial effluent, dumping from ships. But addressing these

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\(^1\)The Submerged Lands Act can be found as 43 U.S.C. 1301 et seq. Other applicable acts are the Act of March 2, 1917 (48 U.S.C. 749), the Covenant to Establish a Commonwealth of the Northern Mariana Islands in Political Union with the United States of America, as approved by the Act of March 24, 1976 (48 U.S.C. 1681 note), and section 1 of the Act of November 20,1963 (48 U.S.C. 1705).

\(^2\)“Excluded from the coastal zone are lands the use of which is by law subject solely to the discretion of or which is held in trust by the Federal Government, its officers or agents and to control those geographical areas which are likely to be affected by or vulnerable to sea level rise.”

\(^3\)Florida and Texas are the exception with 10.4 mile boundaries based on historical jurisdictions.
problems often did little to restore ecological prosperity to the regions, and this is because many detrimental influences occur exterior to the immediate coast. In the late 1970’s, an awareness grew that to achieve environmental protection of coastal resources, managers needed to acknowledge and understand that “One cannot adequately plan and manage an [enclosed] coastal water body without controlling input from the watershed and the marine environment.”[67]

The second critical failure is the lack of attention paid to the transporting medium itself. For these various media impact the coast not only through the “good” and “bad” additives they transport, but also in and of themselves, in terms of quantity, timing, rate and quality. Specifically, the flow of freshwater into coastal bodies is an important variable in the equation for coastal health, yet this variable is only considered when the flows have been so drastically altered as to produce catastrophic results. Perhaps the most dramatic example is that of the southern seas in the former U.S.S.R. where the Soviet dams on the major rivers into the Black, Caspian and Azov Seas have reduced spring freshwater inflows to 15% to 50% of their historic values. Consequently, fish catches have been reduced to less than 5% of pre-dam levels, eutrophication and red tides are uncontrolled, beaches are contaminated: in short, “degradation of [these] seas has progressed to such a state across the southern portion of the USSR that destruction of their habitat has become the Achilles’ heel of the Soviet economic policy.”[57, pp.92-93] And the problems associated with excessive freshwater manipulations have appeared on the shores of the United States, as well.

In the 1981 National Symposium on Freshwater Inflow to Estuaries, John Clark summarized the aforementioned failures thus: “One mistake made [in the early years] was to think that estuarine conservation was largely a coastal problem. ... But now, ..., we find that estuarine conservation is largely a water supply problem dealing with the quantity, the quality, the timing and the rate of flow.”[11] 4

Although the physical dimension of freshwater flow is inextricably linked to issues of pollution and water quality, this aspect continues to be overlooked in political and managerial decisions, except in situations where the freshwater flows alterations have produced severe and persistent damages. To motivate the rethinking of these

4Because this paper will deal exclusively with the issue of freshwater inflow as it influences coastal systems, I will use the terms “estuary” and “coastal water body” interchangeably to refer to the coastal areas that do experience freshwater inflow. To clarify the meaning of “estuary,” we turn to the definition provided by the Congress in the act creating the National Estuary Program. This Act defines an estuary as “all or part of the mouth of a river or a stream or other body of water having unimpaired natural connection with open sea and within which the sea water is measurably diluted with fresh water derived from land drainage.”[67]
decisions, this paper will first address the technical questions of how the timing and quantity of freshwater flowing into the coastal zone can impact the physics, chemistry and biology of the estuary. This scientific evidence is intended to motivate not only an understanding of the interrelations amongst the various disciplines, but also to convince the reader of the magnitude of the deleterious effects caused by freshwater flow alterations. Next, this paper will evaluate some management and mitigation strategies that have been applied to this problem to determine first why this critical piece of the coastal management puzzle has been left in the box, and second why this piece is particularly difficult to handle effectively. This evaluation will be accomplished via in-depth analysis of two case studies, the San Francisco Estuary and the Mississippi River System. These two cases will illustrate a variety of possible repercussions of some fairly different physical alterations. Comparing the studies, particularly the management dynamics, for similarities and differences will highlight first, why the question of freshwater flow alterations is initially not addressed; second, the factors required for this issue to be addressed; and third, some factors impeding implementation of appropriate measures to mitigate the harms caused by flow alterations.

Finally, this paper will show that the large-scale alteration of freshwater inflows to estuaries is, at least theoretically, one of the easiest environmental wrongs to prevent and/or right. Thus the inclusion of freshwater flow considerations, via the expansion of coastal management authority throughout the impacting watershed, could be an important tool in preventing similar catastrophes from developing at other sites.

1.1 The Alterations

Human developments have altered the flow of freshwater into coastal areas in many different ways and for many different reasons. Table 1.1 summarizes some of the developments and the ensuing alterations to freshwater flow. Again, the changes of interests are: quantity, quality, timing and rate.

The most obvious type of project designed to alter freshwater flows is the construction of dams. Dams are used to store water to minimize the likelihood of flooding, to minimize the consequences of drought, to produce electricity and to release water to various consumers – usually agricultural, industrial and urban users – as their demand patterns require. Dams are walls constructed in the middle of streams, and as such, they divide the watershed into artificial subunits. In their operations, seasonal flows are altered, the temperatures of the flows are altered and the annual total quantity is
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<tr>
<th>Project</th>
<th>Purposes</th>
<th>Effects</th>
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<td>Dams (and Diversions)</td>
<td>Flood Control</td>
<td>Decrease Peak Flow</td>
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<td>Electricity</td>
<td>In- or Decrease Offpeak Flow</td>
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<td>Water Supply</td>
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<td>Channelization;</td>
<td>Navigation</td>
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<td>Levees; Canals</td>
<td>Drainage</td>
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<td>Flood Control</td>
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<td>Eliminate Floodplains</td>
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<td>Paving/Roads;</td>
<td>Urbanization</td>
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<td>Deforestation</td>
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<td>Decrease Pollutant Filtering</td>
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Table 1.1: The alterations to freshwater flows caused by various anthropogenic constructions.

often reduced. Often accompanying the construction of dams is the construction of diversion systems used to distribute the water flowing through one watershed either to new locations within the watershed or to totally different watersheds, in quantities and schedules that fit consumption requirements. California’s dam and divert system provides a good example; approximately fifty percent of the annual predevelopment flows into San Francisco Bay in Northern California are now diverted to supply agricultural and urban users in the central and southern reaches of the state.\[58\]

Other regions have devised creative solutions to accomplish the same goals of flood prevention, drought prevention and water supply; the complex system of water conservation areas, canals, levees, reservoirs and rerouted rivers in South Florida accomplishes these ends.

The second type of project intentionally producing alteration of freshwater flows are those conducted in the interests of navigation and commerce. Canals are dredged, channels are deepened, the banks of rivers are built up and reinforced (which also reduces flooding). These alterations allow larger vessels to use riverine areas safely and more rapidly, enhancing the commercial viability of adjacent communities. Physically,
they change the flow rates and in some cases, the flow direction; this changes the mixing processes that occur when the river meets the sea. This type of alteration also reduces the area of floodplain, drying out wetlands and reducing the natural renewal of soil that occurs by sediment transport and deposition during flooding. The restriction of flooding tends to increase the peak flow quantities and rates, for most runoff is now directly and immediately channelled and discharged to the sea.

There is a second class of anthropogenic influences that are generally not directly intended to alter the freshwater flows, yet can have sizable impacts on the rate, timing and quantity of riverine flow. This category of alteration can be produced as a consequence of land development, for industry, agriculture and/or urbanization. Under natural conditions, some portion of the precipitation that falls runs off the land directly and some portion is absorbed. Various parameters, such as rainfall intensity, soil type and thickness of vegetative cover determine this fractioning.[4, p.306] Therefore changing these parameters, for instance by the destruction of the layer of organic debris on a forest floor through deforestation, logging, ground fires or grazing, can produce an increase in both the runoff rate and the sediment load.[4, p.308] Another pathway is via the construction of roads and the paving of land, because pavement prevents precipitated moisture from infiltrating the soil and thereby increases the runoff during the rainy period and consequently decreases the flow in the dry season.[7, p.405] Construction of drainage ditches and canals out of concern for agricultural or human settlement issues can similarly alter the timing and quantity of runoff flows.

1.2 Flow Alterations: A Tour of the U.S.

Several watersheds from various locations throughout the United States have been selected for summary discussions of the specific freshwater flow alterations and ensuing ecological and economic impacts at each site. This tour is intended to motivate comprehension of the widespread character of this type of anthropogenic perturbation. The particular sites were selected not only because of the wide geographical range, but also because the impacts produced by various freshwater alterations at each are well documented and fairly severe. In some cases, an outline of relevant management efforts is also included.

Bear in mind that these cases are presented in a bare form; this thesis will present the San Francisco Estuary and Mississippi River Delta System cases in a considerably more thorough manner.
1.2.1 The Northwest: The Columbia River Basin

The freshwater flow alteration project of choice in this region is the dam. There are 69 dams on the Columbia River and its tributaries; these constructions have reduced the historical stream length from 1240 miles to just 44 dam-free miles. The coastal impact currently considered most critical is the impact on anadromous fisheries.

As a consequence of the dams, the Basin’s salmon and steelhead runs have been reduced to approximately 2.5 million spawning fish, only 20 percent of the historical average of 12 million. Of these, only 10-20 percent of the spawners are from wild stocks; the rest were raised in hatcheries.\(^5\) The Snake River run of coho salmon is believed extinct; the Idaho sockeye salmon is on the endangered species list; several other species on the Snake and Columbia rivers have declined so severely that petitions have been filed with the National Marine Fisheries Service to give the fish endangered species status.\(^9\)

1.2.2 The Gulf of Mexico: Matagorda Bay

As an entity, the Gulf of Mexico is annually deprived of from 40 to 90 percent of the spring runoff from 44 major rivers. This region’s fisheries are particularly dependent upon estuarine habitat; 98% of all commercial fish and shellfish caught in the Gulf spend all or part of their life in near-shore estuarine waters.\(^57\)

Matagorda Bay is situated near the midpoint of Texas' Gulf coast and is supplied with freshwater by the Colorado River. The bay is ranked third in commercial value among all Texas bays. In 1929, a large natural log jam above the bay was dynamited, resulting in rapid downstream transport of the quantities of silt trapped behind the logs. This silt inundated the previously productive bay bottom and accelerated the natural process of delta growth. Certainly this sequence could naturally occur, but to provide for commerce and navigation, the new delta was channelized.

As the banks of the channel built up, the bay eventually (in 1936) became divided into two separate water bodies. The majority of the nutrients transported by the Colorado are now discharged into the Gulf of Mexico, instead of Matagorda Bay.\(^42\) Consequently, the growth of phytoplankton, and subsequently all creatures in the food web, is limited; the once-prolific oyster beds have shrunk dramatically. In the late 1970’s, a plan was proposed to mitigate the ecological damages by diverting part of the Colorado's freshwater inflow directly into Matagorda Bay. This project

\(^5\)Hatchery raised fish lack the survival skills of wild salmon; one expert describes them as “sausage with fins.”\(^46\)
was projected to cost $10 million, and yield the same amount annually via increased commercial fish and shellfish harvests.[75] Completion of this project was stalled in 1991 (after 34 million federal dollars were invested) because of possible interference with navigation along the Gulf Intracoastal Waterway.[20]

1.2.3 Florida

The freshwater flow patterns and alterations in Florida are some of the most complicated and large-scale in the United States. To understand the systems and the implications of alterations clearly, it is easiest to describe the before and after conditions. The geographic region of particular interest is the lower Florida Peninsula, particularly the watershed running from the northern headwaters of the Kissimmee River through the Everglades to Florida Bay and the Keys.

Before the system was altered, the Kissimmee River slowly meandered from Lake Kissimmee to Lake Okeechobee. During heavy summer rains, the lake overflowed and flooded the lands to the south. This freshwater, sometimes called the "river of grass," slowly flowed as a shallow (up to several feet deep) sheet as much as 50 miles wide. This sheet flowed through the saw grass of the swampy Everglades and south to Florida Bay, South Biscayne Bay and Ten Thousand Islands. During the winter, the region became drier, and the region's biological cycles became closely linked with this hydrologic cycle.[27]

Alterations to the aquatic regime began in the 1880's, when a cut was made through the natural dam between Lake Okeechobee and the Caloosahatchee River. The general philosophy from the early 1900's on was that the Everglades would be most useful drained and settled; Governor Napoleon Broward promised in 1905 to drain the Everglades once and for all. Canals and dams were built to this purpose. Following catastrophic hurricanes in the 1920's, the U.S. Army Corps of Engineers was called in to strengthen and improve the water control systems. Today, an incredibly complicated water storage and management system exists to provide for the demands of agriculture, industry and municipalities, and to provide flood control and drainage.[27]

Consequently, the Everglades, a unique system in the United States supporting a variety of rare wildlife, is dying. The area of the Everglades has been reduced by half; the water levels are five feet lower than historically; wading bird populations are down by 90%; sawgrass is increasingly replaced by exotic cattails; other wildlife populations are in decline. Florida Bay, too, has suffered from the flow alterations. The diminished
freshwater releases have rendered Florida Bay hypersaline, killing seagrasses that provide critical habitat for a variety of creatures. This effect combined with the nutrients from agricultural runoff have fed algae blooms which in turn produce the now common phenomena of eutrophication and fish kills.[68] The coral reefs of the south Keys, a delicate, unique ecosystem that has become an important tourist attraction, are threatened by chemicals, nutrients and the excessively saline water from Florida Bay.[13]

The Atlantic coast, the annual recipient of 717 billion gallons of water that previously flowed to Florida Bay, is also suffering because of the freshwater flow alterations.[53] For example, technical discussions about the Indian River Lagoon, a coastal water body located near Cape Canaveral and the collection site of 90 percent of the state’s clam harvest, identified several causes for the ecosystem’s decline. First on the list was “too much fresh water was entering the lagoon from drained lands in the watershed in volumes and hydroperiod inappropriate to the salinity balance of the estuary; the water was carrying organic sediments and coliform bacteria above the assimilative capacity of the system.”[3] Part of the increase is attributable to the increased human population and their discharges; part is related to the aforementioned interior projects, that increased the lagoon’s drainage basin by 400 percent. The results are varied water qualities, varied salinity regimes, and varied flushing times.

1.2.4 Northeast: The Penobscot River

The rivers of the Northeast were heavily dammed to provide power for the Industrial Revolution. Consequently, the wild Atlantic salmon was blocked from returning to spawning grounds in all major regional rivers except one – the Penobscot river in Maine. The Penobscot, too, already supports several dams, but major efforts, such as fish ladders and hatchery restocking, have been made to ensure the salmon’s future on this river. Despite these efforts, only 1700 fish returned to spawn in 1993.

Now, in 1994, the Penobscot faces a new threat in the proposed Basin Mills dam project, designed to provide low cost electricity to some 100,000 people. The project’s managers have included mitigation measures, such as capturing and trucking fish past the dam in the proposal. Nonetheless, Fish and Wildlife Service studies indicate that the probability of a self-sustaining salmon run on the river falls from 72% to 39% with the dam.[46]
Chapter 2

Case Studies: Background

Two case studies have been selected because both have long been identified as having problems relating to freshwater inflow. Planning and management efforts in the two regions have endeavored to remedy the given problems, with varying degrees of success. Two cases were deemed necessary to illustrate not only two vastly different alteration networks, built to attain vastly different social purposes, with rather different (although not exclusive) detrimental impacts, but also to examine how the technical, political and management structures associated with the different sites first identified and assessed the problem and then devised and implemented mechanisms to mitigate the damages.

The cases of the San Francisco Estuary and the Mississippi River/Delta System were selected because serious deterioration was observed at both sites many years ago; the technical issue of freshwater flow alterations causing detriment is quite well established. Since that time, continuing even today, managers at both sites have used a variety of tools in efforts to remedy the harm. Evaluating these efforts as they have evolved through time illustrate some of the difficulties in effectively managing freshwater resources and also illustrate the efficacy – in terms of political, technical and economic factors – the various applied mechanisms have in addressing the problems. Included in these analyses are some outlines of the predicted costs both of remedying and not remedying the detrimental situation.

The case studies have been divided into three chapters. This first chapter will present background information on the cases: the character of the region, both environmental and societal, and a background on the history of the alterations, including the types, the sizes and the motivating factors for their construction. Chapter 3 will summarize the existing technical understanding of the impacts caused by the alterations present in each case. Chapter 5 will outline the management history
and evaluate the factors facilitating, impeding and catalyzing successful restoration efforts.

2.1 San Francisco Bay Estuary

The San Francisco Estuary\textsuperscript{1} is the largest estuary on the west coast of the American continents. Through a narrow gap in the coastal range, the Pacific Ocean meets the mouth of a vast river network that drains almost half of California. Semi-diurnal tides mix the salty water of the ocean with the fresh water from the mountains flowing through the delta into the eight bays that compose San Francisco Bay. Figure A-1 maps the state of California, highlighting the water systems based in the Estuary's drainage basin.

Physically, the northern portions of the San Francisco Bay Estuary, including Central Bay, San Pablo Bay, Suisun Bay and the Delta is generally described as a partially mixed estuary, where the freshwater from the mountains is gradually mixed with the salty ocean waters. The South Bay, on the other hand, is characterized as a tidally oscillating lagoon, with low freshwater inflows and high residence times. Because of its fairly isolated location and the physics of the Bay's flows, the South Bay is particularly dependent upon major freshwater inflows from the delta during the wet season to flush pollutants from its waters.[79, p.410] Figure A-2 provides cartographical information on the Bay-Delta region.

At the time of the California Gold Rush of 1849, this estuarine system was vast and biologically productive, with the Bay and bordering marshlands covering 787 square miles and supporting a thriving ecological community with healthy populations of plant life, fish, shellfish, marine mammals, birds and land mammals.

The estuarine ecosystem provides nursery habitat for fish and crabs, and supports over 150 species of fish, including the commercially important herring and anchovy, and the recreational fishing species salmon, striped bass and steelhead trout. The expanses of wetlands provide wintering grounds for the migrating birds of the Pacific Flyway, making the region "an internationally significant shorebird area."[64]

The land surrounding the estuary is occupied by twelve counties, encompassing

\textsuperscript{1}In accord with the San Francisco Estuary Project, the term Estuary, as used in herein, will refer to the waters of San Francisco Bay, San Pablo Bay, Suisun Bay and the Sacramento-San Joaquin Delta. The terms Bay-Delta, Bay Estuary or Estuary will be used to refer to the entire system. The terms Bay or Delta used individually will refer to those particular segments of the system in question.
thirty waterfront cities and a regional population of seven and a half million people. The estuary is an important resource for many of these people, providing enough water to sustain 45,000 shipping jobs, 51,000 jobs in agriculture and 600,000 jobs in manufacturing.[64] In 1988, the commercial fishing industry landed a catch of salmon alone worth $42 million at Bay area ports.[61] Sport fishing, hunting and boating are significant revenue-producing recreational activities; the area boasts over 290 shoreline recreational areas and three hundred marinas.[61] The region also profits from a large tourism industry: 1990's Bay area visitors spent $3.9 billion on tourist-related activities, supporting 66,000 jobs.[61] Certainly many of these visitors seek the reputed beauty and tranquility of the Bay: the Golden Gate National Recreation Area alone drew over 25 million visitors in 1987. The Bay's aesthetic characteristics are a lure for businesses, as well: the computer company Next, Inc., chose a site in Redwood City for its headquarters because of the proximity to the Bay. In fact, the Bay's beauty as a work of nature helps to unite the millions of area residents – a value incalculable in economic terms.[60, pp.35,42] [49, p.4]

But the urbanization of the Bay area has caused a degradation of the natural system with all its wealth that initially drew people to the area. The demands for land, especially for waterfront land, has led to filling operations that have reduced the size of the Bay by 40%, halved the average depth of the Bay, and eliminated 95% of the original tidal marshes, as compared to historical levels.[60, p.31] With the increases in regional population and industry, the waters of the Bay have been heavily polluted with human and industrial wastewater discharges, with urban and agricultural runoff, with oil spills and aerial fallout. And unfortunately for the now-decimated wildlife populations that depend on these waters, the Bay's ability to cleanse itself has been severely hampered by the diversion of freshwater inflows from the Bay-Delta.

2.1.1 The Projects

The construction of two enormous water resource management projects, the federally operated Central Valley Project and the California State Water Project, resulted in the reallocation of approximately half the historical annual freshwater inflow to the estuary. The diversions in the spring, spawning time for many anadromous species, during the recent years of drought reached 65% to 85% of historical spring flows.[57] This water is now used to irrigate 4.5 million acres of some of the richest farmland nationwide; it is also the primary water supply for 20 million Californians, many in the drier southern part of the state.
The reasons for these projects are thus: California has many of the natural necessities for tremendous growth – abundant water, good soil and a favorable climate – yet the natural distribution of water has not always been convenient to farmers and developers.

The bulk of California’s rainfall is produced by storms coming from the Pacific that dump on average 200 million acre-feet (MAF)² of water on the state annually, the bulk of it in the Sierra Nevada Mountains on the eastern border and Coast Range to the west. Two-thirds of this is lost to the atmosphere, leaving approximately 71 million acre-feet as runoff on average. North coast streams catch 40 percent of this runoff; the Sacramento River carries 31% from the northern Sierra, the Trinity Alps and the Mt. Shasta region south into the Delta and through San Francisco Bay to the ocean. The San Joaquin river carries an additional 9% of the total runoff north into the Delta. Thus the bulk of California’s water supply is in the northern Central Valley; but California’s water demands are dispersed throughout the state.[22, pp.121-122]

In order to utilize the ecological resources of climate and soil in the southern parts of California, the ecological limitations imposed by the scarcity of water needed to be overcome. The improvement of both agriculture and development became the driving force behind the conception and construction of two major water projects. The Central Valley Project (CVP) was planned by California in the 1930’s, but built by the federal government because the Depression impoverished state could not afford construction. The project was designed for the purpose of improving agriculture in the drier parts of the state, and now consists of 20 dams and 500 miles of canals that transport water from above the Sacramento valley to the southern San Joaquin valley at a relatively constant rate throughout the year. Operation of the CVP is regulated by the federal Reclamation Act of 1902. This Act was passed to encourage family farming, and restricts deliveries of subsidized federal waters to farms with a maximum size of 160 acres.[44]

The California State Water Project (SWP) was built largely in reaction to this restriction, for there were (and are) many land owners with large tracts in the San Joaquin valley, and they were unsuccessful in petitioning the federal government for exemptions to the Reclamation Act. In 1960, the Burns-Porter Act was approved by the governor, providing $1.75 billion in bonds to finance the early stages of the

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²An acre-foot is the amount of water needed to cover one acre of land to the depth of twelve inches; approximately 326,000 gallons. For reference, the average California family uses two-thirds of an acre-foot of water each year, and the average crop uses three acre-feet annually.

³The Reclamation Reform Act of 1982 increased this maximum to 960 acres.
project, contingent upon the signing of contracts that would guarantee certain water districts specified amounts of water upon completion of the project.[22, p.29] Contracts were signed, and in 1968 the state was committed to delivering over 4 million acre-feet annually to its contractors. The two largest financing contracts were sold to the Metropolitan Water District (serving urban consumers in the Los Angeles-San Diego region) and to the Kern County Water Agency (serving mainly agricultural consumers in the Southern San Joaquin Valley). This project, like the federal one, transports water from above Sacramento to the southern San Joaquin Valley. The SWP continues from here, however, lifting the water 2000 feet over the Tehachapi Mountains for delivery to southern California via the California Aqueduct.[22]

In addition to these major projects, a number of smaller dam and divert systems are in operation utilizing freshwater from the Sacramento/San Joaquin Delta. These include independent municipal storage and distribution facilities, and irrigation systems for Delta-area farms. Considering all freshwater operations, the San Francisco drainage basin now supplies water for most of the state’s agricultural land and for over twenty million people, many in the population centers in the San Francisco area in the north and the San Diego-Los Angeles metropolitan area to the south. Of these two user groups, agriculture consumes approximately 80 percent of the basin’s exported water.

In 1985, approximately 12.9 million acre-feet of water was exported from the Delta by all projects.[62] This totalled approximately 45% of the water added to the system through precipitation. In the latter years of drought, the total export quantity remained near this level, increasing the export percent to near 85% of the input water. This ability to maintain deliveries was accomplished by storing as much as 8.5 MAF in the projects’ numerous reservoirs.[57]

The basic premise of all these projects has been the expansion of economic growth throughout the state, primarily in the southern reaches, with little regard to impacts at or near the source. “Water politics in Southern California have always been politics of growth, of heating up the local economy by finding strategies to subsidize an increased and reallocated supply of a necessary natural resource so that, no matter how rainfall might fluctuate from year to year, economic growth would anticipate no checks and no limits.”[31, p. xvi]
2.2 The Mississippi River Delta System

The Mississippi River begins its journey in the wilds of Minnesota. As it progresses towards its eventual outlet in the state of Louisiana to the Gulf of Mexico, its waters swell with runoff from all or part of thirty-one states and two Canadian provinces, a land area equal to one-eighth of North America. When it finally reaches the Gulf, the Mississippi River is a muddy torrent, flowing at an annual average of 17,400 $m^3/s$ (approximately 500,000 cubic feet per second).[7] The shaded region in Figure A-4 details this basin and some of the major rivers contained therein.

As this flow reaches the coast, the waters of the Mississippi historically maintained the country's largest network of coastal wetlands, and nourished some of the nation's most productive estuarine habitats. The sediment carried by these flows was deposited in the deltaic plains, sustaining them above sea level. But numerous changes have been made that prevent the Mississippi River from fulfilling these functions. The changes to the river and the coastal plains wrought by humans, when combined with the natural processes of sea level rise and land subsidence, have limited the river's domain, producing an accelerating loss of Louisiana's coastal wetlands.

**Deltaic Processes** Before humans constructed a range of major alterations, the Mississippi River would annually transport over 200 million tons of sediment to the coast. These sediments settled out as the river expanded into the Gulf, beginning the Delta construction process. The sediments built a base platform, establishing the delta plain. Coarser sediments formed natural levees along the river's path, and shoals at the river mouth. As the levees stabilized, and the bays filled in, freshwater and/or brackish marsh plants invaded. These marshes continued to be replenished with sediment during the annual floods, when the river would overflow its banks. As the deltaic base continued to build, the river's hydraulic efficiency decreased, producing an upstream distributary diversion where the river had a shorter and steeper path to the receiving body of water. At this new site, a new delta would form; at the old site, the delta would slowly recede as the waves eroded the shoreline and the sediments compacted, sinking below sea level. The old delta would ultimately revert to sea water.[52] The Mississippi River has been building wetlands in Louisiana for the past seven thousand years, and has changed main channels approximately every thousand years. With each switch, the old delta's wetlands erode, but the net effect has been to push the shoreline fifty to one hundred miles south of its location of 7,000 years ago.[41]
Relative Sea Level Rise  One important point to note is that without adequate
sediment input, the deltaic lowlands even in the active delta would rapidly disappear
because of the high rate of relative sea level rise in the region, a rate approximately
equal to 1.1 cm/yr. The rise of sea level relative to land is due to two factors: eustatic
(global) sea level rise, and land subsidence. The worldwide mean eustatic sea level
rise has been estimated at 0.12 cm/yr; in the Gulf of Mexico, it is closer to 0.23
cm/yr. This rate, however, is increasing due to the so-called “greenhouse effect.”
The second component of relative sea level rise is the sinking of land. One element of
this phenomenon, subsidence, happens because the sheer weight of the accumulated
sediments produces large-scale downward geologic displacement. Other elements in-
clude localized subsidence, caused by overlying forces or subsurface withdrawal (of
mineral resources or water), and compaction and dewatering of the deposited sedi-
ments. From the numbers, it is clear that subsidence is responsible for around 90% of
the total RSLR in coastal Louisiana.[41, 54]

Living Resource Utilization  As these wetlands and estuaries evolve and disin-
tegrate, they provide habitat for a variety of species, many of commercial and/or
recreational importance. Marshes and shallow waters are considered critical nursery
habitat for many estuarine species. In fact, 98% of the commercial catch taken in
the Gulf of Mexico is composed of estuarine dependent species. Louisiana’s commer-
cial fisheries produce 20-25% (by volume) of the nation’s total catch; major species
include menhaden, seatrout, blue crab, brown and white shrimp, and the American
oyster.[52, 30] The state supports four of the nation’s top five commercial fishing
ports, compared by volume landed.[2] Recreational fishing is also significant: in 1986,
an estimated 760,000 people took 3.1 million recreational fishing trips. The impact
of these adventurers on the state’s economy is valued at over one billion dollars.[2]

Louisiana is also the national leader in fur and alligator production. Coastal
mammals like nutria, muskrat, mink, otter and raccoon are commercially harvested.
In 1980, this industry produced 2.25 million pelts worth $16.5 million, plus $.49
million in meat.4 Alligator harvesting for skins and meat, begun in 1972, grew to be
worth almost $11 million in 1988.[52]

The Louisiana coast provides wintering grounds for a huge portion of the nation’s
waterfowl on the Mississippi Flyway. It has been estimated that four million ducks
and geese – two-thirds of the flyway’s birds – utilize this region annually.[8] Sport

4The year 1980 was the peak fur production year; fur prices fell shortly thereafter. This industry
is exposed to significant market variability.
hunting of waterfowl is estimated to produce more than $37 million in revenue for the state.

**Commercial Activity** The Mississippi River Delta also supports a range of human activities not as directly dependent on the living resources of the marshes, but certainly dependent on the marshes themselves. Coastal Louisiana maintains a population of over two million persons, including the nation's oldest bilingual culture. Its location at the mouth of the Mississippi River, outletting to the relatively calm Gulf, makes it an ideal hub for distributing goods into and out of America's heartland. To accommodate the large ships of recent times, the U.S. Army Corps of Engineers has dredged and continues to maintain 2,400 miles of shallow draft and 400 miles of deep draft channels.[8] Louisiana is also particularly rich in the mineral resources our nation is so heavily dependent upon. In 1989, the state contributed 14% and 25% of the nation's total domestic production of, respectively, crude petroleum and natural gas. These energy sources were valued then at $16.6 billion.[8]

To protect these settlements and investments, federal, state and local government entities have constructed a variety of devices designed to control the destructive forces of nature, particularly the forces of flood and hurricane. The U.S. Army Corps of Engineers has been the agency responsible for most of the large projects. These devices, combined with other anthropogenic activities and natural cycles, have resulted in widespread coastal wetland loss. Through 1981, over 800 square miles of coastal wetlands have vanished. The rate of loss has been increasing geometrically since the early 1900's; the current estimated rate of loss is 55 square miles per year.[41]

### 2.2.1 The Alterations

The summary picture of freshwater flow alterations indicates two primary motivations: flood control and commerce. If the Mississippi drainage basin were viewed from afar, and compared to a photograph from two hundred years ago, it would be clear that the once sprawling river, with many tributaries and distributaries in a wide floodplain, has been confined to a few narrow channels. It would be equally clear that the delta plains in Louisiana have been fragmented by canals and levees designed to benefit navigation and petroleum exploration and production. As the focus sharpens, these alterations can be more carefully explored. Table 2.1 provides a chronological ordering of most of the major alterations to the freshwater flows of the Mississippi River System.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event/Legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1699</td>
<td>First flood control levees built</td>
</tr>
<tr>
<td>1718</td>
<td>New Orleans founded  &lt;br&gt; Mississippi River Levee System begun</td>
</tr>
<tr>
<td>1897</td>
<td>Mississippi River Commission est.</td>
</tr>
<tr>
<td>1849</td>
<td>Swamp Land Act: levees enlarged</td>
</tr>
<tr>
<td>1850's</td>
<td>Removal of log jam from Atchafalaya River</td>
</tr>
<tr>
<td>1880's</td>
<td>Bayou La Loutre, Bayou Terre Boeufs and Bayou Grand  &lt;br&gt; Cheniere closed as distributaries</td>
</tr>
<tr>
<td>1902</td>
<td>River and Harbor Act (US)</td>
</tr>
<tr>
<td>1904</td>
<td>Bayou Lafourche closed as distributary</td>
</tr>
<tr>
<td>1912</td>
<td>Bayou Manchac closed as distributary</td>
</tr>
<tr>
<td>1927</td>
<td>Severe Mississippi River flood</td>
</tr>
<tr>
<td>1928</td>
<td>Mississippi River Flood Control Act (US)</td>
</tr>
<tr>
<td>1930's</td>
<td>USACE straightened Mississippi River</td>
</tr>
<tr>
<td>1930's</td>
<td>Lower Mississippi River diking almost complete</td>
</tr>
<tr>
<td>1932</td>
<td>Atchafalaya Floodway leved</td>
</tr>
<tr>
<td>1942</td>
<td>Flow diversion into western Atchafalaya Bay</td>
</tr>
<tr>
<td>1946</td>
<td>First drilling platform in the open Gulf waters</td>
</tr>
<tr>
<td>1950's</td>
<td>Semi-impoundment for furbearer, waterfowl management begun</td>
</tr>
<tr>
<td>1954</td>
<td>Old River Control Structure auth. (River &amp; Harbor Act, US)</td>
</tr>
<tr>
<td>1962</td>
<td>Houma Navigation Canal constructed (Corps of Engineers)</td>
</tr>
<tr>
<td>1963</td>
<td>Mississippi River-Gulf Outlet constructed  &lt;br&gt; Old River Control Structure completed</td>
</tr>
<tr>
<td>1987</td>
<td>Old River Auxiliary structure constructed</td>
</tr>
</tbody>
</table>

Table 2.1: Freshwater Flow Alterations impacting the Mississippi River Delta.
The Mississippi River

The controlling of the Mississippi River has been one of the most significant undertakings in the drainage basin. It began with a straightforward and apparently simple objective: to protect human settlements from floods. When the Louisiana coast and Mississippi River plain were first settled by non-indigenous peoples, the damages floods could inflict were minimized by constructing residences and businesses on the elevated crevasses in the area. Additional protection was provided with the construction of settlement-encircling dikes, dating as far back as 1699.[21] By 1738, New Orleans was surrounded by 68 kilometers of earthen banks for flood control.[34]

Most early levees were built around individual communities by local interests. But as more people arrived, and the desire to utilize the floodplain grew, early protection measures were deemed inadequate, and the protective measures became control measures. That is, instead of banks and walls designed to keep nature out of human settlement, banks and walls were built to keep nature within specified confines. In 1917, the federal government began providing funds for flood control structures on a two-thirds federal/one-third local basis. The severe flooding of 1927 inspired Congress, now aware of the national interest in preventing Mississippi River flooding, to pass the Flood Control Act of 1928, including the Mississippi River and Tributaries Project. Implementation of this project was entirely funded by the federal government.[71]

The transition from protection to control was aided by the efforts to maintain the Mississippi as a navigable river. The importance of this river as a potential path of commerce has been long understood, but sustaining this function involved constant battles. One engineer in the 1870's proposed confining the river to increase flow velocities such that the Mississippi would scour its own bed, eliminating dredging requirements. This theory proved successful in the trial region, and has since been applied along the river's length.[71]

So instead of the Mississippi River flooding the plains as it swelled with melting snow and pelting rain, the river was restricted to a heavily leved channel, and extended to the Gulf of Mexico. Consequently, approximately 70% of the drainage from the watershed flows through a single well defined channel directly into the deeper waters of the Gulf. And as the river's waters flow, so, too, do the sediments and nutrients therein.

As the great floods of 1993 demonstrated, it was only a matter of time before the Mississippi River and its tributaries reclaimed the aptly-named floodplains.
Yet flooding continued to be considered a threat, and to further control the river, most (48 or the 54 existing in the late 1700's) major distributaries and many minor crevasses were closed.[76] So now the main branch of the Mississippi River is restricted to a single outlet, the Head of Passes, and an overflow outlet, the Bonnet-Carré Spillway. For reference, the majority of the levees and other Mississippi River control measures were constructed by the 1930's.

The Atchafalaya River

Another series of river control mechanisms are those implemented to regulate the Atchafalaya River, a distributary of the lower Mississippi River that outlets approximately 130 miles west of the main Mississippi River Delta into Atchafalaya Bay. In the early 1800's, this distributary was blocked by a 20 mile long log jam and carried little flow except in times of severe flooding. In the 1850's, this raft was removed to permit navigation on the Atchafalaya, and because of a distinct gradient advantage over the main branch of the Mississippi River, this distributary captured an increasing portion of the total flow. The banks of the upper Atchafalaya were rapidly eroded, opening the river mouth to encompass greater volumes of water; in the lower Atchafalaya, construction of a new delta began. Upriver residents and governments responded to the increase in flow by constructing fixtures to contain the river. Starting in 1932, the U.S. Army Corps of Engineers constructed levees confining the Atchafalaya to half its historic floodplain. The increase volume also threatened to flood established settlements like Morgan City on the river's lower reaches, and in 1942, a channel was constructed on the lower Atchafalaya to divert 20-30 percent of the Atchafalaya River's water through less populated lands to the western Atchafalaya Bay via Wax Lake.

Despite these efforts, the Atchafalaya River continued to capture an increasing portion of the total Mississippi River system's waters. It became apparent that this branch might eventually capture the entire flow.[73] And although such a shift would be merely the next natural deltaic switch, the threats to existing institutions and investments reliant upon the Mississippi River inspired Congress to pass the Flood Control Act of 1954, authorizing the Corps of Engineers to construct the Old River Control Structure which limits the Atchafalaya’s flow to 30% of the total. Even with these flow restrictions, the transported sediments have filled inland depressions in the Atchafalaya Basin and two new deltas, one at each outlet into Atchafalaya Bay, are forming. These formations account for the only significant wetland creation supported
by the Mississippi River today.[41]

The net effect of these Mississippi River control measures is that the river's waters are discharged at the coast via only three all-stage outlets and one high-level outlet. The all-stage outlets are the Head of Passes, south of New Orleans, and the the Atchafalaya River- and Wax Lake outlets into Atchafalaya Bay. The Bonnet-Carre Spillway outlets to Lake Pontchartrain and is utilized when flows exceed 1.25 million cubic feet per second.[73] In comparison to the unaltered state, when the river supported several major distributaries, a large number of smaller outlets, and the ability to overflow its banks during flood conditions, it is clear that the river's delta maintaining powers have been severely impaired.

Navigation

The second motivator of freshwater flow alteration is the desire for navigation and commerce. The Louisiana coast currently supports approximately 2,400 miles of shallow draft and 400 miles of deep draft channels; perhaps the biggest single navigation project is the Mississippi River-Gulf Outlet (MR-GO), a 78 mile long channel that runs from New Orleans to the Gulf of Mexico. And these channels are responsible for significant land loss: through 1981, the physical excavation, spoil disposal and erosion associated with the MR-GO alone accounted for over 24,000 acres of lost wetlands and marshes.[10]

Navigation channels have been dredged through Atchafalaya Bay as well. The first channel was created in 1910, and was enlarged in 1968 to permit the transport of offshore platforms for oil and gas production. And because this navigation route is an extension of the river path, the channel requires heavy maintenance to remove newly deposited sediments. This also impairs deltaic construction, not only because of dredging efforts, but also because channelization maintains high river flow rates, which promotes sediment transport through the delta area.[75]

Shipping channels are not the only projects, however. Numerous canals, approximately 8200 miles total, have been routed through the deltaic plain. Intensive canal construction began in the 1930's; by the 1960's, canal construction was widespread. The majority of these canals – seventy to eighty percent – have been constructed in relation to oil and gas industry activities for navigation, pipeline routing and access to drill sites.[41, 8] And not only do these canals directly remove large areas of land and alter mixing patterns, but the disposal of dredge spoils alongside the canals further impacts the local hydrology by preventing flows across the enclosed lands.
Other Alterations

Certainly the river confinement and canal construction are the two categories of alterations to freshwater flows that have wreaked the most havoc on Louisiana's coastal systems, but they are by no means a complete accounting of the anthropogenic influences. Within the Mississippi River drainage basin are numerous dams that control the runoff from approximately 58% of the watershed. These dams were built to supply water to residential, urban and agricultural users, to generate power, to control flooding.[73]

Over the length of the Mississippi River, accompanying the levees, are bank stabilization devices, which ensure the river maintains its "intended" course. These devices also reduce the sediment loads transported by the river.

Many of the human activities in coastal Louisiana are possible only because the low lying wetlands were first "reclaimed" – filled or drained. When lands were desired for habitation, elevations were increased from the low, near sea-level plane by filling. When lowlands were desired for agriculture, they were surrounded by walls and drained. Both projects require frequent maintenance because deltaic lands will subside under large structures and will rapidly erode if dried out. The key impact of locally altering land levels from the typical low elevations, either in large parcels or retaining walls, is further impairment of the hydrologic cycle. These projects prevent the surface flow of water across the land, consequently impeding sediment transport and accelerating the processes of land loss.[41]

Of course a variety of other common anthropogenic influences, such as pollutants and sewage disposal, have contributed to the decline of coastal Louisiana. These influences are not entirely separable from questions of freshwater flows, but the magnitude of the interrelated impacts is currently indeterminate. Because these problems have been well evaluated elsewhere, and because the critical symptom of coastal deterioration is attributable to sediment deprivation and canal construction alone, without major effects related to the combination of the flow alterations and pollution, these influences will not be considered further.
Chapter 3

Case Studies: Impacts

The most thorough evaluation of the impacts of these human alterations of freshwater flow will appear in the case studies. Two studies will be presented; representing two sets of manipulations and corresponding sets of repercussions. But because these studies are by no means inclusive of all the impacts, some summary discussion will prove beneficial.

The study of marine and aquatic regimes is typically subdivided into three interacting sciences – physical, geochemical and biological. It is important to recognize the interactions between these categories, for often a change in one will causally produce a change in another. For example, a decrease in the quantity of freshwater (physical) to a coastal body will allow the salty seawater to push upstream. This salinity change (geochemical) can produce a change in the variety, speciation and numbers of organisms (biological) because many creatures are sensitive to changes in salinity.¹

A second triad exists in the study of coastal issues: the triad of physical realms – land, water and air – that intersect at the coast. And like the three sciences, these three realms impact one another in a causal manner and therefore the contributions of all need be observed to fully understand the inputs to the coastal system.

Delimiting these two triads starts to indicate a critical concept in this type of study: the systems in question are incredibly large and complex. Although this study focuses on effects perceived in the coastal zone, the causes that produce these effects are spread over a huge geographic area. The topography of the basin, including the amount of protection from the sea, the slope of the uplands and the bottom topography, the region’s oceanic currents, the climate (via wind and storms) par-

¹Temperature and the availability of a number of major and trace nutrients, among other things, can similarly determine the types and distributions of resident organisms.
tially determine how well the area mixes. The geographical location determines the temperature regime which affects the types of organisms that can exist therein. Precipitation patterns established on a global scale affect foliage growth, salinity levels and other factors in the locality. The use of different chemicals in the drainage basin (or chemicals in upwind regions), the density of urban and agricultural development, the presence and size of wetland marshes, the populations of different organisms all can affect the physical, chemical and biological parameters in the coastal zone. One simple example is that actions of farmers in Minnesota at the Mississippi River headwaters may influence the population of shrimp at the mouth. By precisely how much is unknown. And quantifying this particular effect of this perturbation of the natural system would be practically impossible because of the myriad of other systemic perturbations. This hypothetical cause-and-effect illustrates that although the linkages between cause and effect can theoretically be represented, experimental verification and quantification of these impacts can be difficult to obtain. And this complexity complicates studies of the coastal region.

Bearing these interactions and complexity in mind, the following compilation of impacts should be viewed as technical information available at this period in time. The quantity of information will certainly increase, and the quality improve, as the complexity of coastal systems is more thoroughly explored and understood.

3.1 San Francisco Estuary

The beneficial uses of freshwater diversion have been noted: the economic benefit to central and southern farmers and cities, and via their prosperity, the economy of the state as a whole. However, repercussions of the redistribution of California's water have been detrimental, particularly in the Bay-Delta area from which the water is diverted, in terms of both economic and environmental resources. Figure 3-1 diagrams some of the connections that are understood, networking alterations with a range of effects induced by the reallocation of freshwater. It is important to note that scientific knowledge about the dynamics of the physical, chemical and biological systems in the region is still limited; other connections probably do exist. Complexities notwithstanding, enough is understood about estuarine dynamics to know that the diversions imposed by the Central Valley Project and the State Water Project are major contributors to the decline of the ecological health of the Bay.
Figure 3-1: Network of Impacts: San Francisco Estuary.
Living Resources

The blunt description of what this most obvious negative impact is "No Water = No Fish." The anadromous species have been particularly decimated. One anadromous species, the striped bass, is considered an "indicator species" because it is near the top of the food web, lives most of its life in the Estuary, and has been very successful historically. The abundance of this fish is therefore used as an indicator of the general health of the San Francisco Estuary. The California Department of Fish and Game measures the abundance of young stripers with a tool called the Striped Bass Index. The index reached its peak of 117.2 in 1965 and has averaged 79 since 1959. Yet from 1977-1988, the index has averaged 24.8, reaching a record low of 4.6 in 1988.[60, p.41] Fluctuations in the index are the result of many factors, such as pollution, commercial and recreational harvesting, and changes in the juveniles’ food supply, but they have been strongly statistically correlated with the quantity of freshwater inflow to the Bay. Figures 3-2 and 3-3 present the data documenting historical trends in Delta exports measured in million acre-feet\(^2\), and the Striped Bass Index\(^3\), respectively. The exports indicated here are only exports from the system made by the CVP and SWP, and do not include other small exports or in-basin usages.

Other species have been similarly impacted. From 1945 to 1988, the king salmon runs of the San Joaquin River dropped 90% and the fall salmon run on the Sacramento River and its tributaries decreased 70% to only 150,000 spawning fish.[60, p.41] And the drought of 1987-1992 accelerated this decline. winter run chinook salmon populations fell to 1 to 2% of normal, striped bass egg production is down to 2% of the values measured in the 1960’s and the sport catch of this species is down to 10% of previous levels.[57]

Floyd Anders of the National Marine Fisheries Service describes the linkages thus:

These declines [in Bay-Delta fish] are very likely the indirect result of the export of fresh water from the estuary. The exporting of water reduces Delta outflow, which has been shown to control the primary productivity and water quality in the San Francisco Bay Estuary. ... In short, reductions in Delta outflow reduce the carrying capacity of the estuary and result in lower populations."[22, pp.121-122]

But the problems for the fisheries start even further upstream than this statement indicates.

\(^2\)Source: U.S. Bureau of Reclamation.
\(^3\)Source: California Department of Fish and Game.[62]
Figure 3-2: Water Exports from the Sacramento Delta, 1950 - 1992.

Figure 3-3: Striped Bass Index, 1959 - 1988.
The decrease of instream water volume has reduced the spawning ground for anadromous fish such as salmon, steelheads and striped bass from the historical level of 6000 miles of California rivers to the current level of 300 miles. The Pacific Coast Federation of Fishermen’s Associations blames diminished flows and increased river temperatures (among other causes) for the sharp population decreases of chinook salmon in the past few years, and in 1992, these organizations forecast the potential loss of the whole salmon industry.[23] Other river-dependent fisheries, like steelhead, sturgeon, striped bass, are suffering similarly.

The declines in fish populations due to loss of spawning grounds, a problem common in many dammed river systems, has been exacerbated in a manner unique to San Francisco by the presence of the large pumps used to transport fresh water from the Delta to the southern parts of the state. These pumps entrain millions of fish eggs and larvae annually; as many as 80 million juvenile striped bass (in addition to unknown numbers of salmon, shad, catfish and other fish) pass through the fish screens in front of the federal and state pump stations each summer.[22, p.38] The magnitude of this carnage was described in 1991 by Lowe[58, p.292] thus: “Over the last 36 years, ... striped bass and salmon fry kills at pumps’ screens [totalled] three times higher than that of reported fish kills due to all causes for all 22 coastal states between 1980 – 1989.”

This problem is partially due to the reverse river flow created by the pumps during the drier seasons. Figure A-3 locates within the Delta the streamlengths that experience this phenomenon. Most such streams are located in the southern delta, in the San Joaquin Valley. These reverse flows cause fish to migrate across the delta, towards the pumps, instead of down the delta towards the Bay.[64, p.21] The increases in flow velocities created by pumping also result in decreased production of phyto- and zooplankton in certain channels, decreasing the food available for developing fish.

**Salinity Intrusions**

As the impacts of decreased flows are evaluated down the Delta into the Bay, the next noteworthy impact is the intrusion of saline water into historically freshwater areas. This converts fresh and brackish marsh into salt marsh, altering the characteristics of these wetland areas, changing the ecology of the area and displacing populations dependent on a certain salinity in their habitat. Saltwater intrusion also impacts farmlands lying in the lowlands of the Delta near the mouth of the Sacramento-San Joaquin river system outputs, by inundating the land and rendering it infertile.
Salt contamination affects hundreds of thousands of acres in the San Joaquin Valley alone.[45]

Flushing Capacity

The decreases of freshwater flow into the Bay reduces the flushing capacity of the estuary. As mentioned earlier, the South Bay is particularly dependent on freshwater flows as a flushing mechanism. A 1972 U.S. Geologic Survey study concluded that the "relation between the Sacramento discharge and flushing suggests that soluble waste materials are removed from the south Bay largely during periods of high river discharge."[22, pp.40-41]

State Mussel Watch studies⁴ indicate significant contamination by pesticides such as chlordane, DDE, and dieldrin and PCB contamination throughout the Bay. These pollutants arise primarily from agricultural runoff – the Central Valley uses 10% of the pesticides used nationwide – but urban runoff contributes, among other things, hydrocarbon contamination. The Bay's diminished flushing capacity further increases the observed concentrations.[79, p.410] Additionally, selenium levels in the estuary are elevated due to both oil refineries and the leaching of the metal from irrigated agricultural land. Selenium's effects are not completely understood, but diminished reproductive success in birds has been demonstrated.[79, p.411] These pollutants have resulted in restrictions on shellfish harvesting and consumption, warnings on consumption of Bay area ducks and fish, and noteworthy declines in fish and fowl populations.

Costs

The economic health of the Bay-Delta region has suffered accordingly. The commercial fishing industry is heavily dependent upon anadromous species, and declining populations have cost the state an estimated $2.6 billion since the 1960’s in lost sales, wages and profits.[57, p.89] Recreational fishing has also suffered because of the decreased populations. Because of saltwater intrusions, contaminated farmlands in the lower Delta areas have been removed from tillage. This is an ironic situation because these lands are better suited to farming than many of the drier lands served by the major water projects.

⁴Mussels, like other bivalves, absorb a variety of chemicals from the water that surrounds them. These chemicals concentrate in their tissues, such that examining these tissues can provide information on the current and historical abundance of a range of contaminants.[28] The State of California's Water Resources Control Board has conducted Mussel Watch studies since the late 1970's.
3.2 Mississippi River Delta

The motivating forces driving the alterations to freshwater flows in coastal Louisiana grossly belong to two categories: flood control and navigation. The state of Louisiana and the United States reap many economic rewards from these activities. Increasingly, however, both state and federal governments are realizing that economic and non-economic costs are accruing because of these activities.

The first and most acknowledged cost is the loss of land in coastal Louisiana. As mentioned before, the rate of loss has been increasing geometrically since the early 1900's; the current estimated rate of loss is 55 square miles per year. Figure A-5 indicates the geographical distribution of different rates of land loss during the thirty years from 1955 to 1978 – clearly, the rate is extremely high in certain areas. This loss is occurring because of three factors: a relative sea level rise that is not surpassed by the accretion of new soil; wave erosion; and direct land removal, for example, via canal construction.

Diminished Accretion

Historically, the Mississippi River has deposited sufficient sediments on the deltaic plain to maintain the lowlands, despite a high rate of relative sea level rise. Recall that relative sea level rise has many components, including global sea level rise, regional and localized subsidence, compaction and dewatering. Nonetheless, the Mississippi River Delta gradually built up its vast coastal wetlands, relying on three mechanisms for land accretion: direct sediment deposition during annual spring floods; deposition of resuspended sediments; and accumulation of vegetative debris.

The first mechanism, direct deposition, responsible for the bulk of the input, has been virtually eliminated by controlling the Mississippi River. Atchafalaya Bay is the only remaining site experiencing accretion and deltaic development, otherwise, the Mississippi River is so thoroughly leveed that its suspended sediments and nutrients are deposited off the Continental shelf into the deeper waters of the Gulf. And even if the Lower Mississippi River was allowed to follow its historic path and flow unrestricted, the quantity of transported sediments has been greatly reduced. The reservoirs within the watershed trap sediments as they are carried downriver, and combined with bank stabilization measures and soil-conserving agricultural practices, the Mississippi River’s sediment load has been reduced by fifty percent from historic

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5The word “navigation” encompasses not only channels designed to facilitate trading, but also the canals and levees built to assist offshore industrial activities.
levels.[73]

The resuspension of sediments from the bay floor occurs during high energy storm events. Although these sediments are inadequate to maintain elevations over a wide area, resuspended materials are currently the major contributors to wetland maintenance.[21] In many areas, however, spoil banks and other artificially elevated landforms impede water flows and prevent these sediments, too, from reaching the wetlands.

Vegetation in some areas of the Louisiana coast contributes more than fifty percent of the annually accreted materials in the form of decaying organic material. Yet the growth of vegetation is highly dependent upon the replenishment of nutrients, typically carried by flowing flood waters. Additionally, coastal wetland vegetation prospers only within a narrow elevation range; if the supporting land subsides below the lower limit, the vegetation perishes.[21] Consequently, a non-linearity exists, in that the elimination of water from the floodplain not only removes its own sediment contribution, but reduces the enduring detrital contribution by first reducing the vegetation density, then outright killing the plants.

Sediment deprivation allows relative sea level rise to reclaim coastal lowlands. Spatially, this process generally claims wetlands in stagnant inland areas removed from flowing waters. As the land becomes waterlogged and the vegetation dies, small ponds gradually evolve. As more time passes, these ponds grow and merge, becoming lakes, and eventually bays.[21] This process resembles that of natural delta decay, but it is extremely accelerated, and the losses in one area are not countered by gains in another.

Wave Erosion

Although wave-induced shoreline erosion is an expected, natural phenomenon, human alterations have exacerbated the ensuing effects. First, the aforementioned decreased sediment input has reduced the self-maintaining abilities of the coastal shoreline. Second, the construction of canals has increased the length of shoreline exposed to erosionary forces, increasing the rate of decay. These effects, however, are responsible for only a small portion, around 10%, of the total wetland losses in coastal Louisiana.

Canal-Related Losses

The third mechanism for land loss created by altering freshwater flows arises from the dredging of navigation and access canals. Direct land removal for construction
of canals is only the first canal-related cause of land loss. Frequently, the materials
taken from the canals, called dredge spoils, are left heaped along the sides of the
canals. These elevated banks impair water flow from one side to the other. And this
flow is important to supply nutrients, to prevent waterlogging, to flush poisons and to
supply sediments which maintain the area above sea level. Therefore, heavily canalled
wetland sections sustain even heavier marsh losses because the enclosed lands are cut
off from all sediment supply. Additionally, as ships traverse the canals, the wakes
can erode the banks, further widening the canals. The increased exposure to tidal
and storm erosion has been already mentioned.[41] These secondary effects are not
inconsequential. In fact, several studies have estimated that the actual canal dredging
and spoil disposal account for 16-20% of Louisiana’s wetland losses, and these indirect
canal effects produce an additional 30-45%.[21]

Salinity Intrusions

Salinity intrusions are not a first-level consequence of flow alterations, but rather
a secondary response. The controlling of the Mississippi River has eliminated many
historical sources of freshwater to various areas of the Delta. As the freshwater outflow
diminishes, saltwater flows in to replace it. Saltwater intrusions are also facilitated by
canals and channels. The access canals, especially those oriented parallel to natural
flows, allow increased inland penetration of sea water.[41]

This saline inflow results in the conversion of marshes to saltier varieties – freshwa-
ter marshes become brackish, brackish areas become salt marshes, and salt marshes
become open water. Certain types of lands, particularly cypress swamps and floating
fresh marsh, are unable to make this transition and instead convert directly to open
water.[10]

Marsh conversion reduces available nursery habitat and vegetation losses reduce
organic inputs to the food web. Both result in decreased estuarine biota populations.
Many estuarine fish and shellfish species are particularly sensitive to salinity changes.
For example, the American oyster can survive only within a narrow salinity range:
in low salinities the creature dies; in high salinities, predators are abundant. So
when freshwater flows decrease, salinity increases and the predators can move into
the oyster beds. And although oyster beds can migrate fairly efficiently, inland shifts
bring the organisms closer to pollution sources, creating a potential public health
hazard.[10]

Additionally, certain species of waterfowl, some varieties of mammals and alliga-
tors are all more prosperous in fresher marsh habitats. So as marshes are converted to more saline varieties, or open water, these populations are correspondingly impaired.

Cost of Land Loss

Now that some of the mechanisms for wetland loss are understood, it is important to evaluate why this loss is of interest. First, there are several economic considerations. Certainly the region’s landowners would be negatively impacted if their land were to become water and their investments inundated. Because wetlands serve as a buffer from severe storms and floods, there is an increased risk for coastal parishes and potentially the city of New Orleans for storm-related wind and flood damages. The rate of shoreline erosion along some segments of the Louisiana coast is so high that established structures, including government-financed infrastructure, is in danger of being claimed by the sea.[41] Figure A-6 locates the anticipated coastline for the year 2040 in relation to the 1990 coastline, given continuation of the current rate of loss.

Regarding living resources, studies have shown that estuarine fishery production is causally linked to marsh acreage; one study demonstrated that “inshore shrimp catch is directly proportional to the area of intertidal vegetation.”[30] Furbearing mammals and alligators are more densely abundant in fresh or intermediate marsh than in brackish or saline areas.[30] These population declines have not yet been observed, possibly because wetland deterioration affords better protection and more food for juveniles, inducing a momentary population upswing that will be followed by a longer-term decline.[52] Thus it is fully anticipated that increased wetland losses, or decreased habitat, will diminish the numbers of the region’s living resources—by as much as 30 percent in the next 50 years.[40] Clearly, decreased revenues from both commercial and recreational fishing, hunting and trapping will ensue. Linked industries, such as restaurants and poultry interests (dependent on Louisiana’s huge menhaden catch) would also suffer. Furthermore, increased salinity intrusions could threaten the region’s water supplies.

3.3 Class II Alterations

The second class of alterations encompasses projects such as paving or deforestation, projects not specifically intended to alter freshwater flows. In Chapter 1 some of

6Rather ironic that projects designed to protect from river flooding increase the risk of damage from tidal flooding.
the hydrologic effects of these projects were discussed. For most of the alterations, these impacts included an increase in peak flow, both in quantity and in rate, a corresponding decrease in off-peak flow, and an increase in total flow due to the reduction in time lag between precipitation and runoff.[7]

From discussion earlier in this Chapter, ensuing effects on chemical and biological resources can be roughly predicted. The range of salinities at any particular estuarine location will increase due to the increased peak flow which will reduce peak season salinity, and decreased off peak flow with an accompanying increase in salinity. This would put additional stress on salinity-sensitive organisms. Sessile creatures, such as oysters, may be especially at risk, although depending on the season and the species, the change in salinities could produce either positive or negative results. In other words, the direction and magnitude of biological responses to these perturbations is largely unknown. This is partly because these impacts are gradually implemented, allowing the systems time to adapt, and partly because these alterations of freshwater flows are within natural variability ranges, or 20 to 30 percent of the average.[12]

Perhaps better recognized are the changes to nutrient, sediment and contaminant loads produced by these categories of alterations. These changes vary according to the specific alteration. For example, clearcutting a forest for agriculture can increase sediment loads, because the organic debris that slows the water flow and traps the soil is removed. On that same land, using fertilizers and pesticides can increase nutrient and contaminant loads in the receiving water body.[12] In some ways, it would appear that these land use changes are doubly problematic: altering the landscape increases the immediate rate of runoff, which means improved transport and decreased filtering of the various contaminants produced by the new uses.

Excess nutrients and toxins in coastal waters produce a variety of chemical and biological results: altered plankton populations, algal blooms, eutrophication, reduced reproductive success, shellfish contamination, deformities. And these directly impact human economic systems in terms of potential health hazards, reduced fishing and shellfishing success, and reduced aesthetic appeal, with ensuing decreased recreational value.

These repercussions are only representative examples; currently, scientific information documenting the magnitude of impact produced by these smaller flow alterations is scarce. Scientific progress is also impeded by the interrelations between the water itself and the items it transports. But the impacts of indirect freshwater flow modifications, particularly as they exacerbate chemical and toxin problems, can be significant.
Chapter 4

Preliminary Analysis

The discussion of the impacts caused in the coastal zone by alterations of freshwater flows clearly indicates that some systemic failure has occurred. To explore why this failure has occurred, we first need to examine the underlying assumptions that allowed the various projects and alterations to be produced. From there, we can address why this question, that of freshwater inflow, has been largely ignored in coastal zone management efforts. Finally we will take the case studies, situations where this concern is being addressed and explore what factors drove it into the public forum, what factors resisted this drive, how the problem has been approached, the strategies and management tools that have been applied and the successes and failures of the various efforts.

To evaluate these efforts in a manner relevant to this capital market society, assessments of pertinent costs will be made. Pertinent costs include the costs directly related to the flow diversions (as discussed in Chapter 3), otherwise known as the costs of the problem, but more critical are the costs of implementing various proposed solutions, particularly as compared to the predicted costs of not implementing these solutions. And although it is difficult to accurately predict long-term, long-range impacts, attempts will be made to include the indirect costs of both options.

As mentioned in the previous chapter, there are two classes of human influences to freshwater flows: major projects such as dams or levees directly intended to alter the flow for purposes of navigation, commerce, flood control, water supply or power production; and minor projects such as paving, irrigation and deforestation that alter freshwater flow on a smaller scale, often as an unintended consequence. The second class of freshwater alterations represents in many ways a typical tragedy of the commons. [33] For example, many farmers along a river each draw some of the water for irrigation. No single farmer's share is great, but cumulatively the change is significant.
In the first class, huge projects are designed with the express purpose of affecting huge changes of the hydrologic cycle. A number of assumptions underlie both classes of projects, some are relevant only to one or the other. Exploring these assumptions, and evaluating their shortcomings, will provide a framework for understanding some of the managerial difficulties linked to this particular socio-technical problem.

4.1 Assumptions: Valuation of Freshwater

The primary assumption motivating construction of both classes of alterations is that freshwater has no value outside its value when directly used by humans. This includes positive value, when used for drinking water or irrigation, and negative value, when causing floods. Consequently, water must be controlled to maximize positive and minimize negative value. The impacts discussed in Chapter 3 indicate this in not true, that even in traditional economic terms, freshwater flow through riverbeds into the coast has significant value. Market economics ascribe value to items such as renewable resources, like fisheries or fowl, taken in commercial or recreational enterprises, or the storm protection provided by wetlands. Additionally there are non-market values, for example aesthetic and existence values. These values are created when people derive satisfaction or other positive values from the systems, be it indirectly (by private contemplation) or directly (by physical interaction). Value can also be created when people believe that unimpaired natural systems are important and should be sustained. It is not possible to assess a price for these values in the traditional economic sense – such values cannot be contained, purchased and/or sold.

The combination of marketable commodities and non-market values that are produced by functioning natural systems makes calculating the net worth of unaltered freshwater flows unrealistic. Frankly, even attempting to commoditize an ecosystem removes value, because market economics are fundamentally not capable of assessing a system's worth. But considering only commoditizable values produced by natural systems, such as commercial fisheries production, these values do not appear in economic project evaluations because the impact is neither precisely nor immediately ascertainable.

A corollary to the direct-to-humans-value assumption is that uncontaminated freshwater flowing into the ocean is freshwater wasted.\(^1\) This assumption was origi-

\(^1\)“Uncontaminated” because the use of freshwater as a diluting and transporting medium for unwanted toxins, sewage, effluent or garbage is a positive value use.
nally grounded in the lack of scientific understanding of the role of freshwater flows play in aquatic, deltaic and coastal environments. When the detrimental effects of freshwater flow alterations were initially suspected, the underlying reasoning shifted from ignorance of any instream benefits to an undervaluation of those now-acknowledged benefits. *This type of misvaluation of natural resources is common to all situations of environmental deterioration.* Accurate accounting of a natural system's worth is impossible because the many uses are interrelated, interdependent and therefore synergistic value, in addition to the aforementioned unquantifiable amenity value.

Another assumption relevant to both large and small projects centers around the question of time. This assumption can be stated thus: short-term, identifiable and quantifiable benefits have greater value than any potential long-term, unspecified and uncertain cost. Certainly this statement is related to the aforementioned misvaluation of natural resources, but the overvaluation of short term benefits, at the expense of future consumers, also draws from current economic and business ideas which emphasize immediate returns and quarterly profits over long-term, sustainable success. A traditional economic analysis of this scenario, accepting that this valuation is inaccurate, would indicate that either the discount rate is too high or the cost of externalities is not assessed those who derive benefits from the projects.

A further assumption is that the freshwater supply is inexhaustible. Of course desert residents do not believe this fallacy, but this belief is common in rain-sated areas. This country's tangled system of water rights, devised when the country's small population provided in practice validation of this assumption, is a testament to the invalidity of this belief, in theory, as applied across situations.

## 4.2 The Persisting Problem

When the evidence of detriment is so well documented, and the faulty reasoning underlying the alteration of freshwater flows is exposed, it would seem to logically follow that appropriate solutions to this problem would be devised. This, however, has not happened in the majority of cases.

This failure can be attributed to several factors: the scopes in time and space are large – larger often than coastal resource manager's jurisdiction; appropriate persons\textsuperscript{2} have not been harmed yet; and strong political forces are often vehemently opposed to solving this problem.

\textsuperscript{2}“Appropriate” will be presently defined.
4.2.1 Time and Space

This complexity of watersheds has been discussed; perhaps this complexity itself can be identified as one of the complicating reasons behind much of the ecological deterioration human alterations have wrought. By this, I mean that the extreme difficulty in proving causality, given a multitude of linkages, interactions and both natural and anthropogenic influences, becomes a serious impediment to implementing any restrictive measures designed to mitigate a particular effect. Without strong technical evidence of causality, it becomes difficult to take any legislative or administrative action. In these situations, the fear of legal action and/or voter retribution becomes a motivating factor.

Furthermore, natural systems are dynamic. Physical influences vary from year to year, extraordinary events may occur, biological populations change in abundance. Natural events can render a species extinct, or introduce exotic creatures. So at any two moments in time, natural systems will never be exactly the same. Certainly this complicates efforts to determine cause-and-effect relationships. And this also complicates management initiatives because such efforts often set specific, static goals, that are not necessarily in accord with historical natural variability.

Nonetheless, technical evidence documenting a cause-effect relationship has been the basis for some coastal management actions. For example, the link between the effects of certain health risks or aesthetic unpleasantries, and the causes of riverine disposal of untreated sewage and/or industrial effluent, is quite well supported. However, when contemplating the issue of freshwater inflow to coastal areas, it is often difficult to tie an effect people consider meaningful to any given alteration. The first impacts caused by the projects may be subtle. As the case studies have documented, it often takes many years for even some effects of the alterations to be clearly identified and linked to the alterations themselves.

The second complicating dimension is that of space. This dimension must be considered because effects of any given action may be felt far from the originating site. The aforementioned case of aerial fallout provides a good example. Often the impacting party does not foresee the downstream result; often the impacted region cannot readily identify the problem source. Particularly with the second class of alteration, this spatial shortsightedness is another tragedy of the commons. When farmers irrigate with stream water, the outgoing water may be contaminated with pesticides and metal leachates, and may be several degrees warmer than the stream. Each farmer irrigating may not believe her/his individual actions will cause serious
damage, which could be true if only one person took these actions, but the combined effects of one thousand farmers will be far more serious.

The second complicating aspect of space is the impairment caused coastal managers when natural system boundaries do not align themselves with political system boundaries. The Mississippi River study illustrates this well: coastal resources in Louisiana are impacted by changes wrought throughout the drainage basin – when a farmer in North Dakota uses pesticides on his/her crops, some of that chemical, or some chemical residue, ultimately outlets in Louisiana. Consequently, this coastal state has problems because it is the repository for many pollutants from a huge land area, and because dams and levees throughout that area reduce the riverine water and transported sediments. This makes managing the coastal zone difficult because state (and even many federal) managerial entities are not authorized to regulate far-away, out-of-state activities. On a smaller scale, concerned cities or towns have similar difficulties conserving local coastal resources that are impacted by extra-boundary forces.

4.2.2 Affected Constituents

The second reason that the problems caused by freshwater flow alterations are not appropriately addressed in the political forums empowered to devise solutions is that the appropriate people are not detrimentally impacted. As with most situations, creating meaningful, active attention in a political forum requires the situation to affect, be it economically or metaphysically, one of three categories of persons[37] These categories, with pertinent examples from various coastal management problems, are:

- **One or a few very important people, where importance is in terms of money, power or prestige.** For example, wealthy homeowners near Santa Barbara who found oil on their beaches.

- **A large number of people.** For example, the thousands displaced by Hurricane Andrew.

- **A small number of people, severely impacted.** For example, the hundreds of residents of Minamata Bay whose consumption of mercury-tainted fish and shellfish caused a disfiguring and often fatal disease.[50]

Environmental problems in this country have seen the evolution of a fourth category, the lovable critter, that can inspire one of the first two classes to action. For
reasons presumably related to social psychology, aquatic and marine organisms, with the exception of marine mammals, have not succeeded in generating this effect.

It is important to recognize that the influencing parties need not personally sustain direct economic loss. Coastal management efforts in California have been driven in this manner:

In California, passage of the Coastal Zone Initiative, and of similar protective legislation, represented not as much a triumph of theoretical construct, or of analytical procedure, as a reorienting of metaphysical (value) base. Neither science nor scientists were the moving force. People supported the Initiative ... primarily because 'things had gone too far.'[47]

4.2.3 Forces of Opposition

There are few complexities behind this obstacle to mitigating the detriments caused by freshwater flow alterations: many powerful persons and groups derive significant benefit from these alterations. Referring back to Table 1.1 illustrates the benefactors: water consumers, primarily agriculture, industry and domestic users; electricity consumers, primarily industry and domestic users; shipping interests. Without adequate supplies of freshwater, none of these (except shipping) activities are possible. Without these activities, based at their current locations, the successes of the local, state and national economies are, to varying degrees, impaired.

Clearly, most humans derive benefits, directly or indirectly, from freshwater flow alterations. But the amount of opposition any single human would be inclined to produce is related to the directness and necessity of that personal benefit. It is also related to that individual's perception of the "big picture," or the potential alternate benefits any given quantity of water could produce. For example, the amount of opposition citizen X would present would be different if all X's drinking water were to be taken for any use than if half X's lawn water (or other lower-value water use) were to be taken for some use X perceived as high-value. Thus the magnitude of perceived value trade-offs can shift beneficiaries - generally anyone - from opponent to proponent.

4.3 Application to Cases

The preceding discussion outlines the tools to be used in evaluating the management initiatives implemented in the two case studies. One point that will become clear is
that the valuation of natural resources is dependent on the observer. This is only logical, for the worth of any object is established for an individual, by the individual. Price, a single number assigned an object, is determined by supply and demand, or an aggregation of individual’s perception of worth. Because natural resources are not saleable commodities requiring a price, no pooling of perceptions has been done.

In both case studies, this has created conflicts between those observers who perceive the losses caused by freshwater diversion as exceeding the benefits and those observers who assign less value to the damaged resources. In some instances, these conflicts arise between different levels of government. This is particularly problematic, because it can create barriers to efficiently developing comprehensive plans intended to mitigate the damages.

As the managerial aspects of the case studies are presented, the framework developed in this chapter will be applied to evaluate the operational mechanisms impeding and/or facilitating reform in each of the two systems.
Chapter 5

Case Studies: Remedies

The intention here is to detail the efforts undertaken to address the coastal problems that have arisen because of anthropogenic alterations of freshwater inflows. Attention will be focused on the circumstances under which the problems were brought to the table, the players for and against the proposed mitigative/restorative measures and the cost of the solutions, particularly as compared to the (estimated) future cost of the status quo.

5.1 San Francisco Estuary

The construction and operation of California’s water storage and diversion projects have always encountered some opposition; over the last twenty years these forces have gathered enough strength to start affecting change. This process is not the direct outcome of any single catastrophic event, but rather is largely the product of an evolved awareness of the detriments caused by freshwater diversion. This increase in awareness is directly linked to the increase in detriment; for this, too, has been a gradually evolving process.

One enduring catastrophe, however, has accelerated this process. California’s six year drought accelerated the rate at which detrimental effects became apparent, and highlighted some of the shortcomings of State water policy. These effects increased public awareness and public interest and accelerated managerial responses. Therefore, the consequences of the drought will be analyzed as a separate section.

The discussion that follows has been divided by topic to facilitate understanding of the different strategies utilized by the different players. A chronological listing of selected critical events is provided in Table 5.1.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>1930’s</td>
<td>CVP planned and constructed</td>
</tr>
<tr>
<td>1944</td>
<td>CVP began operations</td>
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<tr>
<td>1960</td>
<td>Burns-Porter Act approved, funding SWP</td>
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<tr>
<td>1968</td>
<td>SWP began operations</td>
</tr>
<tr>
<td>1976</td>
<td>Bay-Delta Hearings began</td>
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<tr>
<td>1978</td>
<td>SWRCB set water quality standards</td>
</tr>
<tr>
<td>1987</td>
<td>Six year drought began</td>
</tr>
<tr>
<td></td>
<td>National Estuary Project began work</td>
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<tr>
<td>1988</td>
<td>SWRCB issued revised standards – report derailed</td>
</tr>
<tr>
<td>1989</td>
<td>Northern cities began water rationing</td>
</tr>
<tr>
<td>1991</td>
<td>Southern cities began water rationing</td>
</tr>
<tr>
<td></td>
<td>Agricultural deliveries reduced</td>
</tr>
<tr>
<td>April</td>
<td>SWRCB set interim (18 month) standards</td>
</tr>
<tr>
<td>Sept</td>
<td>FWS began process to list delta smelt as threatened</td>
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<tr>
<td></td>
<td>Delta salinity standards violated 111 days</td>
</tr>
<tr>
<td>1992</td>
<td>USBOR withheld water from 1 million acres</td>
</tr>
<tr>
<td>Feb</td>
<td>Cities called for water reform</td>
</tr>
<tr>
<td>June</td>
<td>Draft CCMP released by Estuary Project</td>
</tr>
<tr>
<td>Aug</td>
<td>EPA pressured SWRCB for new quality standards</td>
</tr>
<tr>
<td>Aug</td>
<td>CVP Improvement Act signed into law</td>
</tr>
<tr>
<td>Oct</td>
<td>Petition filed to list longfin smelt and spittail</td>
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<tr>
<td>Dec</td>
<td>SWRCB released five year standards</td>
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<tr>
<td></td>
<td>Delta salinity standards violated 71 days</td>
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<tr>
<td>1993</td>
<td>Southern CA water officials called for environmental reforms</td>
</tr>
<tr>
<td>Jan</td>
<td>Delta smelt listed as threatened</td>
</tr>
<tr>
<td>March</td>
<td>SWRCB released revised standards</td>
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<tr>
<td>March</td>
<td>Final CCMP released by SFEP</td>
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<tr>
<td>April</td>
<td>USBOR ‘93 deliveries: more than ‘92, less then pre-drought</td>
</tr>
<tr>
<td>April</td>
<td>EPA sued to provide adequate standards</td>
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<tr>
<td>June</td>
<td>USBOR reduced summer pumping to protect fish</td>
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<tr>
<td>June</td>
<td>SWRCB imposed no penalties for ‘91, ‘92 quality violations</td>
</tr>
<tr>
<td>July</td>
<td>Pacific Institute: Fish/wildlife may never recover from drought</td>
</tr>
<tr>
<td>July</td>
<td>DWR proposed bypassing Endangered Species Act</td>
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<tr>
<td>Sept</td>
<td>EPA settled lawsuit; agreed to produce protection plan</td>
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<tr>
<td>Nov</td>
<td>CA governor approved CCMP</td>
</tr>
<tr>
<td>Dec</td>
<td>EPA approved CCMP</td>
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<tr>
<td>Dec</td>
<td>EPA, FWS, NMFS, USBOR released draft protection plan</td>
</tr>
<tr>
<td>1994</td>
<td>EPA’s water standards approved</td>
</tr>
<tr>
<td>April</td>
<td>Implementation of CVP Improvement Act enjoined</td>
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Table 5.1: Chronology of Management Initiatives: San Francisco Estuary.
5.1.1 Driving Force: The Drought

The recent drought of 1987 – 1992 can be regarded as a catalyst in the movement for change. While annual rainfall is naturally variable, and droughts naturally occur, California’s water management practices during this drought exacerbated the detrimental effects. The decreased water input to the system, when combined with the water export of various projects magnified the ecological deterioration beyond the amounts that either event individually would affect. In fact, due to the nonlinear character of natural systems, the harm done by these two perturbations simultaneously even exceeded the “summed harm,” or the harm of each added together. To clarify, the effects of removing $N$ percent of any component necessary for system survival differ according to whether it is the first or the last $N$ percent to be removed. And consequently, when $N$ percent has been removed, the additional taking of $M$ percent, pushes the system closer to the failure point than if $M$ were removed from an unimpaired system.

When drought struck in 1987, most people believed it would last only a year. When it continued in 1988, most believed it would last only through that year. During both these years, water deliveries proceeded according to schedule. In 1989, when shortages continued, some Bay Area water districts, for example those serving San Francisco and Marin County, began rationing water. For several months, the districts required their customers to reduce usage by up to 45 percent. But 1989 saw no reductions in deliveries to customers served by either the Central Valley Project (CVP) or the State Water Project (SWP). The 1990 situation was similar: Northern California cities experienced limited rationing, but all other users were unimpaired. In fact, the SWP’s deliveries actually exceeded contractual requirements during these first four drought years.

This “the-drought-will-end-soon” philosophy was practiced until 1991 by the operators of the CVP and the SWP, the United States Bureau of Reclamation (USBOR) and the California Department of Water Resources (DWR), respectively. This was the first year deliveries to agriculture and southern California residents were reduced. This was also the first year conservation measures were mandated for the 15 million people served by the Metropolitan Water District (MWD). Urban users responded to these measures with significant water savings: statewide, despite population increases, total urban household water use fell by 20 percent from 1986 levels.[63]

But these cuts were too little, too late. The flow reductions caused by the drought combined with the high export rate of what water remained in the Sacramento/San
Joaquin watershed (mostly stored in reservoirs) meant little water existed to maintain the various aquatic and estuarine ecosystems. The flow reductions resulted in violations of Delta salinity standards on 111 days in 1991 and 71 days in 1992.[5] Other consequences of the drought water management were observed in dramatic population declines of certain representative species. For example, the Striped Bass Index posted the lowest tallies ever from 1988 – 1991. The population of the Delta smelt, a small fish found only in the Bay-Delta, declined by 90 percent from historic levels. Observers of the winter run of chinook salmon in the Sacramento River counted only 191 fish in 1992, down from the 118,000 fish counted in 1969.[63] The fishing industry has, of course, followed the fish in this collapse: 1992 was the worst year ever for California fishers. According to one fisher, the industry was poised “on the brink of failure.”[5]

Despite the environmental disasters and the water rationing in the cities, agriculture was fairly unimpaired by the drought. Cash receipts rose steadily from 1986 (the last wet year) through 1990. In 1990, California’s agricultural revenues attained a record high of $19.8 billion. The decrease in 1991 revenues to $18.5 billion was, according to the Bank of America, largely due to reduced prices and a freeze. During the drought, there was only a slight – four percent – decrease in agricultural acreage.[5]

The disparity between the failing environment and its dependent fishing industry and the successful California agri-business caught many people’s attention. The fact that agriculture had prospered on government subsidized water at the same time the Estuary’s ecology was severely threatened and most people were required to reduce their personal consumption created in many a feeling that a great injustice was occurring. These people believed that the common property of water was not being distributed in a fair manner. And although few would deny agriculture’s importance to California, many people, both in the North and South, saw the need to reevaluate previous decisions that encouraged any agricultural growth at the understood expense of the Estuary and the now-apparent expense of urban interests.

This awareness founded movement to reevaluate California’s water redistribution system, a movement largely driven by the populus. For although there are numerous local, state and federal agencies empowered and directed to govern aspects of the system and the region, the momentum for change has increased as citizens throughout the State have analyzed the freshwater allocation situation – politically, environmentally and economically – and realized that this system, in its current (and planned future) form is not functioning safely or effectively. But these concerned citizens
are not empowered to change the situation; their strength is through the influence they can exert on the relevant empowered bodies. These agencies have answered the growing concerns about the economic and ecological damages with varying degrees of effectiveness.

5.1.2 Management Efforts: Water Quality Standards

The State Water Resources Control Board (SWRCB) is the agency most responsible for monitoring and managing California's water. The State Constitution provides that all water within California is the property of the people, but allows individuals to acquire an exclusive right to use a specified quantity of water. The SWRCB utilizes a permit process to allocate these rights, which are granted under the condition that the water be put to a reasonable and beneficial use. The Board retains authority to alter the permits that convey the water rights in order to prevent unreasonable uses.[61, p.85]

The Board is also responsible for establishing water quality objectives in California, and proposed the first objectives for the Delta in 1965. Establishing salinity standards at certain locations in the Delta is equivalent to defining target freshwater inflow quantities. These standards were originally intended to protect the quality of water destined for human consumption or agriculture. The standards could also be used to ensure that estuarine mixing processes continue, or to ensure the existence of suitable freshwater and/or brackish habitat. The objectives set by the Board are subject to review by the United States Environmental Protection Agency (EPA) as authorized by the Clean Water Act of 1972. If the state standards are deemed inadequate, the EPA can impose its own standards, but the agency generally prefers to defer to the State Board.[64]

In 1976, the Board conducted evidentiary hearings to collect data for use in formulating a water quality control plan for the Sacramento-San Joaquin Delta and Suisun Marsh and determining whether U.S. or State water rights permits should be amended to implement the plan. In 1978, the SWRCB approved a Water Quality Control Plan and accordingly modified the CVP and SWP water rights. These regulations were met by a series of lawsuits, and the state courts ultimately rejected the proposal as an inadequate attempt to protect the deteriorating Bay-Delta ecosystem. Furthermore, the EPA declared the provisions deficient at reviving the Bay-Delta ecology and instructed the board to develop more stringent measures.[66]

After years of deliberation, and under orders from the U.S. Court of Appeals, the
Board put forth a 1988 draft report recommending some reductions of water exports in order to improve the quality of the Bay-Delta ecosystems. The Metropolitan Water District (MWD), the distributor for urban consumers in the Los Angeles-San Diego metropolitan region, responded with a combination of economic and political scare tactics, and the report was derailed.[31, p.25]

For the next few years, the State Water Resources Control Board continued to hold hearings and deliberate on the issue. In January 1991, the Board released a draft water quality plan, which the EPA again declared inadequate. A revised (although still inadequate) plan was adopted in May 1991, setting interim standards for the next 18 months. And although this plan made only a weak attempt to protect wildlife via salinity standards, these standards were violated numerous times because of drought-time overpumping.

In 1992, with the drought’s impacts becoming increasingly severe, environmental organizations and fishing interests renewed pressure on the EPA for water quality standards that would provide adequate freshwater inflow to the Estuary. The EPA, in turn, renewed pressure on the SWRCB by threatening to impose their own water quality standards and flow regulations.[55] Finally, in December 1992, the Board released another “interim plan” to govern water distributions for the next three to five years. This state plan included the following provisions:

- The CVP and the SWP are to shift diversions to times when fish are not likely to be sucked into pumps. This would reduce exports by up to 800,000 acre-feet per year.¹

- Upstream water agencies are to release “pulse flows” to help migrating salmon toward the ocean.

- The Board will charge water recipients fees of $5-10 per acre-foot to generate funds for monitoring and improving environmental conditions.

- Mandatory conservation measures are to be imposed in urban areas using Delta water.

- CVP growers in poorly drained areas are prohibited from using extra water to wash salts from crops.

¹This amounts to approximately three percent of the average year total runoff; or eight percent of the 1985 diversions for both projects.
But this proposal was rejected by conservationists and agricultural interests alike. The Save San Francisco Bay Association called the proposal a huge step backwards from the 1988 proposal. And southern growers and urban water distributors (such as the MWD) forecast certain economic calamity if the measures were to be enacted. The EPA deemed the plan too weak to attain the objective of fish populations equivalent to those of the late 1960’s/early 1970’s.[26] The Board returned to their hearings and deliberations, but in April 1993, Governor Wilson ordered the Board to stop deliberations, claiming federal intervention made further state efforts moot. On this same day, a coalition of environmental and fishing groups filed suit against the EPA, demanding the organization establish adequate standards.

This suit was settled in September 1993, when EPA agreed to produce new standards within three months. Accordingly, in December 1993, the EPA, in cooperation with the Fish and Wildlife Service, the Bureau of Reclamation (USBOR) and the National Marine Fisheries Service (NMFS), released a draft plan that would dedicate up to 1.1 million acre feet annually to environmental protection and restoration. Predictably, state water officials, Governor Wilson, and agri-business have publicly opposed the measures, foretelling countless lost jobs and dollars. Urban interests expressed concern about potential water decreases, but were optimistic at the federal government’s commitment to reduce economic detriment.[56] This draft was approved in April 1994, and the EPA promises implementation by December 1994.

To summarize, the SWRCB has been notoriously slow in establishing water standards that will assure environmental quality. This inaction is largely attributable to the political pressures imposed by State officials, the powerful agricultural lobby and, until recently, the powerful urban water districts. But California’s drought water management policies have shifted the balance of power, drawing the federal government into a more active role. Therefore the past few years have seen the Environmental Protection Agency abandon the non-intervention policy that dominated its relationship with the state through the 1970’s and early 1980’s in order to fulfill its duties as specified by the Clean Water Act and the Endangered Species Act.

The water shortage made it clear that the state water authorities were concerned exclusively with meeting the requirements of first agriculture and secondly cities, and would quite readily allow the San Francisco Estuary ecosystem to collapse. That cities were of secondary consequence in the eyes of the distributors lead many urban water districts to abandon their historical agricultural allies and use their political clout towards water reform. The severity of the environmental deterioration inspired more citizens to take an active role in pursuing reform. With this increase in pub-
lic pressure for federal intervention, the EPA and other federal organizations have increased their involvement. This is not to say that the problem has been solved — water conflicts in California are far from over — but now the fishing and environmental interests, and their new urban allies, have support at this level of government at least. There are three federal policies/programs (besides the EPA's new involvement in the water quality standards) that demonstrate the changing tide: the use of the Endangered Species Act; the National Estuary Program; and the Central Valley Project Improvement Act.

5.1.3 Management Efforts: Endangered Species Act

The Endangered Species Act (ESA) can be considered a management tool because listing a species as threatened or endangered engenders responsibility in the organism's home state(s) to protect the species by, among other things, assuring the integrity of its habitat. The Act's power lies in this habitat protection requirement; the Act thereby protects entire ecosystems linked with the named species. This tool has been applied to the San Francisco Estuary to assure adequate streamflow and pumping precautions consequently protecting both the listed species and also other organisms dependent upon freshwater flows.

The use of this tool also has strong ties to the drought — it was during these periods of extremely low streamflows and high pumping volumes that various fish species were decimated. The first species to attract attention was the delta smelt. The population of this creature, a small fish found only in the Bay-Delta, declined by more than 90 percent from historic levels with the drought conditions. So in September 1991, under pressure from conservationists and fishing organizations, the U.S. Fish and Wildlife Service (FWS) began the formal process to list the delta smelt as a threatened species under the federal Endangered Species Act. State water officials protested this decision, claiming the listing would severely reduce the supply of water available to cities and agriculture. Conservationists, too, protested the decision, claiming that FWS had succumbed to political pressures and should be listing the smelt as endangered (which would require more stringent preservation efforts). The species was listed as threatened in March 1993.

September 1992 saw a coalition of nine fishing and conservation groups petitioning the U.S. District Court to reallocate water for the preservation of riverine fish species, claiming the severe decline of the threatened winter-run chinook salmon caused by freshwater flow alterations — specifically, decreased volume and higher temperatures —
was a violation of the Endangered Species Act.[23] In November 1992, the same group petitioned to add the longfin smelt and the Sacramento spottail to the endangered species list, and urged that the entire estuary be declared endangered.[24] As part of the multi-agency plan released in December 1993, the FWS proposed to designate the Sacramento spottail as threatened, and to change the status of the winter-run chinook salmon from threatened to endangered.[56]

Unfortunately, the efficacy of the Endangered Species Act at providing real protection to the listed species is not by any means assured. The California Governor and some State water agencies, specifically the Department of Water Resources (DWR), have been working to circumvent the Act’s requirements since the time the smelt’s listing was first proposed. First, the State Fish and Game Commission bowed to political pressures in early 1993 and refused to list the smelt under the state’s ESA. Then, when federal authorities declared that pumping during the summer of 1993 should be reduced by twenty percent to protect the fish, the DWR responded with a proposal to bypass the requirements using loopholes in the ESA. And the prospect of drought in 1994 inspired several environmental organizations to file suit against the FWS to ensure continued freshwater flows adequate to protect the smelt. Clearly, the battles here are along the same lines as in the water quality debate, with the drought increasing public pressure on the federal government to intervene when the state government’s inaction persists.

5.1.4 Management Efforts: National Estuary Program

The process of implementing change for the environment was bolstered when the San Francisco Bay/Sacramento-San Joaquin River Delta was accepted as a participant in the EPA’s National Estuary Program in 1987. This program was initiated to produce a consensus-based management strategy, or Comprehensive Conservation and Management Plan (CCMP or Plan), for the Estuary. As authorized under the Clean Water Act, the Plan was required to “recommend priority corrective actions and compliance schedules addressing point and nonpoint sources of pollution to restore and maintain the chemical, physical and biological integrity of the estuary, including restoration and maintenance of water quality, a balanced indigenous population of shellfish, fish and wildlife, and recreational activities in the estuary and assure that the designated uses of the estuary are protected.”

Producing the CCMP was a five year process, involving a diverse group of more

\(^2\)Clean Water Act, Section 320.
than one hundred stakeholders from federal, state and local government agencies, environmental groups, various industries, and agriculture. Federal funds were provided to collect and synthesize existing scientific data on seven issues identified as critical to the San Francisco Estuary's health. These issues were Aquatic Resources, Wildlife, Wetlands, Water Use, Pollution Prevention and Reduction, Dredging and Waterway Modification, and Land Use. Of these issues, water use, land use and waterway modification directly impact freshwater inflow; aquatic resources, wetlands and pollution are directly impacted by freshwater inflow.

In August 1992, the Estuary Project issued a draft plan containing a range of action items intended to reverse the estuary's decline.[25] The final CCMP was released in March 1993 and contained over 150 action items, the implementation of which was forecast to cost almost $1.6 billion. Governor Wilson approved the CCMP in November 1993; the EPA approved it the following month.

The following is a list of some of the measures that directly address the issue of freshwater inflow to the Estuary:

- **Action AR-1.1** Refine and coordinate existing monitoring programs to: (i) better evaluate ecosystem responses to immediate, phased, and long-term water quality and flow standards.

- **Action AR-4.1** Adopt water quality and flow standards and operational requirements designed to halt and reverse the decline of indigenous and desirable non-indigenous estuarine biota.

- **Action AR-5.1** Based on information developed in Action AR-1.1, identify alternative long-term water quality and flow standards, water management measures, operational changes, habitat improvements, and facilities as needed to manage the estuarine aquatic resources (including water) for optimum benefit.

- **Action AR-6.1** Provide necessary instream flows and temperatures to benefit salmon and steelhead in the Central Valley to support the implementation of the state and federal mandates to double the natural production of anadromous fishes.

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3There are measures that are more indirect, and measures that address the California-specific problem of pump-induced damages to fisheries. For example, several Aquatic Resources action items include hard fixes, such as improved fish screens, to mitigate the entrainment of fish eggs and juveniles in the pumps. Some action items in the Land Use and Pollutant sections indirectly address freshwater flows.
• **Action AR-6.2** Implement the Upper Sacramento River Management Plan. [Including the high priority measure, “Re-operation of Central Valley reservoirs to minimize fisheries impacts from flow fluctuations.”]

• **Action AR-6.3** Develop and implement the San Joaquin River Management Plan to identify reservoir operational changes, habitat improvement measures, and other action items to improve habitat and health of the aquatic ecosystem in the San Joaquin River watershed.

• **Action WU-1.4** Ensure that state water quality standards and Basin Plans encourage water reclamation and re-use.

• **Objective WU-2** Develop water conservation methods and facilities to increase the availability of fresh water for instream uses and water supply.

• **Objective WU-3** Improve the legal and regulatory mechanisms to facilitate the voluntary transfer of water in order to increase the availability of fresh water for instream uses and water supply.

• **Action PO-2.4** Improve the management and control of urban runoff from public and private sources.

• **Action DW-5.2** Implement waterway modification policies that protect shoreline areas from detrimental flooding and erosion while maintaining natural resource values.

• **Action RM-1.1** Establish and operate a San Francisco Estuarine Institute for research on and monitoring of land use, biological resources, flow regime, pollutants, and dredging and waterway modification.

Although the Management Plan was approved by all Management Committee members, there was dissent to several sections. Much of this dissent centered on the SFEP’s inclusion of flow standards in their dealings. Both Aquatic Resources Minority Reports, the first written by representatives from the State Department of Water Resources, the State Department of Food and Agriculture, the Association of California Water Agencies and the Santa Clara Valley Water District, and the second authored by the representative from the California Farm Bureau Federation centered on this issue. The first report wrote, “The SWRCB already has plenary authority to regulate in this area; there is a long-established federal deference to state authority
over water allocation; and non-water quality issues are not within the purview of the Clean Water Act." The second report elaborated by saying, "The SWRCB has the advantage of hearing and being required to consider all competing interests in a water rights dispute to ensure that the broad public interest is served as well as is humanly possible under the existing circumstances."[61]

Dissent on this topic was quite apparent when the chair of the flows work group presented the group's technical recommendations at the SWRCB's Bay-Delta hearings. This work group, including diverter representatives, had evaluated the scientific impacts of freshwater diversion and had proposed a salinity standard for environmentally-sound flow management. Following the presentation, work group scientists representing water diversion interests claimed they had not agreed to this recommendation.[72]

The debate on the use of salinity or other water quality standards in the Delta has been particularly heated because it is fundamentally a battle for legal jurisdiction. The state has exclusive rights over how it distributes the entire quantity of freshwater within its bounds. Federal legislation has defined certain quality parameters that this water must meet in order to be used by various consumers. The EPA has oversight jurisdiction, and may intervene if the state persists in non-compliance. The two parts-per-thousand salinity standard proposed by the flows work group can only be met when a certain quantity of fresh water is available to repel the sea water, and therefore has come under attack by state representatives who have perceived the standard as an attempt to regulate quantity (not in EPA's sphere) under the guise of quality (authorized by the Clean Water Act).

5.1.5 Management Efforts: CVP Improvement Act

Perhaps the most significant single step towards remedying the environmental detriment caused by California water management was the passage of the Central Valley Project Improvement Act (Public Law 102-575, Title 34) which was signed by then-President Bush in October 1992. Some of the Act's key provisions include:

- Fish and wildlife protection is explicitly declared to be a purpose of the project.

- Each year 800,000 acre feet (reducible by up to 200,000 acre feet in dry years) is to be dedicated up front to fish and wildlife purposes, in an attempt to implement a Fish and Wildlife Service plan to double the production of anadromous fisheries over 1967-1991 levels by the year 2002.
• Construction of over twenty structural improvements such as improved fish screens and hatcheries, spawning gravel replenishment and a temperature curtain for Shasta Dam, are to be implemented.

• The CVP Restoration Fund is created, requiring beneficiaries of the project, such as power users, to help pay for the cost of environmental restoration.

• CVP growers are to be allowed to sell water on the open market anywhere in California with only limited regulation from water districts.

• Long-term planning is mandated to increase the yield of the Project to benefit all project purposes, including agriculture.[48]

The transit of this Act through Congress had been a long and arduous process, but ultimately the Act was passed, largely due to the strong support of a conglomeration of California water interests led by the organization called Share the Water. This coalition had initially included environmentalists, fishing interests, waterfowl groups and family farming groups, and had developed allies in labor unions, ports, most of the large cities in the state, business leaders, and urban water districts.

This act was strongly opposed by California Governor Pete Wilson, who went so far as to meet with Bush to encourage the President to veto the bill. The passage of this act indicates that planners at the federal level have looked beyond the immediate fiscal benefits of water diversions to recognize that damage has been done not only in terms of indirect revenue losses, but also in terms of the costs of losing natural resources of national importance. The state as a political entity has not made this transition yet, and Governor Wilson has been one of the most powerful opponents to such a transition.

Unfortunately, the implementation of the Act was enjoined in April 1994 by a federal court order in a suit brought by Central Valley Farm interests.

5.1.6 Discussion

The actions that have (or have not) been taken to mitigate the impacts of freshwater diversions are useful in this study not through their character alone, but also through the relationships and priorities that they illustrate. The preceding series of events and management initiatives has illustrated several key factors in the reform process:

• The conflict between state and federal authorities
• The role of citizen's organizations

• The catalytic role of the drought

• The role of California cities

• The use of scientific information

Evaluating the situation and particularly these factors by applying the parameters provided in Chapter 4 will illustrate how and why reform efforts were enabled. That chapter discussed the primary reason why environmental problems typically evolve: the misvaluation of natural resources. Chapter 4 also discussed several obstacles to environmentally sound management of freshwater inflow to coastal areas: the difference in time and space scales that human and natural systems respond to, the need for an appropriate group of impactees, and the strength of the political forces opposing reform.

Valuation of Natural Resources

The conflict between the California government and both the federal government and local groups has been created by differences in valuation systems. It is clear that any given item will have different values at different times for different people (and even for the same person at different times). For example, a hungry person values a piece of bread more than the same person immediately after a large meal. The magnitude of the difference in value that can be assessed an object is dependent upon many factors, including the rarity of the object and the priorities of the assessor. For example, the value of the bread in the aforementioned situations will not vary much. But a unique object, such as the Mona Lisa, will be valued extremely differently by different people: some would call it priceless; some would pay millions of dollars; some would prefer a supply of bread.

In the present case, the San Francisco Estuary is a unique resource. There are other estuaries in California and elsewhere in the United States, but none is quite like it. Consequently, different people hold radically different opinions of the worth of such an ecosystem. On the other hand, there is a fairly well specified range of values assigned to an acre of a particular type of crop. So when any given person weighs these two freshwater-dependent bodies against one another, s/he will define a balance point in accord with personal perception. The federal government certainly acknowledges the value of California agriculture, but it also acknowledges the value of the San Francisco Estuary, presumably both for its functional and amenity values
as a unique national treasure. The federal government also has the perspective to see nationwide declines in environmental resources, and such declines when observed together may represent greater cost than if the ecosystems were viewed individually. Whatever the justifying reason, the federal government's actions have demonstrated that as an entity, it perceives a specified quantity of freshwater (beyond an initial quantity allocated to agriculture) to have greater value sustaining the fisheries and natural resources of the Bay-Delta for the benefit of future generations than it would have in producing more crops this year.

The state government, on the other hand, appears to still hold the assumptions that freshwater flowing as a river into the ocean is valueless; that freshwater has value only when directly utilized by humans. The actions of the SWRCB and other State agencies show that they perceive little benefit from allowing freshwater to run naturally, which indicates the San Francisco Estuary holds little value in their view. The state and private water diversion interests, in fact, often perceive harm in terms of unfarmed acreage and lost jobs at the proposition to reallocate freshwater to natural interests. These may be real consequences. But these consequences are detriments caused by the revocation of a privilege that should never have been granted. The huge quantities of agricultural water were initially granted only because the equations weighing the benefits of the diversion projects in terms of agricultural and urban growth undervalued the countering costs (direct, indirect and amenity) of the loss of natural resources.

**Fisheries: Time/Space, Constituents**

Much of the discussion regarding the conflicts over water distribution has highlighted the detriment caused the fishes and the fishing industry. This is certainly not to shortchange any of the other detrimental impacts caused by freshwater diversion, but fishing groups (with environmental organizations) have been at the front of the push for reform. This pattern repeats itself around the country, in many of the other ecosystems where freshwater flows have been altered, and thus this pattern bears examining. Two questions come to mind: 1) Why has this impact been highlighted?, and 2) Why do fishing interests have so much difficulty affecting change?

To answer the first question, we should grossly review the impacts caused by a dam and divert system: fisheries declines, salinity intrusions, diminished flushing capacity,

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4 "May be" because minor reductions in available water supply, like those proposed (generally less than 10% reductions), could be compensated for with more conservative water use. Estimates of water wasted by agriculture run as high as 50%.[62]
diminished oxygen, sediment and organic inputs to the estuary, reduced mixing capacity, lost wetlands. With the exception of fisheries, all these changes are rather slow in providing tangible feedback. Salinity intrusions can damage Delta croplands; sufficient intrusions can even impair the water quality of the exported water. Lost wetlands translates to lost habitat for a variety of organisms, which translates to lost organisms – a slow feedback loop, and often indistinguishable from the purposeful destruction of wetlands. The impacts of reduced mixing are twofold. The first group, the impacts of altering the nutrient, oxygen, and sediment inputs, and changing the location of the mixing zone, does not independently arouse concern. Only when these changes produce results in higher species, like fish, are they noticed. The second category, the impacts of flushing pollutants from a system, is too intimately linked to the abundance of pollutants to be evaluated as a separate freshwater inflow effect. In summary, fisheries often exhibit the fastest and most obvious response to freshwater inflow alterations.

So why, then, is little reform accomplished even when fishing interests alert the public to the damage? The answer appears in Charles Jones's theory: fishers are not the right class of impactee, they hold too little power.[37] Being aligned with environmentalists produces incrementally more power; in San Francisco, with its long tradition of environmental activism, these two groups in coalition have pressured the EPA rather aggressively, with some tangible results. Yet it was not until the cities shifted sides that the most significant single reform measure, the CVP Improvement Act, had enough support to pass the Congress.

The irony of this situation is that ignoring the fishery signs will ultimately harm agriculture. Salinity intrusions have already damaged Delta farms, and low water quality standards can cause damage to irrigated croplands. The costs to agriculture, in terms of soil damage and lost acreage caused by briny water, that arise as secondary feedback from the current management system, are certainly not included in the state's (or farmers') calculations. Which highlights, again, the question of time: few of the stakeholders involved in this conflict are planning for long-term sustainability of their individual goals.

**Agriculture: Reform Opponent**

At first glance, farming seems similar to fishing: long days, seasonal work, food producing. Yet the two industries have greatly disparate levels of influence and are viewed

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[5] If there were no pollutants, it wouldn't matter how well the water body was flushed.
with disparate levels of respect. The word that best explains why is "agribusiness," for farming in California is hardly a family enterprise (as the authors of the Reclamation Act intended). Rather, corporate farms are the norm, consuming between 70 and 85 percent of the state's water.[44] This water produced $18.2 billion in agricultural commodities in 1992, including 45 percent of the nation's fruits and vegetables, making California the national leader in this economic area. Of these commodities, four crops in particular - rice, alfalfa, cotton and irrigated pasture - consumed forty percent of the state's water, producing less than one tenth the agricultural receipts, or only 0.2 percent of the state's revenue.[64, 74]

The corporate farmers producing these goods not only have a vested interest in protecting the supply of subsidized water, but they have the time and money to assure their needs are met. One observer remarked, "The irrigation and water districts make up California's single largest lobby. The superstructure now attached to the Central Valley Project - the phalanxes of lawyers, flacks and lobbyists - have, in a way, superseded the Project itself. To them, the system exists for its own sake - not because it represents a reasonable use for the water."[44]

The State government, too, is caught in this rut. Historically, the state's policies have long been pro-agriculture and pro-growth, and these policies have proved profitable for California. Now, as more people leave the land and the coastal cities swell in population, the foundation supporting these ideals is crumbling, but regulatory bodies have proved as slow to respond to social systems dynamics as they responded to natural systems dynamics.

Cities: The Swing Vote

In the water reform saga, the cities have been the deciding player. Traditionally, urban water districts have been prime beneficiaries of water diversions and have allied themselves with agricultural interests to protect their supply; one observer described Southern California's MWD as "the scourge of environmentalists, Northern Californians and Colorado River Basin states."[32]

But two factors have compelled many of the urban water interests to abandon their former mates and work for environmentally sound water reform. The first factor was the inequity exposed during the drought, when farms prospered at the expense of both the environment and the cities. The threat of water shortages would of course encourage the urban interests to work for reform, but not necessarily for reforms encompassing environmental water uses.
That component was born of the drought-inspired awareness that freshwater is a finite and potentially expensive resource, and either new supplies were required (expensive) or the current supply needed to be more wisely consumed. Urban consumers saw how successfully they were able to reduce usage; certainly if agriculture were to reduce usage in similar proportions there would be enough water for environmental purposes. One MWD representative described it thus: "We concluded that the environmental problems are real, and that you don't have to ruin the California economy to solve them."[43]

The second factor behind the new mindset of urban interests was the strong popular support for environmental reform. As the state urbanized, fewer people held financial or sentimental attachments to the land and held particularly little interest in maintaining a farm industry ill-suited to desert lands. And while city dwellers are concerned about their water supply, many are part of the state's strong environmental movement. Their willingness and ability to conserve proved a sign to the water districts that environmental concerns were significant amongst the populous.

The MWD's support of the CVP Improvement Act was the first sign of this new philosophy. In early 1993, shortly after the Act was passed, the new MWD Director, Michael Gage, emphasized his commitment to the environment, by stating, "The leadership of Metropolitan is committed to water policy that meets the needs of its customers while providing environmental stewardship that will ensure the lasting integrity of our most important natural resource: water."[32]

To summarize, urban water interests have proved to be the weight that tipped the scales. Before the drought, when water seemed infinitely available, these interests unfailingly worked towards greater exports from the Delta. And environmental reform efforts made little progress. But when the taps were shut down for the cities in 1991, and the citizens began their push, the cities came out in favor of reform. All this is not to say that the new environmental-urban alliance is and forever will be untroubled; rather that the weight of cities was enough to reverse the trend of California water management, in that it both weakened the forces of opposition while adding numbers and power to the forces for change.

5.1.7 Costs

It would be highly illustrative to provide concrete dollar values for each of the scenarios to be proposed. Unfortunately, the problems in accurate "valuation" and the complexity of the systems in question make that impossible. Therefore, the losses
and gains will be presented in a descriptive manner for some of the more extreme possibilities. The intention here is not to pinpoint exactly how much water to which user will maximize total system value, but rather to provide the reader with enough information to understand the relative costs of different water distribution schemes.

There are a range of possible water distribution scenarios possible for the state; each carries a different set of trade-offs of costs and benefits. There are two theoretical premises representing the extremes that need be considered: first, meet all human demands for water; second, meet ecological water requirements.

Meet Human Demand

The first theoretical objective can be met via a number of solutions. The objectives of such a goal are clear: agriculture, industry and residents will have whatever water they desire. Pools will be full, lawns will be green, cotton and rice will grow in the desert. It may be difficult to assess the dollar value of a full pool or a green lawn, but drawing from recent history, human consumers do not appear to give high value to excessive water use and are willing to drain their pools and water their lawns less frequently if necessary.

One possible technique to satisfy this objective would be to export as much water from the Sacramento/San Joaquin watershed as is physically possible. This would require some additional pumping costs, and could potentially require new construction to ensure that the exported water was uncontaminated by seawater. Increased export quantities would produce greater salinity intrusions which could threaten the water supply for some of Northern California residents. These intrusions would also render much of the fertile Delta lands untillable. But the most significant cost would be the destruction of the San Francisco Estuary, for the anadromous fishes, the freshwater and brackish marshes of Suisun Bay, the wetlands of the lower Delta, the creatures dependent on these lands would surely be destroyed. And not only would the people who use these resources for occupation, recreation and aesthetic peace suffer, but the nation and world would be poorer for the loss of a unique entity. Specifying a dollar value for the loss is, however, not realistically possible.

A second possible solution which would mitigate ecological damage by allowing water to run through the system would be to find a new supply to meet demand. In 1991, the worst year of the drought, a number of such solutions were proposed,

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6A project called the Peripheral Canal designed to carry water from the north around the Delta for this very purpose has been discussed in California for many years. Although defeated in referendum in 1982, this canal gained support in the drought years.
involving desalinization projects and/or importing water from other locations. Perhaps the most interesting was the plan proposed by Alaska Governor Walter Hickel to build a 1700 mile long undersea pipeline to export Alaskan water to California. Construction of this pipeline was estimated to cost $150 billion, and the environmental consequences uncalculated. But considering the high value assessed pristine Alaskan lands and waters, the transferral of a portion of California’s degradation to Alaska may be considered quite an expense.

Meet Ecological Demand

Ecological water demands are difficult to quantify. Because annual precipitation and runoff are naturally variable and cycle over many years, there is no single specified requirement. The best way to characterize demand is to establish a goal of estuarine health, and provide enough water to attain that goal. To characterize an extreme, we will establish the goal of anadromous fish populations comparable with pre-diversion levels. This would require a significant reallocation of freshwater.

The diminished availability of freshwater to human consumers would initially encourage wiser use of what water is available. Conservation and best management practices would become the norm. And supposing further reduction in usage would be required it seems only logical that farms, that consume the bulk of the state’s water (70 to 85 percent) but produce only a small fraction of the state’s total revenue (around 2 percent), would be required to reduce further. This would force marginal lands and water-hungry crops out of production. It is not immediately clear what impact this would have on the State’s agricultural revenues. Certainly unemployment of some farm workers and changed land values would be expected. But any decrease in the supply of certain crops would likely result in increased price – or an increased cost to the consumer due to diminished availability of certain products. These are real, calculable phenomena. How these losses compare to the loss of a unique natural system and its associated resources is, of course, subject to the evaluator’s perspective.

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7 Recall that anadromous species are often the best indicator of (in)adequate freshwater flows through a watershed system.

8 The most radical proposal would be to return the system to nature. This is not realistic given the high human dependency on exported water.
5.2 Mississippi River Delta System

The deleterious effects of various alterations to the hydrologic regime of the Mississippi River have been acknowledged since the turn of the century. One general strategy, the diversion of freshwater flows from the controlled channels into historical wetland/estuary areas, has appeared in most recommended plans since that time. Other strategies, like the procedure now called marsh management, have also been recommended for many decades. Yet these recommendations went almost entirely unheeded until the mid- to late-1980's, and only a few restorative efforts were actually implemented before 1989. Since then, some projects have been implemented, but it remains unclear whether or not management strategies that address the problems created by hydrologic modifications on a scale appropriate to affect large-scale change will ever move from the drawing board to the field.

5.2.1 Management Efforts: General Characterizations

Nearly all efforts to restore the Louisiana coast contain one component: freshwater and sediment diversion. This category of project is generally perceived to be the most effective at restoring coastal wetlands. There are several drawbacks to freshwater and sediment diversion projects. The biggest is that to be implemented on the scale required for success, these efforts will be quite expensive and will require cooperation among various federal, state and local entities.

A second large-scale program category frequently recommended is that of barrier island restoration. These programs also require some fair amount of interagency coordination, but generally encounter little opposition.

Finally, there are numerous smaller scale efforts, both proposed and underway, designed to slow the current rate of loss. These efforts will not provide huge changes, but are necessary to maintain the system until the large and expensive projects are authorized, funded and ultimately built (a potentially long sequence of events).

Because most planned recommendations for reversing the losses caused by freshwater flow alterations contain most if not all of these element projects, similar in character if not in specifics, general descriptions of the three restoration project categories will be provided. Presenting this information before the analysis of the history of management efforts will alleviate the need for extensive discussion of the actual proposals, thereby facilitating analysis of the sociopolitical currents.
Freshwater Diversion

The term "diversion" is used to encompass any project that redirects flows from the leveed main branches of the Mississippi River in an attempt to restore natural hydrologic or deltaic processes. These efforts are motivated by the understanding that large tracts of the delta have been starved for water and the sediments and nutrients transported therein. The logical relief, therefore, is the resumption of this transport by controlled means, in other words, reconfiguring the Mississippi River to resume its delta-building and -maintaining functions.

Diversion projects proposed throughout the years range from the very small to the very large. Proposed small projects have been as simple as reopening filled natural crevasses. Many mid-scale projects\(^9\) have been proposed, several authorized and funded, and a few, specifically the Whites Ditch, LaReussite, and West Point a la Hache siphons and the Caernarvon diversion structure, have been built and are now operating.[76] Most of these projects involve the construction of structures and pipes to control the river and distribute the water to the target area.

A handful of large diversion projects have also been proposed. These plans are designed to restructure the Mississippi River's flows to provide for both significant long-term wetland creation and wetland maintenance via water and sediment delivery to areas distant from the main channel. One proposal, raised by Dr. van Heerden of Louisiana State University's Center for Coastal, Energy and Environmental Resources involves a major diversion of the Mississippi River into Breton Sound. Other proposals are to reconnect the now-closed Bayou Lafourche as a major (ten percent) distributary and/or to increase discharge down the Atchafalaya River.[76, 41]

The potential benefits of diversion are new wetland construction, older wetland maintenance and decreased marsh salinities. These physical effects translate into more and better protected fresher marsh and wetland habitats, which in turn implies increased fish, shellfish, waterfowl, alligator and marsh mammal populations and improved storm and flood protection.

Concern exists over detriments that may evolve: the relocation required for residents, businesses and infrastructure along the diversion's path; the Mississippi River's diminished ability to maintain a self-scouring navigation channel; the negative impact of Mississippi River pollution and temperature differences on estuarine species; the costs to fishing interests of displacement of estuarine species downstream from current habitats. Because of these concerns, diversion proposals are typically met with

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\(^9\) "Mid-scale" meaning a diversion of several thousand cubic feet of water per second.
significant opposition through all phases of the project.

But overall, according to the 1987 Louisiana Wetland Protection Panel, diversion options have "the greatest chance of permitting the long-term survival of Louisiana's wetlands because they imitate the natural processes that have created and sustained these wetlands for the last several thousand years."[41]

Barrier Island Restoration

Although Barrier Island restoration does not involve reconfiguring freshwater flows for coastal management purposes, these plans work to reduce the impacts caused by freshwater flow alterations particularly as exacerbated by marine forces. To clarify, barrier islands work as buffers between the open sea and the landward estuarine areas. As such, these buffers can absorb a significant portion of periodic wave and exceptional storm energy, protecting the enclosed land masses from erosion. Barrier islands also limit tidal mixing, which helps stabilize salinities in the enclosed estuarine waters. So the presence of stable barrier islands around the Louisiana coast can reduce the nonlinear enhancement of detrimental effects caused by freshwater flow alterations.

Restoring barrier islands generally involves constructing a retaining structure, filling the region behind the structure with sand and revegetating the island to better retain the sediments.[70] Unfortunately, barrier island restoration efforts have only a limited ability to curb long-term wetland loss because they prevent neither relative sea level rise nor sediment deficit (the combination of which produces marsh submergence), nor canal-related marsh erosion.[41]

These restoration projects do, however, have the political components necessary for success. Because barrier islands are located in remote sites and are usually uninhabited, restoration will not interfere with existing societal institutions and therefore these projects face little opposition. These projects are also generally cost effective, because construction costs are much less than the benefits conferred by the storm protection these islands afford to human settlements, to estuarine nursery habitats, to erodible wetlands and to older oil and gas infrastructure.[76]

Small-Scale Support Projects

A variety of efforts have been proposed intended to maintain marshes, restrict new impacts, restore abandoned marshes, improve sediment retention, and prevent continued erosion.
• **Regulatory Mechanisms** The canal permitting process can be strengthened to discourage construction of new canals, to require proper spoil disposal or to require filling old canals in exchange for new canal permits. Marsh traffic, via buggy or boat, could be regulated to minimize, respectively, localized subsidence or erosion. In keeping with the "no net loss" goal expressed by the President and the Environmental Protection Agency, wetland creation projects can be required of any developer who destroys wetlands.[41]

• **Marsh Management** A phrase encompassing many activities, marsh management projects generally use an enclosure of levees and dikes with water control structures to regulate the flows to and from the enclosed marsh to maintain salinity and water depth at levels best suited to a given purpose.[11][41]

• **Beneficial Use of Dredge Spoils** Instead of piling dredged materials alongside canals and further impeding freshwater flows, dredge spoils can be placed in a thin layer over subsiding marshes in an artificial replication of flood-time sediment deposition.[13]

• **Brush Fences** Brush fences are used in Louisiana to close canals or breaches thereby impairing the landward flow of seawater and reducing the damages caused by wave erosion and salinity intrusions. These fences also trap sediments behind them, allowing marshes to rebuild. One popular program involves recycling Christmas trees for this purpose.

Other wetland-loss mitigation measures include revegetation efforts, herbivore control measures, canal filling efforts, and use of foreign materials, such as tires, for barriers to reduce wave erosion and encourage sediment retention.

The advantages to these programs is that implementation is fairly easy and costs are fairly low. The scale is small, so some of these programs can, and have been,
implemented by individual landowners or parishes; almost all are within the state's jurisdiction. The disadvantage of these projects is the small scale of the results: none of these programs will affect the wide-reaching changes that a significant diversion effort would. Nonetheless, even large-scale diversion is not a panacea, and many of these small scale projects would still be required to repair and conserve Louisiana's coastal areas, supplementing larger efforts. Overall, these projects are perceived as worthwhile, because they are technically, politically and economically feasible and they provide desirable results on a local scale. And considering that coastal deterioration has nonlinearly proceeded partially due to synergistic effects of incremental changes, it may be that the results produced by many small-scale solutions will be similarly nonlinear, providing future protection that is currently unanticipated.

5.2.2 Management Efforts: The Early Years

There were few real accomplishments before 1989. The following account is a detail of the struggles, the measures proposed and the reasons for inaction. Table 5.2 provides a chronological record of the management progress through June 1994.

Although until recently few steps were taken to ensure Louisiana's environmental and related economic stability, restorative measures were proposed as long ago as 1902. In that year, the second Biennial Report of the Oyster Commission of Louisiana was published. This report noted the ecological impacts of the containment of the Mississippi River, and claimed that the continuous extension of Mississippi River levees below New Orleans had interfered with natural oyster conditions. The report recommended allowing gaps through the river banks to maintain oyster-productive estuarine conditions.[52]

Two and a half decades later, naturalist Percy Viosca commented on the decline of Louisiana's wetlands and living resources, and suggested measures for reversing this decline. These measures included structures for water level control, siphons to distribute freshwater from the Mississippi to the wetlands and Mississippi River relief outlets for use in times of flood. Viosca concluded,

It seems that the time is ripe for an enormous development of the Louisiana wet lands (sic) along new and intelligent lines, the ideal conditions to be demonstrated by observation and research, and that this development should be included in a broad program of conservation which has for its object the restoration of those conditions best suited to an abundant marsh and swamp fauna, but under some degree of control at
<table>
<thead>
<tr>
<th>Year</th>
<th>Event/Legislation</th>
</tr>
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<tbody>
<tr>
<td>1906</td>
<td>Second Biennial Report of the Oyster Commission of Louisiana</td>
</tr>
<tr>
<td>1928</td>
<td>Viosca Paper recommending intelligent wetland management</td>
</tr>
<tr>
<td>1959</td>
<td>USFWS proposed freshwater diversion plan to USACE</td>
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<tr>
<td>1965</td>
<td>Mississippi Delta Region Salinity Control Project authorized (US)</td>
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<tr>
<td>1969</td>
<td>Diversion planning begun; halted by local opposition</td>
</tr>
<tr>
<td></td>
<td>National Environmental Policy Act</td>
</tr>
<tr>
<td>1970</td>
<td>Land-loss rate quantified</td>
</tr>
<tr>
<td>1973</td>
<td>Gagliano multi-use management plan published</td>
</tr>
<tr>
<td><em>mid-1970's</em></td>
<td>Land loss problem moved to common awareness</td>
</tr>
<tr>
<td>1977</td>
<td>Clean Water Act (US)</td>
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<tr>
<td>1978</td>
<td>Louisiana State and Local Coastal Resources Management Act</td>
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<tr>
<td>1980</td>
<td>Louisiana’s Coastal Zone Management program est.</td>
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<tr>
<td>1981</td>
<td>Coastal Environment Protection Trust Fund est. (LA)</td>
</tr>
<tr>
<td>1985</td>
<td>Coastal Protection Master Plan approved (LA)</td>
</tr>
<tr>
<td>Sept</td>
<td>Caernarvon Freshwater Diversion project authorized (US)</td>
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<td></td>
<td>Louisiana Wetland Protection Panel convened</td>
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<tr>
<td>1988</td>
<td>Water Resources Development Act (US)</td>
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<tr>
<td></td>
<td>Coalition to Restore Coastal Louisiana formed</td>
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<tr>
<td>1989 Oct</td>
<td>Wetland Conservation and Restoration Fund est. (LA)</td>
</tr>
<tr>
<td>Dec</td>
<td>Christmas tree restoration projects begun</td>
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<tr>
<td>1990 Mar</td>
<td>Draft wetland conservation &amp; restoration plan submitted</td>
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<tr>
<td>Apr</td>
<td>Draft plan revised (for industry) and approved</td>
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<tr>
<td>Apr</td>
<td>Barataria-Terrebonne estuary added to National Estuary Program</td>
</tr>
<tr>
<td>Nov</td>
<td>Coastal Wetlands Planning, Protection and Restoration Act (US)</td>
</tr>
<tr>
<td>1991</td>
<td>USACE began using dredge spoils for marsh creation</td>
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<td></td>
<td>Caernarvon diversion structure completed, opened</td>
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<tr>
<td>1992 Apr</td>
<td>West Pointe a la Hache freshwater diversion siphon opened (Plaquemines Parish)</td>
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<tr>
<td></td>
<td>Violet Siphon (St. Bernard Parish) restored</td>
</tr>
<tr>
<td>Jun</td>
<td>Hurricane Andrew caused $2.4 billion in damages</td>
</tr>
<tr>
<td>Aug</td>
<td></td>
</tr>
<tr>
<td>1993 Feb</td>
<td>Lareussite siphon opened (Plaquemines Parish)</td>
</tr>
<tr>
<td>Apr</td>
<td>Davis Pond Diversion project funded (US)</td>
</tr>
<tr>
<td>Summer</td>
<td>Heavy flooding along the Upper Mississippi River</td>
</tr>
<tr>
<td>Nov</td>
<td>CWPPRA comprehensive plan submitted to Congress</td>
</tr>
<tr>
<td>1993-1994</td>
<td>Debate over merits of Bonnet Carre Diversion Project</td>
</tr>
</tbody>
</table>

Table 5.2. Chronology of Management Initiatives: Mississippi River/Louisiana Wetlands.
all times.

It should be considered a state and national problem equal in significance to agricultural development, to the end that the state and nation may enjoy a more balanced diet, more healthful recreation, and enduring prosperity.” [52, p.326]

The U.S. Army Corps of Engineers has been instructed by Congress several times, starting in the late-1950's, to study the merits of providing freshwater flow diversions in the interests of conservation and the enhancement of fish and wildlife resources. The results of the first study won federal authorization (via the Flood Control Act of 1965) of the Mississippi Delta Region Salinity Control project, as part of the Comprehensive Plan for Modification of Flood Control and Improvement of the Lower Mississippi River. The project consisted of four salinity control structures, two on each bank of the Mississippi, connected by leveed channels to wetlands and bays within the lower Delta. The goal was to increase wetland biological productivity by establishing favorable habitat for fish, shellfish, waterfowl, and mammals. This plan has not yet been implemented.[77]

Non-implementation is largely because of local opposition. Again, this is a classic example of the reasoning behind the tragedy of the commons. The proposed projects would cause severe local impacts: they require land from the river to the destination wetland; and they will likely cause local detriment at the site of freshwater introduction. Therefore the people along these corridors who would be displaced by the projects, the governments along the corridors who may be required to relocate roads, water and sewer facilities, railroad tracks or utilities, and the people who utilize the natural resources near the outlet, who may see their income sources displaced, all perceive strong, immediate, negative impacts.[77] On the other hand, the benefits created by the diversion projects would be reaped in a more diffuse manner, by many people, over many years. Combining the two groups, it is only logical that strong local opposition will in most cases easily overwhelm diffuse regional support.

A second factor behind local and state opposition to early diversion efforts was the cost-sharing requirement. For despite evidence that the ecological deterioration was almost entirely linked to federal flood control projects, the mitigation efforts were classified as “enhancement,” requiring state and/or local interests to fund 25 percent of the project costs.[30] Thus, in the case at hand, when the U.S. Army Corps of Engineers began detailed planning of one structure proposed by the Salinity Control Project in 1969, local interests derailed the plan.

Paralleling the Mississippi Region Delta study, the U.S. Army Corps of Engineers
undertook two studies which geographically encompassed the remainder of Louisiana's coastal region. These two studies, the Louisiana Coastal Area study and the Mississippi and Louisiana Estuarine Areas study, were authorized under a 1967 U.S. Senate resolution to evaluate options for mitigation.[41] Both studies ultimately recommended specific freshwater diversion projects.[77]

In 1970, the first quantitative accounting of Louisiana land loss was published by Gagliano and van Beek; their estimates, based on map comparisons, was 16.5 square miles per year. This study is significant because it marked the end of the period of ignorance. Louisiana's land loss situation had been no mystery, but now numbers, the stamp of scientific certainty, had been applied to the scenario. Hence any further inaction could not be attributed to ignorance.

The first attempt at a comprehensive plan designed to reverse the ecological decline and land loss caused by human alterations was a report produced by Gagliano et al for the U.S. Army Corps of Engineers in 1973. The report's authors also produced a multi-use management plan that recommended controlled freshwater diversions for subdelta building and salinity control, surface water management including freshwater introduction, barrier island management and maintenance, and erosion control measures.[30]

Three years later, in 1976, the U.S. Congress passed a resolution to further study possible sites for reintroducing freshwater and sediments into the coastal areas of Louisiana.

In 1979, the Louisiana Legislature directed the state's Secretary of the Department of Transportation and Development to prepare a freshwater diversion plan for Louisiana. This plan was to complement the diversion plans anticipated to arise from the aforementioned federal initiatives.[30]

A 1980 study for the USFWS's National Coastal Ecosystems Team indicated an annual loss rate in the Mississippi Deltaic Plain Region alone of 31.6 mi²/yr. Combining this result with studies conducted in the Chenier Plain, the 1980 estimated rate of land loss for the entire Louisiana Coastal region was over 39 mi²/yr, more than double Gagliano and van Beek's 1970 estimate.[30]

In 1981, the state legislature established the Coastal Environment Protection Trust Fund with a one-time grant of $35 million. This fund was provided to support projects that would combat erosion, repel saltwater intrusions, and slow subsidence and wetland loss in the Louisiana coastal zone.[41]

In 1982, the Louisiana Geologic Survey developed a Geologic Review procedure to be used in cooperation with the Louisiana Coastal Management Division in eval-
uating permit applications from oil and gas interests. The Geologic Review brings representatives of the agencies with commenting and permitting authority together with the industrial applicant's representative to evaluate the environmental and economic merits of the proposal. If the proposal is deemed inadequate by any agency, modifications are made until agreement is reached that will satisfy the concerns of all parties. In 1984, the Corps of Engineers incorporated the Geologic Review process into its own permitting process.

This program has produced noticeable results: from 1982 to 1988, the annual sum length of oil and gas canals in the state's coastal zone decreased by 78 percent; in fiscal year 1986, only 42 percent of the dredge and fill footage applied for was permitted. In that year, no applications were entirely denied. Less damaging, but technically and economically feasible alternatives were agreed upon for all altered proposals.[36]

Also in the early 1980's, the U.S. Army Corps of Engineers produced recommendations on specific freshwater diversion projects. The three mid-size planned structures Caernarvon, Davis Pond and Bonnet Carre would supply freshwater to, respectively, the Breton Sound Basin, the Barataria Basin and Lake Pontchartrain. Figure A-7 locates the three projects within the Louisiana Coastal Zone. The projected costs (in millions of 1989 dollars) are 26.1, 44.9 and 69 each.[15]

In 1985, the U.S. Congress authorized construction of the Caernarvon Freshwater Diversion structure, designed to introduce freshwater into the wetlands and estuarine waters of Breton Sound. Louisiana dedicated its 25% share of the project costs in the Master Plan; the federal moneys – 75% of the total $26 million price tag – were provided in 1988. The structure has been constructed, and was opened in 1991. Too little time has elapsed to date to assess the project's level of technical success.

Also in 1985, the Louisiana Legislature approved the Coastal Protection Master Plan, which presented a ten-year state-based strategic plan for coastal rehabilitation. The first five-year phase focused on barrier island restoration; the second phase concentrated on wetland protection programs.[41]

It is worth noting here that this agenda was designed not to attain various goals of environmental restoration, but rather to protect the state's share of oil and gas royalties. For as coastal lands erode away, the state's territorial three mile boundary recedes, threatening hundreds of millions of dollars in annual revenues.[38]
5.2.3 The Mid-1980's: Oil and the Changing Tide

The middle of the decade saw the success of several efforts designed to improve biological resources and stem the loss of Louisiana's coastal lands, but these efforts were largely implemented on an individual basis, without the structure of a larger guiding plan. This was soon to change, however, and this transition can be linked to the dramatic alterations Louisiana's economic makeup underwent in these intervening years.

The alterations of concern are those related to the oil industry crash of 1985-1986 and the impacts this had on the Louisiana economy. To better understand the impacts, it is necessary to present a summary history of the state’s oil dependency.

The first successful Louisiana well was drilled in 1901. The century's early decades were a time of exploration and technical development. In 1933, a submersible drilling rig was designed that facilitated the rapid growth of near-coastal production. Offshore technology was developed in the 1940’s, and the following two decades sustained exponential industrial growth. Louisiana's in-state production peaked in 1969, but technological advances fueled increased development in the offshore areas under federal jurisdiction. Outer Continental Shelf (OCS) oil production was at a maximum in 1972; natural gas production peaked in 1979.[39]

Nationwide, oil prices, which had been generally rising since the 1960’s, increased more than threefold from 1979, when the average domestic barrel cost $8.96, to 1981, when the same quantity cost $31.77.[35] From 1981 through 1984, prices slowly decreased, but the industry continued to be extremely optimistic and extensive exploration continued.[69]

In Louisiana, the 1983 oil and gas industry directly supported 165,000 jobs, producing over $3.5 billion in salaries, $545 million in taxes and royalties and $859 million in state taxes. Additionally, support services and linked industries sustained many jobs in Louisiana's coastal areas, and produced significant revenue for the state and the local parishes.[39] One observer described this time period thus:

This era can be best characterized by high employment, excellent wages, well funded public services and facilities and a high demand for unskilled jobs. With the price and demand for oil continuing to rise, many believed that this trend would continue well into the future.[19]

The decrease in oil prices became significant in 1985; by 1986, prices had fallen to $12.51. This fall was the result of decreased worldwide demand coupled with increased OPEC production. With this fall, continued exploration and production
in Louisiana became unprofitable. Additional factors, such as the depletion of many nearshore reserves, and the high cost of United States operations (both in terms of labor and environmental regulations), decreased incentives for the industry to remain. In other words, the backbone of the state economy was suddenly removed. This produced immediate consequences for Louisiana — many jobs were lost, salaries were reduced, state and local tax income fell, population outmigration began. The region's economic prosperity, particularly in coastal parishes, had become too dependent on a single industry, dependent upon a non-renewable resource.

Survival required economic diversification; the logical avenue was renewable resources. Louisiana, the "Sportsman's Paradise," could improve its utilization of fish and wildlife resources, increase efforts to draw tourists, perhaps even start "Eco-Tourism" ventures. And this increased awareness of the importance of renewable natural resources to local and state economies increased awareness of the damages that had been inflicted on those resources. One report notes, "The downturn in the petroleum industry has forced a large percentage of the local population back into natural resource harvesting occupations. Thus there is a real need to improve the biological productivity of both the Barataria and Terrebonne basins."[76]

5.2.4 The Late-1980's: Rapid Progress

In 1986, meetings were held among environmental activists, area scientists and concerned residents to formulate an action plan. The purpose of the meetings was "to change the predominant attitude from 'Isn't coastal loss too big to tackle?' to 'What can we do about it?'"[14] This group later became the Coalition to Restore Coastal Louisiana (Coalition), a grassroots organization that has produced technical documents and educational materials, lobbied for legislative remedies, organized field expeditions and supervised small restoration projects. The Coalition's first major impact was the publication of the report Coastal Louisiana, Here Today and Gone Tomorrow?, released in draft form in April 1987 and finally published in April 1989. This report not only makes a strong argument for the need for coastal restoration, but also outlines specific measures to be implemented at local, state and federal levels to attain the program's objectives.

The same month the Coalition's draft report was issued, the U.S. Environmental Protection Agency released the report of the Louisiana Wetland Protection Panel. This group of over twenty scientists and policy analysts was convened in 1985 by the EPA and the Louisiana Geological Survey to "outline a study to evaluate strategies
to substantially reduce wetland loss in coastal Louisiana through the end of the next century, for use in developing a comprehensive wetland protection plan."[41] This report's conclusions were quite similar in overall character (although not as specific) as the Coalition's report.

Both reports were emphatic that wetland loss is a problem of national importance demanding national attention. Both reports focused on the need for comprehensive planning to produce a number of coordinated projects that would address the situation on an appropriate scale. For despite all the scientific research and management proposals of the 1970's and 1980's, no enduring comprehensive plan had been adopted by either state or federal government.

But under pressure from both local citizen's groups and national agencies, with the new mindframe produced by the oil crash, the state was ready to take the first steps to demonstrate its own commitment to finding solutions to the problems.

The Wetland Conservation and Restoration Trust Fund

In early 1989, the Louisiana State Legislature approved a measure establishing the Wetland Conservation and Restoration Fund. That October, by overwhelming popular vote, the fund was amended to the Louisiana State Constitution, and afforded the protection of Constitutional status. Moneys for the Fund were to be supplied by redirecting $5 to $25 million annually from oil and gas revenues.[59]

The legislation authorizing the state's Trust Fund directed the Coastal Restoration Division (CRD) of the Louisiana Department of Natural Resources to "plan, implement, operate, maintain, and monitor projects that are designed to conserve, create, restore, and enhance the vegetated wetlands of Louisiana." It also established a cabinet-level position, the Wetlands Conservation and Restoration Authority, to develop a comprehensive plan, administer the funding and coordinate state and federal restoration efforts.[80, 70] The Coalition to Restore Coastal Louisiana considered passage of this act a sign of the state's new dedication to coastal restoration.

But planning and implementing restoration programs has been anything but easy. The first project proposal under the enabling legislation contained 42 projects costing $20 million and was submitted to the state legislature in March 1990. Several days later, the legislature denied the plan on the grounds it inadequately protected industrial interests, a decision that inspired a flurry of angry editorials. Ultimately, a weaker plan was approved by the legislature in April.[6]

Some action has resulted, though: from the time of authorization, through 1 June
1992, the CRD has initiated 48 construction projects and 56 vegetation planting projects, and spent over $18.6 million.\[70\]

The Trust Fund-supported project garnering the greatest public support has been the use of discarded Christmas trees in constructing sediment-trapping fences for wetland restoration. This project was started in 1989 by the St. Charles Parish, and was sufficiently successful that funding for the 1991-1992 project season was provided by the Louisiana Department of Natural Resources - Coastal Restoration Division in the form of a matching grant of up to $15 thousand per parish, covering 85 percent of expenses. Ten parishes actively participated and six other parishes contributed funds to their neighbors' projects.\[29\]

Certainly one of the objectives behind establishing the Trust Fund and the Wetlands Authority was to demonstrate to the federal government that Louisiana was ready to take coastal restoration efforts seriously. Capitalizing on this opportunity, the two U.S. Senators from Louisiana quickly initiated legislation designed to provide some much needed federal assistance. With increasing national attention being focused on Louisiana's environmental and economic difficulties, the legislation moved successfully through Congress.

The Coastal Wetland Planning, Protection and Restoration Act of 1990

The result was the Coastal Wetland Planning, Protection and Restoration Act,\[14\] or title III of Public Law 101-646. This act was signed on 29 November 1990. This act is significant because it finally demonstrated national awareness of a national problem, for the incurred and expected costs of Louisiana's coastal degradation are largely by-products of federal projects designed for national benefits. The legislation committed federal financial and organizational leadership to the Louisiana coastal restoration efforts. Provisions of the act include:

- An interagency Task Force, composed of representatives from the U.S. Army Corps of Engineers, the National Marine Fisheries Service, the U.S. Soil Conservation Service, the U.S. Fish and Wildlife Service, the Environmental Protection Agency and the State of Louisiana.

- Lists of projects designed to provide for the long-term conservation of coastal wetlands and dependent fish and wildlife populations, prioritized according to

\[14\] Also known as the Breaux-Johnston Act, for the two Senators authoring the legislation.
cost effectiveness and wetland quality. This priority list will be annually submitted by the Task Force to Congress.

- A Coastal Restoration Plan to provide for the long-term protection, restoration and conservation of Louisiana's coastal wetlands, integrating and coordinating existing and proposed new projects. This plan was to be submitted to Congress by the Task Force before 29 November 1993.

- Funding of projects will be on a 75% federal, 25% state basis.

- Thirty-five million federal dollars provided annually through 1996.

To this date, all three annual priority lists have been submitted according to schedule. By the summer of 1993, thirty-eight projects had been developed and approved, and cost sharing agreements for ten projects had been reached.[16] However, it was not until April 1994 that any projects were actually completed. At that time, only the La Branche wetlands project, designed to create 205 acres of brackish marsh out of ponds produced by a failed agricultural impoundment effort, had fully proceeded. And this success was partially attributed to the cooperation and support of the area's landowners.[17]

In November 1993, the Task Force presented to Congress the Louisiana Coastal Wetlands Restoration Plan. The plan divided the Louisiana coastal zone into nine distinct basins, and developed restoration strategies at this level. Additionally, the plan included regional measures, primarily focused on the management of the Mississippi and Atchafalaya Rivers. Specifically, these measures include: freshwater diversions into the Barataria Basin; abandonment of the current delta in favor of a new delta, possibly in Breton Sound; reactivation of closed distributaries; seasonal flow increases down the Atchafalaya River; control of salinity intrusions in navigation channels; and barrier island restoration. Implementation costs are forecast at one to three billion dollars, and modifications to existing navigation, transportation, flood control, oil and gas systems are anticipated.[40]

**Other Efforts**

Several other changes in wetland management efforts have been accomplished since 1986.

*1990* Following pressure by the Louisiana Coastal Management Division, and in an effort to comply with the consistency provision of the Coastal Zone Management
Act, the U.S. Army Corps of Engineers agreed to make "beneficial use" of dredge spoils from navigation projects within the Louisiana coastal zone.[65]

1991 The State Senate passed a resolution that applied the beneficial use requirement to all ship channel dredging projects.

April 1990 the Barataria-Terrebonne LA estuary was added to the National Estuary Program, making as much as $1 million a year available from the federal government for management planning through 1995.

April 1993 The federal budget included $81.2 million for Louisiana wetland restoration efforts, including $70 million for the Davis Pond Freshwater Diversion Project.

May 1994 The U.S. Army Corps of Engineers and two Atchafalaya Basin cities agreed to remove the flow control structure limiting outflow through Wax Lake. This measure is expected to lower flood levels in Morgan City, badly damaged by Hurricane Andrew, and increase annual Wax Lake delta building threefold.[18]

In summary, by the early 1990's, federal and state legislative actions have been taken providing dedicated funding to formulate and begin implementing comprehensive management efforts intended to stem the deterioration of Louisiana's coastal area, deterioration caused primarily by the restriction of historical freshwater and sediment distribution.[29]

But despite all the ongoing efforts, representatives from the Coastal Restoration Division acknowledge, "coastal restoration is still in its infancy, and will require many years before the ultimate benefits from projects currently underway are felt."[70]

5.2.5 Discussion

There are several questions that the above discussion raises. First, it is important to evaluate why, for so many years, very little real action was taken. That evaluation leads into the second topic, which is why so little action has been taken during the past few years, even when technical evidence has documented Louisiana's increasingly severe problems. These two questions encompass issues of scientific knowledge and understanding, local, state and federal interests and interactions, in addition to the issues of valuation and political motivation raised in Chapter 4.

The next question concerns the paradigm shift that appeared at the mid-1980's. The role of the oil crash has been discussed, but considering the history of mitigation
efforts following this crash, was that enough? Or is there a need for another catalytic event before mitigation efforts are undertaken at an appropriate scale?

To utilize a parallel format to section 5.1.6, the following analysis of Mississippi River/Louisiana Delta environmental reform will include consideration of the difference in time and space scales that human and natural systems respond to, the need for an appropriate group of constituents, and the strength of the political forces opposing reform.

Historical Inaction

The phrase "inaction" encompasses two arenas: first, the scarcity of management initiatives; and second, the lack of implementation of those initiatives that have been proposed.

Valuation The first arena is linked to the valuation of natural resources. When Louisiana joined the United States in 1812, it contained over 16 million acres of wetlands, 4.5 million acres of which would now be considered coastal wetlands. In 1989, the area of coastal wetlands had decreased by 26 percent to 3.3 million acres. This is a phenomenal quantity, and as with any item, abundance decreases perceived value. It has been generally understood for many decades that freshwater control structures cause land loss. Since 1980, it has been scientifically demonstrated that the rate of land loss accelerates over time. The direct detrimental impacts of canals on wetland areas have also been well understood for many years.\(^{15}\) But the economic benefits conveyed by such constructions greatly exceeded the value of the impacted lands when the lands were only a tiny fraction of a gigantic parcel. And this attitude sets the stage for a tragedy of the commons, for as bigger and stronger levees are built and more canals are dredged, the public wetland resource is piece-by-piece degraded.

Time Lag The second element underlying the history of non-action relates to those parties detrimentally impacted by the alterations. In this case, few were immediately detrimentally impacted. This is partially because of a long time lag between alteration and significant impact. For example, fishing resources are predicted to severely decline over the next fifty years, but because deteriorating marshes afford better protection and more food for juvenile species, wetland deterioration can produce an

\(^{15}\)The indirect effects, and non-linearity of canal formation have only been evaluated since the late-1970’s.
initial increase in such populations, followed only several years later by a decrease.[52] A time lag on the order of decades has been noted between the time of alteration and the time when wetland loss becomes significant.[21] This is likely due to the fact that the losses accelerate with time. A study of Barataria Basin marshes noted an accelerating rate of wetland erosion from the time the basin's major distributary, Bayou Lafourche was closed in 1904 through 1980. The wetlands were stable through 1944, then lands changed into open water at the rate of 0.20% annually from 1945 – 1956; 0.32% annually from 1956 – 1969; and 1.49% annually from 1969 – 1980. The net result was that marshes which from 1904 through 1945 were composed of 91% stable lands, had been reduced to only 28% stable lands in 1980.16[15]

Impactee Requirement An additional reason for inaction is that few people physically occupy the deteriorating regions. Louisiana's shoreline has not sustained much of the intense development that have exploited the sandy resources of other coastal states like New Jersey, Florida and California. Much of the region is, and has been, considered largely uninhabitable because of marsh and mud instabilities. Oil companies also own a large portion of the coastal landforms, and their interests generally do not favor restoration. Some sections of the Louisiana coast have been developed – the coast supported 10,000 individual structures by 1978 – but the population density in the coastal zone, especially when compared to other coastal states, remains low.[38] As a consequence, few people directly sustain losses associated with the disappearance of land. Thus the impactee requirement for motivating political action has gone largely unfulfilled.

Failures The earliest proposed initiatives, such as the diversions proposed in the late-50's and early-60's were designed for specific enhancement purposes in specific regions. The Mississippi Delta Region Salinity Control project was intended "to increase wetlands productivity by the establishment of an ecological regimen favorable to the production of oysters, shrimp, fish, furbearing animals, and migratory waterfowl."[77] This was in response to marked declines in biological resources in certain locations. Because the goal was increased biological productivity, the project was categorized as enhancement requiring state or local interests to fund 25% of project costs. This was the first reason for failure. There was, and continues to be, strong sentiment in Louisiana that the state's environmental and land loss problems have been caused

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16 "Stable" means composed of less than 10% water.
by federal projects undertaken in the national interest and consequently any efforts to remedy these problems should be undertaken by the federal government. This, coupled with a fair amount of federal-state mutual distrust, has made negotiations difficult and cooperation scarce.\[1\]

The second reason for failure, and a reason that continues to appear, is the strong opposition posed by various interests that would be personally disturbed by the mitigation project. These interests include not only land owners in the path of proposed diversion structures, but also fish and shellfish leaseholders in the destination marsh whose harvests will disappear as the estuarine species move downstream. As discussed above, the valuation problem in this situation is that specific individuals who are but few of many beneficiaries of the original constructions are required to bear significant costs to provide small benefit to a many individuals within a larger group. This can be paralleled to the Not In My Back Yard, or NIMBY, syndrome that opposes efforts to site a variety of socially necessary institutions. Most people acknowledge the necessity for such projects but do not want to personally bear the costs associated with the facility.

Catalysts

The collapse of the oil industry in 1986 sent a signal to Louisiana residents that oil would not sustain the state's economy forever, and that the health of the economy, as dependent on petroleum, was subject to global forces outside their control. This awareness of the state's precarious position redirected some commercial areas into other venues: renewable resources, such as fish, shellfish and logging, and tourism. And at the same time Louisiana realized its dependence on natural resources, a number of studies were published indicating the magnitude of past and anticipated future losses, both in terms of acreage and revenues.

This growing awareness, particularly as embodied in new citizen's organizations, worked to inspire state and federal legislation committing initial finances for restoration. But as the various comprehensive plans have indicated, this funding is several orders of magnitude too small to affect any change. The amount of money required – one or more billion dollars – necessitates federal cooperation.\[17\] But federal environmental measures are typically applied in a fire-fighting style, where efforts and funds are funneled into one area of concern only until the next fire appears. And shortly after Louisiana was the focus of national attention, the environmental problems in

\[17\]The state's 1993 budget totalled a mere $9.5 billion.
Florida, with the deterioration of the Everglades, Florida Bay and the coral reefs, took over the spotlight. With the completion of the Task Force's Comprehensive Plan, the federal government is now required to decide whether or not (or to what degree) it is willing to commit the required funds for Louisiana coastal restoration. So all observers must patiently wait to see if the federal commitment is real, or if Louisiana's environmental situation was merely one in a string of many fires.

Additional Catalysts? If that is the case, it may be that the catalytic event required to inspire reevaluation of the Mississippi River/Louisiana Wetlands management structures on the scale required for successful mitigation has not yet occurred.

Two natural events happened in 1992 and 1993 that could have provided the appropriate impetus, but for their geography. In August 1992, Hurricane Andrew struck the southeast corner of the United States. In Louisiana, ten people were killed, 429 injured and $2.4 billion in property damaged. Morgan City and the resources of Atchafalaya Bay were destroyed, but New Orleans escaped serious harm. But these impacts were only a fraction of the estimated $20 billion of damages caused in Florida. This differential is attributable to several factors: the path of the hurricane; the density of development within the path; and the continued ability of Louisiana's barrier islands and wetlands to absorb much of the storm energy. Regardless, the comparative severity of Florida's situation ensured its capture of the bulk of the nation's attention.

The second natural event of importance was the extreme flooding in the upward reaches of the Mississippi River and its tributaries. These floods proved catastrophic for many Midwestern farmers, and provided solid evidence that the projects implemented by the U.S. Army Corps of Engineers truly could not contain this great river. And the fact that the floodwaters were contained in the lower reaches of the river was by no means proof of the strength of that area's levee system. Certain analysts predicted the overflow of the river in the Lower Mississippi Valley in future years, given the right combination of melting snowpack and rainfall. This has not yet happened, but it is only a matter of time before a severe natural event – be it flood or hurricane – strikes the population centers of Louisiana.

Events like these are important because they demanded immediate national attention, not only for emergency relief measures, but also for longer-term evaluations of the systemic failures that allowed extreme natural events to cause significant damages. Both Hurricane Andrew and the Upper Mississippi River floods were succeeded by a flurry of studies designed to rethink the requirements for living and developing
within certain environments – namely, on the Gulf coast or in the floodplain. And although much of Louisiana is located within one or both of these environments, disaster-inspired research is typically confined within specific disaster-affected geographical boundaries. Therefore it seems unlikely that this understanding will be transferred until Louisiana itself is severely impacted by one of these natural events. And that could be the turning point that would assure adequate support to restore the Mississippi's delta-building potential.

If this hypothesis proves true, a double cost will be produced. First, the state and nation will pay costs associated with mediating the effects of disaster. After disaster, these entities would be willing to pay the costs associated with preventing further catastrophes. But at that point, the cost of prevention will likely have increased, because the catastrophe itself will further the detriment initially produced by the original alterations. For example, high storm energies would remove vegetation and erode the shoreline, accelerating the rate of coastal land loss.

Opposition to Reform

The general efforts to restore coastal Louisiana have met with little directed opposition. These efforts have encountered some amount of apathy at the federal level, but because the drive for reform has long been loosely structured, the federal government has never been required to take a strong stance on the topic, either for or against the status quo. Advocates of reform were isolated and not especially powerful, so the nation funneled sufficient money into Louisiana to maintain the appearance that coastal restoration was a concern, without really committing to reform.

The active opposition to management efforts tends to take a directed, as opposed to general, form. There are two examples, both mentioned earlier, that illustrate this well. First is the fierce opposition posed by local interests to projects that would negatively impact areas of their particular concern. These parties perceive the specific proposed measure as unduly burdening them, but few such persons would claim to oppose the concept of coastal restoration. The second example is the debate the State of Louisiana and various coastal parishes have waged with the federal government over the issue of project funding. Both sides on this question strongly believe in the merits of their own position, and until very recently, neither has been willing to compromise. By preventing implementation of restorative measures, these two generic conflicts have produced a fair share of the real inaction besetting coastal Louisiana.

A single sentence summary of the situation could be that reform efforts are op-
posed not so much in principle as in specific. This can perhaps be explained by investigating the proponents of reform. In this case, at this point in time, impactees appropriate to motivate large-scale change have not yet become active. Consequently when individual projects are proposed by various bureaucracies, no group is willing to take on localized forces of opposition to ensure implementation.

5.2.6 Costs

The alterations of the Mississippi River flows have produced a variety of ecological and economic losses over the past hundred years. Only a few sources have attempted to estimate the dollar value of this loss. The van Heerden report references Costanza and Farber's 1985 paper that estimated the value of Louisiana coastal wetlands in terms of natural services and renewable resource productivity at approximately $4,000 per acre. Using a more conservative real estate value or $400 per acre, and including a similar number for the benefits of storm protection, van Heerden estimated the total value of wetland loss since the 1950's at over $6.6 billion.[76]

Anticipated Future Costs

Predictions for the economic consequences of inaction fifty years hence are contained within the Coastal Wetlands Restoration Plan produced under the authority of the CWPPRA. This report estimates that commercial fisheries harvests will decline thirty percent. This decline will threaten the region's 50,000 jobs related to fishing, processing and wholesaling. Waterfowl, alligator and furbearer populations are also expected to decline, reducing those revenue sources. Coastal Louisiana's agricultural-based contributions to the nation's food supply, namely sugar, rice and lime, will also experience production decreases. Production of minerals like salt and sulphur will be impaired. The loss of these resources has national implications.[40]

The diminished capacity of coastal wetlands to absorb storm impacts will also affect the region. Additional protective measures will be required, at significant cost. And as the wetlands recede, billions of dollars of infrastructure in the forms of roads, highways, ports, pipelines, oil and gas facilities will be further exposed to erosive forces and require increased maintenance expenditures. In fifty years, many of these investments will be claimed by the Gulf of Mexico. Billions of dollars will be lost; billions more required to protect remaining structures. The report summarizes thus: "The economic and environmental futures of all residents, whether in the City of New Orleans or in the homesteads of southwest Acadiana, are threatened by the loss of
the coastal marshes."[40]

Other reports, like the Coalition's plan for coastal restoration, include less quantifiable values that would be lost with the coastal lands. This report notes the contribution of Cajun culture to American history and the history of a number of different Native American tribes and waves of immigrants. Because these cultures are linked to the region, displacement would be tantamount to elimination. The cost of that possibility is incalculable.[15] Additionally, aesthetic and amenity values of the region would be lost.

**Restoration Costs and Benefits**

The plan recommended by the Task Force is predicted to prevent 65 percent of the wetland loss projected to occur in the forthcoming twenty years. This plan can be implemented via an investment of one to three billion dollars over that time period. Van Heerden notes that this investment will protect not only environmental and biological resource values, but also employment in the region. The restoration efforts alone will generate a number of jobs. Enhanced marshes and their dependent biota will provide future job security as the oil industry continues to shrink. Tourism, already important to the City of New Orleans, could be expanded based on recreational opportunities and eco-tourism alike.[76]
Chapter 6

Conclusions

Water is one of life's basic necessities. As such, humans have altered the flow patterns of freshwater for thousands of years. The first alterations were intended to ensure adequate supplies of this resource, for consumption and for food production. When populations expanded, increasing quantities of water were needed to fulfill these traditional functions. As the world industrialized, water was required for new functions, such as power supply or industrial cooling. Particularly considering these two trends, the magnitude of potential destruction of human life and property by uncontrolled water increased, and greater efforts were made to regulate water to minimize this potential.

There are some initial assumptions underlying decisions to build these projects:

- Freshwater has value only via functions it directly provides to humans.
- Uncontaminated freshwater flowing into the ocean is wasted.
- Short-term, identifiable benefits have greater value than long-term, unspecifiable costs.

Many years ago, operating within these parameters may have been validated, because water was plentiful. The human alterations that were constructed were on a small scale, and natural systems are resilient and can adjust to some perturbation. But over the past fifty to one hundred years, the number and size of these alterations have exploded. In the state of California alone, there are over 1300 major dams.[51] The Mississippi River has been straightened and channeled with thousands of miles of levees and dikes. Natural systems have not been able to absorb changes of this magnitude.
However, because the grounding assumptions are accepted as the status quo, although backed with only limited evidence, changing systems based on these premises requires proving them false. This is often difficult, because natural systems respond in nonlinear ways. Detriments caused natural systems by various alterations may occur many years and many miles from the original perturbation. Scientific efforts are able to separate specific detriments from other anthropogenic influences and natural trends only with great difficulty. In some cases, adequate technical information has been produced to refute the second assumption. For example, in the San Francisco Estuary, many people now perceive value in allowing water to flow through the river beds into the ocean to maintain certain fisheries.

The first and third assumptions are harder to refute at least partially because they rely upon traditional concepts of value, concepts fundamentally incompatible with environmental preservation. These market economic ideals require objects to have discernible value that can somehow be priced. But some values natural systems provide are unpriceable, values such as existence or amenity values. Additionally, natural resources function as systems, so the loss of some component in a particular year may affect certain other components in a manner unforeseen today. In other words, it is impossible to predict the net present value of a specified environmental resource. Understanding this illustrates how natural resources are misvalued, and implies that market economics may not be the optimum framework to assess the net effects of projects that influence natural systems.

When freshwater flows are altered, not only are the natural systems in direct proximity to these constructions impacted – like the valleys that are now reservoirs, or the wetlands of the floodplain that are now dried out – but natural systems far removed from the alteration are also impacted. This downstreaming effect poses difficulties for the coastal manager. The first complexity involves the technical issues: direct cause-and-effect is difficult to prove, and often may not become apparent until after a time lag, at which point severe damage may already have been inflicted. Another complexity is produced by the economic issues: the undervaluation of environmental resources feeds the perception that the benefits flow-altering projects produce in fulfilling a variety of social goals outweigh the (foreseeable) detriments they cause to other social and natural systems. In addition to the technical and economic aspects of disproving the founding assumptions, difficulties in terms of jurisdictional boundaries and authorized power often confound the coastal manager.

In Chapter 1 a rough outline for this thesis was provided:

- To address technical issues to:
- Establish cause and effect.
- Indicate the magnitude of effects.

- To evaluate management strategies to determine:
  - Why this problem is largely not managed.
  - Why this problem is difficult to adequately manage.

- To demonstrate why these alterations are preventable.

The first topic, the provision of technical justification for this work, has been well addressed with the compilation of evidence presented in the two case studies. Therefore the objectives of this Chapter are to expound on the second and third topics. The immediate objective is to expand on the managerial aspects of the case studies to better understand the difficulties involved with remedying freshwater alteration problems. The final section will present and justify the claim that the detrimental impacts caused by large-scale alteration of freshwater inflow to coastal areas are largely preventable.

6.1 Problem Management

This work's intermediate Chapters have evaluated two cases within the United States where authorities in impacted coastal regions have attempted to remedy a range of problems caused by upstream freshwater flow alterations. The cases were selected partly because they represent the two largest types of alterations, and therefore illustrate some different physical flow alterations, with different ensuing repercussions in terms of the physical, chemical and biological resources of the impacted coastal areas.\(^1\) In both cases, while not a seamless body of knowledge, the science documenting the link between the alterations and the repercussions is well established.

The cases of the San Francisco Estuary and the Mississippi River/Louisiana Wetlands considered as a pair provide added value because despite similar levels of technical understanding, the efforts undertaken to manage the environmental problems in the two cases have produced fairly different results, at least at this point in time. Understanding the factors at work in each setting that drive the social processes towards these different outcomes provides a clearer picture of the required managerial components than either case taken singly could. Specifically, searching for critical factors

\(^1\)Where the word "coastal" encompasses "estuarine."
that are similar or varying from case to case will highlight the elements necessary for success. Extrapolating these results could predict in which situations proposed remedies will or will not become operational realities.

In the two cases at hand, a single-sentence assessment of the efficacy of various restorative measures would be that in California and not in Louisiana, progress has been made in implementing actions to address, at the source, the environmental problems caused by freshwater flow alterations. This summary warrants some explanation.

The recent management efforts in Louisiana have produced little more than documents proposing management schemes. Many of these documents are similar in content to documents written twenty years ago. The legislation passed on both the state and federal levels authorized production of many more papers, and provided funds for only a handful of physical projects. The physical projects that have been implemented are typically small scale, producing small scale benefits. The larger projects, like the Caernarvon Diversion Structure, became operational realities only after over twenty years of planning and disputes. With the exception of freshwater diversion efforts, most of these projects mitigate the effects, and do not affect the causes. With the production of the Management Plan, with its large-scale proposed remedies, the Louisiana case is now at a crossroads, waiting to see if funding will be made available to change the trend and address the cause of the land-loss problems on an appropriate scale. But considering the more than fifty years of evidence that controlling the Mississippi River will produce negative impacts, the dearth of tangible fixes indicates the case has not yet been adequately addressed.

The management efforts in California have produced their fair share of documents, and are by no means over, but they have produced action. The Central Valley Project Improvement Act can be considered active legislation, for not only does it specify certain concrete measures designed to mitigate the project’s effects, but it also requires measures that address the causes of the effects. The Act specifically requires management of water flows in order to protect environmental resources, including annual dedication of a quantity of freshwater to environmental purposes. The quantity is not large compared to the unaffected quantity, but if released appropriately, it is expected to provide a fair measure of protection. These provisions are restorative in nature, not just mitigative and not just paperwork. For these reasons, it is reasonable to conclude that the managers in the San Francisco Estuary region are having better success in restoring their damaged ecosystems than the managers in coastal Louisiana.
<table>
<thead>
<tr>
<th>San Francisco</th>
<th>Year</th>
<th>Mississippi</th>
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<tr>
<td></td>
<td>1850's</td>
<td>Projects (leves) initiated</td>
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<td>1860's</td>
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<td></td>
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<td>1910's</td>
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<td>1920's</td>
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<tr>
<td>Projects initiated</td>
<td>1930's</td>
<td>Projects (leves) completed</td>
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<td>Project (CVP) operational</td>
<td>1940's</td>
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</tr>
<tr>
<td>Project (SWP) operational</td>
<td>1959</td>
<td>First mitigation proposed</td>
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<tr>
<td>First mitigation proposed</td>
<td>1960's</td>
<td>Projects (canals) widespread</td>
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<tr>
<td></td>
<td>1970</td>
<td>Damage quantified</td>
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Table 6.1: Two Case Studies: Comparative Timeline.

6.2 Case Comparison

Despite the ultimate differences, the two case studies have followed fairly similar historical paths. And the similar factors in these cases have parallels in other regions where extensive freshwater flow alterations have produced detrimental ecological results. But at a certain point, the cases diverged and unique aspects of the individual situations manifested themselves in the management efforts. Evaluating the parallels, and the subsequent divergence of the two studies will highlight the elements that are critical to successful problem resolution.

The best way to illustrate the parallels is to construct a comparative timeline. Table 6.1 contains this information.²

One of the first noticeable items is that the rate of the San Francisco time series is much faster. Only sixty years have elapsed from project initiation to the present day; in the Mississippi case, it is closer to 150 years. From initial mitigation proposal

²The phrase "project" refers to constructions built to alter freshwater flows.
to federal legislative response, the respective times are 14 and 30 years.

Setting aside the difference in rate, it is clear that both cases proceeded along the same path. The process from problem initiation through response passed through a common sequence of stages. Projects were constructed with the intention of acquiring certain benefits for the region or state or nation. Several decades later, scientific studies indicated that these projects may be producing detrimental effects on natural resources. Further studies were conducted that confirmed these effects; some studies endeavored to quantify the damage. These explorations identified the time-lag between cause and effect and the nonlinear nature of the various effects. These two considerations combined predict increasingly severe future impacts.

Scientific evaluations, and problem formulation, tended to be couched in terms of a specific component problem: fisheries for San Francisco, land loss for Louisiana. This is not to imply that these are the only problems, these are merely the highlighted symptoms of the underlying disease. In Section 5.1.6 we explored reasons why fisheries impacts were the impetus for change in California: these impacts exhibited the most visible and fastest response to freshwater flow alterations. In Louisiana, land loss has been highlighted for much the same reason.

In both cases, a managerial time lag also exists. Despite scientific evidence, long available and increasingly quantitative, few efforts were initially made to address the problems. In both cases, initial mitigation proposals failed. Not until some event happened that was outside the control of the impacted parties did the appropriate people perceive the harm in a manner that inspired them to become political and try to attract the attention of outside parties, including but not limited to the federal government. When this happened, the result was generally a new initiative, presumably with a greater chance of success than previous endeavors.

So in that general manner, the two cases can be seen to follow parallel paths. The primary difference between the two cases is that in the case of the San Francisco Estuary, the undertaken initiatives directly address the cause of the environmental deterioration in a style that may alleviate some of the negative effects. In the Mississippi River/Louisiana Delta case, the initiatives have produced paperwork which in turn produced projects that do not address the problem on the appropriate scale. How can this disparity be explained?
6.2.1 Size of the Problem, Size of the Solution

Certainly the freshwater flow management efforts in the San Francisco Estuary are aided by the fact that there are a finite number of dams and a finite number of pumps. The operators of these fixtures are state and federal agencies, bound by state and federal law, and accountable to higher state and federal authorities. In other words, the institutional causes of environmental degradation are confined within well-structured bounds.

Second, the simplified cause of the region’s problems is the shortage of freshwater flowing in streambeds. The logical solution is to increase this freshwater flow, a simple measure to affect – release waters from the dams and do not pump it away. All structures required to perform this procedure are already in place, and the personnel required for the procedure are responsible to higher bodies for their compliance. Of course, there are some efforts required, such as monitoring the streams to determine the optimum release time, not contained in the system’s existing structure. However, many of these auxiliary functions are contained within other responsible agencies. The net result is that adjusting the flow alteration systems to restore impacted natural and economic systems involves few fiscal expenditures and few operational adjustments. In other words, technically effective remedies are well defined, inexpensive, implementable and enforceable.

In the Mississippi River Delta case, however, the systems of problems and proposed solutions are amazingly convoluted. The causes of the problem: have two major components – controlling of the Mississippi River and its tributaries and widespread canal construction. The first set of projects were constructed by U.S. Army Corps of Engineers and involve thousands of miles of large, solid structures designed to channel the river’s waters. The Corps continues to be responsible for maintaining these structures. This cause component is extensive, but fairly well-bounded.

The second set of projects, the navigation and access canals, were constructed largely by two groups: the Corps and the oil industry. The Corps designed and dredged and still maintains the large shipping channels, such as the Gulf Intracoastal Waterway and the Mississippi River-Gulf Outlet. The oil industry built thousands of miles of canals as needed for exploration and production. When these canals were originally permitted, no requirements were imposed to govern the disposition of unused canals. Consequently, most canals, including many miles of pipelined canal, were simply abandoned when their use was no longer required. But now that filling old canals is deemed desirable, the owners cannot be held responsible. This component of
the cause of Louisiana's problems is poorly bounded – the physical and institutional dimensions intimately involved are huge.

It comes as no surprise that effective solutions to Louisiana's problems will be similarly scaled. Some solutions designed to address the problems caused by confinement of the Mississippi River involve constructing structures to redistribute freshwater. These projects would be intensive in terms of time, money and labor, both during the initial construction phase and during ensuing stages of maintenance and operations. Presumably, the Corps would construct these projects, so at least enforcement would be realistic. Freshwater diversion projects are anticipated to have a range of negative impacts, including displacement of people and investments, both public and private, and possibly localized negative environmental impacts in the receiving body.

Handling the problems associated with canals is equally complicated. The responsibility for abandoned oil canals is not well defined. Some parishes have undertaken initiatives to fill local canals. But the lengthy mileage of these canals, constructed over several decades through many coastal parishes, elevates the problem to the state or national level, and total elimination becomes a time, money and labor intensive process. Navigation canals were primarily constructed and maintained by the Corps, and this agency has taken responsibility for minimizing some of the negative impacts associated with these canals. But these efforts, too, require new investments in technology, equipment and personnel. In other words, proposed remedies are expensive, involve new construction, are complicated by issues of ownership, and may not even be technically optimal.

To summarize, implementing freshwater flow management initiatives for environmental restoration is a much simpler and cheaper process in the San Francisco Estuary's watershed than in the Mississippi River Basin.

6.2.2 Project Beneficiaries vs. Solution Beneficiaries

The previous section focused on the direct costs required for solution implementation. But the conflicts over implementation arise largely because of the costs of altering an existing economic dependency. Assessing these costs and benefits, and the parties that reap each, allows the observer to evaluate a situation as "fair" or "not fair." The question of fairness or equality is a particularly strong political motivator in this country; if a situation is believed to be unfair by one of the critical appropriate groups, change is possible. Of course this evaluation is completely subject to the viewer's perspective.
In California, the beneficiaries of freshwater diversion are, ordered by quantity of water received, agriculture and cities. The losing parties are natural resources, particularly fisheries, local agriculture, resource dependent industries and, in times of drought, cities. Reallocating freshwater and restructuring the water management system transfers positive value from the primary project beneficiary to the primary project impactees. This is perceived by many as a fair transfer.

In Louisiana, the situation is not nearly as clear. Most of the state's residents are beneficiaries of the flood protection provided by controlling the Mississippi River. Most, either directly or indirectly, also derived significant benefit from the oil industry's activities. Yet these coastal residents are also negatively impacted by these same projects. Economic activities dependent on natural resources will suffer, and the improved protection from river flooding increases the damage potential from coastal flooding. And although certain industrial and commercial segments prospered via these projects, many in the state believe that the primary beneficiary is the entire United States. This view is explained by indicating the benefits that accrued throughout the Midwest, along the Mississippi River's length, due to improved navigability and flood protection; by indicating the relative energy independence our country has maintained by exploiting Gulf reserves; and by indicating the state's relatively poor economy. A listing of the parties most benefited by canals and river control would vary from observer to observer.

Similarly, the parties positively and negatively impacted by restorative measures may not be exclusive, and may not directly mirror the parties negatively and positively impacted by the original project. For example, mid-scale freshwater diversion projects are intended to produce benefits diffused through the region, benefits defined mainly in terms of natural resources, with some added flood protection. Yet these projects encounter serious opposition because of the high level of local detrimental impact. In this example, some of the project beneficiaries will experience an incremental increase in value from restoration, while other project beneficiaries will experience a significant value loss. Many restorative efforts in coastal Louisiana fit this pattern. The absence of clear boundaries between beneficiaries of project and solution makes it difficult for the observer to evaluate which value transfers are "fair" and which are not.

6.2.3 Valuation Units

Another consideration that may help explain the different outcomes in the two case studies is the way the impacted natural resources are perceived and valued, particu-
larly relative to the project beneficiaries.

In California, there is the San Francisco Estuary. The individual natural resources and ecological units within this body are typically viewed as composing a single entity. This is apparent from a glance at the history of management initiatives: the Bay Conservation and Development Commission, the San Francisco Estuary Project, etc. Of course, some partitioning is used for practical management purposes, but by and large, this resource is perceived as unique. And uniqueness, as previously discussed, increases the possible valuation range of the item. Some people would go so far as to describe the Estuary as invaluable.

Therefore, when freshwater flow distribution is being evaluated, the perceived trade off is between maintaining a unique natural resource at the expense of some fraction of California’s abundant farmland or losing the resource and maintaining those extra few acres. When phrased in these terms, as a choice between sacrificing one of one, or a few of many, deciding for restoration appears more logical.

Environmental restoration in Louisiana is hampered by the other possible valuation system. In many ways, the wetlands are viewed as their name implies – as a plural form of land. Thought patterns do not focus on the Lower Mississippi River/Deltaic Plain System, but rather on the lands that compose the system. Even after a century of deterioration, Louisiana still has several million acres of wetlands and is the national leader in renewable resource (specifically fish, shellfish, fur and alligator) production. This continued commercial success with only 75% of the historical wetland acreage could allow the observer to conclude that the lost wetlands contributed negligible value to the state. The next step in this thought process is to conclude that losing a few more thousand acres would not significantly impact renewable resource production. But mentally dividing the system into many parcels removes all synergistic value each parcel has as a component of the system.

Comparing these two perceptions indicates that metaphysical value may be more important in motivating action than dollar value. In California, the anticipated future economic costs of non-action are the loss of commercial and recreational fisheries, the loss of some farmland, potential water supply quality deterioration, loss of recreation areas and income. This is not inconsequential, but is only a small portion of the anticipated future economic cost of inaction in Louisiana. There, a large portion of the state could erode into the Gulf, requiring abandonment of investments and resident relocation. Significant construction would be required to provide hurricane protection, maintain infrastructure, reduce erosion and drain occupied areas. Additionally, losses are expected of a similar character as California’s: fisheries, farmland, water supply,
and recreation. These potential costs would be truly catastrophic.

Therefore, explaining the difference in response indicates that perhaps the high value of the San Francisco Estuary as a unique resource adds sufficient value beyond the strictly market economic assessment to effectively motivate change.

6.2.4 Conflict

Another difference between the two cases is the amount of conflict between various concerned interests. In California, the water management structure that developed gave most people a stake in the game, although some interests had more power to execute their will than others. When drought struck, the structure’s response created a situation some viewed as unfair. This caused some commotion, which forced more people to develop opinions about the situation. This alone would not be enough to immediately affect large scale change, however, for the angry parties were far less powerful than their opponents. When the cities shifted to the pro-reform side, however, powerful interests were on both sides of the debate. The resulting public conflict ensured that people in the state and the federal government were aware of issues.

Coastal restoration efforts in Louisiana have not experienced such conflicts. In Section 5.2.5 it was noted that the region’s problems have not generally affected an appropriate group of impactees. This is one factor for the lack of conflict. Additionally, the project beneficiaries are not as pinpointable as in the California case. There are no David and Goliath waging this battle. In fact, the conflicts that have arisen, between individual property owners or smaller towns and the Corps, over permitting decisions or project-related displacements, have produced a perception of injustice that in many cases favors the property owner who is restricted from damaging wetlands in her/his control. This particular situation has motivated a U.S. Representative from Louisiana, Billy Tauzin, to introduce a “Property Owner’s Bill of Rights,” that would severely limit the government’s ability to regulate wetland destruction. Overall, however, the large scale problems facing Louisiana because of freshwater alterations have not yet produced major battles.

It might appear that an absence of conflict would facilitate reform, but when reform requires federal input, attracting federal attention is imperative. From the California experience, it appears that the perception of injustice alone may not mobilize reform efforts. However, a conflict between two groups, where one is believed to be unfairly benefiting at the other’s expense, will attract active attention. Perhaps
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<th>Louisiana</th>
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<td>Rural/Farm</td>
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<td>6.6%</td>
<td>9.6%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Below Poverty Level</td>
<td>12.5%</td>
<td>23.6%</td>
<td>13.1%</td>
</tr>
</tbody>
</table>

Table 6.2: Two Case Studies: Comparative Demographics.

the lack of major battles in Louisiana has, at least partially, prevented the parties concerned with coastal degradation from attracting enough attention to develop into a group of impactees with sufficient political clout to be heard.

6.2.5 Demographics: Impactees

Comparing certain demographic characteristics of California and Louisiana may also provide a clue as to why implementation of restorative solutions has been more effective in the first state than in the second. This comparison is most useful in evaluating how the appropriate impactee groups developed or failed to develop. Table 6.2 contains this information.³

To summarize earlier discussion, attracting political attention to any given situation requires an appropriate group of persons/organizations waving signal flags. “Appropriate groups” are one of three general categories: few people with great power; few people experiencing severe impacts; or a great number of people.

Evaluating only two California characteristics – total population and rural percentage – presents the conclusion that any event that negatively impacts the state’s urban residents will attract political attention via the “great number of people” pathway. Recalling the history of water distribution during the drought indicates that mandatory urban conservation measures may well have triggered this type of response.

In Louisiana, the population is neither as great nor as densely urbanized. This situation not only diminishes the power of the city within the state, but also impairs the state’s ability to attract national attention. With only 4 million of the nation’s 250 million residents, ranking twentieth in total population, Louisiana has little of the political clout larger states, like California, carry.

³Data taken from U.S. Bureau of the Census, 1990 Summaries.
Evaluating a number of the listed parameters provides some basis for understanding why Louisiana has had trouble focusing on what on the presentation level appear to be mere environmental problems. For one, high relative levels of unemployment and poverty indicate many people are concerned with basic survival requirements. Concern for environmental degradation will invariably fall from the fore when these more basic needs are unfulfilled. This shift in perspective occurs at both the level of the individual and of the state. To consider the state specifically, Louisiana's 1989 budget was only nine billion dollars. Implementing a comprehensive restoration plan is estimated to directly require at least one billion, which would be a significant share the state's revenue even in the best circumstances. It seems highly unlikely that the state would consider it politically or socially appropriate to make that size outlay given the below-average condition of the populus.

6.2.6 Summary

The previous discussion sections have focused on specific facets of the technical, political, economic and social dimensions that confound and/or facilitate efforts to appropriately manage coastal problems caused by freshwater flow alterations. This intentional deviation from the framework posed in Chapter 4 was utilized to demonstrate the interconnections between the items contained in the framework. Previous discussion has addressed the interrelations, complexities, and dynamics within natural systems that impede the development of technical understanding; similarly, complexities within dynamic anthropological systems impede the development of managerial efficiency.

The existence or evolution of a variety of linked circumstances in a problem-solving context will determine the course the solution will take. The first analysis structure emphasized resource valuation, time and space, appropriate impactees and forces of opposition. The case comparison indicates that these factors are not separable and are influenced by a range of exogenous parameters. And although certain topics have been presented herein, that encompass a number of important factors to predicting managerial success or failure, evaluating only these topics may not predict the true result in all cases.

To the concerned participant, then, strategizing a path to the implementation of restorative measures is a difficult task. Which brings this paper to its final proposition

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4The problems caused by canals and levees are economic and social problems as well, but are often formulated as environmental concerns.
which is that the coastal problems caused by altering freshwater flows are (theoretically) easily preventable.

6.3 The Unnecessary Problem

The primary justification for this claim is that projects designed to alter freshwater flows are produced by identifiable and accountable authorities. Large projects such as dams or levees are almost entirely constructed by state and/or federal agencies. As such, these agencies can be held accountable for their actions. First class alterations are hardly a tragedy of the commons, where the combined small actions of many individuals chip away at the health of the common resource. These alterations are big perturbations. True, their presence contributes some structured benefit to many individuals in the area. But the structure of the problem is different. Remedying a tragedy of the commons involves asking many individuals to perform actions that will decrease the personal benefit each derives from the resource. Ensuring compliance is difficult. Remedying the problems caused by a dam involves one specifiable agency performing certain actions. Compliance is obvious. And any ensuing loss of benefit is distributed amongst the many initial beneficiaries equitably.

For example, the new proposed Penobscot dam project would be constructed by the State of Maine to provide cheap electricity to many persons. Not constructing the dam would result in higher electricity prices. But all the persons impacted would be required to bear this cost in the same proportional manner – a few cents more per kilowatt-hour for everyone.

A tragedy of the commons scenario can be devised that could produce net effects similar to those of the single large dam. Suppose streamside family A constructed a small dam on their property to generate power. In order to keep up with the neighbors, streamside families B, C and D would build their own small projects. The stream would ultimately be reduced to a series of ponds and near-dry areas, with impacts on habitat, wetlands, fisheries, etc. But the wide distribution of ownership would make restoring the system a logistical nightmare.

The majority of intentional freshwater flow alterations parallel the first example. The authorities holding control over such structures know, to the degree such things are generally known, the impacts these projects will cause. The question of privately constructed canals in the Louisiana coastal area is, however, not in this category. Consequently, as a situation closer to a tragedy of the commons than not, this subsegment of Louisiana’s coastal problems has proved uniquely difficult to remedy. This
is the exceptional case.

Of the two specified discussion topics, remedying existing problems will prove much more difficult than preventing new problems. Although both situations involve many trade-offs, the first involves trading benefits already accruing for future costs and/or benefits, or taking something that's already been given. The second involves trading amongst a variety of future benefits and/or costs. The difference is exemplified by the difference between taking a toy from a child, or never giving the toy to the child. Resistance is much stronger in the first case.

This resistance, when targeting efforts to reform existing systems, is the sum of many elements previously discussed in the context of the San Francisco and Louisiana case studies: valuation of natural resources; forces of opposition; perceived costs of remediation. For when the systems were designed and constructed, the responsible institutions also constructed a theoretical framework justifying these systems. So reform involves also changing an ideological structure in which many people hold vested interests. But for this specific cause of natural system degradation, consolidated operational authority implies the means to affect a solution are readily available. This is what is intended by the claim made in Chapter 1 that the large-scale alteration of freshwater inflow to estuaries is, at least theoretically, one of the easiest environmental wrongs to right.

Preventing new construction of large scale flow altering projects should have added operational ease. The best example is the proposed dam on the Penobscot River. For this problem, scientific knowledge precedes investment. The impacts this project could have, particularly on the abundance and perhaps even existence of wild salmon runs, have been well predicted. The related economic costs, as much as they are quantifiable, could be predicted. Other costs are incalculable. For example, the Penobscot Indians hold tribal fishing rights and depend upon fish and wild animals for food. The impact to the tribe of either the proposed mitigation measure – trucking fish past the dam and the reservation – or the potential elimination of fish from the river, is not easily valued in dollars. And also considering the abundance of dams already existing within the drainage basin, this new project does not appear to be justifiable, neither technically, economically, nor socially.

Given this understanding that the predicted net costs of the project outweigh the predicted net benefits, the next step, not constructing the dam, is an easy one to take. Provided this understanding is publicly available, elected representatives within state or federal governments would realize that project construction is not in the(ir) best interest. Specifically, construction of a large project requires authorizations,
funding and time. Such construction produces obvious changes to the landscape; changes impossible to cover up. In other words, no path of subterfuge is available for implementation of a undesirable initiative of this character. Given the wealth of scientific evidence forecasting harm, and within the context of the prevalent valuation perspectives in the United States in the 1990’s that could perceive such harm as undesirable, the logical conclusion is that such initiatives should not be constructed.

The phrase *within the context of the prevalent valuation perspectives in the United States in the 1990’s* is key to this claim. This is demonstrated by the different outcomes of two proposals for new dam projects in Canada and China. The proposals in question are the James Bay project to be built by Canadian utility Hydro-Quebec and the Chinese government’s Three Gorges Dam. Environmental evaluations of both have forecast destruction of huge proportions. Evaluations of the human impacts, to Canadian Native populations and to resident Chinese, have been equally bleak.

And while the James Bay project has been stalled because of strong oppositional forces based on these grounds, the Three Gorges Dam on the Yangtze is under construction. The different result is attributable to differences in political and economic perspective in the two countries. In the view of the highest powers in China, industrialization is attributed high value, and little value is assessed the natural and human resources that will indisputably be harmed. Canada’s citizens perceive the relative values of industrial progress and natural and human resources in a manner similar to their southern neighbors.
Appendix A

Maps
Figure A-1: California's Water Systems. The San Francisco Estuary's drainage basin is indicated, along with several major dams and canals associated with the large water diversion projects. Source: *The Bay Watcher*, Jan. 1993.
Figure A-2: The Sacramento-San Joaquin Delta, including major river networks and elements of San Francisco Bay. Source: Mahmud, 1985.
Figure A-3: Reverse Flows through the Sacramento-San Joaquin Delta. Arrows indicate flow directions. Source: Dennis, 1981.
Figure A-6: Predicted Louisiana Coastline for 2040. Figure produced by extrapolating current trends in land changes. Source: Carney & Watson, 1991.
Figure A-7: Freshwater Diversion plan devised by the U.S. Army Corps of Engineers for coastal restoration. Source: Coalition to Restore Coastal Louisiana, 1989.
Appendix B

Abbreviations

CCMP  Comprehensive Conservation and Management Plan
CRD   Coastal Restoration Division of the Louisiana DNR
CVP   Central Valley Project
DNR   Department of Natural Resources
DWR   Department of Water Resources
EPA   U.S. Environmental Protection Agency
ESA   Endangered Species Act
FWS   U.S. Fish and Wildlife Service
MAF   Million Acre-Feet
MWD   Metropolitan Water District
NMFS  National Marine Fisheries Service
OCS   Outer Continental Shelf
SFEP  San Francisco Estuary Project
SWP   State Water Project
SWRCB California State Water Resources Control Board
USACE U.S. Army Corps of Engineers
USBOR U.S. Bureau of Reclamation
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