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Agriculture in the Sacramento-San Joaquin Delta : a case study of farming revenue versus levee maintenance costs

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AGRICULTURE IN THE SACRAMENTO-SAN JOAQUIN DELTA:
A CASE STUDY OF FARMING REVENUE
VERSUS LEVEE MAINTENANCE COSTS

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ABSTRACT

AGRICULTURE IN THE SACRAMENTO-SAN JOAQUIN DELTA: A CASE STUDY OF FARMING REVENUE VERSUS LEVEE MAINTENANCE COSTS

by Nancy Johnston D'Attilio

The Sacramento-San Joaquin Delta is tidal marshland, reclaimed into islands and tracts protected by an elaborate network of deteriorating levees. Highly productive commercial agriculture is supported on this land. The Delta is also a major migratory waterfowl, wildlife, and fish resource area, with recreational and shipping facilities, and plays a pivotal role in California's water transfer programs. Competition between agricultural, environmental, recreational, navigational, and water agency interests is resulting in changing priorities regarding land use in the Delta.

Agricultural production on these islands has been considered economically feasible despite recurrent land-use problems. However, recent economic strains have left some flooded farmland unreclaimed. A cost/revenue assessment is applied to ten islands used exclusively for agriculture, using agricultural income generated versus the costs of maintaining the protective levees. Islands and tracts that do not generate sufficient agricultural income to cover maintenance costs may no longer be unconditionally reclaimed in the future.

TABLE OF CONTENTS

3. PROBLEMS FOR RECLAMATION IN THE DELTA

4. CASE STUDY: FARMING REVENUE VERSUS LEVEE MAINTENANCE COSTS

5. CONCLUSION

MAPS

TABLES

FIGURES

ABBREVIATIONS

AF (af)	Acre Feet
BOR	Bureau of Reclamation
CFS (cfs)	Cubic Feet per Second
CVP	Central Valley Project
DFG	Department of Fish and Game
DPR	State Department of Parks and Recreation
DWR	California Department of Water Resources
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
HMP	Hazard Mitigation Plan
MAF	Million Acre Feet
MSL	Mean Sea Level
OES	Office of Emergency Services
PPM	Parts Per Million
SCPR	Sacramento County Parks and Recreation
SJCPD	San Joaquin County Parks Department
SLC	California State Lands Commission
SWP	State Water Project
SWRCB	State Water Resources Control Board
USGS	United States Geological Survey

CHAPTER 1
INTRODUCTION

Problem Statement

The Sacramento-San Joaquin Delta is a vital component of California's largest estuarine system. Reclamation activities begun in the latter nineteenth century have transformed eighty percent of this tidal marsh into islands and tracts that are protected by an elaborate network of levees. Varied uses characterize this region, with agriculture, navigation, recreation, fisheries, waterfowl and wildlife habitat sharing the Delta's resources. The Delta is also pivotal to California's water transfer program, moving water from the relatively moist north to the more arid southern portions of the state. Any changes in the Delta's structure could affect these uses, yet the cumulative effects of these varied uses are undermining the very elements for which the Delta is valued.

This thesis addresses one aspect of use in the Delta, intensive agriculture. Farming is under pressure in the Delta, economically, and environmentally as well. Incomes generated through crop production barely keep up with the high costs of maintaining continually deteriorating levees. If emergency expenditures to mitigate the damaging flood events common to this area are taken into account, the economic impacts can be debilitating, even with the contribution of state and federal funds. Intensive agriculture in the Delta is also cited as the main contributor to increased land subsidence and pesticides that eventually enter Delta waters. With such criticisms in mind, the question arises as to the continued support of agriculture in the Delta. This thesis approaches the question from an economic viewpoint. Ten islands, used exclusively for agriculture, are examined in terms of income generated from agriculture versus the costs of levee maintenance. The primary question addressed by this study is, in terms of revenues and costs, do these islands pay their way?

Background to the Problem

Reclamation activities in the late nineteenth and early twentieth centuries transformed the tidal marshland of the Delta into highly productive agricultural lands, despite continual land-use problems. Natural levees were augmented, and at first these low levees were sufficient to protect the land for farming. However, debris from hydraulic mining activities in the Sierra Nevada raised river levels and necessitated the need to increase levee height. Land subsidence also contributed to the need to build higher levees.

Gradational forces such as water, wind, gravity, and oxidation contribute to subsidence of the Delta's peat soils, causing some islands in the central Delta to be as much as fifteen feet below sea level (Burke, 1980; Newmarch, 1980, 1986, 1989; Weir, 1950). Natural land subsidence is accelerated by cultural activities such as agriculture and the extraction of irrigation water and natural gas. Subsidence lowers the island floors, making it necessary to build the levees continually higher, increasing the chance of hydrostatic collapse from water pressure on riverside slopes. Seasonal flooding is also common to this area caused by heavy winter rainfall, snowmelt runoff, and tidal fluctuations. Floodwaters, high tides, and high-crested waves can combine to overtop levee crowns, resulting in flooded land and levee failures, even with vigilant maintenance. Levee slopes are constantly compromised by burrowing rodents, increasing the chances of seepage through or under the levees. Erosion on waterside levee slopes is exacerbated by the wakes of boats utilizing the sloughs and channels that separate the islands.

The levee-protected islands serve as barriers to saltwater intrusion into the freshwater of the Delta. This function gained importance as the Delta became a pivotal cog in California's water transfers (MacDiarmid, 1975; Jackson and Paterson, 1977).

The Importance of Levee Maintenance

The federal Central Valley Project, the State Water Project, and other water suppliers are dependent upon high quality water in the Delta. The importance of levee maintenance in support of the State Water Project's transfers through the Delta became obvious soon after Project operations began in 1971. Levee failures in 1972 caused two islands to flood, creating a giant suction that drew sea water into the Delta. Massive releases of fresh water stored upstream were required to flush salt water from the Delta (Jackson and Paterson, 1977). At least twice since water diversions began, consecutive years of drought have reduced fresh water inflow considerably. Should there be similar levee failure during drought periods, there would be insufficient fresh water in upstream reservoir storage for such a massive release of fresh water to flush the Delta (Dorgan, 2/25/91). Also, the alteration of steam flows from water transfer pumps, and the reduction of freshwater inflow due to these diversions, has compounded saltwater intrusion problems. Water quality has deteriorated in the Delta, and with it the fish and wildlife populations dependent on the fresh- and salt water mix of this estuary (Fischer, 1983; Gilliam, 1989; Heath, 1989).

The feasibility of these water diversions through such a fragile component as the Delta is questionable. Should the levees fail due to a catastrophic event such as flood or earthquake, the Delta would essentially become an inland sea of undrinkable water. Even with the present arrangement, concerns are rising due to natural organic material picked up by water as it flows through the Delta. When combined with germ-killing chlorine added at water treatment plants, cancer-causing compounds known as trihalomethanes are produced (Diringer, 4/19/91; McClatchy, 2/27/91; California State Lands Commission, 1991). The issues surrounding these water transfers have been the focus of much research and debate, and the Delta, due to its central role in these transfers, is at the heart of innumerable studies relating to California water politics and subsequent physical and sociological impacts (Anthrop, 1982; Erman et al, 1982; Jackson and Paterson, 1977; MacDiarmid, 1975; Riebsame and Jacobs, 1988).

The costs of maintaining the Delta's status quo continue to rise. The current arrangement is only as secure as the weakest levee, reinforcing calls for alternative strategies (Appelbaum, 1973; Drabelle, 1987; Rogers, 8/16/86). One proposed solution to protect exported water, the Peripheral Canal, would divert freshwater around the Delta. Water quality for transfers would be improved, but possibly at the expense of water quality within the Delta. This alternative has been repeatedly delayed and rejected, because of the enormous costs involved, environmental concerns, and political battles. Since defeat of the Peripheral Canal by voters in 1982, there has been an increase in state monies invested to protect water quality in the Delta, particularly toward levee improvements on the islands (Campbell, 1/22/89).

Each island or tract (the terms are often used interchangeably) is essentially its own Reclamation District. Reclamation Districts were formed in the early reclamation period for the expressed purpose of protecting the lands from floods and keeping the land in a farmable condition. Reclamation District provisions include irrigation and drainage facilities, as well as maintaining levees, through fees collected from assessments, service fees, and tax allocations (Stefani, letter 6/3/91; Alexander, letter 9/24/91).

Although floods have continually been a problem throughout the Delta's history of reclamation, the recurrent flooding of the 1980s severely strained local resources, leaving many in debt for money borrowed from state and federal agencies for levee repair and restoration. Some land was left unreclaimed. Continued reclamation may not be feasible for islands that cost more to maintain than can be generated through agricultural income, leading to the possibility that more islands may remain flooded in the future (Logan, 1990; Riebsame and Jacobs, 1988). The numerable flood events of the 1980s brought attention once again to the fragility of the Delta region, in spite of the considerable expense and effort that have gone into maintaining its present usage (California Department of Water Resources, 1987). Alternative strategies, such as Sherman Island's development into a wildlife area, may mitigate some of the problems in the Sacramento-San Joaquin Delta. Also being explored are proposals to develop some islands as alternating water storage units and managed wetlands. Such solutions deserve attention (Abell, 1986; Erman et al, 1982; McClatchy, 4/27/91).

Theoretical Linkages

Early studies in agricultural geography examined the mapped relationship between agricultural land use and physical characteristics such as landforms and soils. Such a map of the Delta, for example, would illustrate the correlation between peat soils and agricultural production in comparison to the mineral soils in surrounding areas. Subsequent agricultural geography studies incorporate variables such as settlement patterns, transportation systems, and other measures of human activity (Taaffe, 1970). Many contemporary agricultural and rural land-use research themes address commercial agricultural production such as that practiced in the Delta, and include the analysis of farmland conversion, the impacts of urban growth and land-use conflicts, the direct and indirect impacts of government policy-making, and how determinations are made on which farmland could or should be saved. The economic influences on agricultural land-use decisions are integral to such research (Napton, 1989).

Farm management, whether as an individual or as a corporation, uses economic decision-making tools to determine land use. Such decisions include questions that any economic system must address: what to produce; how to produce; how income is to be distributed between labor, management, capital, and resource owners; and when to produce (Casavant and Infanger, 1984). The results of land-use decisions made by farm management can then be mapped for cartographic analysis: the types of crops grown; the level of technology used; the scale of operation; the number of plantings and harvests possible per season, depending on the length of the growing season.

Financial evaluations are tools used by agricultural decision-makers to measure the overall financial strength and solvency of farm operations. Two basic forms of financial analysis are used by farm management: (1) the balance sheet, which summarizes financial conditions at a point in time; and (2) the income statement, which summarizes financial transactions (costs and revenues) over a period of time. As every cost and revenue affects financial conditions, the balance sheet is continually changing, thus emphasizing the point-in-time concept in financial analysis by farm management (Kay, 1981).

The cost/revenue approach used in this study is basic to the decision-making process used by farm management to determine land use. However, the applicability of the results from this study are constrained due to the limited access to information encountered by this writer. These limitations are presented in the section on Methodology which follows. How they affected the study results are discussed in the summary assessment of the islands included in this case study.

Methodology

The primary question addressed by this study is whether reclamation of the Delta islands and tracts is economically feasible. The cost/revenue approach used in this thesis begins with the estimation of an island's worth through its agricultural production. Income generated through agricultural production versus maintenance costs should earmark islands that should be reclaimed and those best left unreclaimed should they flood in the future. In addition, alternative solutions for the Delta are examined.

The market worth of these islands and tracts is, at best, a mere estimation, determined through their primary agricultural use. Also, the various capital improvements on Delta land must be taken into account, such as transportation facilities (roads and railroads), water transfer systems, communities, and power transmission lines. Such improvements would greatly increase the effort extended to protect the islands and tracts that support such elements.

To establish a worth estimate for each island in the study area, crop reports were obtained from the Agricultural Commissioner for each of the four counties in the study area: Contra Costa, Sacramento, San Joaquin, and Solano. These figures reveal crop production and the income each crop generates. However, the information is not broken down to the level needed as it is reported on a county-wide basis. Edward Mayer, Chief Deputy Agricultural Commissioner for Contra Costa County, provided the desired breakdowns for islands in Contra Costa County that are in the study area as well as providing contacts for additional information. Ron Landingham, an economist for the California Department of Water Resources, provided crop and acreage breakdowns for the individual islands in all four counties.

In order to obtain information on the individual tracts from sources other than State publications, letters were written to the individual reclamation districts with limited success (see sample, Appendix A). Addresses for fifty-one of the sixty reclamation districts in the study area were obtained from a mailing list included in the draft environmental impact report on the Sherman Island project. In some cases, an individual was involved with multiple Reclamation Districts. Single letters were sent to such individuals requesting information on all applicable districts. Of forty-six letters sent, seven written responses were received; three letters were returned as undeliverable. One phone interview was generated with a farmer on Upper Jones Tract.

Two major mitigation projects are underway: Delta Wetlands, a private endeavor, and the Sherman Island Wildlife Management Plan, a joint venture of California's Department of Water Resources and Department of Fish and Game. Information on the four islands in the Delta Wetlands project--Bacon, Bouldin, Holland, and Webb--is included in the project's environmental impact report provided by Dave Forkel, along with a video presentation of the project. The desired information on Sherman Island in Sacramento County is found in the multiple reports available on the planned development of this island currently underway.

In theory, levee maintenance expenditures should reflect the importance placed on each island's integrity, as well as highlighting the desired elements each island supports. Levees are the means by which the Delta islands are protected from inundation. Levee maintenance costs for the period 1980-1986 for each island in the Delta are available from the California Department of Water Resources, as are levee construction methods and standards. A comparison of maintenance standards and costs between project (federal/state) and nonproject (local agencies) levees can be made from the information available from the the Department of Water Resources. Initially it was hoped that DWR figures could be compared to those recorded by the individual Reclamation Districts; however, the scanty responses from the districts made this infeasible.

The original intention was to include all of the islands in this study. Again, the limited response from the individual Reclamation Districts derailed this plan, as well as the unavailability of consistent data for every single island. Therefore, this study is confined to ten islands for the following reasons: consistent data could be obtained for each of these islands (i.e., crops, maintenance costs); none of them support capital improvements (highways, utilities, etc.) that would influence the decision to reclaim them; and each is still primarily used for agriculture. This sampling also includes a range in size from small islands (100 acres) to larger tracts (6,834 acres). The ten islands included in this case study are: Coney Island, Dead Horse Island, Fay Island, Little Mandeville Island, Mandeville Island, Medford Island, Prospect Island, Rindge Tract, Rio Blanco Tract, and Venice Island. Of these, responses were received from Dead Horse Island, Rindge Tract, and Rio Blanco Tract to augment available information.

By taking these factors into consideration - market value of the land and continued reclamation costs - it should be possible to postulate which of these islands will continue to be reclaimed, and which islands could remain flooded.

Summary

The Sacramento-San Joaquin Delta is an area of abundant natural resources. The estuarine system of which the Delta is a part is noted for the diversity of fish and wildlife typical of such an environment. The Delta has been only sparsely populated, utilized primarily for agriculture, but the Delta serves many functions. Large natural gas deposits underlie the Delta, and the region is also one of California's major recreational areas with fishing, boating, hunting, hiking, and biking opportunities. Shipping channels to the inland ports of Sacramento and Stockton are deep enough for ocean vessels, and several state highway routes transverse the Delta, either on levee crowns or across island floors. Portions of Interstate 5 also cross Delta lowlands. These uses, along with agriculture and water diversions, exemplify the diversity of the Delta.

Recurrent land-use problems have plagued the agricultural users of the Delta region since early reclamation. These problems of land subsidence, flooding, and saltwater intrusion are natural occurrences that have been exacerbated by cultural modification. Yet, in spite of the instability of the levees that facilitate farming, continued and costly reclamation of the Delta islands was considered economically feasible. Recently, however, severe economic strain has left some flooded land unreclaimed. The primary question of this thesis, whether or not these islands pay their way through agricultural production in light of the high costs of maintenance, is an examination of which Delta islands might face non-reclamation in the future.

Two additional concerns threatening agricultural use in the Delta are discussed, namely global warming and seismic activity. Global warming may affect sea level and fresh water inflow. Predictions of the possible effects of global warming include a rise in sea level, which would increase the probability

of inundation of lands in the Delta that have already subsided below sea level. The timing and quantity of fresh water inflow may also be affected, thus compounding existing problems with salt water intrusion (Buddemeier, 1988; Riebsame and Jacobs, 1988). Seismic activity could have a catastrophic effect on already-questionable levee stability as well. At least three faults underlie the Delta, in addition to the nearby Hayward and San Andreas faults, both capable of producing great quakes. Activity on any of these faults could result in massive levee collapse (Kearney, 1980; Reisner, 1989).

Should a number of levees fail simultaneously, the Delta would essentially become an inland sea. Simply to allow islands to flood is not a solution, either. In addition to the loss of farmland, the resulting open expanses of water would be detrimental to wildlife. Farm stubble does provide substantial amounts of feed for wildlife, as the original marshland vegetation once did (D. Forkle, phone conversation); open water negates this food source. Furthermore, there would be an increase in the likelihood of the "domino effect," in which wind-driven waves, particularly during storms, build across the open expanses of water that result from flooded islands; levee erosion is exacerbated on adjacent islands, increasing the chances of additional islands being inundated. Thus, this writer believes it is very important to include possible solutions now in development to mitigate current Delta land-use problems. Common themes among these alternatives are the arrest of land subsidence, the increase of wetland habitat and recreational facilities, as well as the protection of water quality and increased availability of quality water in support of water diversions.

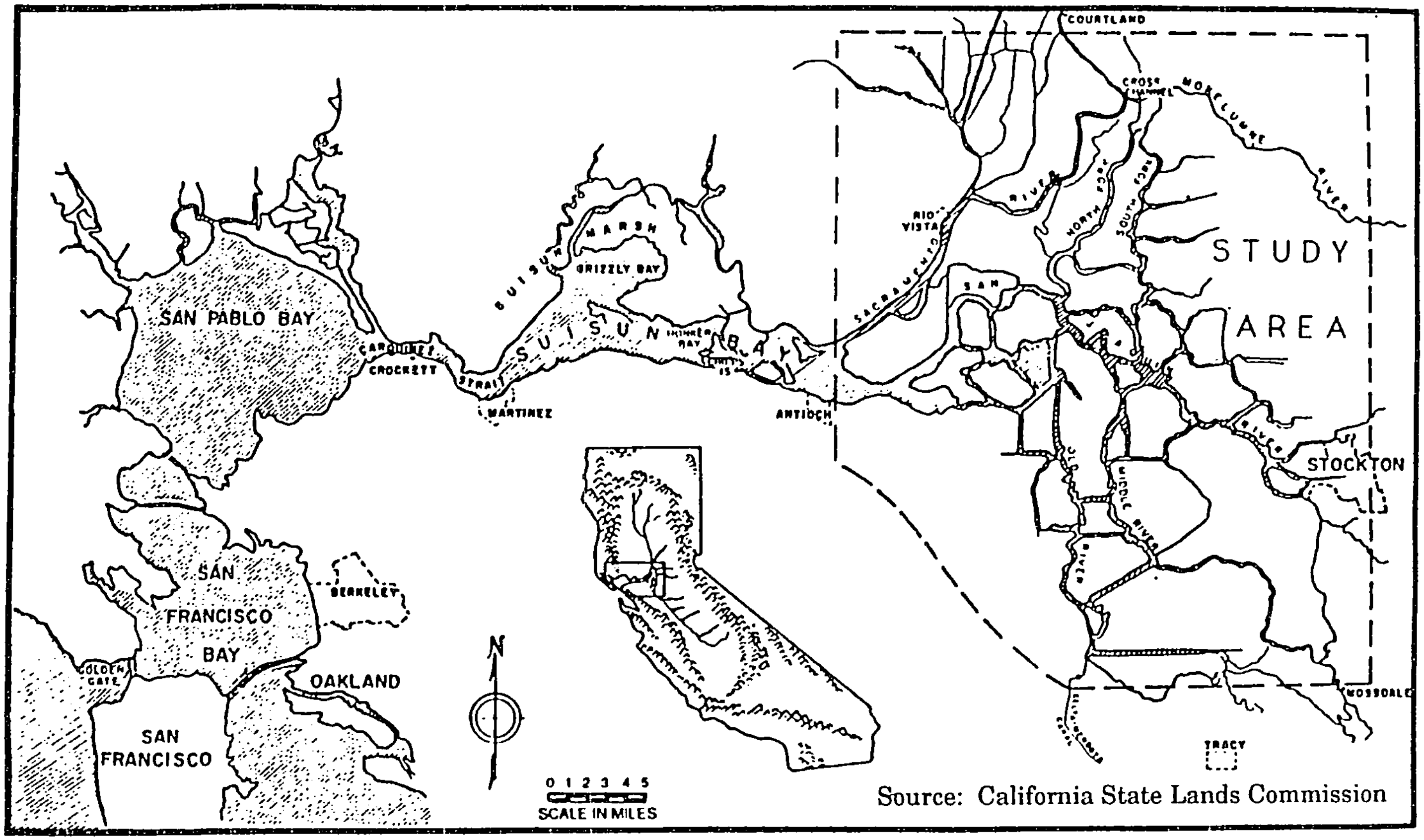
The Sacramento-San Joaquin Delta reflects changing attitudes regarding land use. Initial reclamation activities proceeded on the credo that land could be reshaped in any manner deemed profitable, as illustrated by the resultant islands and tracts. That optimistic belief carried over into engineering wonders such as dams, canals, and gargantuan pumps that could reconfigure natural drainage systems to transport water where it was wanted (Reisner, 1986; Worster, 1985). Witness California's elaborate water transfer system. As the repercussions of such manipulations become more evident, ways to reduce or prevent losses from these problems, natural and human-exacerbated, are actively sought (California State Lands Commission, 1991; Mitchell, 1989; Riebsame and Jacobs, 1988).

CHAPTER 2
GEOGRAPHIC CHARACTERISTICS OF THE DELTA

Physical

The Sacramento-San Joaquin Delta differs from most deltas in that sediment depositions have been laid down inland, rather than seaward (Shlemon, 1971). The Delta is the confluence of the two major rivers that drain the Central Valley of California. The 400-mile-long Sacramento River originates in the Klamath Mountains in the relatively moist northern portion of the state. The San Joaquin River, 350 miles long, begins in the Sierra Nevada south of the Delta and flows through part of the arid southern portion of the Central Valley. The Sacramento and the San Joaquin are joined by the Mokelumne, the Cosumnes, and the Calaveras Rivers flowing into the Delta from the east. The Sacramento and San Joaquin Rivers, along with their tributaries, account for forty-seven percent of California's total runoff. The combined waters flow through a narrow gap in the Coastal Range, with the Montezuma Hills to the north and the Diablo Range to the south, into Suisun Bay, through the Carquinez Strait, into the San Pablo and northern San Francisco Bays, passing through the Golden Gate to the Pacific Ocean (Map 1).

The size of the Delta depends upon the criteria used to differentiate this area. The California Legislature, in the California Water Code, Section 12220, designates its boundaries as the 738,000 acres irrigated with water from the Delta. Thompson uses the 535,000 acres within the 10-foot contour. McClain associates 425,000-435,000 acres of Delta land with characteristic crops and irrigation methods; MacDiarmid also uses this figure as the median of other



Source: California State Lands Commission

Map 1. San Francisco Bay and Delta Estuary estimates. Harding sets the figure at 400,000 acres as the irrigated area within the Delta. Nuttonson distinguishes the Delta as unique geographically from the rest of the Central Valley, delineating 307, 840 acres based on soils, physiography, and agriculture (MacDiarmid, 1975). In spite of the many years of modification of the Delta through reclamation and intensive agriculture, the sequence of depositions can be deduced through water well drilling logs. Such logs, required by law, are submitted on prescribed forms to the California Department of Water Resources. Each log notes location and depth of the well dug, type of casing used, and nature of sediments penetrated (Shlemon, 1971).

Quaternary Evolution

Approximately 10,000 years ago, a rapid rise in sea level followed the last Ice Age, inundating the alluvial valleys of the Sacramento and San Joaquin Rivers. The rate of sea level rise over the last 6,000 years appears to have been about the same as the rate measured over the last 130 years (California State Lands Commission, 1991).

The confluence of rivers responsible for the Delta formation dates to at least middle Pleistocene. The ancestral Delta responded to Pleistocene climatic change by expanding and contracting areally with each glacioeustatic oscillation. Channels of the lower Sacramento and San Joaquin Rivers were apparently incised and backfilled repeatedly with each major climatic fluctuation. While present-day rivers meander across the Delta floodplain, Pleistocene rivers cut deep channels and had greater hydraulic capacity, able to transport glacially-derived boulders and cobbles. Such mineral deposits were overlaid with interglacial deltaic sediments, and most of the peat beds in the Delta are separated by layers of mineral sediments. As the gradient of streams flowing into the Delta was reduced, tule and reed marshes developed.

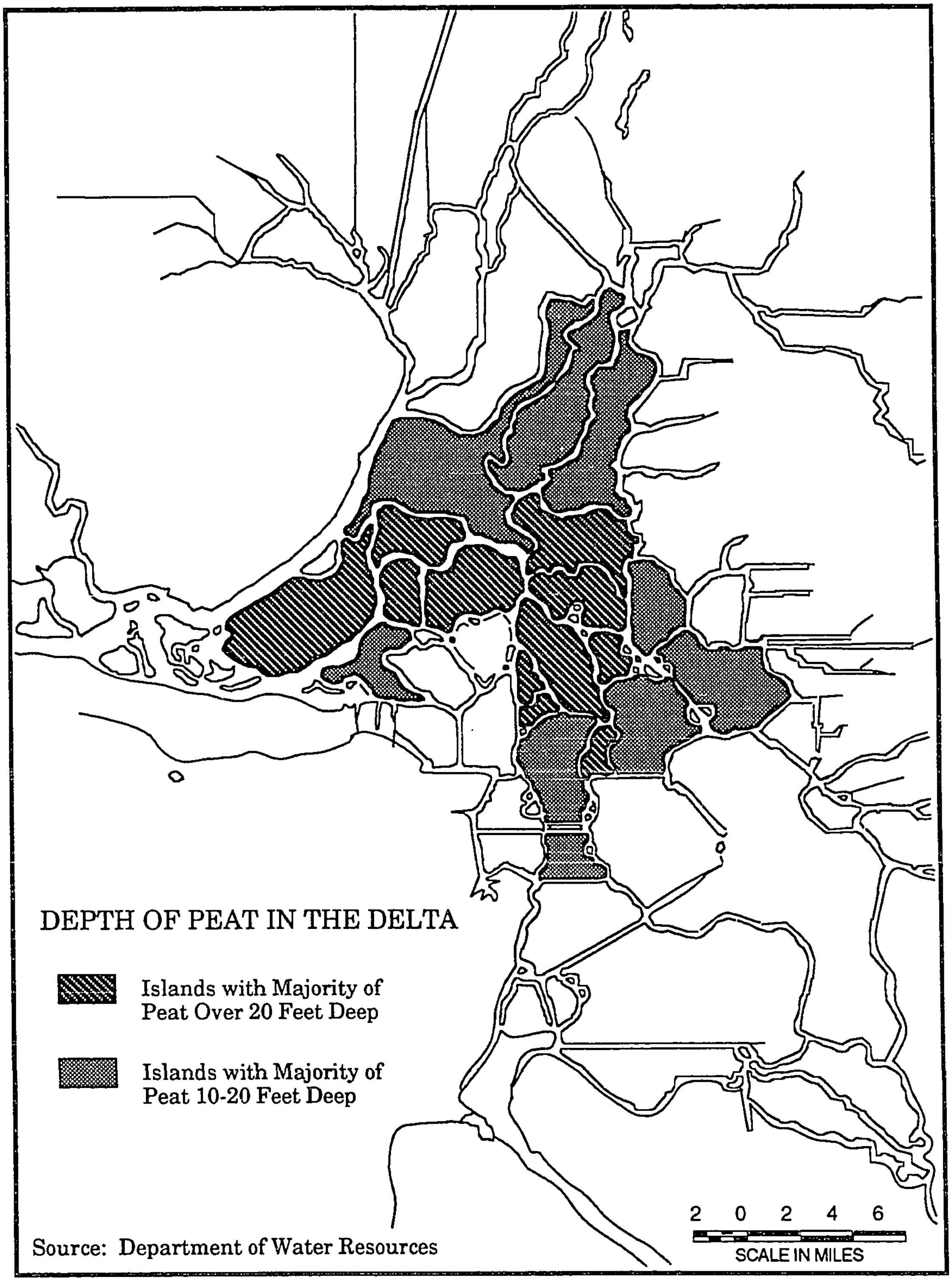
The decomposition of this plant material evolved into the widespread peat beds for which the Delta is prized.

The peat beds of the Delta can be radiometrically dated, providing data on the Pleistocene-Holocene boundary in this part of California. Significant subsidence seems to have occurred during the Pleistocene, with little occurrence during the Holocene (Shlemon, 1971). These peat beds have been measured at up to sixty feet in depth, deepest under Sherman Island in the western portion of the Delta, and gradually thinning eastward (Map 2). However, peat beds of forty to fifty feet also underlie the modern river channels. The peat underlying Sherman Island in the western Delta is up to thirty feet in depth (fifty feet below mean sea level). Peat also underlies the Sacramento, San Joaquin, and Mokelumne Rivers (MacDiarmid, 1975). The formation of these peat beds has been attributed to both sedimentation, settling out of floating reed mats into deep water, and to accumulation of organic material near sea level in an area undergoing slow and continuous geologic subsidence. The peat formed in interdistributary basins, now islands, in a freshwater environment close to sea level, and the collection of vegetative remains kept pace with rising sea levels (Shlemon, 1971).

Soils

The approximately 464,894 acres of Delta lowlands are made up of three general soil types: mineral (42.9%), transitional (22.2%), and organic (34.9%). The considerable number of peat beds make the soil eminently rich for agriculture.

There is a great deal of land subsidence of the Delta's soils. As with theories regarding the formation of the Delta's peat beds, there are two schools of thought regarding the phenomenon of subsidence in this area. One holds



Map 2. Depth of Peat

that subsidence is the result of reclamation, whereas the other contends these lands have always been subject to subsidence but the process has been accelerated by reclamation activities (MacDiarmid, 1975).

With levee-building and flood controls, the regenerative soil replenishment associated with flooding ceased. The tule marshes in island interiors, cut off from the floods that perpetuated them, no longer replenished peat deposits. Dried-out peat soils are also highly susceptible to wind erosion. Thus, with the soil equilibrium no longer maintained, increased land subsidence began. Also, with reclamation came the loss of the Delta's natural tidal prism. Slough channels fill with silt, requiring constant maintenance dredging to sustain navigation (California State Lands Commission, 1991).

Flora and Fauna

The Sacramento-San Joaquin Delta is a vital component of the San Francisco Bay estuarine system, as well as one of California's major wetlands that support many species of migratory birds. The diversity of wildlife, birds, plants, and aquatic life is typical of an estuarine environment, where saline and fresh waters mix.

Several species of anadromous fish migrate from the sea to spawn in the various waterways flowing into the Delta. The major groups include salmon, striped bass, steelhead trout, American shad, and sturgeon. There are 45 other species of fish, and 8 species of amphibians. At least 200 species of birds can be found in the Delta. Land life forms are also numerous, with 45 species of mammals, 15 species of reptiles, and 150 species of flowering plants (see Table 5, Appendix B) (California State Lands Commission, 1991; Delta Atlas, 1987).

The stress on this environment, however, is evidenced by the recent declines in fish, animal, plant and waterfowl populations, many of which are included on endangered species lists by federal and state agencies (see Table 6, Appendix B). Salmon and striped bass populations have dropped dramatically due to several factors. Chinook salmon, for example, on the federal endangered species list, has had an alarming drop in population. Pumping plants in the southern Delta alter, and, in some cases, reverse streamflow, allowing upstream displacements of freshwater with saltwater. Spawning grounds are disrupted, eggs and fish are transported out of the Delta through pumping facilities (Erman et al, 1982), and not enough cool waters are held in reserve for release during the spawning season, resulting in waters too warm for the salmon (Fortney, 3/6/91).

Tule elk, deer, and antelope were all once abundant in the Delta marshlands, but now only small animals are present, such as rodents, which have adapted to life close to human activities. Continual waterway dredging displaces underwater and shoreline vegetation. The wetlands of the Sacramento-San Joaquin Delta support ten percent of the migratory waterfowl of the Pacific Flyway, a bird migration corridor that extends from the tip of South America to Alaska. Recent estimates of these bird populations show a decrease of over five million in the last decade (California State Lands Commission, 1991).

At the time of writing, the future level of water diversion operations was in question because of the impact upon a species of fish found only in the Sacramento-San Joaquin Delta: the delta smelt. Steps were underway by the U.S. Department of Fish and Game to declare the delta smelt threatened under the Endangered Species Act. The delta smelt is the only fish in the Delta and San Francisco Bay system able to live in both salt and fresh water. In 1979, the population of this species was estimated at two million. In 1991, however, the delta smelt's population had plummeted to 250,000 (Robinson, 9/28/91).

During the 1977-1978 drought, salinity incursion caused damage to marshland vegetation and Delta fisheries, some of which have yet to recover (Anthrop, 1982; California State Lands Commission, 1991). The full effects of drought conditions from 1987 to the time of this writing have yet to be ascertained; however the striped bass index has fallen dramatically. Striped bass are considered an indicator of the health of the Delta due to their sensitivity to changes in the estuary. Prior to the 1976-77 drought, the average index was 66; the highest on record was 117 in 1965. Since 1977, the average index has been 22. Recent indexes have fallen from 64.9 in 1986 to 4.3 in 1990. The most important factors in this decline are attributed to reduced freshwater outflow and increased diversions since the 1970s (California State Lands Commission, 1991).

Climate

The Delta is situated at the only sea level gap in the mountain ranges encircling the Central Valley of California. The Pacific Ocean exerts a Maritime climatic influence on the Delta through the Carquinez Strait, modifying the Mediterranean climate of the Central Valley. The temperature differential between these two regions accounts for the characteristic Delta breezes. These winds can reach 50 miles per hour. The strong winds across the Delta generate basin-wide circulation superimposed upon tidal circulation. Wind-generated waves resuspend sediment, oxygenate the water, and disperse dissolved and particulate matter, and organisms throughout the shallow estuarine waters. The strong winds across the Delta also contribute to deflation of peat soils, which become very lightweight as they dry out (California State Lands Commission, 1991).

The average annual temperature is 60°F, with extremes ranging from 100°F in the summer, to 30°F in the winter. Average temperatures are 75°F in the summer, and 45°F in the winter. In spring and summer, the climate is modified by cool, moist marine air flowing through the Carquinez Strait. Land breezes prevail during the winter and, in the late fall and winter, dense ground fog periodically covers the islands. Annual mean precipitation is 19.9 inches in the central Delta, falling mainly in the fall and winter months. The growing season is long, averaging 324 frost-free days per year, and the planting and harvesting of two crops per year is common (Proposed Sherman Island Wildlife Management Plan, 1990; Proposed South Delta Water Management Program, 1990).

Cultural Impacts Upon the Delta

Early Human Occupance

The rich resources of the Delta drew early habitants between 12,000 and 20,000 years ago, at the end of the last Ice Age. Wandering tribes associated with the Hokan language group occupied the region, at one time reaching an estimated population of 30,000. Approximately 4,000 years ago, a relatively warmer and drier climate developed, replacing lakes with a vast marsh. Peoples of the Penutian language group, from eastern Washington and Oregon and western Idaho, migrated to the Delta region during this period, settling in areas not occupied by the Hokans. Descendants of these groups were peacefully occupying the Delta along with Miwok and Yakut tribes when Europeans first arrived in the latter part of the Eighteenth Century (California State Lands Commission, 1991).

Reclamation Activities of the Nineteenth Century

The number of people in the Delta region swelled with the discovery of gold in California in the mid-nineteenth century. Settlements were first built in the Delta to serve waterway transportation to the gold fields in the mid-nineteenth century, springing up upon natural levees formed by riverine depositions. These natural levees rose about five feet above sea level along the major channels, around the perimeter of natural islands, which were saucer-shaped with a lower center that was often flooded and filled with tules. As gold rush activity slowed down, farmers commenced utilization of the Delta soils, enriched by centuries of fine silt depositions and deep peat bed development (California State Lands Commission, 1991). Human activity has significantly altered the Sacramento-San Joaquin Delta since the days of the California gold rush, although the basic configuration of the natural islands was very similar to that of the present-day islands.

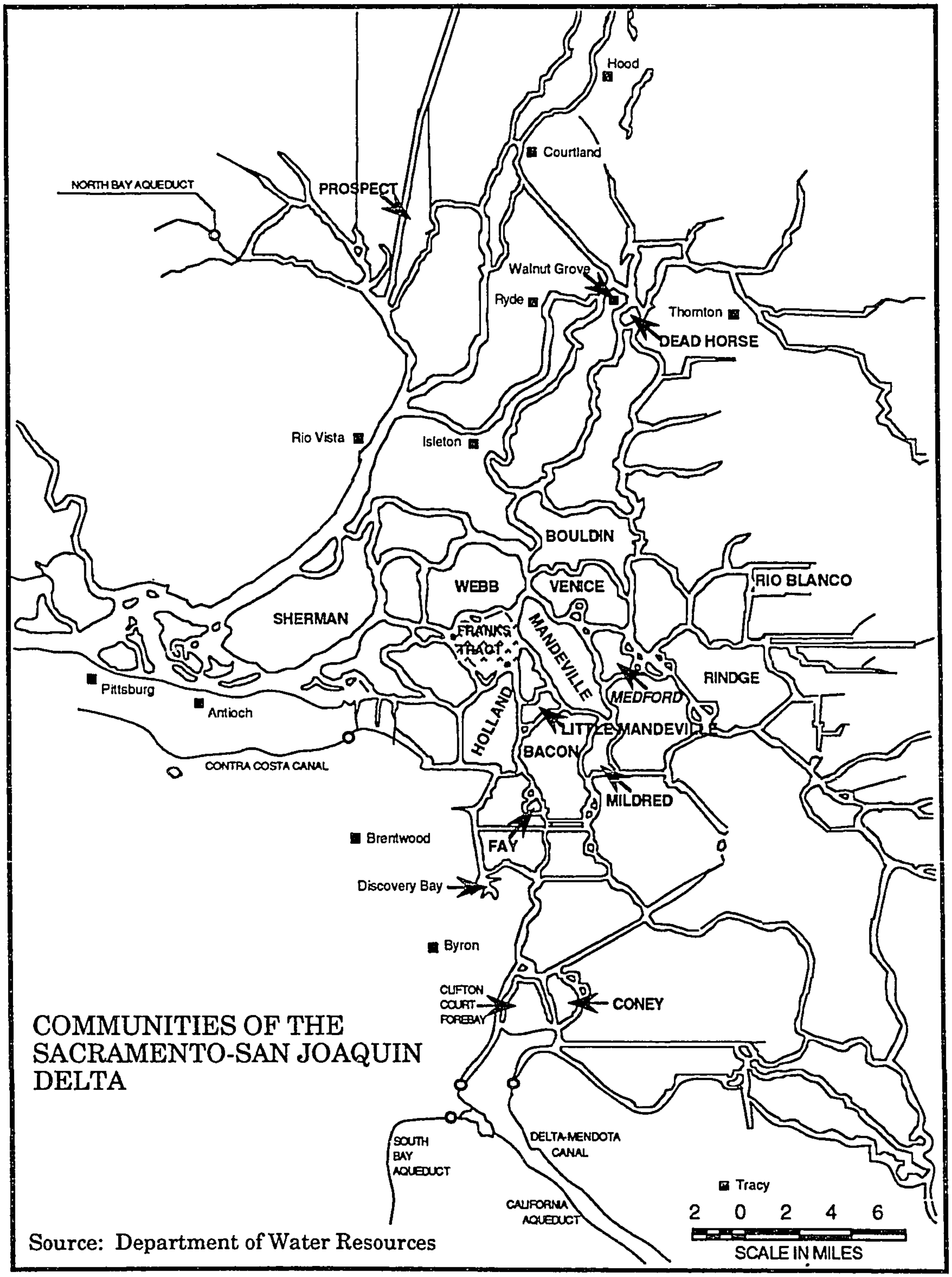
In order for reclamation to be profitable, whole islands required levee protection. The Swamp and Overflow Land Act of 1850 conveyed ownership of the tidal marshes of the Delta from the Federal Government to the State of California. Proceeds from the sale of this land by the State was to be applied to reclamation costs. The State Legislature created the Board of Swamp and Overflowed Land Commissioners in 1861 to manage reclamation projects. The Board's authority was transferred to county boards of supervisors in 1866. The Legislature removed acreage ownership limitations of 640 acres in 1868, and most of the Delta was in private ownership by 1871 (Delta Atlas, 1987). The removal of acreage limitations was particularly important to Delta developers due to the high cost of reclamation. The removal of the acreage limitations brought in land speculators with the necessary capital (MacDiarmid, 1975).

Gold rush activity continued to impact upon the Delta. Between 1853 and 1884, hydraulic mining operations in the Sierra Nevada contributed increased sediment loads into the streams feeding into the Delta. Almost one billion cubic yards of sediment, sand, and cobbles clogged Delta river beds. Debris raised channel levels in Delta waterways by as much as twenty feet, seriously impacting on navigation, and damaging farmland in the northern Delta. Finer sediments were deposited in the Delta and northern portion of the San Francisco Bay, resulting in increased shoaling and flooding, the obliteration of fish breeding grounds, and the creation of new tidal marsh. Higher levees were required to protect farming on the islands. Although hydraulic mining was banned in 1884, the cycle of building higher levees to protect the islands had begun.

<u>Population</u>

Fourteen unincorporated towns and villages are within the legal bounds of the Delta. These include Locke (population 600), Walnut Grove (1,500), Ryde (60), and Terminous (250). The community of Discovery Bay (3,385) was designed on the edge of the Delta lowlands to accommodate waterside living. Other communities include Freeport (50), Clarksburg (575), Hood (300), Courtland (400), Thornton (850), Lodi (43,300), Manteca (35,450), Tracy (25,450), Byron (1,000), and Rio Vista (3,390). In 1986, approximately 200,000 people lived within the Delta (Delta Atlas, 1987).

The Delta lies partially in six counties: Alameda, Contra Costa, Sacramento, San Joaquin, Solano, and Yolo. Cities and towns comprise 35,000 acres of the 738,000 acres of the officially defined Delta (Map 3). The region has been only sparsely populated because urban development is constrained by the problems of land subsidence and flooding. However, there has been



Map 3. Communities of the Sacramento-San Joaquin Delta

considerable urban expansion on the Delta's margins. The population of the San Francisco Bay Area, for example, rose to over six million between 1980-1990, an increase of fourteen percent. The Bay area is now the fourth most populous metropolitan area in the country. The Sacramento area, with a population of 1.38 million, experienced one of the highest growth rates in the nation in the 1980s. This development impacts upon the resources of the Delta, however indirectly, through loss of habitat and increased pollutant loads (California State Lands Commission, 1991). Table 1 illustrates the level of projected urban growth on the peripheries of the Delta.

TABLE 1 .--Urban Growth on Delta Peripheries

CITY	1980	1986	1990
Sacramento	275,741	322,500	346,600
Stockton	149,779	181,600	195,200
Pittsburg	33,034	40,500	45,650
Antioch	42,683	49,250	62,000
Brentwood	4,434	---	7,050
Tracy	18,428	25,450	32,700

COUNTY	1989	2000-PROJECTED
Alameda	1,261,500	1,330,245
Contra Costa	790,000	876,000
Sacramento	1,007,300	1,186,600
San Joaquin	464,900	513,600
Solano	330,200	397,230
Yolo	136,200	158,780

Source: City, 1986: Delta Atlas, 1987; City, 1980 and 1990, and County: California State Lands Commission, 1991.

Economy

The economic base of the Delta is agriculture, and there are large natural gas deposits under the Delta that in 1980 were valued at $26,900,000 annually (Delta Atlas, 1987). Levee maintenance has created its own economy (Campbell, 1/22/89), along with a significantly growing recreational economy.

Agriculture. The rich peat soils of the Delta notably benefit agriculture. Production on these soils generates significantly greater crop yields in comparison to similar crops grown on mineral soils (Orr & Sills, 1989; Thompson, 1957). These excellent soils combine with the level topography of the Delta for superb agricultural production (California State Lands Commission, 1991). Approximately 520,000 acres of the 738,000 acres, or seventy-one percent of the land, are used for agriculture. The average annual gross value of crops is $375,000,000. The main crops are corn, grain and hay, sugar beets, alfalfa, tomatoes, asparagus, fruits, and safflower, along with acreage used for pasture and rangeland (Delta Atlas, 1987). These cropping patterns are illustrated in detail in the profiles of the islands included in this case study.

Cropping patterns on the Delta islands have gradually shifted over the years as have agricultural patterns throughout California. Farm operations have been impacted by fluctuating crop prices, transport accessibility, and the individual grower (Edward P. Meyer, letter, 5/22/91). Asparagus, for example, is a perennial crop that, once established, can be harvested for ten years but also requires a great deal of hand labor (Proposed Sherman Island Wildlife Management Plan, 1990; Dick Klein, Rindge Tract, letter, 5/21/91). Twenty years ago, eighty percent of the world's asparagus supply was grown in the Delta. That figure has been reduced to forty to fifty percent. Much of this reduction is attributed to competition from asparagus production in Mexico, where labor is paid five dollars per day, compared to labor costs of five dollars per hour in the Delta (Coleman Foley, phone conversation, 9/9/91).

Agricultural lands in the Delta are covered under the Williamson Act, which provides a reduced tax base if the lands are kept in agriculture. However, even with this tax break, many farmers in the Delta are just breaking even. Each additional legislative measure regarding levee maintenance requirements is another burden for the farmer to bear in the struggle to make a living (I.N. Robinson, Jr., letter, 5/24/91). Thus, farmers have gotten a reputation for keeping to themselves. They have been labeled anti-recreationists, as boat wakes are major contributors to waterside levee erosion; anti-Department of Fish and Game, which now has the authority to inspect and approve any levee repair and maintenance to be done; anti-State, due to the great deal of frustration on the farmers' part who feel victimized by the State of California; and anti-Peripheral Canal, which would divert all the good water away from the Delta and allow the Delta to "go to hell" (Hal Schell, phone conversation, 5/16/91).

As noted in the introduction, agriculture is under pressure in the Delta, not only economically, but also environmentally. Farming is cited as the main contributor to increased land subsidence. Also, pesticides used on crops eventually enter Delta waters. Such pesticides have been detected in sediment and fish samples taken from the Delta. Studies by the Department of Fish and Game have also shown a correlation between pesticides used in Sacramento River Valley rice farming and declines in striped bass populations (California State Lands Commission, 1991).

Recreation. One of California's major recreational areas, recreation activity and related services rank third in the Delta's economy after agriculture and natural gas exploration. Much of the activity is water-related, such as boating, boat fishing, swimming, water skiing, sailing and canoeing (Table 2). Many facilities are accessible only by water, due to the large percentage of privately-owned land in the Delta.

Land-based recreational access is limited to a few roads and includes camping, picnicking, hunting, channel bank fishing, bird watching, nature studies, hiking, bicycling, sightseeing and car touring, and horse back riding (California State Lands Commission, 1991). Most of the recreational users of the Delta are not its inhabitants but rather people from the adjacent San Francisco Bay area (Sunderland, 5/16/91), and recreational attendance has been steadily increasing over recent years (Table 3). In 1973, the Delta accounted for three million Recreation Days annually, one Recreation Day representing one day or part of one day spent by one recreationist (MacDiarmid, 1975). By 1990 this figure had risen to twelve million Recreation Days annually (California State Lands Commission, 1991). An estimated 82,000 registered pleasure boats use the Delta, serviced by twenty-two public recreation facilities, twenty-two private recreation associations, one hundred and sixteen commercial recreation facilities, with 8,534 berths, one hundred and nineteen docks, and twenty-seven launch facilities. Marinas in the Delta are valued at $100,000,000 (Delta Atlas, 1987).

Transportation and Communication. Transportation evolved in this region from water-based facilities to the present-day road system (Thompson, 1980). Interstate Highways 5, 80, and 205 cross the legal boundaries of the Delta. State Highways 4, 12, and 160 all cross the below-sea-level land of the Delta study area. Railroads crossing the Delta include the Southern Pacific, the Western Pacific, the Atchison, the Topeka and Santa Fe, and the Sacramento Northern lines. Combined, these railroad lines through the Delta

Table 2. Public Recreation Facilities

Brannan Island State Recreation Area, State Department of Parks and Recreation (DPR): land and water access; launch ramp, swimming beach, campsites, picnic areas, parking, restrooms, interpretive center

Franks Tract and Little Franks Tract, DPR: water access only; few facilities

Delta Meadows, DPR: land and water access; few facilities

Clifton Court Forebay, Department of Water Resources (DWR) and Department of Fish and Game (DFG): land access; only portion of reservoir available for fishing with special permit

Borrow Ponds, DWR: land access; fishing ponds (part of undeveloped Peripheral Canal right-of-way

Antioch Fishing Pier and fishing sites, City of Antioch: land and water access; parking, restrooms

Hogback Park, Sacramento County Parks and Recreation (SCPR): land and water access; launch ramps, guest dock, picnic area, parking, restrooms

Lower Sherman Island, SCPR: land and water access; launch ramp, parking, restrooms

Georgiana Slough Fishing Access, SCPR: land and water access; parking, restrooms

Cliff House Fishing Access, SCPR: land and water access; parking, restrooms

Buckley Cove Marina Park, City of Stockton: land and water access; water frontage, fishing berths, launch lanes, parking, restrooms, gas and repair services, snack bar, playgrounds, organized recreational program

Table 2. Public Recreational Facilities (continued)

Louis Park, City of Stockton: land and water access; water frontage, bank fishing, dock launch lanes, boating, parking, bicycle racks, picnic areas, playing fields, restrooms, gas and repair services, snack bar, organized recreational activities

Fritz Grupe Park, City of Stockton: land and water access; water frontage, fishing, picnic area, parking, bicycle racks, playing fields, restrooms, organized recreational programs

Table 2. Public Recreation Facilities (continued)

Channel I-5 Boat Ramp Park, City of Stockton: land and water access; dock, launch lanes, sailing, low speed boating, picnic area, restrooms

Mandeville Tip Park, Port of Stockton: water access only; boat dock, picnic area, restrooms

South Spud Island County Park, San Joaquin County Parks Department (SJCPD): water access only; undeveloped natural reserve, water related activities only

Oak Grove Regional Park, SJCPD): land access; lake, picnic areas, dock, nature trails, interpretive center

Dos Reis County Park, SJCPD: land and water access; water frontage, launch ramp, water activities

Mossdale Crossing Park, SJCPD): land and water access; launch ramp, parking, restrooms

Clarksburg Boat Ramp, Yolo County Parks Department: land and water access; launch ramp, unpaved parking, restrooms

Rio Vista Public Launch Ramp and riverbank, City of Rio Vista: land and water access; parking, launch ramp, pier, barbecue pits

Sandy Beach Park, Solano County Parks Department: land and water access; campsites, showers, picnic areas, parking, beach area, paved roads

Source: California State Lands Commission, 1991.

Table 3. Recreation Attendance

Attendance Record - Brannan Island State Park Recreation Area
Number of visitors per year

1974	134,248
1975	129,890
1976	145,963
1977	72,910
1978	174,722
1979	170,247
1980	169,376
1981	168,841
1982	173,260
1983	159,824
1984	181,504
1985	191,169
1986	191,668
1987	213,294
1988	220,872

Delta Meadows Recreation Area - Attendance
Number of visitors per fiscal year

1986 / 87	1,494
1987 / 88	1,946
1988 / 89	3,228
1989 / 90	3,748

Source: California State Lands Commission, 1991.

are valued at $11,000,000. Power transmission lines for Pacific Gas and Electric Company, and Western Area Power Administration cross the Delta. Deepwater channels to Sacramento and to Stockton transport six million tons of cargo annually (Delta Atlas, 1987).

Water Diversions

Next to reclamation, the alteration of the Delta's natural streamflows in support of various water diversions have had the greatest impact on the Delta. Two types of water diversions can be found in the Delta--directly from Delta waters and via aqueducts through or around the Delta. Of the first type, the Central Valley Project and the State Water Project are perhaps best known. The Contra Costa Canal and the City of Vallejo also draw water directly from the Delta as does western Delta industry and over 1,800 agricultural users. Aqueducts transport water through or around the Delta for the San Francisco Public Utilities Commission, and for the East Bay Municipal Utility District, i.e., the Mokelumne Aqueduct (Delta Atlas, 1987; Logan, 1990).

The two largest water diversion agencies, the Central Valley Project and the State Water Project, operate on the basic principle of moving fresh water from where it is to where it is used. Two-thirds of California's water supply is carried in the streams and rivers of the northern third of the state; approximately ninety-five percent of the fresh water inflow to the Delta occurs as runoff. However, two-thirds of the state's water consumption is in the southern two-thirds of California. Water diverted through and exported from the Delta accounts for forty-eight percent of California's total net water use of 34.2 million acre-feet (MAF), and fifty-one percent of California's total water supply. Annual Delta outflow has been reduced by approximately fifty percent from its estimated natural flow of 30.23 MAF. From the Sacramento basin comes 22.39 MAF, from the San Joaquin 6.39 MAF, and 1.54 MAF from the other Delta tributaries (MacDiarmid, 1975; California State Lands Commission, 1991).

The Central Valley Project (CVP) is operated by the Bureau of Reclamation (BOR), a division of the federal Department of the Interior (California State Lands Commission, 1991). In 1985, the CVP carried 7.4 MAF of water to Californian consumers; 2.79 MAF of this water was from the Delta. Begun in 1937, the CVP was the implementation of the California State Water Plan, a state project taken up by the federal government when state funding failed during the Depression years of the 1930s, with the intent of providing cheap water for family farms. CVP water is used primarily for agriculture.

The CVP stores and transfers water in 20 reservoirs and 500 miles of canals and other facilities within the drainage basins of the Sacramento, Trinity, American, and San Joaquin Rivers. Key features of the CVP include Shasta Dam, completed in 1944, and Lake Shasta, with a storage capacity of 4.5 MAF, used for power generation as it flows into the natural channel of the Sacramento River. Folsom Dam, on the American River, stores up to one million acre-feet of water and regulates the flow of the American River into the Sacramento River. Six pumps at the Tracy Pumping Plant in the southern Delta are capable of lifting up to 4,600 cubic feet of water per second vertically 197 feet into the Delta-Mendota Canal for water delivery to the southern San Joaquin Valley. The Contra Costa Channel extends from Rock Slough in the southern Delta to the San Francisco Bay area. The Friant Dam on the San Joaquin River, regulates discharge in the 150-mile-long Friant-Kern Canal, the longest man-made channel in the CVP.

CVP facilities provide water for agriculture, urban supplies, water quality maintenance, flood control, power generation, recreation, and enhancement of fish and wildlife (California State Lands Commission, 1991; Worster, 1985). However, officials of the Bureau of Reclamation, the operators of the CVP, have claimed that CVP obligations to salinity control within the Delta extend only as far as necessary to protect the quality of export water at the intakes to the Contra Costa Channel and the Tracy Pumping Plant (Anthrop, 1982; MacDiarmid, 1975).

The State Water Project (SWP) is operated by the State Department of Water Resources (DWR). Authorized in 1959, the SWP was basically an extension of the Central Valley Project. CVP facilities were, as previously mentioned, originally components of a state project which, when funding failed, was taken up by the federal government. However, the SWP was also initiated due to conflicts over State versus Federal control and to circumvent the acreage limitations of 160 acres associated with the federal CVP. Through projects completed in phases, the SWP annually delivers approximately 1.1 MAF to municipal, industrial, and other users; agriculture uses an additional 1.3 MAF (California State Lands Commission, 1991).

Lake Oroville, behind the Oroville Dam on the Feather River, a tributary of the Sacramento, is the principal storage facility of the SWP, with a capacity of 3.54 MAF. The North Bay Aqueduct in the northern Delta delivers water to Napa and Solano Counties. SWP facilities in the southern Delta include the Clifton Court Forebay, John E. Skinner Delta Fish Protective Facility, and the Harvey O. Banks Delta Pumping Plant. The Forebay at present has a storage capacity of 28,700 acre-feet (af). The Banks Pumping Plant has seven pumps capable of lifting 6,400 cubic feet per second (cfs) into the California Aqueduct, for delivery to the San Joaquin Valley and southern California; future development plans include four additional pumps to increase capacity to

10,300 cfs. The South Bay Aqueduct servicing the Santa Clara Valley extends from the California Aqueduct. The California Aqueduct transports water from the Banks Pumping Plant south through the San Joaquin Valley. A series of pumps then lifts this water over the Tehachapi Mountains to consumers in southern California, the largest of which is the Metropolitan Water District (California State Lands Commission, 1991).

Much of the impetus behind both the CVP and the SWP were problems of salinity incursion during the drought years of 1917-1935, during which Delta agriculture was threatened. The regulated release of water stored upstream by both the CVP and SWP was to maintain fresh water inflow into the Delta to keep salinity incursion at bay (Anthrop, 1982). However, as noted, CVP priorities went only as far as to protect export water at the Contra Costa and Tracy intakes. SWP developments, such as channel widening and additional pumps, have concentrated on increasing supply capabilities.

A major issue of contention is between the growing demands for exported water and the needs for maintaining the biological health and diversity of the Delta, particularly during periods of drought and reduced fresh water availability. Salinity incursion has in effect been exacerbated by CVP and SWP pumping operations. This problem of salinity incursion in the Delta, with the Peripheral Canal as one proposed solution, are discussed further in the next chapter.

CHAPTER 3
PROBLEMS FOR RECLAMATION IN THE DELTA

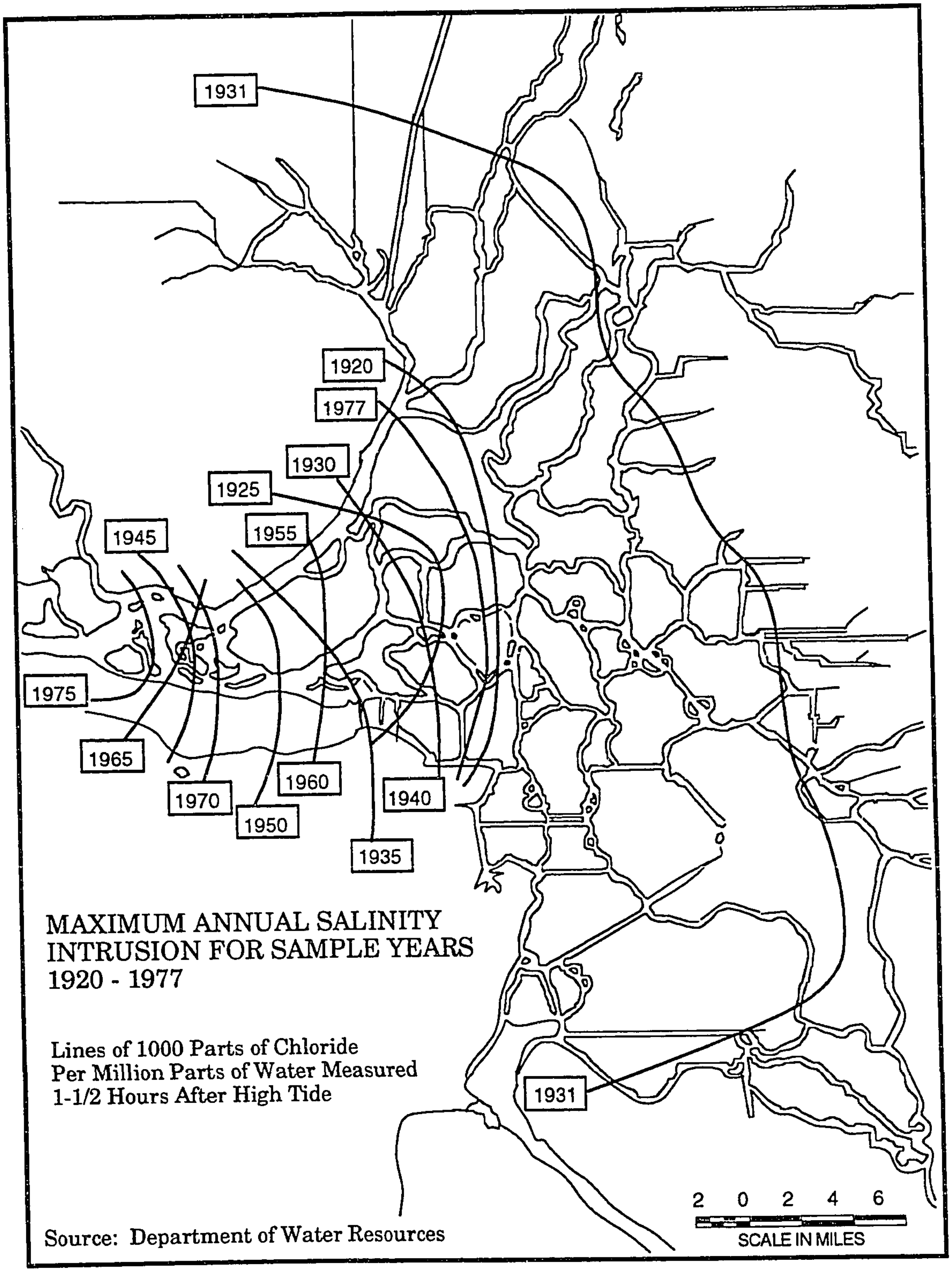
Recurrent Problems

Recurrent problems for users in the Delta, saltwater intrusion and land subsidence, are natural occurrences. However, they are exacerbated by the area's present usage. The present use of the Delta is also threatened by the stability of the levees that protect the land from inundation.

Saltwater Intrusion

The fresh waters draining the Central Valley converge in the Delta, and flow to the Pacific Ocean by way of Suisun Bay, Carquinez Strait, San Pablo Bay, the upper San Francisco Bay, and through the Golden Gate. Fresh and saltwater mix at the western edge of the Delta. This mixing, or null, zone fluctuates two to six miles within the estuarine system with daily tidal action (California State Lands Commission, 1991).

The fresh water flowing into the Delta acts as a barrier against saltwater tides. How far water high in salinity migrates into the Delta is dependent upon the daily tidal cycles, the amount of fresh water discharge into the Delta's waterways, as well as the level of pumping operations for water transfers (Map 4). The point of transition is determined by various testing stations throughout the Delta, measuring saline levels of 1,000 parts of chlorides per million parts of water (MacDiarmid, 1975; Delta Atlas, 1987). The degree of salinity intrusion into the Bay-Delta estuarine system was markedly checked after the completion of Shasta Dam in 1944 as part of the Central Valley Project. The dam allowed a steady flow of 3,300 cubic feet per

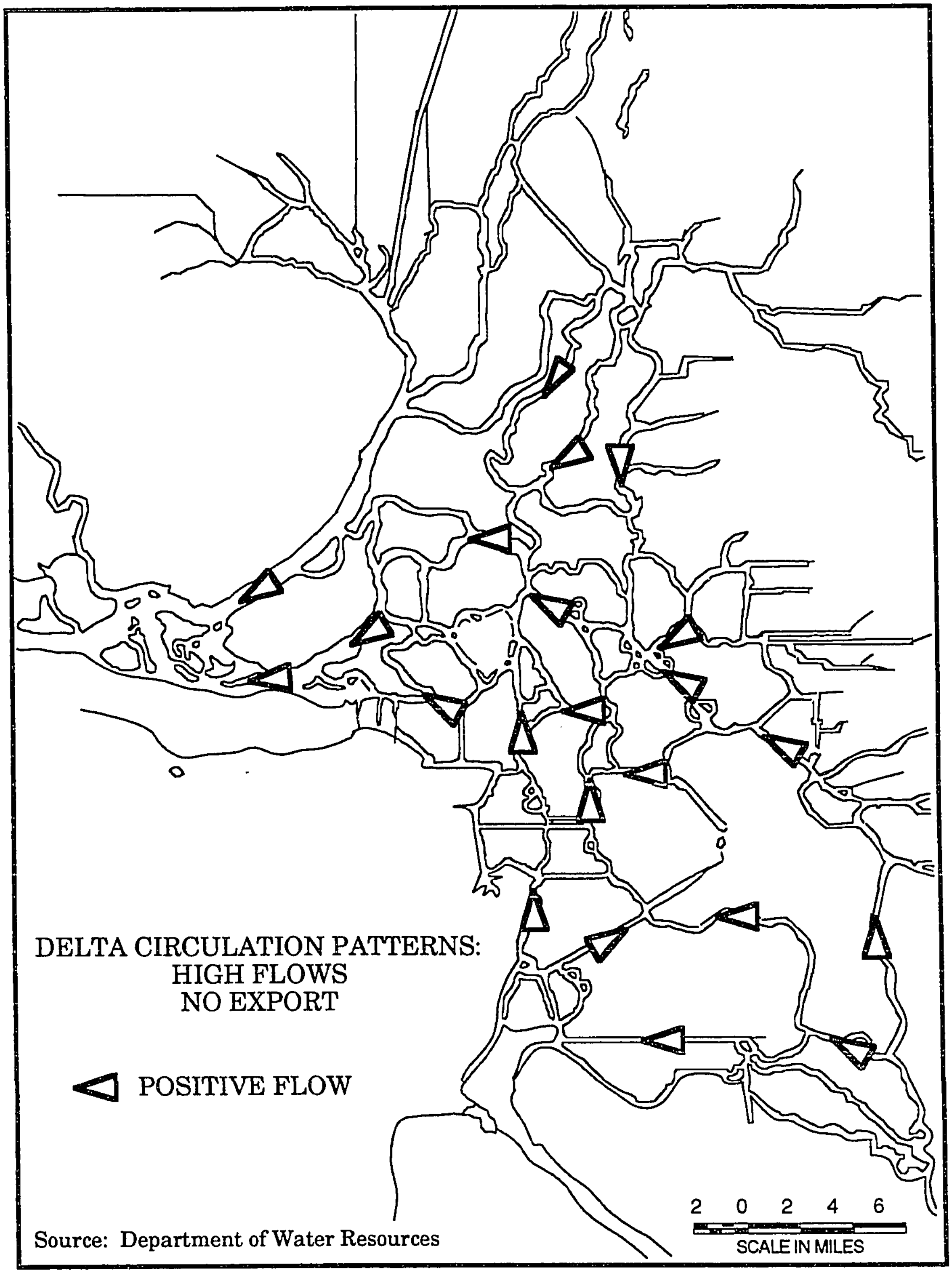


Map 4. Maximum Annual Salinity Intrusion For Sample Years 1920 - 1977

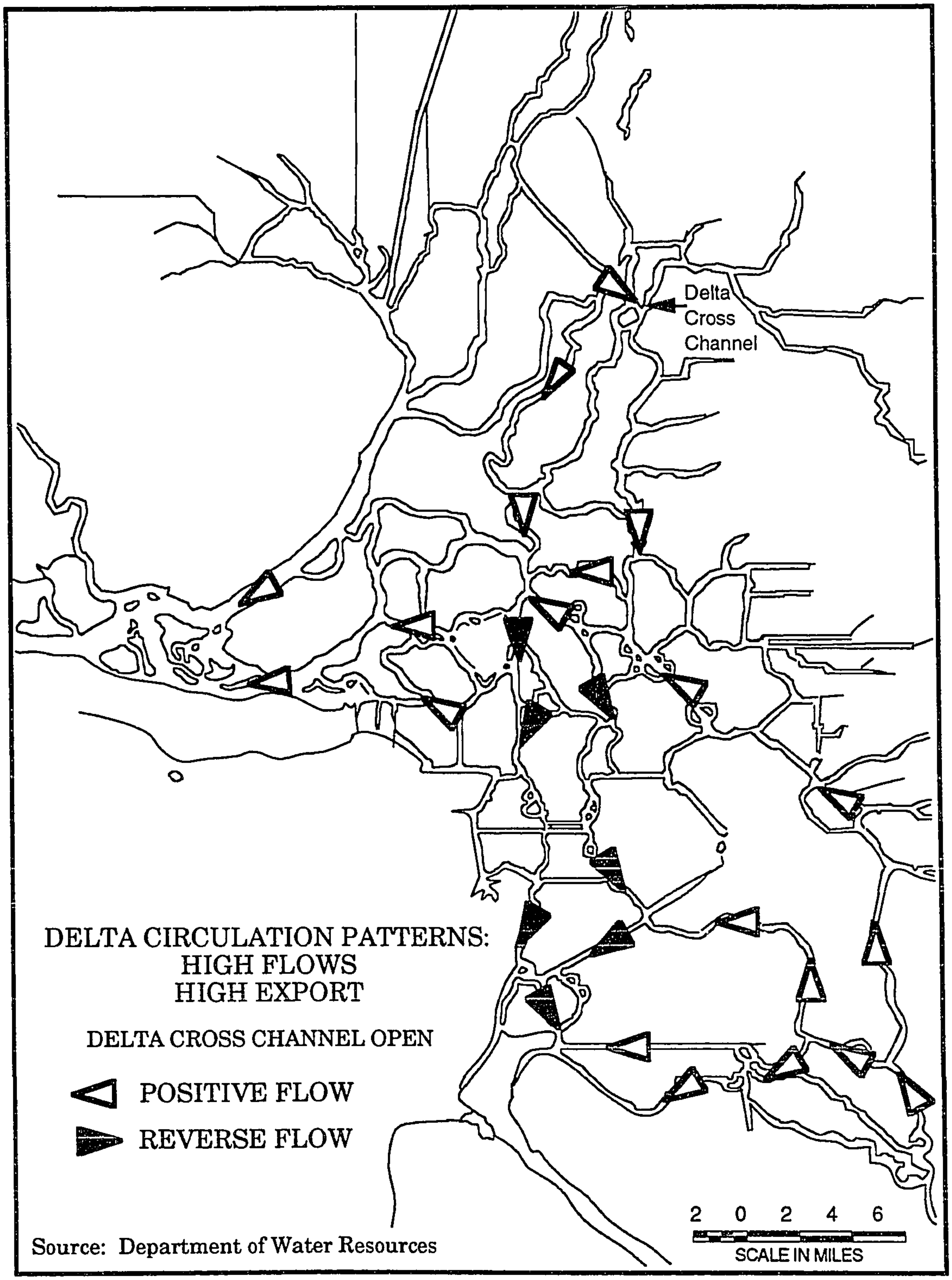
second (cfs) of fresh water to repel saltwater intrusion into the Delta (Anthrop, 1982). As previously mentioned, much of the impetus behind the flood control devices of the CVP and SWP was to forestall the damaging impacts of future droughts, such as that which affected Delta agriculture during the drought years of 1917-1935, by insuring regulated freshwater inflow into the Delta. However, during the drought of 1976-1977, saltwater intrusion into the Delta was exacerbated by the water transfer programs that were then in operation.

The drought of 1976-1977 had great impacts upon Delta agriculture, waterfowl and wildlife, and fish populations. Poor water quality damaged crops and contributed to salt build-up in soils. Habitat for waterfowl and other wildlife diminished as fresh water marsh dried up. This caused crowded conditions in the remaining habitat, increasing the threat of disease, as well as depredation of agricultural crops sought out as an alternate food source. Fish, particularly anadromous species, were victimized by reduced river flows and higher temperatures in these waters, as noted in the section on Flora and Fauna (The Continuing California Drought, 1977). Fish were also victimized by alterations in circulation within the Delta, which is greatly affected by the ratio of freshwater inflow and the level of export pumping (Maps 5, 6, 7).

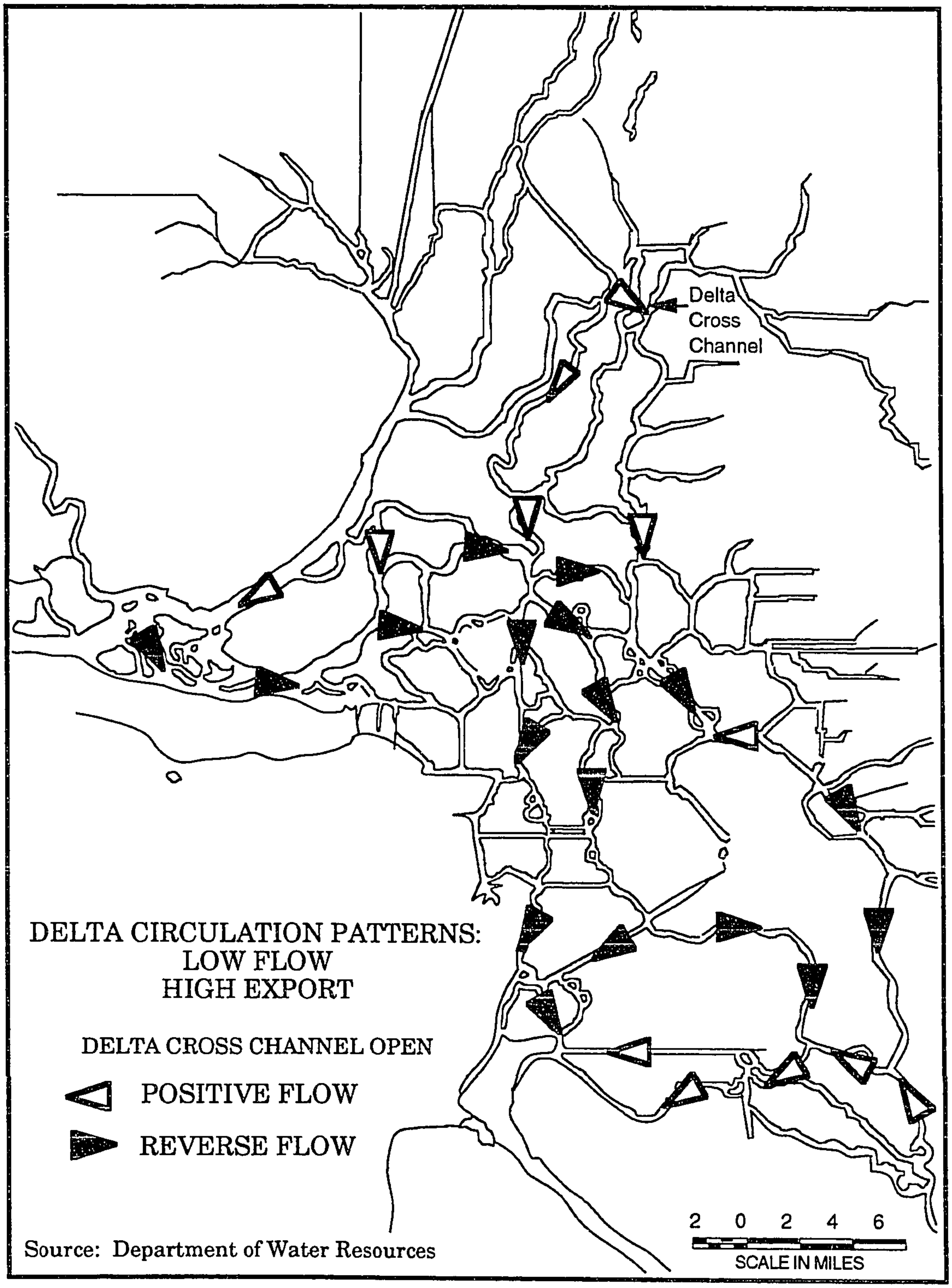
The State Water Resources Control Board (SWRCB) passed Decision 1485 in August 1978, setting numerical water quality standards for Delta outflow, export rates, chloride levels, and electrical conductivity. Electrical conductivity (EC) is a general measure of dissolved materials in water, and is indicative of salinity levels. EC levels are the most commonly measured water quality variable in the Delta by the monitoring stations placed throughout the Delta. These water quality standards were aimed to protect fish and wildlife, agriculture, and municipal and industrial uses, at the same time adjusting to year-to-year hydrologic changes. Decision 1485 also amended previous water



Map 5. Delta Circulation Patterns: High Flows, No Export



Map 6. Delta Circulation Patterns: High Flows, High Export



Map 7. Delta Circulation Patterns: Low Flows, High Export

rights permits of the DWR for SWP facilities, and the BOR for CVP facilities. Nevertheless, the Environmental Protection Agency (EPA) deemed the 1978 water quality standards inadequate (California State Lands Commission, 1991; Jones and Stokes, 1990).

Water quality in the Delta is again under pressure because of reduced streamflow after five successive years of drought in California and growing demands of water transfers. Such pressures are evidenced by the impacts on aquatic life in the Delta mentioned previously. SWRCB hearings have been held since 1978, with limited success, in an attempt to establish water flow and quality standards that will both accommodate water transfers by the CVP and SWP as well as protect the fish and wildlife species of the Delta, to avert reoccurrence of the damaging effects of the 1977-1978 drought (California State Lands Commission, 1991).

This most recent drought resulted in severe conservation programs throughout California; Los Angeles had the stiffest water rationing in the city's history (Kramer, 3/6/91). Once again, major criticisms of California water policies and transfers, and subsequent impacts of diversion operations, have come to the fore. (Associated Press, 3/22/91; McClatchy, 3/14/91 and 5/10/91; Perlman, 4/19/91; Robinson, 2/27/91). One strategy to increase the availability of exportable water is a recent development instigated by these severe drought conditions, namely "water banking." This concept has holders of water rights, namely farmers, transferring water allotments to state and federal agency water banks to increase available water supplies to meet export oblications (McClatchy, 4/30/91 and 5/9/91).

The Peripheral Canal is one of the phased projects included in the State Water Plan designed to provide high quality export water. The canal would divert water from the Sacramento River, low in salinity, directly to the Tracy pumping plants, bypassing the Delta. Release gates would maintain positive flows in Delta channels, designed to eliminate problems of reverse flow in the San Joaquin River, reduce the amount of water needed for salinity repulsion, as well as meet fish and wildlife needs. However, two decades of legislative study and debate have failed to assure the canal's ability to meet water flow and quality standards. California voters rejected the project in a 1982 referendum election over both environmental and cost concerns. Still, proposed variations of a Delta by-pass canal are introduced in almost every legislative session (Anthrop, 1982; MacDiarmid, 1975; California State Lands Commission, 1991; Reisner, 1986). Proposals have also been made to allow greater levels of chlorides in the transferred water, resulting in saltier-tasting drinking water, as happened during the 1976-1977 drought. Chloride can be tasted in water at levels of 250 PPM, the drinking-water standard level recommended by the U. S. Public Health Service. During the more recent drought, since 1987, chloride levels have reached as high as 265 PPM. Such proposals to loosen water quality standards are countered with more demands for water conservation measures to lessen water demands, and hesitation to permit new development when the ability to supply water is in question (McClatchy, 2/27/91; Fortney, 1991).

Land Subsidence

The primary contributor to subsidence in the Delta today is attributed to oxidation of the peat soils, followed by wind erosion and other factors such as compaction from heavy farm equipment. Some Delta island floors are subsiding at a maximum rate of almost three inches per year. Sherman Island, for example, has subsided twenty feet since its reclamation in 1869, averaging about two inches per year (West Delta Water Management

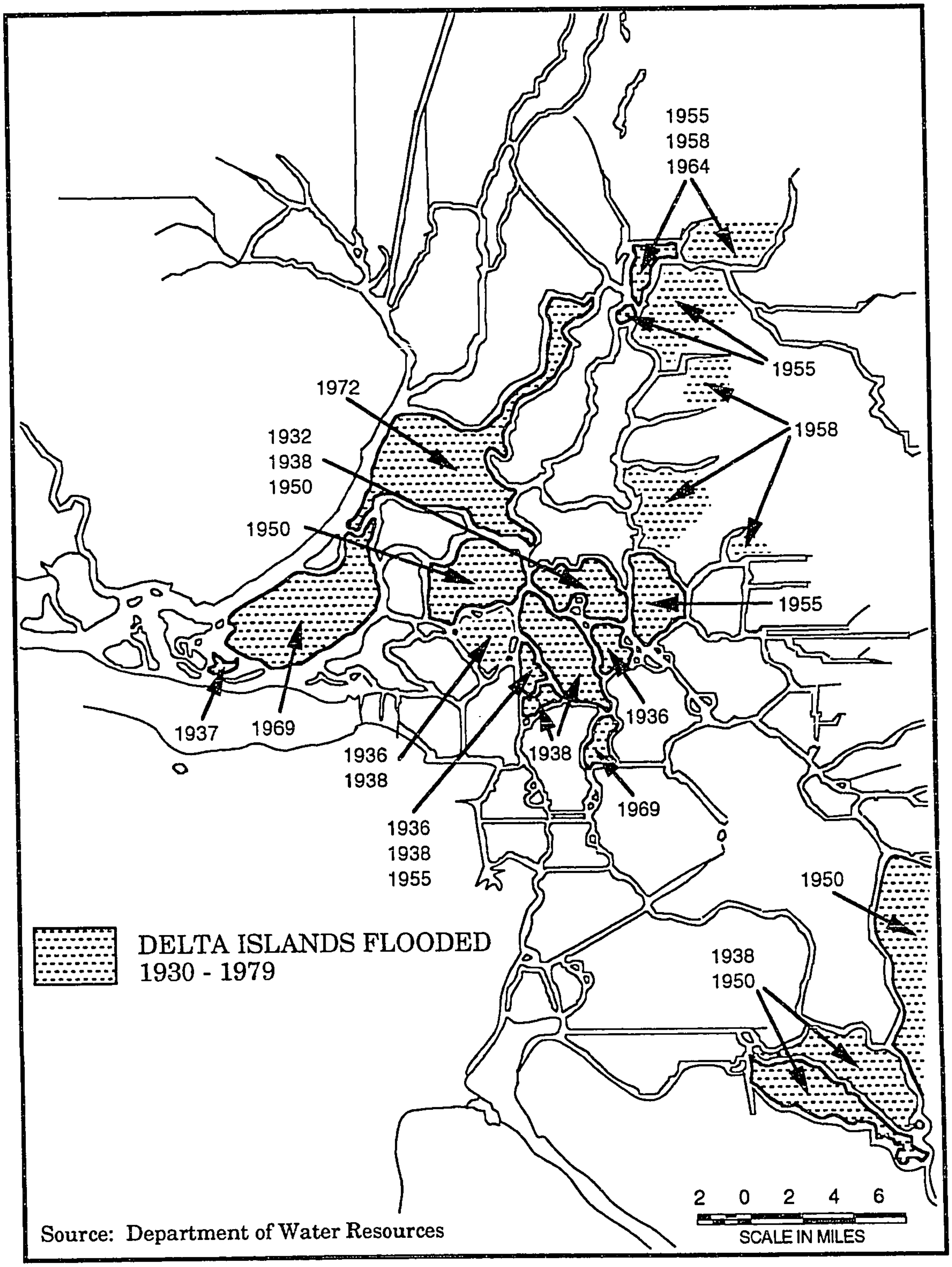
Program, July 1988).

Oxidation occurs when water is removed from organic soils, exposing the soil to aerobic decomposition. Tilling the soil not only increases oxidation but exposes the soil to wind erosion. Wind contributes to subsidence by carrying away dried peat soil, which is very light and easily blown away. The wetting and drying cycle of crop irrigation adds to subsidence problems because peat soils shrink as they dry. The practice of controlled burning of the peat soils for weed and pest removal is a further cause of soil loss. Other possible contributing factors under investigation include natural consolidation, tectonic movement, and extractions of ground water, gas, and oil (Newmarch, 1989).

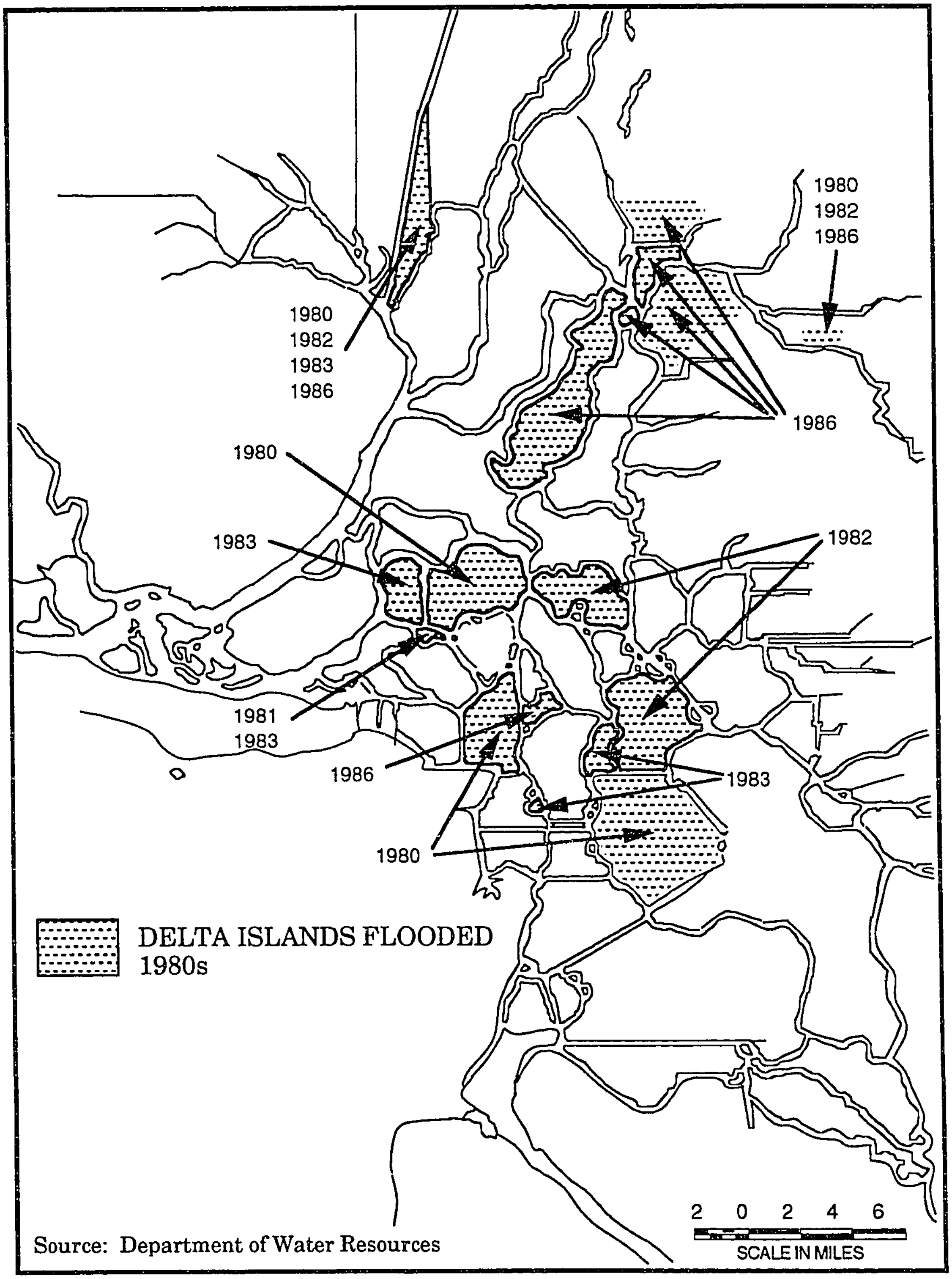
Levee Instability

Levees are some of the easiest and, initially, cheapest forms of flood control and land reclamation. The levees in the Delta are categorized as either project or nonproject levees. Project levees are part of the Federal Flood Control Project, and are maintained by the Army Corps of Engineers or according to the Corps guidelines. Nonproject levees are maintained by local agencies. Of a total 1,100-mile levee network, 165 miles are classified as project levees, 110 miles are direct agreement levees, and 825 miles are nonproject levees (Delta Atlas, 1987).

Flooding has been a continual problem in the Delta (Map 8). Floods and levee failures in the Delta between 1980 and 1986 (Map 9) incurred costs of $97 million, $92 million of which was emergency disaster assistance through State and Federal programs. Federal Emergency Management Agency (FEMA) funds are channeled through the Office of Emergency Services (OES) (Riebsame & Jacobs, 1988). Due to the enormous costs of repairs in such an area of recurrent flooding, FEMA pushed for the inclusion of minimum



Map 8. Delta Islands Flooded 1930 - 1979



Map 9. Delta Islands Flooded 1980s

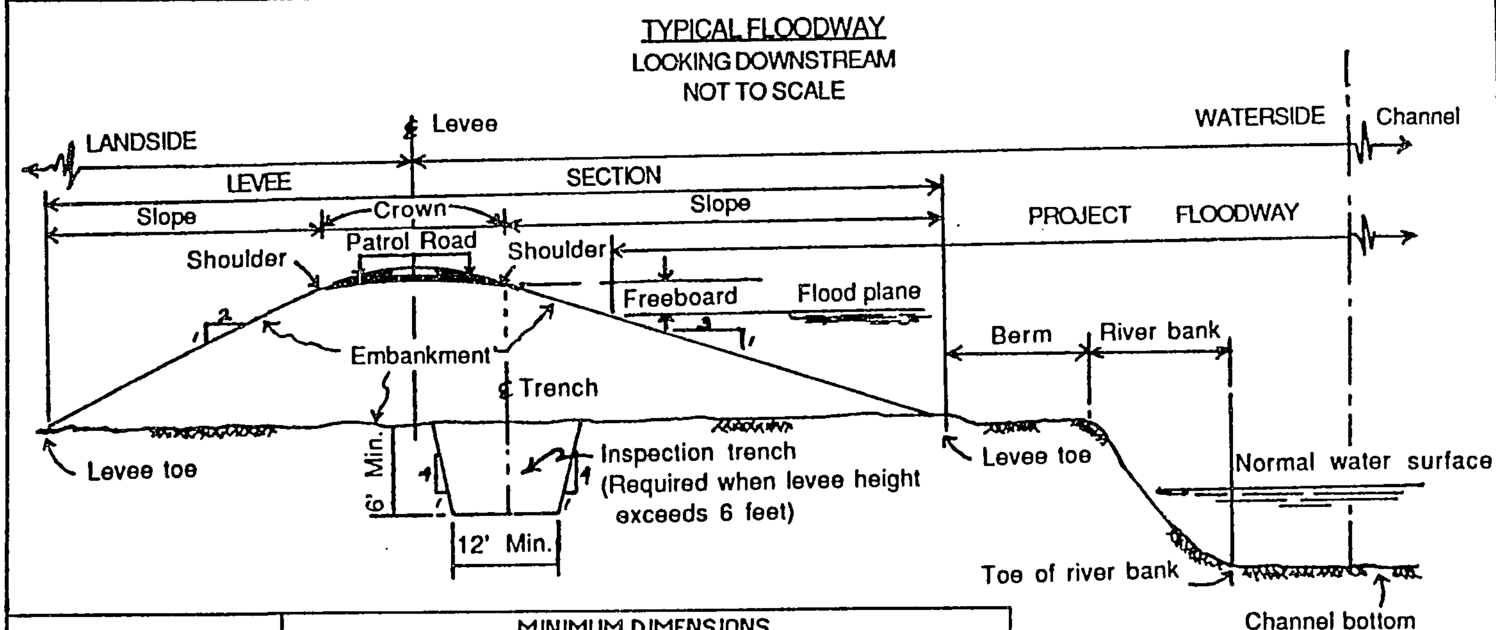
standards of levee maintenance in the Delta (Figure 1). If Reclamation Districts have not conformed to the proposed 1991 deadline, they might not be eligible for emergency relief from FEMA in future flood events. The minimum criteria for levees incorporated into the 1986 Hazard Mitigation Plan are: (1) One foot of freeboard above 100-year-flood elevations; (2) Minimum crown width of sixteen feet; (3) Waterside slopes of 1.5 horizontal to 1 vertical; and (4) Landward slopes of 2 horizontal to 1 vertical (Nozuka, 1989).

A status report for fiscal year 1986-87 indicated that forty-one out of fifty-six islands had submitted Hazard Mitigation Plan (HMP) packets as requested. Of those forty-one islands, twenty-three (56%) met or exceeded the FEMA criteria; four of these islands are included in the case study. Five islands (12%) had eighty to ninety percent of their levees at or above the criteria; none of the islands in the case study fall into this designation. Thirteen islands (32%) had seventy-nine percent or less of their levee system up to the set standards; the remaining six case study islands are in this category (Nozuka, January 1989).

The Delta Flood Protection Act of 1988 (Senate Bill 34) authorized $12 million per year until January 1999 for levee restoration and associated projects in the Delta. One such project is the protection of eight western islands--Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb--considered essential to prevent salinity intrusion into the delta. Two of these islands, Holland and Webb, are included in the Delta Wetlands project previously mentioned. The ten islands examined in this thesis, however, are utilized solely for agricultural purposes; neither capital improvements, such as highways, nor water quality maintenance are dependent upon whether these islands remain intact or flood in the future.

As mentioned in the introduction, the importance of maintaining levee

Figure 1. Project Levee Standards and Terminology



ITEM	MINIMUM DIMENSIONS OF STANDARD LEVEE SECTIONS			
	MAIN RIVER CHANNELS	MAJOR TRIBUTARIES	MINOR TRIBUTARIES	BY-PASSES
CROWN WIDTH	20'	20'	12'	20'
LAND SLOPE	1 on 2	1 on 2	1 on 2	1 on 2
WATER SLOPE	1 on 3	1 on 3	1 on 3	1 on 3
FREEBOARD	3' *	3'	3'	4' to 6'
PATROL ROAD WIDTH	12'	12'	10'	12'

NOTE * 5 feet on Main Channel below Cache Slough (Sacramento River)

Source: Snow, 1990.

integrity in support of water transfers in the Delta became apparent early in the operation of the State Water Project. The A. D. Edmonston Pumping Plant, located at the southern end of the San Joaquin Valley, went into operation in October 1971, pumping the first waters from the California Aqueduct over the Tehachapi Mountains. Eight months later, on the morning of June 21, 1972, the levee separating Andrus Island from the San Joaquin River in the Delta began to fail. Andrus and adjoining Brannan Island were flooded within days. The rush of water into these Delta islands created a giant suction drawing sea water into the Delta. To reduce chloride levels from a high of 440 PPM to the 250 PPM drinking water standard levels recommended by the U. S. Public Health Service, about 300,000 acre-feet of stored water was released and 53,000 tons of additional salts were removed form the Delta through project canals (Jackson and Paterson, 1977).

Potential Problems for Reclamation

Besides the historical problems of saltwater intrusion, land subsidence, and flooding, other concerns could cause havoc to present land use in the Delta, namely global warming and seismic activity.

Global Warming

Controversy exists on whether global warming is occurring or not, but research has been underway to determine possible consequences. Global warming may affect fresh water inflow and sea level, both of which could have major impacts on a low-lying area such as the Delta.

The timing and quantity of fresh water inflow may be affected, compounding existing problems with saltwater intrusion (Buddemeier, 1988; Riebsame and Jacobs, 1988). An interim report by the Intergovernmental

Relations Committee of the California Energy Commission estimates that temperatures in California could increase by 2.7°F to 8.1°F by the mid twenty-first century. An increase of 5.4°F, the median of these two estimates, could cause increased winter streamflows and decreased spring streamflows.

Sea level could increase from 1.6 to 4.9 feet due to thermal expansion and glacial melting, increasing the probability of inundation of land already below sea level in the Delta. Coastal habitats and other lowlands would be reduced, with a possible tripling in size of the San Francisco Bay system. A sea level increase of 3.2 feet is predicted to increase pressure on the Delta's levees by sixty-five percent. Even a modest estimate of a one foot sea level rise predicts severe effects on the Delta. River levels in the past have exceeded critical overtopping levels 31.5% of the time. A one foot rise in sea level would increase the probability of such occurances to 61.3%. Associated costs of continued reclamation of all Delta islands would increase by eighty-six percent, from an average annual total cost of $18.2 million (in 1986 dollars) to an expected annual cost of $34 million (Logan, 1990).

Seismic Activity

Seismic activity could have a catastrophic effect on already questionable levee stability (Table 4). Levees are composed primarily of unconsolidated soils--peat, silts, sand, and mud--with sandy foundations. These materials are very susceptible to liquefaction, a process in which intense shaking causes water-saturated soils to become semi-liquid. Levees in the Delta may have been damaged after the 1906 San Francisco earthquake, but studies are inconclusive. The levees at that time were not built nearly as high, nor were island interiors as far below sea level as at present. However, during the 1907 flood season, the first since the earthquake, 53 of the 60 major

Table 4. Earthquake-Related Damage to Delta Levees

Coyote Lake, epicenter 8/6/79 5.9 magnitude

Mandeville Island (65 miles from epicenter): 500-foot section of west levee moved landward several feet

Livermore, epicenter 1/24/80 5.9 magnitude

Bacon Island (15 miles from epicenter): 250-foot land-side rotational slip-out dropped several feet

Empire Tract (20 miles from epicenter): 200-foot land-side rotational slip-out dropped 6 inches

Coalinga, epicenter 5/2/83 6.7 magnitude

Webb Tract (150 miles from epicenter): 500-foot crack opened along levee crown up to 5 feet wide; 4 or 5 land-side rotational slip-outs caused bulldozer to fall off levee; "Garratt Well", an abandoned artesian well and the site of seepage for many years, stopped flowing

Venice Island (150 miles from epicenter): 500-foot crack opened on land-side toe of levee and dropped from several inches to over 2 feet; seepage stopped in an area of persistent leakage; several cracks opened at site of 1982 levee break, 1 crack 400 feet long and 10 to 20 feet deep, another crack had water pouring out of it; 1,000-foot crack ran along levee toe, up to 3 feet wide and 10 to 15 feet deep; 14 wooden pilings, the foundations of an abandoned horse barn, popped up in a field, the piling tops evenly 9 feet above ground surface

King Island (160 miles from epicenter): concrete floor of shed cracked for a length of 25 feet and settled about 8 inches

Pittsburg, epicenter 6/5/83 3.6 magnitude

Webb Tract (15 miles from epicenter): several minor cracks at right angles to Coalinga damage area

Morgan Hill, epicenter 4/24/84 6.2 magnitude

Webb Tract (60 miles from epicenter): 6 parallel cracks, 1 inch wide and 75 feet long, and a 25-foot long and 1 inch wide crack developed

Venice Island (60 miles from epicenter): a preexisting 25-foot long crack lengthened 75 feet, and the land side of levee dropped 2 inches

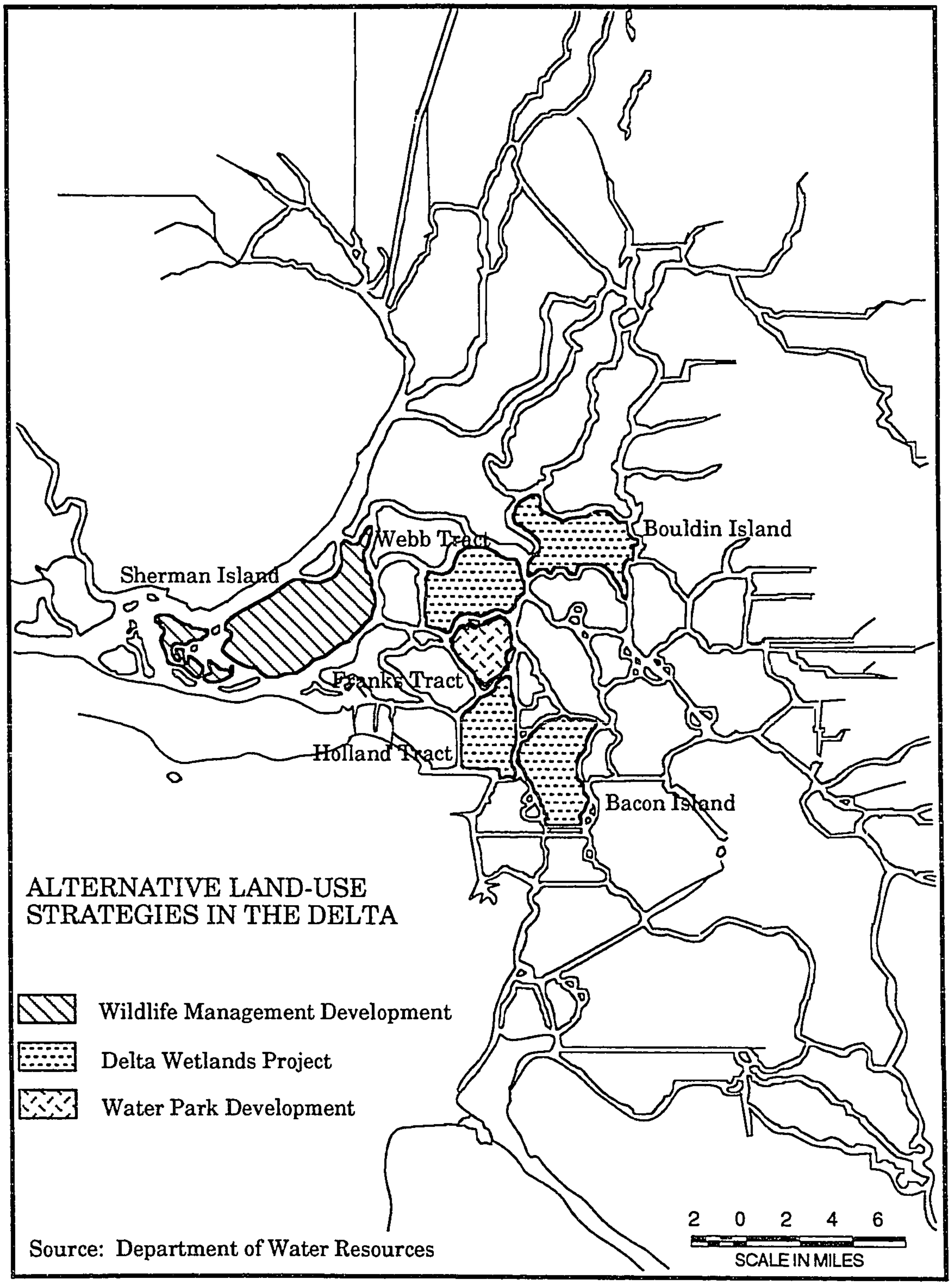
Source: California State Lands Commission, 1991.

islands flooded. Levee damage may also have occurred after the 1979 Coyote Lake earthquake, the 1980 Livermore earthquake, the 1983 Coalinga earthquake, the Pittsburg earthquake in 1983, and the Morgan Hill earthquake in 1984, even with epicenters as far away as 150 miles or more. No visible damage to Delta levees was reported after the magnitude 7.1 Loma Prieta earthquake in 1989 (California State Lands Commission, 1991; Reisner, 1989).

Complex groupings of fault fractures are found west of the Delta, including the Green Valley Fault. Also proximal to the Delta are the Midland, Sunol-Calaveras, and Winters-Vacaville Faults. While seismic activity data is not conclusive on all faults, the Antioch Fault crosses the western edge of the Delta, and has shown recent displacement activity. The Hayward and San Andreas Faults are approximately fifty and sixty miles, respectively, from the Delta. Both faults are known to be capable of producing earthquakes greater than magnitude eight on the Richter scale. Activity on any of these faults could result in levee failures, considering both the composition and condition of the levees. Saltwater intrusion would be exacerbated, as well as threatening the foundations of the Mokelumne Aqueduct (Kearney, 1980; Reisner, 1989; California State Lands Commission, 1991).

Alternative Strategies

Rather than wait for catastrophic events such as flood or earthquake to decide the future of these islands, alternative projects are now underway designed to mitigate existing land-use problems (Map 10). One strategy involves the development of the western-most island, Sherman Island, as a wildlife management area, with the Department of Water Resources as the Lead Agency, and the Department of Fish and Game as the Cooperating Agency. Another is the Delta Wetlands project, a privately-financed endeavor



Map 10. Alternative Land-Use Strategies in the Delta

that would alternate winter and spring water storage with summer and fall recreational use. Similar water storage has already been experimented with on a small scale on Tyler Island. Both strategies aim at the equalization of water pressure on the levees, the reduction of land subsidence, increased wetland habitat for wildlife and recreational facilities, as well as the protection and augmentation of quality water availability in support of water diversions.

Enhancement of Wildlife Habitat

Sherman Island is the focus of a wildlife habitat enhancement program jointly operated by the Department of Water Resources (DWR) and the Department of Fish and Game (DFG). The island, situated in the western Delta, is considered an essential barrier to saline intrusion in the waters flowing around the west end of the Delta to the Banks Pumping Plant. The major issues addressed by this program are also applicable to the rest of the Delta, namely flood control, water quality, water supply reliability, and wildlife concerns. As well, this program attends to the matters of a changing agricultural economy, increased levee maintenance costs, continuing land subsidence, and increased recognition of environmental needs.

Sherman Island was reclaimed in 1869, the first of the Delta's peat islands to be leveed completely. Peat is deepest in the western Delta, however, and the basic instability of the island's foundation resulted in repeated levee failures. The southwest portion of Sherman Island was eventually abandoned to its original tule marsh, as levees there could no longer be maintained. Since the late 1940s, crop production on Sherman Island remained fairly constant on about 9,700 acres, shifting from primarily asparagus to a mixture of wheat and corn. This crop shift is typical throughout the Delta, as mentioned in the previous section on Agriculture.

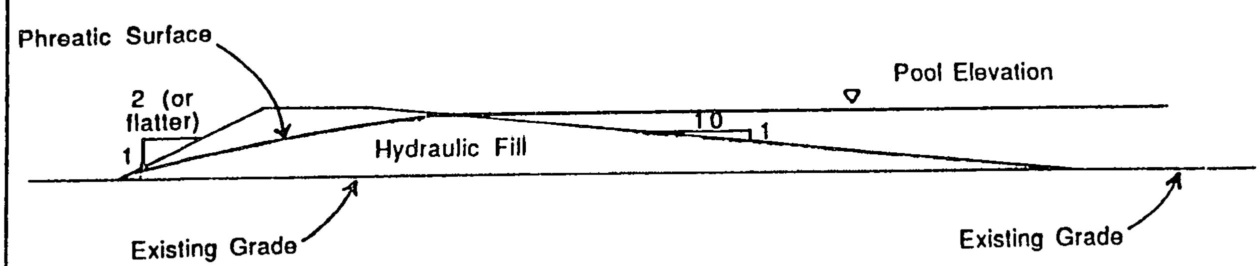
Subsidence on Sherman has been measured at twenty feet since 1869, coming to a subsidence rate of two to three inches per year (MacDiarmid, 1977; Proposed Sherman Island Wildlife Management Plan, 1990; Thompson, 1957). With the planned conversion of Sherman Island, approximately 10,000 acres of wildlife and waterfowl habitat are provided, subsidence is reduced, and recreational opportunities are increased. Rehabilitation of nonproject levees provides flood control benefits and water supply reliability to both the State Water Project and the Central Valley Project (Management of the State Water Project, September 1989).

Island Water Storage

A pilot project in water storage is underway on part of Tyler Island. On 360 acres of the 8,583-acre island, a farmer stores 800 to 1,000 acre-feet of water to sell to the Department of Water Resources for State Water Project supplies. All of Tyler Island's interior is below mean sea level (MSL); portions of the southern end are 17 feet below MSL (McClatchy, 4/27/91).

Delta Wetlands is a privately-financed project to have four islands--Bouldin, Bacon, Webb, and Holland--alternately serve as water storage units and as waterfowl wetlands. Levee interiors on the four islands would be reinforced (Figure 2). These islands would then be allowed to fill up during the wet winter and spring seasons, when channel flows are highest and subsequently the time for the greatest amount of hydrostatic pressure upon levees. During the dry summer months, up to 200,000 to 300,000 acre-feet of water would be available for sale to any water agency that wants it. The release of water to buyers in early summer would drain the islands, creating approximately 20,000 acres of waterfowl wetlands for migratory game birds. In conjunction with the wetlands, Bedford Properties, the Delta Wetlands

Figure 2. Typical Cross Section of New Interior Levees Proposed for Islands in Delta Wetlands Project



Source: Jones and Stokes Associates, Inc., 1990.

developer, would establish private boat docks, hunting clubs and clubhouses for a maximum of 800 people. There would not be public access to hunting, although guided tours of wildlife areas would be allowed. The developers estimate that 5.7% of corn and 2.1% of wheat would be taken out of production, but that wetlands acreage would be doubled. Peat oxidation and erosion would be eliminated, thus arresting subsidence and enhancing soil productivity, and pesticide runoff to Delta waters would be reduced (McClatchy, 4/27/91; Jones and Stokes, 1990).

Water Parks

Recreation is one of the major uses for the Delta, and is a likely activity to fill the economic gap left by diminishing agricultural production. Bethel Island is an example of such a shift from agriculture to recreation over time. This island supports the community of Bethel Island as well. Once intensively cultivated, the land has been abandoned to pasture (Meyer, 1991). Instead, the island is now known for its numerous recreational facilities, and is readily accessible by county roads. Bethel Island was flooded in 1926 due to levee failure caused by the improper installation of an irrigation box (Thompson, 1957). The 11.5 miles of nonproject levees are subject to severe strain due to waves whipped up by winds across the open expanse of water that was once Franks Tract, flooded since 1938.

A project is underway to mitigate this problem. Four million dollars approved by voters in 1988 is to be applied to the development of Franks Tract as a unique recreation area. The state Department of Parks and Recreation bought the tract in 1950s for about $490,000. The tract's former levees are to be reinforced, which will in turn protect Bethel Island levees. The open expanse of water would be broken up with the construction of new islands with picnic and camping areas, and with piers and docks. The primary purpose of protecting Bethel Island would thus be accomplished, at the same time providing major recreational facilities (Rasmussen, 5/7/90).

Summary

Problems with salinity intrusion, land subsidence, and levee instability have plagued users of the Delta for years. The potential havoc that global warming and seismic activity could inflict upon the present arrangement has given additional fuel to arguments in favor of alternative strategies. The levees could be completely rebuilt to withstand earthquake and flood, but the cost to do so would be enormous. Such monies might be better spent by the state of California toward the acquisition of the more vulnerable islands, and allowing them to revert to their original marshland status (Campbell, 1/22/89; California State Lands Commission, 1991; Reisner, 1989).

The discontinuation of agriculture in the Delta has been suggested, cited as the prime contributor to land subsidence, as well as the source of pesticide contamination found in Delta waters and sediments. If farming were immediately discontinued, the problem of land subsidence would be arrested, although farm stubble has became a significant food source for waterfowl and wildlife once met by the original marsh vegetation. The question of continued support for agriculture is explored further in the next chapter.

CHAPTER 4

CASE STUDY: FARMING REVENUE VERSUS LEVEE MAINTENANCE COSTS

A fundamental question regarding the Delta's present use by multiple interests is how much longer the status quo can be maintained, considering the continuing problems such multiple use generates. This thesis is directed at the question of continual reclamation and maintenance of islands in the Sacramento-San Joaquin Delta for intensive agricultural use. Such reclamation is expensive, is often damaging to aquatic life and wildlife, and is an attempt to maintain a deteriorating status quo rather than aimed at the mitigation of recurrent problems. The problematic issues associated with agriculture include: land subsidence, accelerated by intensive agriculture; high costs, generated by the continual need to raise the level of levees protecting reclaimed land as levee foundations subside and levee slopes erode; water pollution, from the pesticides used for agriculture. Herein examined are islands utilized solely for intensive agriculture by comparing income generated by crops to maintenance costs. Those islands operating at a loss would be considered at risk of non-reclamation in the event of inundation.

Delineation of Study Area

Because this thesis tests the feasibility of continued agriculture in the Sacramento-San Joaquin Delta, the study area is confined to an appropriate sample of those islands used solely for agricultural production. Therefore, those islands that support capital improvements, such as roads and utility lines, are eliminated from this study. Also eliminated are those islands that have been designated as vital to the maintenance of water quality within the Delta in support of present water transfer policies. Of the remaining islands, those for which the desired data were not available, i.e., crops grown and levee maintenance expenses, have been eliminated as well.

Islands eliminated from this study due to the capital improvements they support are:

Island	Public Roads	Railroads	Utilities	Communities	Resorts
Bacon	X		X		
Bethel	X		X	X	X
Bishop					X
Bouldin	X				
Brack	X				
Bradford			X		
Brannan-Andrus	X		X	X	X
Byron	X		X	X	X
Canal Ranch	X				
Drexler			X		
Empire	X		X		X
Fabian	X				X
Grand Island	X		X	X	X
Holland	X				X
Holt Station	X	X	X	X	
Hotchkiss	·X		X	X	X
Jersey	X		X		
Jones, Lower	X	X	X		X
Jones, Upper	X		X		X
King	X		X		X
McCormick-Williamson			X		
McDonald			X		
Naglee-Burke	X	X	X		
New Hope	X	X	X	X	X
Orwood	X	X	X		X
Palm			X		
Pierson District	X		X	X	X
Quimby			X		
Roberts, Lower		X	X		X
Roberts, Middle	X	X	X		
Roberts, Upper	X		X		
Ryer	X				X
Sargent-Barnhart	X		X		
Sherman	X		X		X
Shima	X		X		
Stark	X				

(Capital Improvements on Delta Islands - Continued)

Island	Public Roads	Railroads	Utilities	Communities	Resorts
Staten	X		X		
Stewart Tract	X	X	X	X	X
Sutter Island	X				X
Terminous	X		X	X	X
Twitchell	X		X		X
Tyler	X		X		X
Union, East	X		X		
Union, West	X		X		
Veale	X		X		
Victoria	X		X		
Walnut Grove	X			X	X
Weber	X		X		
Woodward			X		
Wright-Elmwood	X		X		

Of the remaining islands, Webb Tract's integrity is considered vital to the preservation of water quality in the Delta, thus warranting continued reclamation under present water transfer policies. Webb tract is also a component in the Delta Wetlands project, discussed previously. Franks Tract has remained flooded since 1938 but, as mentioned earlier, the area is to be developed as a water park. Donlon and Mildred Islands have been flooded since 1983. Mildred Island, however, does serve as an example of an island once used for agriculture, as are the ten islands in the case study, that remained flooded because it was no longer considered worth reclaiming. Therefore Mildred Island is included in the profiles of islands in the case study for comparative purposes.

Some islands are listed as marsh land, and are not utilized for agriculture These islands are:

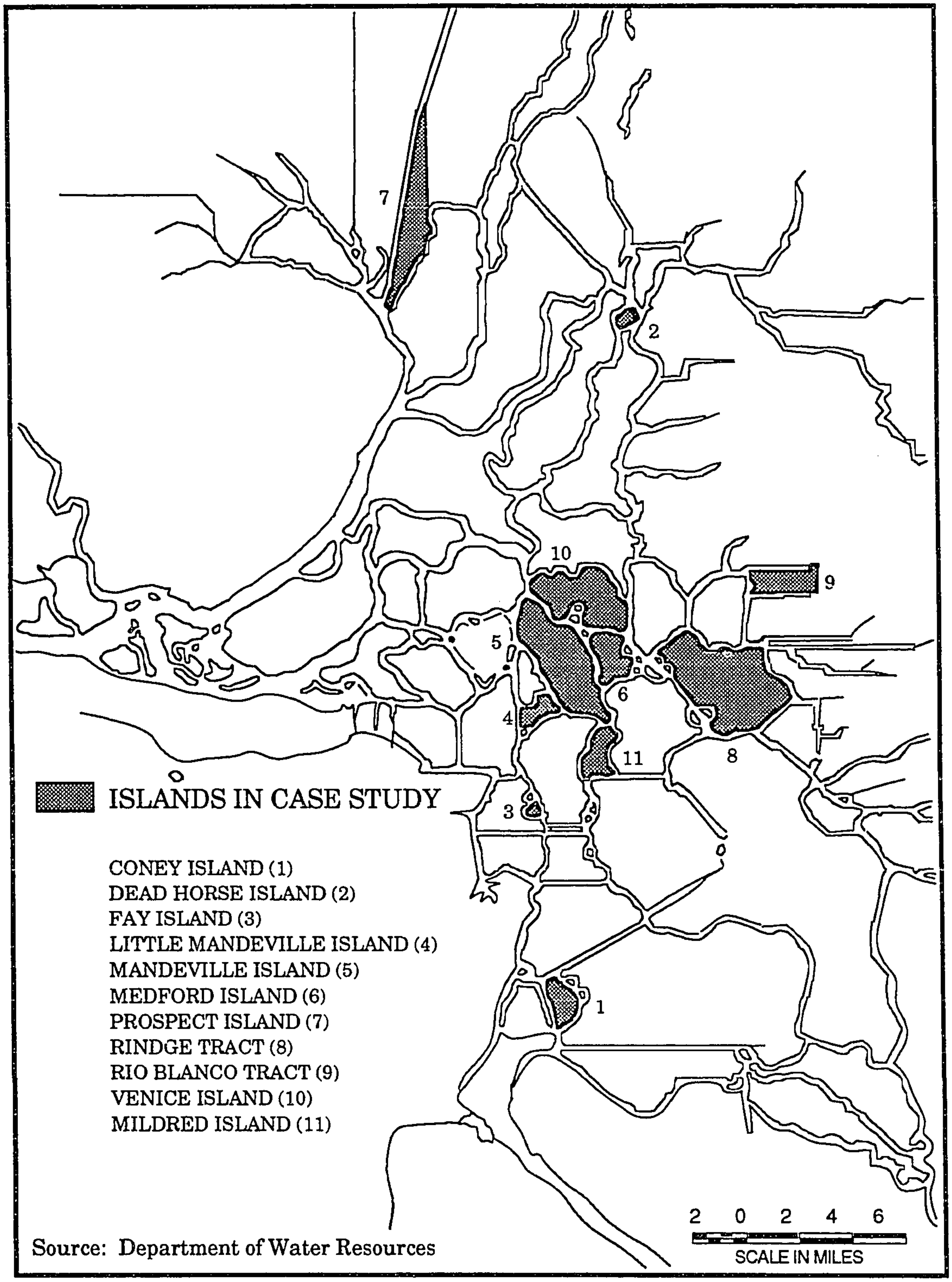
Browns Island (Regional Shoreline)
Chipps Island (SE & NE)
Rhode Island
Kimball Island
Widdow Island
Van Sickle Island (SE & NE)
Fern Island
Tinsley Island

Of the units remaining, levee maintenance expenditures were unavailable for the following islands:

Acker Island
Atlas Island
Decker Island
Hog Island
Ida Island
Liberty Island
Little Hastings Tract
Morrison Island
Morrow Island
Moss Tract
Pescadero
Pico & Naglee
Rough and Ready Island (Naval storage yard)
Shin Kee Tract
Smith Ranch
Smith Tract
Spud Island
West Island

The remaining ten Delta islands are the focus of this thesis (Map 11). All are used solely for agricultural production, with crop data and levee maintenance expenditures available for the same approximate time period, the early 1980s. These islands are:

Coney Island
Dead Horse Island
Fay Island
Little Mandeville Island
Mandeville Island
Medford Island
Prospect Island
Rindge Tract
Rio Blanco Tract
Venice Island



Map 11. Islands In Case Study

Profiles of Islands in Study Area

Basic background for the ten islands in this study includes Reclamation District Number, county and water agency jurisdiction, levee mileage and maintenance costs, acreage, crops, lowest surface elevation, when the island was reclaimed, and historic flood events. Mildred Island is included for comparison. Mildred Island, flooded in 1983, was not reclaimed as it was no longer considered economically feasible to do so. Such a decision could also be made for the ten islands examined in this thesis.

It should be noted that available acreage figures for Delta islands do vary somewhat, as will be seen in the individual profiles, because there are varying methods of measurement. The Department of Water Resources arrives at acreage figures through aerial photographs of the counties, transferring the fields from the photos to 1:24 000 United States Geological Survey (USGS) topographic maps. After initial identification, field checks are made of each field, although crops are not identified. Agricultural Commission acreage figures are arrived at through tree counts, estimates, or by asking the farmer. Unit values for individual crops in Agricultural Commission reports are derived by dividing the total income for the particular crop by the acreage (Ron Landingham, letter 6/3/91).

For the following island profiles, much of the basic information is available in the Delta Atlas, a compilation of study results gathered by the California Department of Water Resources (DWR) such as: Reclamation District, or Levee Maintenance District, numbers (p. 15); County lines (p. 56); Water Agency and District Boundaries (p. 9); annual maintenance expenditures (p. 47); emergency expenditures (p. 43); lowest surface elevation (p. 37). The status of levee conditions in relation to Hazard Mitigation Plan (HMP) and FEMA guidelines are found in the Sacramento-San Joaquin Delta

Flood Hazard Mitigation Status Report Fiscal Year 1986-87 (Nozuka, January 1989). Island flood events are charted in the Delta Atlas (p. 39), the California State Lands Commission (SLC) Report (p. 60, 61), MacDiarmid (p. 50-51), and Thompson (Appendices A and B). Crop reports for each island were provided by DWR Economist Ron Landingham for the period 1980-1986, and are supplemented by those Reclamation Districts in the study area that did respond to my questionnaire, namely Tim Wilson of Dead Horse Island, Dick Klein of Rindge Tract, and I. N. Robinson, Jr. of Rio Blanco Tract. Acreage designated as pasture or rangeland is also included in island cropping patterns because this land is incorporated and evaluated as a crop in county agricultural reports.

Coney Island

Coney Island, Reclamation District Number 2117, is located in Contra Costa County, within Contra Costa County Water Agency jurisdiction. The island is protected by 5.4 miles of non-project levee. Annual levee maintenance expenditures for the period 1981-1986 were $19,360 per levee mile, for a total of $104,544. Ninety percent or more of the island's levees meet or exceed HMP standards. Cropping patterns on Coney Island in 1985 include 202 acres of grain (unspecified), 34 acres planted to safflower, and 86 acres of pasture or rangeland. Farmsteads make up 3 acres, recreational residential 13 acres, with 151 acres designated as lakes, rivers, and reservoir. These land-use figures total 557 acres. However, other DWR figures list the acreage for Coney Island at 935. Originally reclaimed between 1893 and 1897 as Reclamation District Number 802, levees occupy 10 percent of Coney Island's 1,000 acres. Levee failure occurred on Coney Island in 1907. The lowest surface elevation on the island has been measured at -9 feet below sea level.

Dead Horse Island

Dead Horse Island, Reclamation District Number 2111, is located in Sacramento County, within the North Delta Water Agency jurisdiction. The island is protected by 2.6 miles of non-project levees. Annual levee maintenance expenditures for the period 1981-1986 amount to $6,890 per mile, or $17,914 total annually. Ninety percent or more of the island's levees meet or exceed HMP standards. In 1984, the crops grown on Dead Horse Island were 190 acres of field or sweet corn, with 14 acres devoted to pasture or rangeland. These figures total 204 acres; DWR levee maintenance figures list 211 acres for the island. In his reply to my questionnaire, Tim Wilson of Dead Horse Island indicates 220 acres gross, 180 acres of which are farmland. All of the land is planted to corn, tomatoes, and wheat on a rotating basis. Dead Horse Island was leveed in 1900, but has tended to be flood prone. Twelve percent of the island is levee and berm. The island was flooded in 1955, 1980 and 1986. Emergency expenditures for the period 1980-1986 came to $1,930 per acre, for a total of $406,593. Lowest surface elevation has been measured at -4 feet below sea level.

Fay Island

Fay Island, Reclamation District Number 2113, located in San Joaquin County, is accessible only by ferry. Within the jurisdiction of the Central Delta Water Agency, the island is protected by 1.6 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $26,900 per mile annually, totaling $43,040 annually. Less than eighty percent of the island's levees meet HMP standards. In 1982, field or sweet corn was grown on 61 acres, pasture or rangeland accounted for 49 acres, totaling 110 acres. DWR lists Fay island at 100 acres. Fay Island flooded in 1983. Emergency expenditures for the period 1980-1986 came to $1,020 per acre, for a total of $102,068. The lowest surface elevation measurement for Fay Island is -5 feet below sea level.

Little Mandeville Island

Little Mandeville Island, Reclamation District Number 2118, is located in San Joaquin County, and requires ferry access. The island is within the Central Delta Water Agency jurisdiction. Little Mandeville Island is protected by 4.5 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $3,750 per mile, $16,875 total, annually. Ninety percent or more of the island's levees meet or exceed HMP standards. DWR levee maintenance figures list 376 acres for the island. In 1982, field or sweet corn was grown on 292 acres, and pasture or rangeland made up 42 acres; this acreage totals 334. Little Mandeville Island flooded in 1986, however no dollar amount for emergency expenditures were available. Lowest surface elevation has been been measured at -6 feet below sea level.

Mandeville Island

Mandeville Island, Reclamation District Number 2027, is located in San Joaquin County, within the Central Delta Water Agency jurisdiction. Mandeville Island is protected by 14.3 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $6,660 per mile annually, for a total average of $95,238. Less than eighty percent of the island's levees meet HMP standards. DWR levee maintenance figures list 5,300 acres for the island. In 1982, the crops grown on Mandeville Island were 2,466 acres of field or sweet corn, 239 acres of grain (unspecified), 542 acres of grapes (unspecified), 309 acres of oats, 253 acres of sorghum, and 263 acres of sunflower. In addition, 7 acres are designated as farmstead, and 26 acres for storage and distribution. The remaining land use is denoted as 34 acres fallow, 155 acres of marshland, and 457 acres of previously cropped land. The total of these figures come to 5,266 acres. Mandeville Island was reclaimed in 1918. The island flooded in 1938. Inundation was averted for Mandeville Island during three major Federal disasters between 1980-1986, but still emergency expenditures for this period came to $320 per acre, totaling $1,675,983. Lowest surface elevation has been been measured at -19 feet below sea level.

Medford Island

Medford Island, Reclamation District Number 2041, is located in San Joaquin County, and requires ferry access. The island is within the Central Delta Water Agency jurisdiction. Medford Island is protected by 5.9 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $7,310 per mile annually, or $43,129 total. Less than eighty percent of the island's levees meet HMP standards. DWR levee maintenance figures list 1,219 acres for the island. In 1982, land use on Medford Island was designated as 8 acres of farmstead, 38 acres of lakes, rivers, and reservoir, 86 acres of marsh land, 136 acres of pasture or rangeland, and 1,024 acres of land previously cropped, for a total of 1,292 acres. Medford was reclaimed in 1916, and has more than five percent of its area in levee. The island flooded in 1936. Flooding was averted during three federal disasters between 1980-1986. Emergency expenditures for this period came to $400 per acre, for a total of $484,390. Lowest surface elevation has been been measured at -14 feet below sea level.

Prospect Island

Prospect Island, Reclamation District Number 1667, is located in Solano County, within the North Delta Water Agency jurisdiction. Prospect Island is protected by 10 miles of levee, 2.9 project and 7.1 non-project. Levee maintenance expenditures for the period 1981-1986 come to $15,820 per mile annually, totaling $158,200. Less than eighty percent of the island's levees meet HMP standards. DWR levee maintenance figures list 1,228 acres for the island. In 1980, field or sweet corn was grown on 358 acres, grain (unspecified) on 36 acres, 15 acres of sudan, and 632 acres were denoted as pasture or rangeland. Lakes, rivers, and reservoir made up 28 acres, for a total of 1,069 acres. Prospect Island was reclaimed during World War I, with levee accounting for 5.3-7 percent of the land area. This island has flooded in 1938, 1940, 1980, 1982, 1983, and 1986. Emergency expenditures for the period 1980-1986 came to $230 per acre, for a total of $280,660. Lowest surface elevation is measured at -3 feet below sea level.

Rindge Tract

Rindge Tract, Reclamation District Number 2037, is located in San Joaquin County. The island is within the Central Delta Water Agency jurisdiction. Rindge Tract is protected by 15.7 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $36,340 per mile annually, for a total of $570,538. Less than eighty percent of the island's levees meet HMP standards. DWR levee maintenance figures list 6,834 acres for the tract. Crops grown on Rindge Tract in 1982 were 778 acres of asparagus, 150 acres of grain (unspecified), 4,011 acres of field or sweet corn, and 1,462 acres of sunflower. Farmstead made up 12 acres, pasture or rangeland 371 acres. This total is 6,784 acres. Written response to the questionnaire indicates 6,800 farmable acres, with an estimated market value of $1,500 per acre, excluding acreage planted to asparagus, valued at approximately $2,500 per acre. Corn is the predominant crop, taking up 70% of the planted acres, at a gross market value of $500 per acre. Other crops consist of 10% asparagus, market value $2,500 per acre; 10% sugar beets, market value $1,200 per acre; and 10% wheat, market value $350 per acre. Asparagus is a perennial crop, harvested for a period of approximately 10 years. Other crops are planted on an annual basis, depending on respective market values at the time of planting. Rindge Tract was leveed between 1905-1907 and was flooded in 1907. Emergency expenditures for the period 1980-1986 came to $880 per acre, totaling $6,032,677, but inundation was prevented during three Federal disasters during this time. Lowest surface elevation has been been measured at -15 feet below sea level.

Rio Blanco Tract

Rio Blanco Tract, Reclamation District Number 2114, is located in San Joaquin County. The island is within the Central Delta Water Agency jurisdiction. Rio Blanco Tract is protected by 4.0 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $12,630 per mile annually, $50,520 total. Ninety percent or more of the island's levees meet or exceed HMP standards. DWR levee maintenance figures list 705 acres for the tract; the owner of the property states 700 acres as the size of this tract, but unfortunately gave no detailed information, such as the land-to-levee percentage, flood history, or current cropping patterns. Crops grown on Rio Blanco Tract in 1982 were 220 acres of tomatoes, 196 acres of sunflower, and 164 acres of grain (unspecified). Farmstead made up 9 acres, pasture or rangeland 71 acres, for a total of 660 acres. Lowest surface elevation has been

been measured at sea level.

Venice Island

Venice Island, Reclamation District Number 2023, is located in San Joaquin County, and requires ferry access. The island is within the Central Delta Water Agency jurisdiction. Venice Island is protected by 12.3 miles of non-project levee. Levee maintenance expenditures for the period 1981-1986 come to $6,320 per mile, $77,736 total, annually. Less than eighty percent of the island's levees meet HMP standards. DWR levee maintenance figures list 3,220 acres for the island. In 1982, the crops grown on Venice Island were 1,794 acres of field or sweet corn, 743 acres of grain (unspecified), 163 acres of sunflower, and 393 acres of pasture or rangeland. Farmstead made up 14 acres, pasture or rangeland 393 acres, 18 acres of land previously cropped, and 16 acres of lakes, rivers, and reservoir. These total 3,141 acres. Venice Island was reclaimed in 1906, with more than five percent of its area in levee. The island has flooded in 1906, 1907, 1909, 1938, 1950, and 1982. Emergency expenditures for the period 1980-1986 came to $2,750 per acre, for a total of $8,845,076. Lowest surface elevation has been been measured at -17 feet below sea level.

Mildred Island

Mildred Island, in San Joaquin County, was Reclamation District Number 2021. The 998-acre island was protected by 7.3 miles of nonproject levee at an average annual cost of $3,650 per mile, or $26,645. Crops grown in 1982 included 766 acres of field or sweet corn, 34 acres of grapes (unspecified), and 165 acres of pasture or range. Lakes, rivers, and reservoir made up 24 acres, for a total of 989 acres. Reclamation of Mildred Island began in 1913, and was farmed by 1921. Lowest surface elevation had been measured at -14 feet below sea level. The island flooded in 1963, 1980, and 1983. The island remained flooded after inundation in 1983.

Procedure Used to Estimate Agricultural Worth Versus Maintenance Costs

A list of the cropping pattern for each island in the study area - crop types, the acreage planted to each crop, and the year of the reported data - is generated from the data provided by Ron Landingham of the Department of Water Resources. In some cases, crop identification was vague, most notably with grain crops. For this reason, estimates were made of both minimum and maximum gross incomes for each island (Tables 7-17, Appendix C). Minimum estimates were applied to low-value crops such as barley; maximum estimates, wheat, a high-value crop. Crop values were obtained from Agricultural Commissioner annual reports of the county in which the island is located. Agricultural Commissioner reports specify production per acre, the unit in which the crop is measured, and the gross dollar amount generated for the unit produced. In cases where there is no such breakdown for a particular crop in the county report in which the island is located, information from the adjoining county's report is used. Data for 1990 are included for Dead Horse Island and Rindge Tract. Mildred Island is incorporated for comparison. These gross agricultural income estimates, less the 1981-1986 average annual levee maintenance expenditures, are recapped in Table 18 (Appendix D).

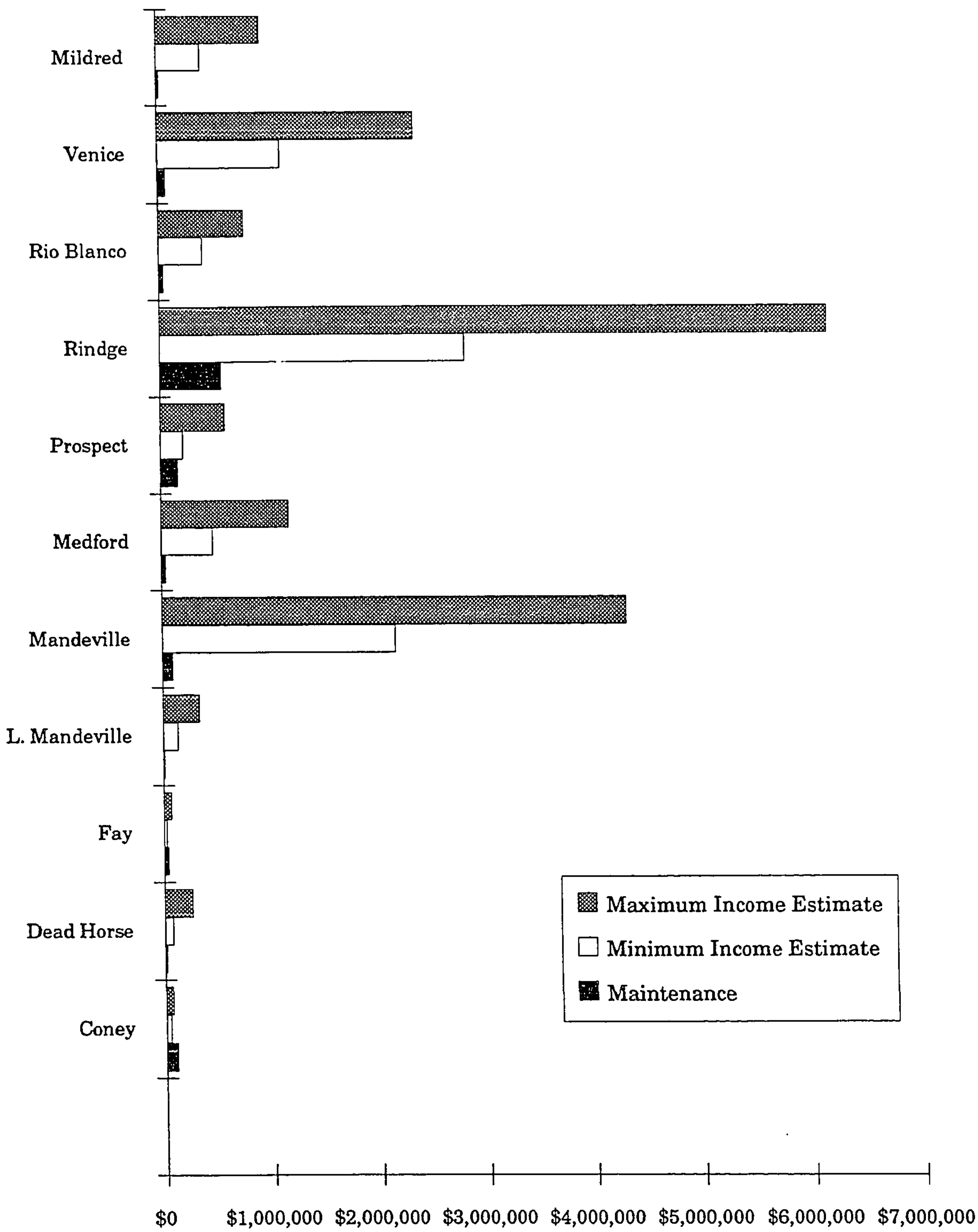
Net income is derived from formulas used in a University of California crop cost study (Orr and Sills, 1989). This study takes into account operating costs such as fuel and seed, irrigation, chemicals, harvest and labor, debt interest, and depreciation. The study also includes comparisons of the productivity of field corn and wheat on peat soils, for which the Delta is highly valued, compared to mineral soils (Orr and Sills, 1989; Thompson, 1957). Both crops are grown at a loss on mineral soils, whereas on peat soils field corn generates a ninety-two percent profit and wheat a seventy-six percent profit. Net income generated for the other crops in the sample studies fall between the two percentages. To accommodate the range these income estimates might cover, net income is figured at seventy-five percent and at ninety-two percent of the minimum and maximum gross estimates. From these net estimates are subtracted total annual maintenance costs from 1981-1986 (Table 19, Appendix D). Emergency expenditures are not included.

To illustrate the procedure used to derive income estimates, attention is directed to Table 7 in Appendix C (Coney Island). The crops grown in 1985 include 202 acres of an unspecified type of grain, 34 acres of safflower, and 86 acres devoted to pasture or range. For the minimum estimate, barley is used, as it was the lowest-valued grain crop. Barley is measured by the ton, with 1.34 tons per acre produced in 1985, and each ton worth $110. Thus, total gross income generated by 202 acres planted to barley is estimated at $29,774.80 (number of acres multiplied by the unit amount produced per acre multiplied by the dollar amount received per unit). Wheat, the highest-valued grain crop, is used for the maximum estimate. Safflower was lumped with other seed crops in Contra Costa County's Agricultural Report for 1985, therefore information on safflower is garnered from adjoining San Joaquin County's report for that year.

Summary Assessment of Islands in Study

Total annual maintenance costs subtracted from minimum gross annual income estimates (Figure 3) indicate two islands, Coney and Fay

Figure 3. Comparison of Gross Minimum and Maximum Agricultural Income Estimates to 1981-1986 Average Annual Levee Maintenance Expenditures



Islands, operating at a loss. The same calculations using maximum gross income show only Coney Island operating at a loss. Minimum net annual income estimates of seventy-five percent and ninety-two percent of estimated gross income, less total annual maintenance costs, suggest a greater number of islands operating at a loss. Coney, Fay, and Prospect Islands are shown to operate at a loss at both the seventy-five percent and ninety-two percent minimum net estimates. Dead Horse, Little Mandeville, Medford, Ridge, and Rio Blanco Islands indicate negative income at ninety-two percent of gross minimum estimates (Figure 4).

Maximum net annual income estimates, less annual maintenance costs (Figure 5), again show Coney, Fay, and Prospect Islands operating at a loss. Rindge Tract operates at a loss with the ninety-two percent net income estimate.

Mandeville and Venice Islands are both shown to operate at a profit in each estimation. In comparison, Mildred Island is also shown in each estimation as operating at a profit. Yet this island was considered no longer economically feasible for reclamation following inundation in 1983.

The agricultural estimations for Dead Horse Island and Rindge Tract (Tables 8 and 14, Appendix C) include data from both the DWR source, and questionnaire responses. The 1990 crop data for Rindge Tract are particularly detailed. Both show the estimations derived for this study to be close approximations to actual income. In fact, maximum estimations are considerably on the high side. Therefore, based on the estimations of agricultural income versus maintenance costs for the ten islands studied, the following suppositions are made:

Coney, Fay, and Prospect Islands would be prime candidates for non-maintenance and non-reclamation if flooded in the future. These islands

Figure 4. Comparison of Net Minimum Agricultural Income Estimates to 1981-1986 Average Annual Levee Maintenance Expenditures

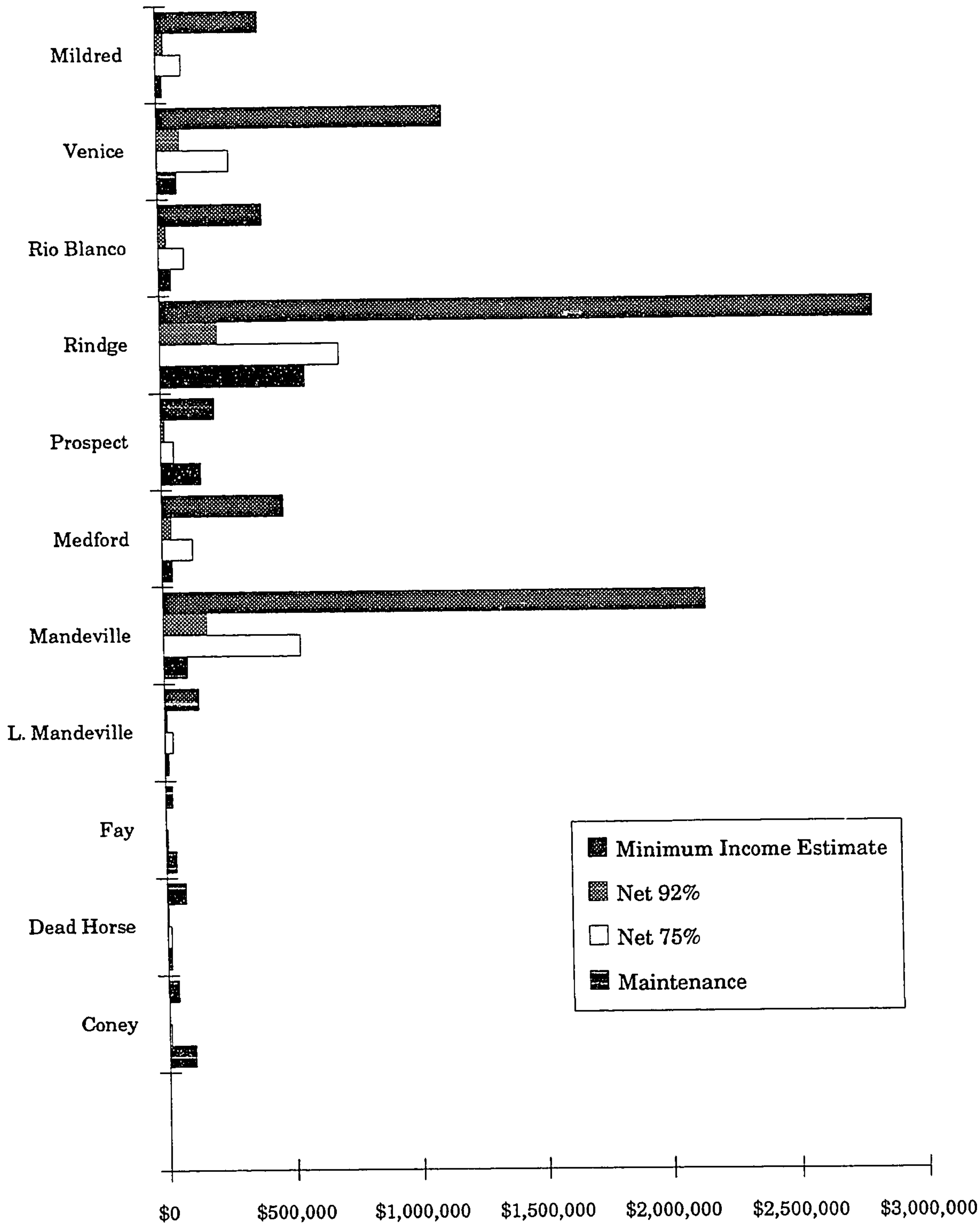
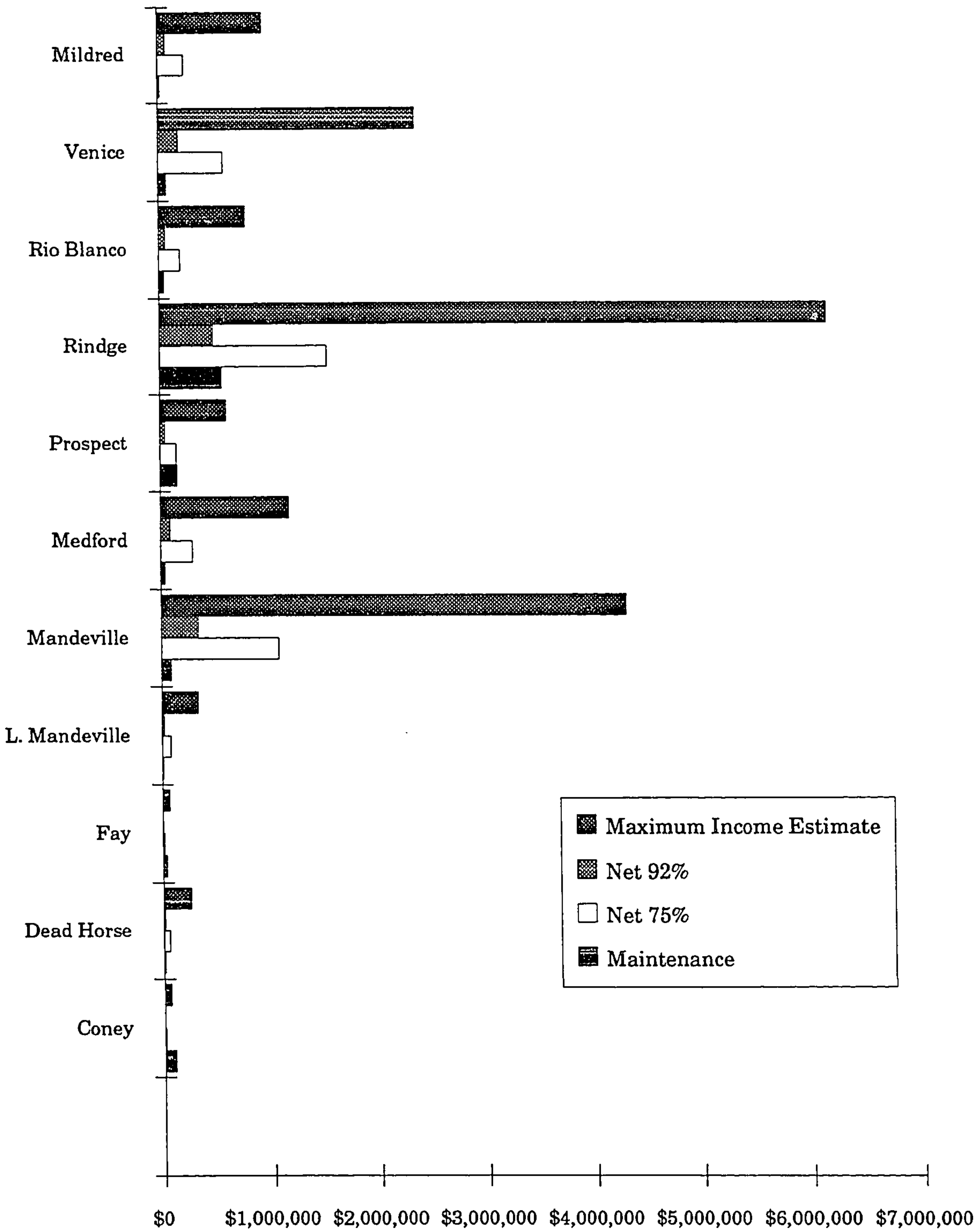


Figure 5. Comparison of Net Maximum Agricultural Income Estimates
to 1981-1986 Average Annual LeveeMaintenance Expenditures



operate at considerable loss in relation to maintenance costs, even when a high estimated income is applied. Coney Island has, however, only one record of flooding in 1907. Fay Island also has only one flood incident listed, and ninety percent or more of both islands' levees meet or exceed HMP standards. Prospect Island, on the other hand, has been particularly prone to inundation, and less than eighty percent of Prospect's levees meet HMP standards. Continued reclamation would be questionable unless inundation would pose a hazard to shipping in the deepwater channel to Sacramento which Prospect Island borders.

Dead Horse, Little Mandeville, Medford, Rindge, and Rio Blanco Islands would be next likely to remain inundated if flooded in the future, based on agricultural income versus maintenance costs. Of these, Dead Horse Island has been the most flood-prone. Little Mandeville last flooded in 1986. But both islands do have ninety percent or more of their levees meeting or exceeding HMP standards. Medford has not had a recorded flooding since 1936, nor Rindge Tract since 1907, but less than eighty percent of either island's levees meet HMP standards. Rio Blanco's flood history could not be determined, but ninety percent or more of its levees meet or exceed HMP standards.

As mentioned, Mandeville and Venice Islands maintain positive agricultural income flows in each estimation. Mandeville has remained flood-free since 1938. Venice Island, on the other hand, has had repeated flood events. Less than eighty percent of the levees for Mandeville or Venice meet HMP standards. Regardless, both Mandeville and Venice Islands seem to generate sufficient income to warrant continued reclamation.

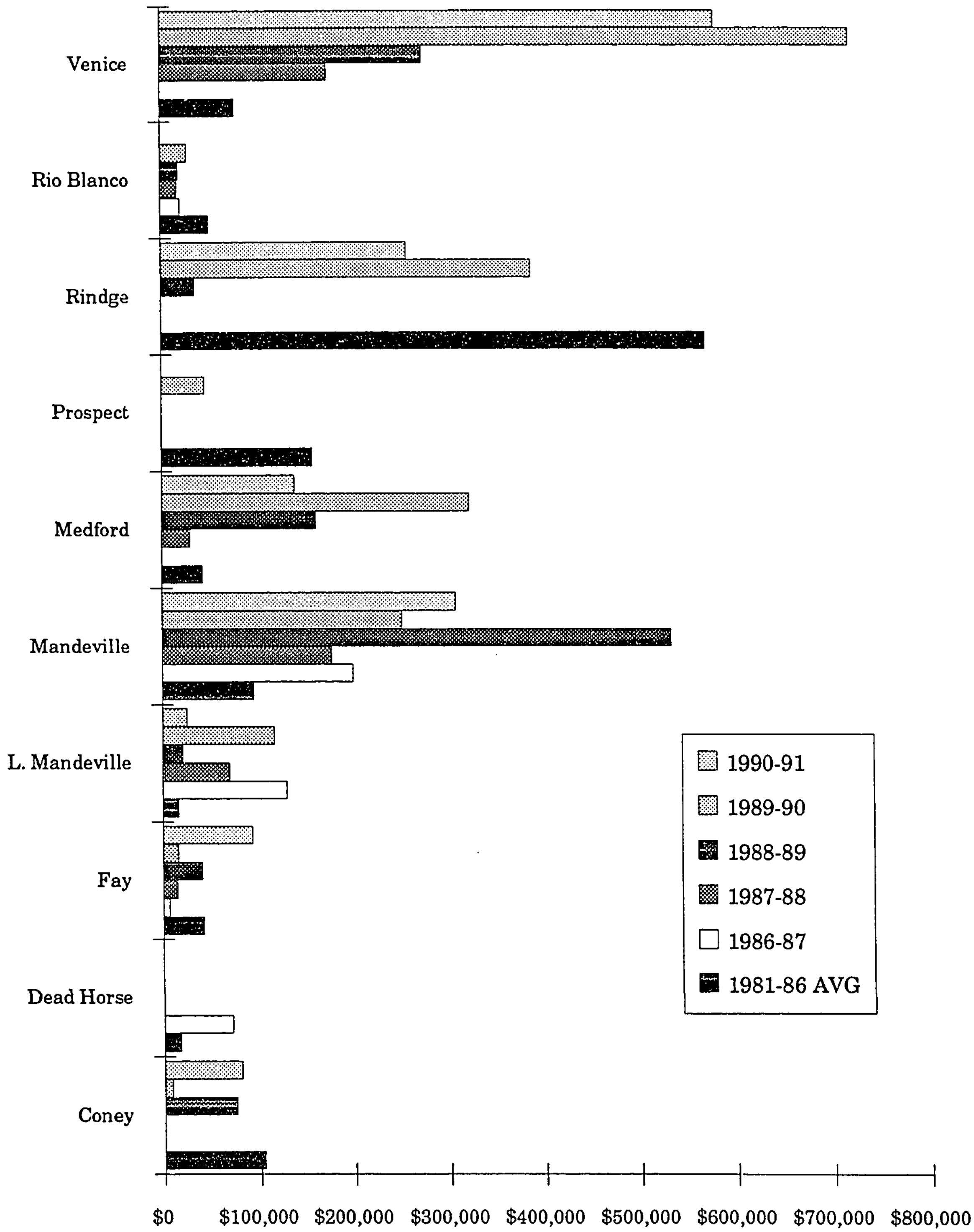
Critique of Model, Data, and Conclusions Reached

The problems encountered in this study were first mentioned in the discussion of methodology, namely difficulties in the acquisition of current cropping data. The initial desire to obtain such information directly from farmers in the Delta was undermined by the limited number of responses to the questionnaire sent to each reclamation district. However, through the use of county Agricultural Reports, it is possible to derive close approximations of agricultural income. These reports, localized to the county level, reflect fluctuations in crop market values from year to year, and the market price can be applied to the specific crops and year for which the data is generated.

The annual maintenance figures used in this study were those derived from costs averaged over the 1980-86 period. This period is notable for numerous flood events in the Delta, although emergency expenditures for levee repair and island drainage are not included in the estimations for this study. Hazard Mitigation Plan levee standards were not yet in effect, for it was after the 1986 floods that the Federal Emergency Management Agency took steps to reduce future flood vulnerability through the levee improvement program requirements already mentioned. The present condition of the levees protecting these islands are taken into account through the inclusion of the Hazard Mitigation Plan report assessment of the individual islands. A more recent year by year accounting of levee maintenance expenditures illustrates the difference between the annual levee maintenance figures used in these estimations and more recent expenditures (Figure 6). For some islands, the information is incomplete (Table 20, Appendix D), however, for Mandeville, Medford, and Venice Islands in particular, the increase in levee expenditures is notable.

From the estimations of agricultural income versus annual levee maintenance costs arrived at through this study, a generalized picture emerges. Even with high estimates of maximum agricultural income, gross

Figure 6. Annual Levee Maintenance Expenditures 1981-1991



and net, the islands whose maintenance costs far exceed estimated agricultural income do stand out. In this respect, the study has successfully investigated one aspect of assessing the vulnerability of particular Delta islands, islands solely used for agriculture, to non-reclamation in the event of future flooding.

CHAPTER 5
CONCLUSION

Summary of Major Points

In many respects, the Delta represents past, present, and future attitudes about land use. Reclamation activities dating from the mid-nineteenth century transformed tidal marshlands to islands protected by an elaborate system of levees. Agriculture, navigation, recreation, fisheries, waterfowl and wildlife are all supported by the rich resources of the Delta. Future users of the Delta, however, may have to decide which of these varied activities should take precedence as divergent, sometimes conflicting, demands are placed on this system. These demands threaten to undermine the very attributes for which the Delta is valued.

The Sacramento-San Joaquin Delta is a major component of California's remaining wetlands. Many species of migratory birds depend upon the resources of the Delta, as do multiple wildlife and amphibious species. The diverse estuarine environment also sustains numerous species of anadromous fish, such as salmon, striped bass, and sturgeon, which migrate from the Pacific Ocean to spawn in the various streams that feed into the Delta. However, wildlife, aquatic, and waterfowl populations are in severe decline, and blame is primarily attributed to water transfers and agriculture.

Historically, land use in this region has been hampered by problems of flooding, levee failures, saltwater intrusion, and land subsidence. Nevertheless, expensive reclamation has been considered worthwhile. To offset the high costs of reclamation as well as the protection of agricultural production from these threats, Reclamation Districts were formed in the latter nineteenth and early twentieth centuries, and the rich peat soils of the Delta have supported a multi-million dollar agricultural economic base. Deepwater channels maintain the cities of Sacramento and Stockton as inland ports. The many miles of sloughs and channels that interweave through the Delta islands provide countless recreational opportunities for boating, waterskiing, and fishing, as well as hiking, camping, bicycling, and nature study.

Such varied uses will not in themselves degrade an environment. However, if any activity becomes too intrusive, other uses are compromised and the environment is degraded. Millions of dollars have been spent maintaining the fragile 1,100-mile levee network to protect the man-made islands of the Sacramento-San Joaquin Delta, and numerous studies have addressed the efforts to maintain the present status quo in the Delta. Yet there is acknowledgement that such attempts may be futile. In addition to already-existing problems with flooding, salinity intrusion, and land subsidence, the potential havoc caused by seismic activity and global warming could also undermine present Delta usage.

Alternative land-use strategies for Delta islands are being developed. Sherman Island, for example, is part of a land-use management program jointly developed by the California Department of Water Resources and Department of Fish and Game. The program would discontinue the intensive agricultural practices associated with increased land subsidence and, instead, develop the island as wetland habitat. Another mitigation plan, the privately-financed Delta Wetlands Project, would also discontinue agriculture on four islands in the Delta. Wetland habitat would instead be augmented on Bacon, Bouldin, Holland and Webb, but in addition, the islands would alternate as water storage units. Plans for the flooded Franks Tract call for the development of a water park recreational facility. Remnant levees of this tract would be reinforced, and new small artificial islands created. Besides providing additional recreational facilities, levees on adjoining islands would be subject to less damage caused by wind-driven waves that build up across the open water left when the tract was left flooded in 1938. All of these alternative strategies have similar goals of equalizing water pressure on levees, the reduction of land subsidence, increased wetland habitat for wildlife and recreational facilities, and protection and augmentation of quality water availability in support of water diversions.

California's present water transfer policies are criticized for the damaging impacts on the Delta's aquatic life. Alteration of natural flow by water transfer pumps in some cases results in reverse streamflow, which displaces upstream fresh water with saltwater. Spawning grounds are disrupted, eggs and fish are transported out of the Delta through pumping facilities. Not enough cool fresh waters are stored in reserve upstream for release during spawning season, resulting in waters too warm for spawning fish. The freshwater needs of the Delta to maintain it's biological health are engaged in a tug-of-war with increasing demands of urban and agricultural consumers; this has been exacerbated by drought conditions.

Arguments against continued support of agriculture in this region include accelerated land subsidence due to farming, damaging impacts upon the Delta's aquatic life through the introduction of pesticides, and escalating costs of levee maintenance. The peat-based levees of the Delta are prone to repeated failure, but policies have supported their repair and maintenance regardless of the costs involved. However, there have been precedents in which continued reclamation was no longer considered economically justified. The southern portion of Sherman Island was subject to repeated levee failure and was finally abandoned in 1925. Such was also the case of Frank's Tract, given up in 1938 after repeated flooding. In 1983, Donlon and Mildred Islands remained flooded; estimated reclamation costs were considered to be in excess of these islands' value. How many other islands would not be cost-effective to reclaim if flooded in the future?

To examine this question, questionnaires were sent to Reclamation Districts in the Delta to obtain data on current agricultural practices in these Districts, as well as augment information available from state and county sources. Poor response to these questionnaires, however, led to the alternative approach of maximum and minimum crop income estimations, gross and net, based on older data from the early 1980s. These income estimations are compared to average annual levee maintenance expenditures for the same time period. Study results, based on these estimations, are thus more generalized than originally intended. A sample of islands that support only one activity - agriculture - was selected as a case study. These islands are: Coney, Dead Horse, Fay, Little Mandeville, Mandeville, Medford, Prospect, Rindge, Rio Blanco, and Venice. Mildred Island is included in this study for comparison, representative of an island allowed to remain flooded because it was no longer considered economical to reclaim. Also taken into consideration are the conditions of the levees protecting each island and previous flood history.

The assumption of this study is that islands with maintenance costs exceeding agricultural revenue would be particularly vulnerable to non-reclamation if flooded in the future. Such an assumption is based on simple farm management economics. Through the income estimations used in this study, islands fall into three general categories: 1) islands operating at a loss based on gross income estimates, 2) islands operating at a loss based on net income estimates, and 3) islands operating at a profit in each estimation. In the first category fall Coney and Fay Islands. The second category is comprised of Dead Horse Island, Little Mandeville Island, Medford Island, Prospect Island, Rindge Tract, and Rio Blanco Tract. In the third category, Mandeville and Venice Islands operate at a profit in each estimation, as does, interestingly, Mildred Island. These study results thus indicate degrees of vulnerability to non-reclamation of each island included in this case study. However, without more concrete income figures, any assumption of whether these islands would continue to be reclaimed if flooded in the future could only be of a very general nature.

Assessment of Study Process

The Sacramento-San Joaquin Delta is an area that has generated a great deal of interest, study, and, at times, heated discussion. As a result, a great deal of information is available. In the first stages of gathering data related to the Delta, a reference indicated that one of the Delta islands, Mildred, had recently been left flooded. Yet, this island still showed up on most of the maps available. This inconsistency led to the ultimate focus of this thesis. In determining whether Mildred Island was intact or not, led to the question of which other islands might next face non-reclamation.

Many people helpfully answered questions through phone conversations, sent unpublished information, and refered me to sources that might be able to provide me with relevant information. Sorting through this ample information convinced me of the lack of research on the ratio of agricultural profits versus maintenance costs. The study was limited to the ten islands once I realized how massive an undertaking it would be to attempt to incorporate all of the Delta islands.

The low number of responses to the questionnaires sent to the individual Reclamation Districts meant more reliance on government publications, such as those from the Department of Water Resources and county Agricultural Commissioners. As well, the study results are much more generalized than had been originally intended. Questionnaire responses received from islands not included in the sample of this particular study do provide enlightening commentary from the farmers' perspective regarding the Delta. These responses were from Lawrence Stefani of Bishop Tract, Vic Leonardini of King Island, Bill Mendelson of Weber Tract, and Richard W. Johnson, the attorney for Upper Jones Tract, who provided names and addresses for the farmers on that tract. Through Mr. Johnson's referrals, written response was received from Elliott Alexander, and a phone interview generated with Coleman Foley. Mr. Foley now farms on Upper Jones Tract, although his family did once own Mildred Island (not, however, when the decision was made not to reclaim the island after inundation in 1983).

Implications of This Study

Priorities are shifting away from the support of agricultural production in the Delta. Therefore, some islands will be less likely to be reclaimed if flooded in the future. Precedent has been established to discontinue reclamation when levee maintenance has proven futile or is no longer economically feasible. Early historical examples include Franks Tract and the southwest portion of Sherman Island, and more recently, Donlon and Mildred Islands. Economics has been the deciding factor, although environmental considerations are gaining precedence. The discontinuation of agriculture would reduce land subsidence and pesticide runoff into the Delta, which would be beneficial to Delta wildlife and fish. However, most of the impetus is the protection of water quality in support of water transfers.

A more comprehensive study of the feasibility of continued support for agriculture, based on economic criteria, should be based on more specific income and maintenance expenditures than was possible with this thesis. Access to maintenance expenditure information is not problematic as there is so much involvement with state and federal agencies and thus open to public scrutiny. However, detailed income figures from private parties, as these farmers are, requires their cooperation, and is not readily available. As well, access to privately-owned islands is limited for firsthand field study. Thus, study results are highly generalized as are the findings of this examination.

Suggestions for Further Study

The Sacramento-San Joaquin Delta is as diverse as the varied interests who share its resources, and there are many unanswered questions regarding its future use. These include future land-use changes and water policy developments, the long-term impacts of which include what, if any, policy adjustments will be made to protect Delta fish and wildlife resources.

Any future land-use changes will affect the land values and level of vulnerability of the islands in the Delta. An example of this is Bethel Island, as mentioned in the island's relationship to the Franks Tract area's conversion to a water park. Bethel Island, once farmed intensively, has been abandoned to pasture. The growth of recreational facilities has provided economic opportunities to fill gaps left from the move away from an agricultural foundation. Similar land-use changes warrant continued attention, as does the success of managed wetland conversions such as the program on Sherman Island and the Delta Wetlands project.

Water policies and transfers are part of an ongoing debate. The concept of some sort of peripheral, or isolated, canal continues to surface as one answer to the problems associated with water transfers through the Delta. Whether such a project ever comes to fruition bears watching, as would the resultant effects on the Delta.

As mentioned, the severity and duration of the most recent drought will have unknown impacts on many of the Delta issues discussed in this thesis, particularly those related to California water policies. The severity and duration of the most recent drought resulted in severe conservation programs throughout California. One strategy to increase the availability of exportable water is a recent development instigated by severe drought conditions, namely water banking. This concept has holders of water rights, primarily farmers, transferring water allotments to state and federal agency water banks to increase available water supplies to meet export oblications. How this form of water reallocation evolves deserves attention. Land may be taken out of agricultural production should farmers find it more profitable to market the water to which they hold rights.

Also unresolved at the time of this writing is the status of Delta fish and wildlife. There has already been evidence presented on the impacts of the drought of 1976-77. What long-term impacts will this most recent drought have? What about future droughts? And what, if any, policy adjustments will be made to protect or sacrifice fish and wildlife resources? Only continued research on the Delta will answer these questions.

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APPENDIX A

SAMPLE LETTER SENT TO RECLAMATION DISTRICTS

May 16, 1991

I am a geography student at San Jose State University, currently doing research on the Sacramento-San Joaquin Delta region. The project is an examination of land use and cropping patterns, broken down to the individual islands and tracts.

I have found it difficult to get specific figures just on the Delta (the county Agricultural Commissioner provides general figures on a county-wide basis). Therefore, I am writing to you in hopes of getting such figures for your individual Reclamation District.

The statistics I am looking for would include recent figures on:

* Acreage for your island or tract
* Estimated market value of this real estate per acre
* Crops raised and their market value
* Percentage of land planted to particular crops
* Seasonal cropping patterns

Any assistance in obtaining this information would be greatly appreciated. I would also be very interested in learning more about your Reclamation District, such as how it operates, its history, and particular concerns about the Delta as a whole.

Sincerely,

Nancy J. D'Attilio
5648 Prospect Road
San Jose, CA 95129-4850
(408)973-1335

APPENDIX B

Table 5. Abundance of Fish of the Sacramento-San Joaquin Delta

Common name*	Scientific name	Abundance**
Pacific lamprey (N)	Entosphenus tridentatus	Common (A)
River lamprey (N)	Lampetra ayresi	Uncommon (A)
White sturgeon (N)	Acipenser transmontanus	Common (A)
Green sturgeon (N)	Acipenser medirostris	Uncommon (A)
American shad (I)	Alosa sapidissima	Common (A)
Treadfin shad (I)	Dorosoma petenense	Abundant (R)
Brown trout-sea run (I)	Salmo trutta	Rare (A)
Steelhead (N)	Oncorhynchus mykiss	Common (A)
Pink salmon (N)	Oncorhynchus gorbuscha	Occasional (A)
Coho salmon (N)	Oncorhynchus kisutch	Rare (A)
Chinook salmon-4 runs (N)	Oncorhynchus tshawytscha	Common (A)
Chum salmon (N)	Oncorhynchus keta	Occasional (A)
Sockeye salmon (N)	Oncorhynchus nerka	Occasional (A)
Longfin smelt (N)	Spirinchus thaleichthys	Common (A-R)
Delta smelt (N)	Hypomesus transpacificus	Common (R)
Thicktail chub (N)	Gila crassicauda	Extinct
Hitch (N)	Lavinia exilicauda	Common (R)
California roach (N)	Hesperoleucus symmetrucus	Rare (N)
Sacramento blackfish (N)	Orthodon microlepidotus	Common (R)
Splittail (N)	Pogonichthys macrolepidotus	Common (R)
Hardhead (N)	Mylopharodon conocephalus	Uncommon (N)
Sacramento squawfish (N)	Ptychocheilus grandis	Common (R)
Fathead minnow (I)	Pimephales promelas	Occasional (R)
Golden shiner (I)	Notemigonus crysoleucas	Common (R)
Goldfish (I)	Carassius auratus	Common (R)
Carp (I)	Cyprinus carpio	Abundant (R)
Sacramento sucker (N)	Catostomus occidentalis	Common (R)
Black bullhead (I)	Ictalurus melas	Common (R)
Yellow bullhead (I)	Ictaluras natalis	Rare (R)
Brown bullhead (I)	Ictaluras nebulosus	Common (R)
White catfish (I)	Ictaluras catus	Abundant (R)
Channel catfish (I)	Ictaluras punctatus	Common (R)
Blue catfish (I)	Ictaluras furcatis	Rare (R)
Inland silversides (I)	Menidia beryllina	Abundant (R)
Mosquitofish (I)	Gumbusia affinis	Common (A-R)
Striped bass (I)	Morone saxatilis	Abundant (R)
Sacramento perch (N)	Archoplites interruptus	Extirpated
Bluegill (I)	Lepomis machrochirus	Common (R)
Redear sunfish (I)	Lepomis microlophus	Uncommon (R)
Green sunfish (I)	Lepomis cyanellus	Common (R)
Warmouth (I)	Lepomis gulosus	Uncommon (R)
White crappie (I)	Poxomis annularis	Common (R)
Black crappie (I)	Poxomis nigromaculatus	Uncommon (R)

Table 5. Fish Abundance in the Delta (continued)

Common name*	Scientific name	Abundance**
Largemouth bass (I)	Micropterus salmoides	Common (R)
Smallmouth bass (I)	Micropterus dolomieui	Uncommon (R)
Bigscale logperch (I)	Percina macroplepida	Common (R)
Yellow perch (I)	Perca flavescens	Extirpated
Tule perch (N)	Hysterocarpus traski	Common (R)
Yellowfin goby (I)	Acanthogobius flavimanus	Common (R)
Staghorn sculpin (N)	Liptocottus armatus	Common (M)
Starry flounder (N)	Platichthys stellatus	Common (M)
Rainwater killfish (I)	Lucania parva	Rare (R)
Prickly sculpin (N)	Cottus asper	Common (R)
Threespine stickleback (N)	Gasterosteus aculeatus	Uncommon (R)
Chameleon goby (I)	Tridentiger trigoncephalus	Common (R)

*Introduced (I), Native (N)

**R=resident, A=Anadromous, N=nonresident visitor, M=euryhaline marine

Source: California State Lands Commission, 1991.

Table 6. Delta Special Status Species

Species	Status*	Habitat in Delta
MAMMALS:		
Riparian Brush Rabbit	FC, CSC	Riparian
Salt Marsh Harvest Mouse	FE, SE	Salt marsh (W Delta only)
San Joaquin Pocket Mouse	FC	Grassland
San Joaquin Kit Fox	FE, SE	Grassland (SW edge of Delta)
BIRDS:		
Common Loon	CSC	Open water (rare visitor)
American White Pelican	CSC	Open water
Double-crested Cormorant	CSC	Open water; Marsh
Least Bittern	CSC	Marsh; Agricultural land
White-faced Ibis	FC, CSC	Marsh; Agricultural land
Aleutian Canada Goose	FE	Marsh; Agricultural land (flooded)
Fulvous Whistling Duck	FC, CSC	Marsh (rare visitor)
Northern Harrier	CSC	Marsh; Agricultural land; Grassland
Sharp-shinned Hawk	CSC	Riparian; Marsh; Grassland; Agricultural land;
Cooper's Hawk	CSC	Riparian; Marsh; Agricultural land; Grassland
Swainson's Hawk	ST	Riparian; Agricultural land; Grassland
Golden Eagle	CSC	(rare visitor)
Bald Eagle	FE, SE	(rare visitor)
Merlin	CSC	Marsh; Grassland
Prairie Falcon	CSC	(rare visitor)
American Peregrine Falcon	FE, SE	(rare visitor)
Greater Sandhill Crane	ST	Grassland; Agricultural land (flooded)
California Black Rail	FC, ST	Tidal Marsh
Long-billed Curlew	FC	Grassland; Agricultural land
Burrowing Owl	CSC	Grassland; Agricultural land
Long-eared Owl	CSC	Riparian
Short-eared Owl	CSC	Marsh; Agricultural land; Grassland
Willow Flycatcher	SE	Marsh; Riparian
Vermillion Flycatcher	CSC	(rare visitor)
Purple Martin	CSC	Urban
Saltmarsh Common Yellowthroat	FC, CSC	Tidal Marsh (W Delta)
Yellow Warbler	CSC	Riparian/oak woodlands; Urban
Suisun Marsh Song Sparrow	FC, CSC	Tidal Marsh (W Delta)
Tricolored Blackbird	FC	Marsh

Table 6. Delta Special Status Species (continued)

Species	Status*	Habitat in Delta
REPTILES:		
Southwestern Pond Turtle	FC, CSC	Marsh; Riparian
California Horned Lizard	CSC	Grassland (SW Delta)
Giant Garter Snake	FC, ST	Marsh; Riparian
AMPHIBIANS:		
California Tiger Salamander	FC, CSC	Vernal pools; Other aquatic
California Red-legged Frog	FC, CSC	Marsh; Riparian
Foothill Yellow-legged Frog	CSC	Marsh; Riparian
FISH:		
River Lamprey	CSC	Anadromous
Spring-run Chinook Salmon	CSC	Anadromous
Winter-run Chinook Salmon	FT, SE	Anadromous
Coho Salmon	CSC	Anadromous
Pink Salmon	CSC	Anadromous
Delta Smelt	FC, CSC	Resident
Thicktail Chub	Extinct	Was resident
Sacramento Splittail	FC, CSC	Resident
Hardhead	CSC	Resident
Sacramento Perch	FC, CSC	Was resident, extirpated in Delta
INSECTS:		
Delta Green Ground Beetle	FT	Vernal pools (Jepson Prairie)
Valley Elderberry Longhorn Beetle	FT	Riparian
Lange's Metalmark Butterfly	FE	Antioch Dunes
PLANTS:		
Suisun aster (Aster chilensis v. lentus)	FC	Freshwater ,marsh;Riparian
Slough thistle (Cirsium crassicaule)	FC	Freshwater ,marsh; Riparian
Suisun thistle (Cirsium hydrophilium v. hydrophyllum)	FC	Tidal marsh (W Delta)
Soft bird's beak (Cordylanthus mollis ssp.mollis)	FC, SR	Salt marsh (W Delta)
Palmate bird's beak (Cordylanthus palmatus	FE, SE	Grassland (Alkali sink)
Delta button celery (Eryngium racemosum)	FC, SE	Riparian
Contra Costa wallflower (Erysimum capitatum v. angustifolium)	FE, SE	Antioch Dunes

Table 6. Delta Special Status Species (continued)

Species	Status*	Habitat in Delta
California hibiscus (Hibiscus californicus)	FC	Riparian; Freshwater marsh
Contra Costa goldfields (Lasthenia conjugens)	FC	Vernal pools; Grassland
Delta tule pea (Lathyrus jepsonii ssp. jepsonii)	FC	Riparian; Freshwater marsh
Legenere (Legenere limosa)	FC	Vernal pools
Mason's lilaeopsis (Lilaeopsis masonii)	FC, SR	Freshwater marsh; Riparian
Colusa grass (Neostapfia colusiana)	FC, SE	Vernal pools
Antioch Dunes evening primrose (Oenothera deltoides v. howellii)	FE, SE	Vernal pools
Slender orcutt grass (Orcuttia tenuis)	FC, SE	Vernal pools
Sacramento orcutt grass (Orcuttia viscida)	FC, SE	Vernal pools
Bearded popcornflower (Plagiobothyrus hystriculus)	FC	Vernal pools
Caper-fruited tropidocarpum (Tropidocarpum capparideum)	FC	Grassland (extinct?)
Solano grass (Tuctoria mucronata)	SE, FE	Vernal pools

* FE: Federally-listed as endangered
FT: Federally-listed as threatened
FC: Federal list candidate
SR: State-listed as rare
ST: State-listed as threatened
SE: State-listed as endangered
CSC: California state species of special concern

Source: California State Lands Commission, 1991.

APPENDIX C

Table 7. Agricultural Income Estimation Worksheet:
Coney Island 1985

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME EST
GRAIN (UNSPEC) - Barley	202	1.34	TON	$110.00	$29,774.80
PASTURE/RANGE	86		ACRE	$14.30	$1,229.80
SAFFLOWER*	34	1.42	TON	$252.00	$12,166.56
TOTAL ACRES	322			MINIMUM EST	$43,171.16
GRAIN (UNSPEC) - Wheat	202	2.35	TON	$108.00	$51,267.60
PASTURE/RANGE	86		ACRE	$14.30	$1,229.80
SAFFLOWER	34	1.42	TON	$252.00	$12,166.56
TOTAL ACRES	322			MAXIMUM EST	$64,663.96
Source: Contra Costa Co.					
Agricultural Report 1985					
*San Joaquin Co.					

Table 8. Agricultural Income Estimation Worksheet:
Dead Horse Island 1984 and 1990

CROPS - 1984	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN, FIELD	190	3.65	TON	$110.00	$76,285.00
PASTURE/RANGE	14		ACRE	$11.00	$154.00
TOTAL ACRES	204			MINIMUM EST	$76,439.00
CORN, SWEET	190	180.00	45 LB.	$7.50	$256,500.00
PASTURE/RANGE	14		ACRE	$11.00	$154.00
TOTAL ACRES	204			MAXIMUM EST	$256,654.00
Source: Solano Co.					
Agricultural Report 1984					
CROPS - 1990	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN, FIELD	180	4.5	TON	$115	$93,150
CORN, SWEET	180	4	TON	$400	$288,000
CORN, SILAGE	180	24	TON	$24	$103,680
TOMATOES, FRESH	180	12	TON	$500	$1,080,000
TOMATOES, PROCESS	180	30	TON	$55	$297,000
WHEAT	180	3	TON	$110	$59,400
				MINIMUM EST	$59,400
Source: Sacramento Co.				MAXIMUM EST	$1,080,000
Agricultural Report 1990				AVERAGE EST	$320,205

Table 9. Agricultural Income Estimation Worksheet: Fay Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	TOTAL GROSS INCOME
CORN, FIELD	61	4.5	TON	$103.00	$28,273.50
PASTURE/RANGE	49		ACRE	$41.50	$2,033.50
TOTAL ACRES	110			MINIMUM EST	$30,307.00
CORN, SWEET	61	258	46 LB.	$4.44	$69,876.72
PASTURE/RANGE	49		ACRE	$41.50	$2,033.50
TOTAL ACRES	110			MAXIMUM EST	$71,910.22
Source:San Joaquin Co.					
Agricultural Report 1983					

Table 10. Agricultural Income Estimation Worksheet:
Little Mandeville Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	TOTAL GROSS INCOME
CORN, FIELD	292	4.5	TON	$103.00	$135,342.00
PASTURE/RANGE	42		ACRE	$41.50	$1,743.00
TOTAL ACRES	334			MINIMUM EST	$137,085.00
CORN, SWEET	292	258	46 LB.	$4.44	$334,491.84
PASTURE/RANGE	42		ACRE	$41.50	$1,743.00
TOTAL ACRES	334			MAXIMUM EST	$336,234.84
Source: San Joaquin Co.					
Agricultural Report1983					

Table 11. Agricultural Income Estimation Worksheet: Mandeville Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN, FIELD	2,466	4.5	TON	$103.00	$1,142,991.00
GRAIN (UNSPEC), BARLEY	239	2	TON	$119.00	$56,882.00
GRAPES, WINE	542	7.28	TON	$167.00	$658,941.92
OATS	309	1.92	TON	$130.00	$77,126.40
PASTURE/RANGE	515		ACRE	$41.50	$21,372.50
SORGHUM	253	3	TON	$98.00	$74,382.00
SUNFLOWER	263	0.87	TON	$466.00	$106,625.46
TOTAL ACRES	4,587			MINIMUM EST	$2,138,321.28
CORN, SWEET	2,466	258	46 LB.	$4.44	$2,824,852.32
GRAIN (UNSPEC), WHEAT	239	2.49	TON	$127.00	$75,578.97
GRAPES, TABLE	542	10.9	TON	$191.00	$1,128,389.80
OATS	309	1.92	TON	$130.00	$77,126.40
PASTURE/RANGE	515		ACRE	$41.50	$21,372.50
SORGHUM	253	3	TON	$98.00	$74,382.00
SUNFLOWER	263	0.87	TON	$466.00	$106,625.46
TOTAL ACRES	4,587			MAXIMUM EST	$4,289,630.48
Source: San Joaquin Co.					
Agricultural Report 1982					

Table 12. Agricultural Income Estimation Worksheet: Medford Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
PASTURE/RANGE	136		ACRE	$41.50	$5,644.00
PREV. CROP: FIELD CORN	1,024	4.5	TON	$103.00	$474,624.00
TOTAL ACRES	1,160			MINIMUM EST	$480,268.00
PASTURE/RANGE	136		ACRE	$41.50	$5,644.00
PREV. CROP: SWEET CORN	1,024	258	TON	$4.44	$1,173,012.48
TOTAL ACRES	1,160			MAXIMUM EST	$1,178,656.48
Source: San Joaquin Co.					
Agricultural Report 1983					

Table 13. Agricultural Income Estimation Worksheet:
Prospect Island 1980

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN, FIELD	358	3.90	TON	$140.00	$195,468.00
GRAIN (UNSPEC) - HAY	36	2.50	TON	$72.00	$6,480.00
PASTURE/RANGE	632		ACRE	$8.00	$5,056.00
SUDAN, CERTIFIED*	15	2,600.00	POUND	$0.14	$5,460.00
TOTAL ACRES	1,041			MINIMUM EST	$212,464.00
CORN, SWEET	358	270.00	45 LB.	$6.00	$579,960.00
GRAIN (UNSPEC) - WHEAT	36	2.85	TON	$140.00	$14,364.00
PASTURE/RANGE	632		ACRE	$8.00	$5,056.00
SUDAN, HYBRID*	15	3,100.00	POUND	$0.16	$7,440.00
				MAXIMUM EST	$606,820.00
Source: Solano Co.					
Agricultural Report 1980					
*Sac.Co.					

Table 14. Agricultural Income Estimation Worksheet:
Rindge Tract 1982 and 1990

CROPS - 1982	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
ASPARAGUS, PROCESS	778	0.50	TON	$824.00	$320,536.00
GRAIN (UNSPEC) - SORGHUM	150	3.00	TON	$98.00	$44,100.00
CORN, FIELD	4,011	4.50	TON	$103.00	$1,859,098.50
SUNFLOWER	1,462	0.87	TON	$466.00	$592,724.04
PASTURE/RANGE	371		ACRE	$41.50	$15,396.50
TOTAL ACRES	6,772			MINIMUM EST	$2,831,855.04
ASPARAGUS, FRESH	778	0.93	TON	$1,280.00	$926,131.20
GRAIN (UNSPEC) - WHEAT	150	2.49	TON	$127.00	$47,434.50
CORN, SWEET	4,011	258.00	46 LB	$4.44	$4,594,680.72
SUNFLOWER	1,462	0.87	TON	$466.00	$592,724.04
PASTURE/RANGE	371		ACRE	$41.50	$15,396.50
TOTAL ACRES	6,772			MAXIMUM EST	$6,176,366.96

Source: San Joaquin Co.
Agricultural Report 1983

CROPS - 1990	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN	4,760	4.32	TON	$108.00	$2,220,825.60
ASPARAGUS, FRESH	680	1.23	TON	$1,050.00	$878,220.00
SUGAR BEETS	680	24.9	TON	$40.00	$677,280.00
WHEAT	680	2.66	TON	$110.00	$198,968.00
TOTAL ACRES	6,800			TOTAL	$3,975,293.60

Source: San Joaquin Co.
Agricultural Report 1990

Table 15. Agricultural Income Estimation Worksheet: Rio Blanco Tract 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
TOMATOES, PROCESSED	220	22.7	TON	$55.60	$277,666.40
SUNFLOWER	196	0.87	TON	$466.00	$79,462.32
GRAIN (UNSPEC), SORGHUM	164	3	TON	$98.00	$48,216.00
PASTURE/RANGE	71		ACRE	$41.50	$2,946.50
TOTAL ACRES	651			MINIMUM EST	$408,291.22
TOMATOES, FRESH	220	9.89	TON	$301.00	$654,915.80
SUNFLOWER	196	0.87	TON	$466.00	$79,462.32
GRAIN (UNSPEC), WHEAT	164	2.49	TON	$127.00	$51,861.72
PASTURE/RANGE	71		ACRE	$41.50	$2,946.50
TOTAL ACRES	651			MAXIMUM EST	$789,186.34
Source: San Joaquin Co.					
Agricultural Report 1983					

Table 16. Agricultural Income Estimation Worksheet: Venice Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN,FIELD	1,794	4.5	TON	$103.00	$831,519.00
GRAIN (UNSPEC), SORGHU	743	3	TON	$98.00	$218,442.00
PASTURE/RANGE	393		ACRE	$41.50	$16,309.50
SUNFLOWER	163	0.87	TON	$466.00	$66,083.46
TOTAL ACRES	3,093			MINIMUM EST	$1,132,353.96
CORN,SWEET	1,794	258	46 LB.	$4.44	$2,055,062.88
GRAIN (UNSPEC), WHEAT	743	2.49	TON	$127.00	$234,958.89
PASTURE/RANGE	393		ACRE	$41.50	$16,309.50
SUNFLOWER	163	0.87	TON	$466.00	$66,083.46
TOTAL ACRES	3,093			MAXIMUM EST	$2,372,414.73
Source: San Joaquin Co.					
Agricultural Report 1983					

Table 17. Agricultural Income Estimation Worksheet: Mildred Island 1982

CROP	ACRES	PROD/ACRE	UNIT	$/PROD.UNIT	GROSS INCOME
CORN, FIELD	766	4.50	TON	$103.00	$355,041.00
GRAPES (UNSPEC), WINE	34	7.28	TON	$167.00	$41,335.84
PASTURE/RANGE	165		ACRE	$41.50	$6,847.50
TOTAL ACRES	965			MINIMUM EST	$403,224.34
CORN, SWEET	766	258.00	46 LB	$4.44	$877,468.32
GRAPES (UNSPEC), TABLE	34	10.90	TON	$191.00	$70,784.60
PASTURE/RANGE	165		ACRE	$41.50	$6,847.50
TOTAL ACRES	965			MAXIMUM EST	$955,100.42
Source: San Joaquin Co.					
Agricultural Report 1982					

APPENDIX D

Table 18. Minimum and Maximum Gross Agricultural Income Estimates in Comparison to Annual Levee Maintenance Expenditures (1981-1986 Average)

ISLAND	MIN GROSS INCOME EST	MAINT/YR	DIFFERENCE
CONEY	$43,171.16	$104,544.00	($61,372.84)
DEAD HORSE	$76,439.00	$17,914.00	$58,525.00
FAY	$30,307.00	$43,040.00	($12,733.00)
LITTLE MANDEVILLE	$137,085.00	$16,875.00	$120,210.00
MANDEVILLE	$2,157,018.25	$95,238.00	$2,061,780.25
MEDFORD	$480,268.00	$43,129.00	$437,139.00
PROSPECT	$212,464.00	$158,200.00	$54,264.00
RINDGE	$2,831,855.04	$570,538.00	$2,261,317.04
RIO BLANCO	$408,291.22	$50,520.00	$357,771.22
VENICE	$1,132,353.96	$77,736.00	$1,054,617.96
MILDRED	$403,224.34	$26,645.00	$376,579.34
	MAX GROSS INCOME EST	MAINT/YR	DIFFERENCE
CONEY	$64,663.96	$104,544.00	($39,880.04)
DEAD HORSE	$256,654.00	$17,914.00	$238,740.00
FAY	$71,910.22	$43,040.00	$28,870.22
LITTLE MANDEVILLE	$336,234.84	$16,875.00	$319,359.84
MANDEVILLE	$4,308,327.45	$95,238.00	$4,213,089.45
MEDFORD	$1,178,656.48	$43,129.00	$1,135,527.48
PROSPECT	$598,936.00	$158,200.00	$440,736.00
RINDGE	$6,176,366.96	$570,538.00	$5,605,828.96
RIO BLANCO	$789,186.34	$50,520.00	$738,666.34
VENICE	$2,372,414.73	$77,736.00	$2,294,678.73
MILDRED	$955,100.42	$26,645.00	$928,455.42

Table 19. Minimum and Maximum Net Agricultural Income Estimates in Comparison to Annual Levee Maintenance Expenditures (1981-1986 Average)

ISLAND	MIN INCOME EST	NET 75%	NET 92%	MAINTENANCE	DIFF./75%	DIFF./92%
CONEY	$43,171.16	$10,792.79	$3,453.69	$104,544.00	($93,751.21)	($101,090.31)
DEAD HORSE	$76,439.00	$19,109.75	$6,115.12	$17,914.00	$1,195.75	($11,798.88)
FAY	$30,307.00	$7,576.75	$2,424.56	$43,040.00	($35,463.25)	($40,615.44)
LT. MANDEVILLE	$137,085.00	$34,271.25	$10,966.80	$16,875.00	$17,396.25	($5,908.20)
MANDEVILLE	$2,157,018.25	$539,254.56	$172,561.46	$95,238.00	$444,016.56	$77,323.46
MEDFORD	$480,268.00	$120,067.00	$38,421.44	$43,129.00	$76,938.00	($4,707.56)
PROSPECT	$212,464.00	$53,116.00	$16,997.12	$158,200.00	($105,084.00)	($141,202.88)
RINDGE	$2,831,855.04	$707,963.76	$226,548.40	$570,538.00	$137,425.76	($343,989.60)
RIO BLANCO	$408,291.22	$102,072.81	$32,663.30	$50,520.00	$51,552.81	($17,856.70)
VENICE	$1,132,353.96	$283,088.49	$90,588.32	$77,736.00	$205,352.49	$12,852.32
MILDRED	$403,224.34	$100,806.09	$32,257.95	$26,645.00	$74,161.09	$5,612.95
ISLAND	MAX INCOME EST	NET 75%	NET 92%	MAINTENANCE	DIFF./75%	DIFF./92%
CONEY	$64,663.96	$16,165.99	$5,173.12	$104,544.00	($88,378.01)	($99,370.88)
DEAD HORSE	$256,654.00	$64,163.50	$20,532.32	$17,914.00	$46,249.50	$2,618.32
FAY	$71,910.22	$17,977.56	$5,752.82	$43,040.00	($25,062.45)	($37,287.18)
LT. MANDEVILLE	$336,234.84	$84,058.71	$26,898.79	$16,875.00	$67,183.71	$10,023.79
MANDEVILLE	$4,308,327.45	$1,077,081.86	$344,666.20	$95,238.00	$981,843.86	$249,428.20
MEDFORD	$1,178,656.48	$294,664.12	$94,292.52	$43,129.00	$251,535.12	$51,163.52
PROSPECT	$606,820.00	$151,705.00	$48,545.60	$158,200.00	($6,495.00)	($109,654.40)
RINDGE	$6,176,366.96	$1,544,091.74	$494,109.36	$570,538.00	$973,553.74	($76,428.64)
RIO BLANCO	$789,186.34	$197,296.59	$63,134.91	$50,520.00	$146,776.59	$12,614.91
VENICE	$2,372,414.73	$593,103.68	$189,793.18	$77,736.00	$515,367.68	$112,057.18
MILDRED	$955,100.42	$238,775.11	$76,408.03	$26,645.00	$212,130.11	$49,763.03

Table 20. Levee Maintenance Expenditures 1981-1991

ISLAND	1981-86 AVG	1986-87	1987-88	1988-89	1989-90	1990-91*
CONEY	$104,544	$0	n/a	$75,266	$8,559	$80,835
DEADHORSE	$17,914	$71,350	n/a	n/a	n/a	n/a
FAY	$43,040	$7,098	$15,569	$41,502	$16,837	$92,970
LT. MANDEVILLE	$16,875	$129,455	$70,007	$21,779	$116,316	$25,834
MANDEVILLE	$95,238	$200,408	$177,688	$533,668	$251,347	$308,183
MEDFORD	$43,129	$0	$30,380	$162,015	$322,389	$139,292
PROSPECT	$158,200	$0	n/a	n/a	$45,388	n/a
RINDGE	$570,538	$0	n/a	$35,769	$387,601	$257,935
RIO BLANCO	$50,520	$20,873	$17,432	$19,093	$28,325	n/a
VENICE	$77,736	$0	$175,249	$275,081	$720,995	$581,401
						*projected
Source: Delta Atlas, 1987; DWR Central District 1991.						