Status and Trends of Delta-Suisun Services

Prepared by:
URS Corporation
Prepared for:
California Department of Water Resources

March 2007

Public Review Draft

Contents

CD in Back Pocket

Status and Trends of Delta-Suisun Services – PDF
Reference List
Copies of Select References
Maps

Acronyms and Abbreviations

ABAG	Association of Bay Area Governments
BCDC	San Francisco Bay Conservation and Development Commission
cfs	cubic feet per second
CVP	Central Valley Project
Delta-Suisun	Sacramento-San Joaquin Delta, Suisun Bay, and Suisun Marsh
DPC	Delta Protection Commission
DRMS	Delta Risk Management Strategy
DWR	California Department of Water Resources
GWH	gegawatt hours
IEP	Interagency Ecological Program
maf	million acre-feet
MHHW	Mean Higher High Water
POD	pelagic organism decline
SACOG	Sacramento Area Council of Governments
SJCOG	San Joaquin Council of Governments
SWP	State Water Project
SWRCB	State Water Resources Control Board
TMDL	total maximum daily load
USGS	U.S. Geological Survey

Summary

Covering only about 1 percent of California's area, the Sacramento-San Joaquin Delta, including Suisun Bay and Marsh (hereafter referred to as Delta-Suisun), contributes much more to the state and nation than one might expect from its small size. The Delta-Suisun provides a set of environmental and economic services whose benefits extend well beyond its borders. To help people gain a common understanding of these services, this report provides an overview of the existing status of these services and a perspective about how these services may change in the future.

This report was prepared to highlight observations and to present a common understanding about the status and trends of key Delta-Suisun services. The Delta Risk Management Strategy (DRMS) is considering these observations while conducting a risk assessment for the Delta-Suisun and will report on its findings in spring 2007. Having a common understanding of the area's services will benefit ongoing and new Delta-Suisun studies and initiatives. Information in this report will be considered by members of the Delta Vision Blue Ribbon Task Force and Stakeholder Coordination Group as they begin work on the Delta Vision and Strategic Plan.

Services Provided by the Delta-Suisun

- Land Uses (agricultural, urban and conservation)
- Flood Management
- Ecosystem
- Water Supply
- Water Quality Management and Discharges
- Transportation
- Utilities
- Recreation/Tourism
- Local and State Economics

A list of references and select documents for various topics can be found on the CD at the end of this report.

Status of Services

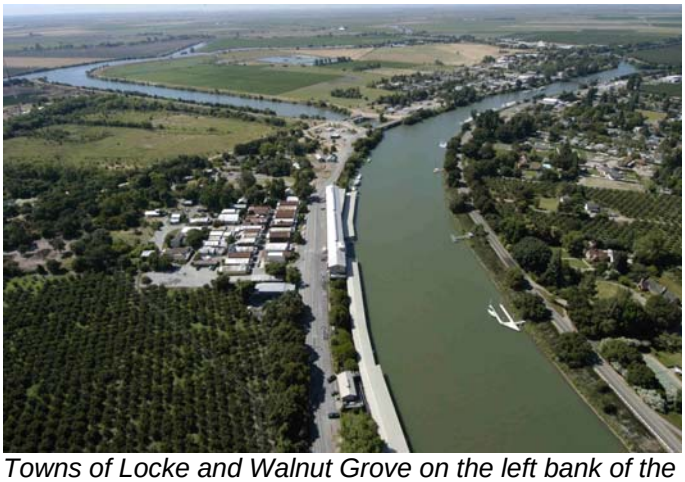
There is growing recognition of the importance of the Delta-Suisun as a changing, dynamic system. Within the past year, the Delta-Suisun area has gained an unprecedented level of political, public, and funding support. Although knowledge about the area is growing, the area's complexity continues to present data gaps and uncertainties. New studies and initiatives aimed at making the area, and its services, sustainable are under way.

The area and its services are highly influenced by today's regulatory and management practices, most established at a time when the system was viewed as relatively static. Another complicating factor is that the Delta-Suisun has a remarkable number of regulatory and management jurisdictions, making it difficult for all entities to coordinate efforts on a regional scale, especially when most have different missions and standards. In addition, the lack of long-term funding continues to limit the sustainability of its services.

Suisun Marsh with foothill buffer zone in background

The services are interrelated, yet there is a history of conflicts between some of the services, especially those provided by the ecosystem and water supply. All of the area's services are dependent on an antiquated levee system that is in danger of collapse.

The following are key observations about the status of each service provided by the Delta-Suisun:



Towns of Locke and Walnut Grove on the left bank of the Sacramento River with Delta Cross Channel in upper left

Land Use (agriculture, urban, and conservation)

- Suisun Marsh Preservation Act and Delta Protection Act both contain provisions to limit urban growth
- More than 1,315 square miles (about 840,000 acres); 67 percent agriculture, 9 percent urban, 14 percent conservation and other lands, and 10 percent water
- Predominately agricultural in the Delta and wetland conservation lands in the Suisun Marsh
- About one-half million acres of highly productive farmland
- Land use conversions (about 40,000 acres) from agriculture to urban and conservation from 1990 through 2004
- 165,000 dwellings and a population of about 470,000 within Delta-Suisun (2000 census)
- Surrounded by some of the fastest growing areas in California

Flood Management

- About 65 island and tracts in the Delta rely on levees
- More than 1,100 miles of Delta levees and about 230 miles of Suisun Marsh levees, mostly with low levels of protection for adjoining lands
- Most levees locally built and maintained
- Most land below sea level, some areas as much as 25 feet below sea level
- Land subsidence rates of 0.5 to 1.5 inches per year are common
- Sea level about 0.6 foot higher today than it was in 1920
- Levee failures possible throughout year
- Most islands have flooded at least once from levee failures
- 166 islands have flooded from levee failures since 1900
- Bond money for Delta flood management presently at all-time high
- All other existing Delta-Suisun services dependent on levee system

Ecosystem

- Unique estuarine habitat for many resident and migratory fish and birds, some listed as threatened or endangered species
- Very different from historical ecosystem in which the native organisms evolved
- Subject to rapid change
- More than 10 percent of California's remaining wetlands in Suisun Marsh
- Most important wintering and nesting area for waterfowl of the Pacific Flyway, and largest contiguous estuarine marsh remaining on the west coast of North America
- Biomass in benthic samples typically 95 percent or more from introduced (non-native) species
- Declining pelagic (open water) organisms such as delta smelt and longfin smelt

Water Supply

- About one-half million acres of agricultural land irrigated in the Delta-Suisun
- About 2.5 million acres of additional agricultural land irrigated with exported water
- Source of part of the drinking water to two-thirds of Californians
- 87 percent of municipal water used in East Bay is diverted from Delta or transported across it
- Last critically dry year for the Sacramento River was 1994
- Record exports (2000-2006)
- One of few estuaries in the world used as a major drinking water supply

Water Quality Management and Discharges

- 42,500 square miles drain to Delta-Suisun
- Water quality can be negatively affected by upstream discharges, in-Delta discharges, and seawater intrusion
- Both the Delta and Suisun Marsh are managed to control salinity

Transportation

- Most corridors serve other areas of state (highways, shipping channels, and rail)
- Transportation in Delta-Suisun follows more of a maze pattern than a straight corridor
- Bridges and ferries connect Delta islands

Utilities

- Wide variety of utilities (electrical transmission, natural gas pipelines, and water pipelines)
- Most serve large areas of the state

Recreation/Tourism

- Focused on water-based activities
- Private land ownership limits land-based recreation
- Wide range of activities including fishing, waterfowl and upland game bird hunting, wildlife viewing, bird watching, sightseeing and photography

Local and State Economics

- Total asset value more than $35 billion
- Employment more than 250,000 jobs
- Contributes to statewide economy, especially through water exports

Trends

The Delta-Suisun's waterways are a complex network. Water volumes, velocities, salinity, and pollutants all affect the ecosystem, agriculture, and drinking water supply. Changes in one area can create changes in other areas. There are a number of influences or "drivers," generally beyond human control, that may change the Delta-Suisun in the future (see textbox).

Drivers of Change

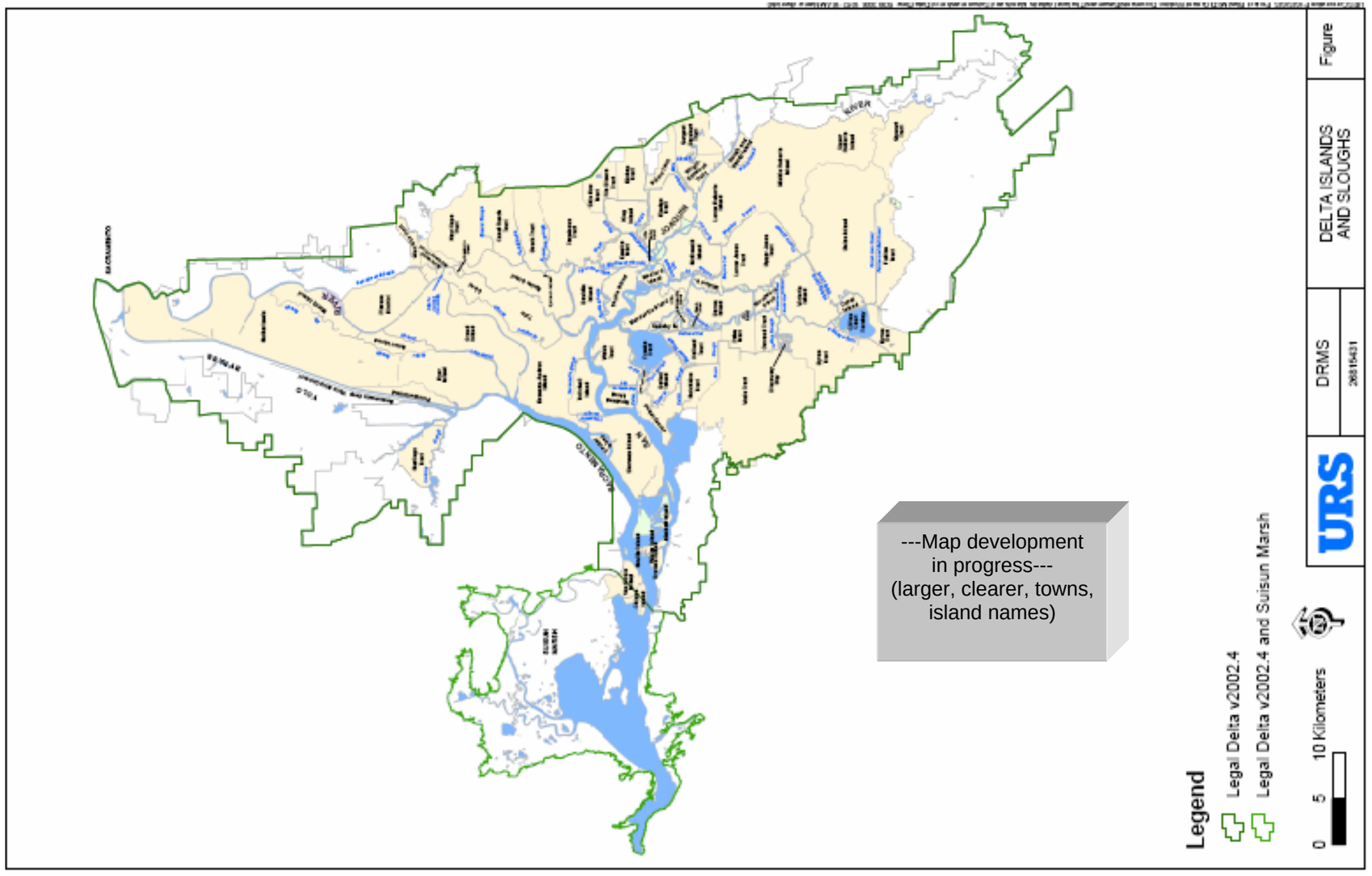
- Subsidence
- Global Climate Change – Sea Level Rise
- Regional Climate Change – More Winter Floods
- Seismic Activity
- Introduced Species
- Population Growth and Urbanization

Key observations about future trends include:

- Continued land subsidence where peat soils continue to be conventionally farmed
- Rates of land subsidence can far outpace rates of sea level rise
- Changes in agricultural management and crop types may help stabilize or increase Delta elevations
- More pressure on levees from continued sea level rise by another 0.6 foot to 1.9 feet by 2100, with a possible additional 0.5 foot rise if the rate of Greenland ice melt increases
- Higher salinities from sea level rise
- More winter precipitation falling in the mountains as rain rather than snow (decreased mountain snowpack by as much as 25 percent by 2050)
- Average winter floodflows to the Delta likely to become larger
- Natural summer flows likely to be lower, adding to dry season water supply and quality problems
- About a 2 out of 3 chance of at least one magnitude 6.7 or greater earthquake in the Bay Area before 2032 with potential for multiple islands flooded from levee failures
- Possible that some islands may remain permanently flooded
- One multiple island inundation scenario (85,000 acres of agricultural land and crops flooded, 3,000 homes flooded, shipping channels blocked, highways and utilities damaged, hazardous spills, 15 months or longer levee repairs, job losses exceed 30,000, disruption to water exports from the Delta, $30 billion to $40 billion loss to California's economy)
- Species known to be problems in other regions, such as northern pike, zebra mussel, and various aquarium plants, are likely to invade the Delta-Suisun
- 130,000 new homes in the Delta-Suisun within the next decade
- Urbanization of available land within the Secondary Zone could add 600,000 to 900,000 people
- More demand on the Delta-Suisun's services (recreation, transportation, utilities, water supply, and urban runoff) from population growth and urbanization
- Pressures on agriculture and other open space uses from urbanization
- Reduced options for future management choices for other resources with urbanization covering more land

The combination of future subsidence, sea level rise, more winter runoff, and seismic activity appear to make the Delta-Suisun levees more vulnerable to failure. All Delta-Suisun services would be affected by levee failures. Flooding that disrupts the export water supply would create significant losses for the state economy. Population and urban growth inside and outside the Delta-Suisun will place more demands on transportation, utilities, and recreation. Introduced species have the potential to further alter the ecosystem to the detriment of native species and human uses.

Vicinity Map



The Delta-Suisun is a product of river flows from above and ocean forces from below. It provides services locally and to the state as a whole. While focusing on the challenges facing the Delta-Suisun, we must recognize that many solutions lie not just in the Delta-Suisun itself, but in the bay and ocean, the watershed, and the floodplains and population centers on its periphery.

Historical Perspective and Timeline

DELTA TIMELINE:

"We will not restore or re-create the conditions of the original San Francisco – Delta estuary, nor is that the goal. But history can help us understand the Delta's problems."

Thousands of Years Before Present | **1850s** | **1860s** | **1870s** | **1880s** | **1890s** | **1900s** | **1910s** | **1920s** | **1930s** | **1940s** | **1950s** | **1960s** | **1970s** | **1980s** | **1990s** | **2000s** | **2010s**

Area relatively unaltered by humans

Peat soils accumulate

Flows into the Delta-Suisun and salinity levels are highly variable between the seasons and between the years

Land subsidence begins with reclamation of Delta-Suisun land and continues with farming

Main period of levee construction and island draining

Water flows become more stable with upstream dams and Delta water becomes generally fresher (less salty)

Federal Tracy Pumping Plant exports Delta water

State Banks Pumping Plant exports Delta water

Declining fishery populations and heightened competition for water

Some fish populations, especially salmon, appear to be increasing, but pelagic (open water) organism decline demonstrates that there is still much to learn about the ecosystem.

Sea Levels and the Delta – Suisun

People often think of the physical conditions in the Delta-Suisun as remaining relatively the same over time. Sea levels are one striking example that existing conditions in the Delta have not always been the same:

- About 20,000 years ago, sea levels were about 400 feet lower than they are today.
- About 130,000 years ago, sea levels were as much as 10 feet higher than they are today.
- Imagine the Delta-Siusun was not a Delta when the sea level was near the Farallon Islands, almost 30 miles west of the Golden Gate or when sea level extended more than a hundred miles upstream into the Central Valley.

Hydraulic mining in the mountains sent sediment into the rivers and the Delta

Riverboats used to routinely navigate Delta Channels

Dredging was one levee construction method that followed the original hand work

Decade of Reclamation

- 1860-1870
- 1870-1880
- 1880-1890
- 1890-1900
- 1900-1910
- 1910-1920

History of Delta Conflict Up to the 1994 Delta Accord

Throughout the 1970s, 1980s, and 1990s, as water users attempted to increase their use of water from the Delta in response to growing demands, conflicts between urban users, agricultural and the environmental water users continued to escalate. This led to a crisis that resulted in the CALFED Bay-Delta Program.

North-south divisions within California politics have always played an important role in conflicts over water, as most of the water in the state falls in the north, while most of the people and demand for water is in the south. This conflict came to a head in 1982, when California voters defeated the Peripheral Canal, a plan to allow the Central Valley Project (CVP) and State Water Project (SWP) to divert water directly from the Sacramento River and carry it around the Delta to the export pumps.

Without the canal, the CVP and SWP continued to divert water from the South Delta, and these diversions increasingly became the focus of legal and regulatory battles. In 1978, the State Water Resources Control Board (SWRCB) issued Decision-1485, establishing water quality standards for the Delta and requiring the CVP and SWP to meet these standards. In 1985, EPA declared D-1485 inadequate under the Clean Water Act. In 1991, SWRCB issued a new Delta salinity plan which was also rejected by EPA.

Also in 1991, the winter-run Chinook salmon was listed as threatened under the Endangered Species Act (ESA), and restrictions on CVP and SWP pumping were imposed. The Delta smelt was listed as threatened under the ESA in 1993 and additional restrictions on export pumping were imposed, sometimes halting exports completely during peak irrigation times. Also in 1993, the Governor rejected the SWRCBs latest attempt to set Delta water quality standards (D-1630).

By 1994, Governor Pete Wilson became increasingly concerned about the declining state of the Delta ecosystem, the increasing uncertainty associated with Delta water supplies for urban and agricultural uses, and the increasing amount of rancor and litigation surrounding SWRCB's unsuccessful 16-year effort to establish Delta water quality standards. He led an effort to bring together the numerous federal and state agencies with responsibilities in the Delta, and stakeholder representatives to work toward a resolution of the conflicts over the Delta. In December 1994, the Delta Accord was signed which set interim water quality standards and established the CALFED Bay-Delta Program to: develop long-term Delta water quality standards, coordinate operations of the state and federal water projects, and develop a long-term solution for the Delta.

1. Introduction

Purpose

This report, *Status and Trends of Delta-Suisun Services*, was prepared to provide a common understanding of the environmental and economic services provided by the Sacramento-San Joaquin Delta, including the Suisun Bay and Marsh. The report uses the term, "Delta-Suisun" when referring to the collective area of the Delta, the Suisun Bay and the Suisun Marsh. At times, when necessary to distinguish among the areas, the report uses their individual names.

Services Provided by the Delta-Suisun

- Land Uses (agricultural, urban and conservation)
- Flood Management
- Ecosystem
- Water Supply
- Water Quality Management and Discharges
- Transportation
- Utilities
- Recreation/Tourism
- Local and State Economics

The report highlights key observations about the Delta-Suisun. The Delta Risk Management Strategy (DRMS) is considering these observations while conducting a risk assessment for the Delta-Suisun and will report on its findings in spring 2007. Other new studies and initiatives will benefit from a common understanding of the area's services summarized in this report. Information in this report will be considered by members of the Delta Vision Blue Ribbon Task Force and Stakeholder Coordination Group as they begin work on the Delta Vision and Delta Strategic Plan (see textbox below).

Few people know about the full array of Delta-Suisun services. For example, people interested in recreational opportunities may be unaware of all the other services that the area provides. People living outside the area may not be aware that the area provides services, like water supply, that directly impact their standard of living. Regardless of how it is viewed--individually or collectively--these services provide benefits locally and to the state and the nation.

This report provides an overview of the existing status of each service. It also provides a perspective of how these services may change in the future. Both the status and the trends are influenced by existing regulatory and management practices. It is beyond the scope of this report to describe how the trends may be different pending other possible regulatory management practices; those issues will be addressed in other studies and initiatives.

Governor Schwarzenegger's Delta Vision Initiative

The Delta Vision initiative will identify a strategy for managing the Sacramento-San Joaquin Delta as a sustainable system that would continue to support environmental and economic functions that are critical to the people of California. Delta Vision is based on a growing consensus (scientists, legislators, and others) that the Delta is not sustainable for:

- Environmental conditions
- Current Delta "architecture"
- Current land and water uses and related services
- Current management practices and regulatory requirements
- Infrastructure
- Other uses

A key component of Delta Vision is a Governor-appointed independent Blue Ribbon Task Force that is responsible for recommending future actions to achieve a sustainable Delta. The process includes a diverse Stakeholder Coordination Group and broad public outreach to evaluate different Delta visions and management scenarios. The Task Force will submit a Delta Vision Report by the end of 2007 and a Delta Strategic Plan in October 2008. A Cabinet-level Delta Vision Committee will submit the Delta Strategic Plan to the Governor and Legislature by December 31, 2008.

See the Delta Vision Web Portal for updated information on the initiative at www.deltavision.ca.gov.

Setting

The Sacramento-San Joaquin Delta and Suisun Marsh are at the confluence of the Sacramento River and San Joaquin River basins, which provide drainage to about 40 percent of California (see map). This confluence is unique because the respective river deltas merge into an inland delta. The Delta-Suisun is the major source of California's water supply and an ecological treasure, as well as the intersection to a variety of businesses, transportation corridors, utilities, and recreation.

Watershed

The Delta-Suisun drains roughly 40 percent of California's land area

The Delta-Suisun is a part of the West Coast's largest estuary on the west cost of North America. The Delta-Suisun covers approximately 1,315 square miles in portions of 6 California counties.

Before the 1849 California Gold Rush, the Delta-Suisun consisted of hundreds of miles of tidally influenced sloughs and channels, and hundreds of thousands of acres of marsh and overflow land. The Delta-Suisun once supported large mammal species such as the grizzly bear, tule elk, and gray wolf. Since then, the Delta has been reconstructed to reclaim land, primarily for agricultural use. More than 1,100 miles of Delta levees and about 230 miles of Suisun Marsh levees now line the channels. More than 1,800 diversions take water from the channels for use within the Delta, and large state and federal projects export water for use in other parts of California.

The Delta (738,239 acres) was given a legal boundary (Section 12220 of the Water Code) in 1959 with the passage of the Delta Protection Act. The 1992 Delta Protection Act refined the definition to provide primary and secondary zones within the previously defined legal Delta (see map on next page). The Primary Zone (about two-thirds of Delta area) was intended to remain relatively free from urban and suburban encroachment to protect agriculture, wildlife habitat, and recreation uses. Urban development in the Secondary Zone (about one-third of Delta area) was intended to include an appropriate buffer zone to prevent impacts on the lands in the Primary Zone. The 1992 Act also established the Delta Protection Commission (DPC) to prepare and maintain a Resource Management Plan for the Primary Zone.

Delta Protection Act

Recognizing the possible threat to Delta resources from urban encroachment having the potential to significantly impact agriculture, wildlife habitat, and recreation uses, the Delta Protection Act was passed by the Legislature and signed by the Governor in 1992. The act is codified in the State Public Resources Code beginning with Sections 29700.

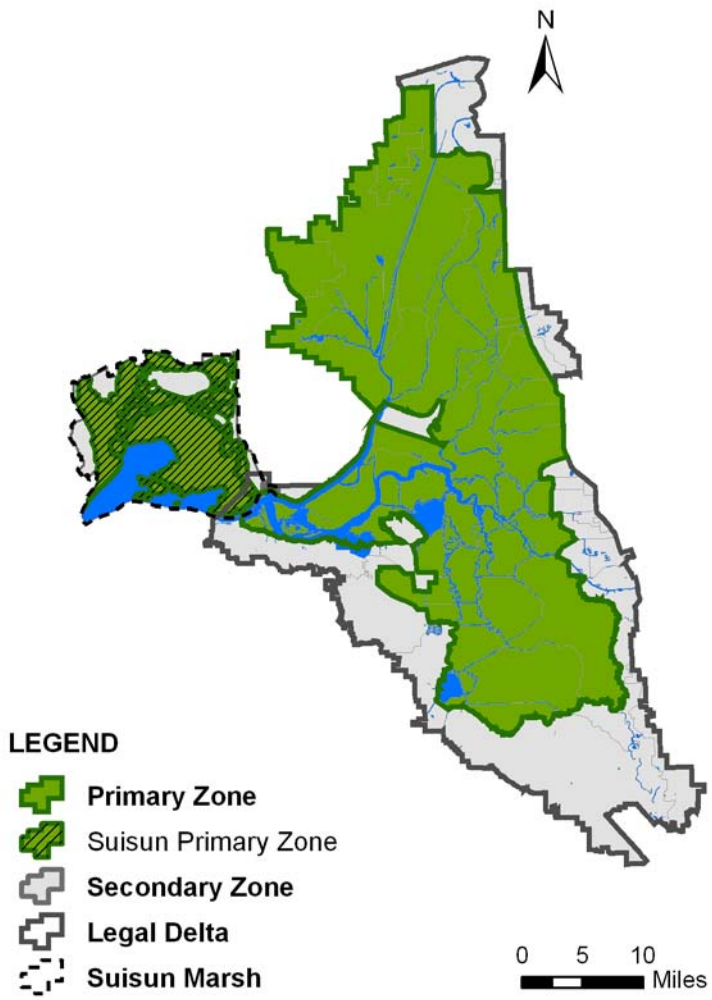
The Suisun Marsh Protection Plan includes a primary management area encompassing the 89,000 acres of tidal marsh, managed wetlands, adjacent grasslands, and waterways. A secondary management area includes approximately 22,500 acres of significant buffer lands. San Francisco Bay Conservation and Development Commission (BCDC) represents the state government interest, serving as the land use permitting agency for projects in the primary management area and as an appellate body in the secondary management area.

See Chapter 5 for references

Suisun Marsh Preservation Act

Recognizing the threats to the Suisun Marsh from potential residential, commercial, and industrial developments, and the need to preserve this unique wildlife resource for future generations, the California Legislature passed and the Governor signed in September 1974, the Nejedly-Bagley-Z'berg Suisun Marsh Preservation Act of 1974. The Act directs the San Francisco Bay Conservation and Development Commission and the Department of Fish and Game to prepare the Suisun Marsh Protection Plan. The objectives of the Protection Plan are to preserve and enhance the quality and diversity of the Suisun Marsh aquatic and wildlife habitats and to assure retention of upland areas adjacent to the Marsh in uses compatible with its protection.

Delta-Suisun Area



The Delta-Suisun encompasses about 1,315 square miles, with the Primary Zone (including Suisun Marsh primary management area) intended to remain relatively free from urbanization

2. Status of Services

The Delta-Suisun provides a wide variety of services. The following pages give an overview of the status of each key service. In most cases, the Delta-Suisun services are influenced by activities outside its borders. Ocean tides flow twice each day into the area. The upstream watershed provides freshwater flows to the Delta-Suisun. Urban areas around the Delta-Suisun influence transportation that crosses it and recreational opportunities within the Delta-Suisun.

Land Uses (Agricultural, Urban, and Conservation)

Surrounded by the burgeoning Sacramento, Stockton, and San Francisco Bay areas, the Delta is under enormous pressures for development.

The Delta is dominated by highly productive agricultural land. It was reported in 2004 that $1.65 billion in agricultural crop value was generated from the 6 Delta counties. Urban areas within the Delta-Suisun are near its outer edges (see map on next page). Conservation lands are scattered throughout the area. The Suisun Marsh includes managed wetlands that are an important component of the Pacific Flyway for wintering waterfowl. Sherman Island, Jersey Island, Twitchell Island, Staten Island, McCormack Williamson Tract are held as conservation lands, but are currently operated as farmlands.

Since 1990, urban and other land uses have gained substantial acreage while agricultural land use has declined (see table). “Other Land” shown in the table includes conservation areas, low-density rural developments, natural areas not suitable for livestock grazing, and other nonagricultural areas.

Small, unincorporated communities and historic towns within the Delta’s Primary Zone serve as social and service centers for surrounding farms: Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove. A small portion of Rio Vista lies within the Primary Zone. Some communities within or just outside the Secondary Zone are the incorporated city of Isleton and portions of Stockton, Pittsburg, Antioch, Oakley, Sacramento, and West Sacramento. The expanding cities of Fairfield and Suisun City are encroaching on the edges of the Suisun Marsh secondary management area. The Delta Protection Act and the Suisun Marsh Preservation Act have provisions to limit urban growth.

Land Use Change Within the Delta and Suisun Marsh

Land Use	*Acres 1990*	*Acres 2004*	*Percentage of total 2004*	*Acreage change 1990-2004*	*Percent change 1990-2004*
Urban and Built-up Land	57,351	74,098	9	16,747	29
Agricultural	596,603	557,896	67	-38,707	-6
Other Land	100,090	120,535	14	20,445	20
Water	83,170	85,065	10	1,895	2
Total*	837,214	837,594	100		

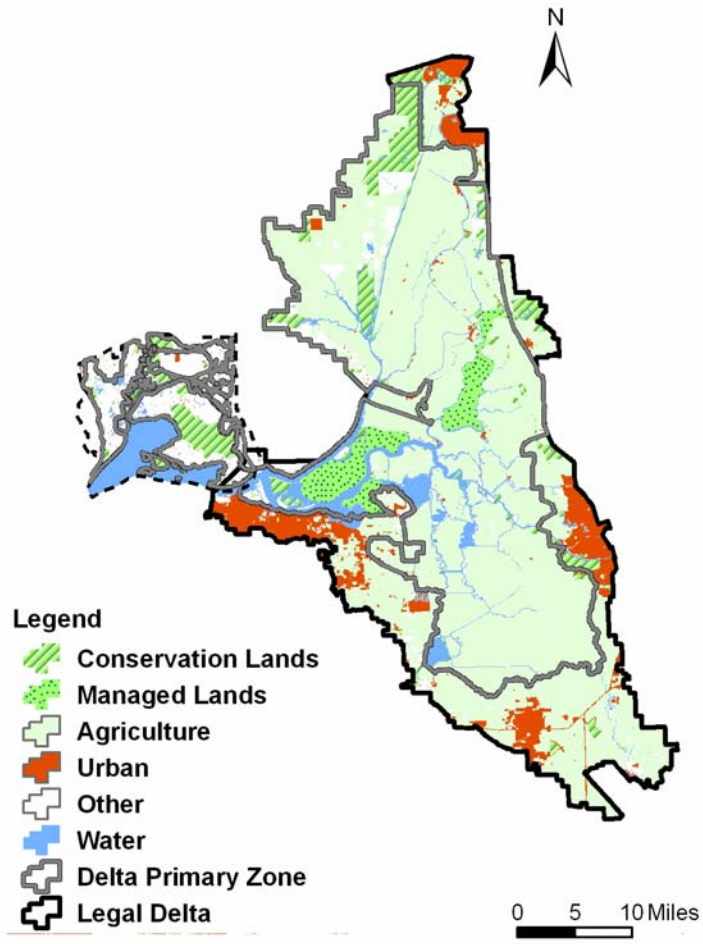
*Discrepancy in acreage may be due to refined mapping techniques or changes in land use definition between 1990 and 2004. Note: the mapping area used in this report is about 1 percent larger than the total acreage in the table.

Based on California Department of Conservation Farmland Mapping and Monitoring Program data.

Governments and non-governmental organizations purchase land for conservation. There are numerous agricultural land and conservation trusts, reserves, wildlife areas, and wetland areas, mostly in non-contiguous parcels. Most of the Suisun Marsh is privately owned by ranchers, farmers, and waterfowl hunting clubs. Numerous public agencies own more than 20,000 acres within the Suisun Marsh.

Five counties within the Delta have Habitat Conservation Plans that include land banking and other programs to set aside Delta land for conservation. The Bay Delta Conservation Plan, currently under development, will provide for the conservation and management of aquatic species and regulatory assurances related to water supply reliability and water quality.

Delta-Suisun Land Uses



Land use is predominately agricultural in the Delta and conservation in the Suisun Marsh

See Chapter 5 for references

Flood Management

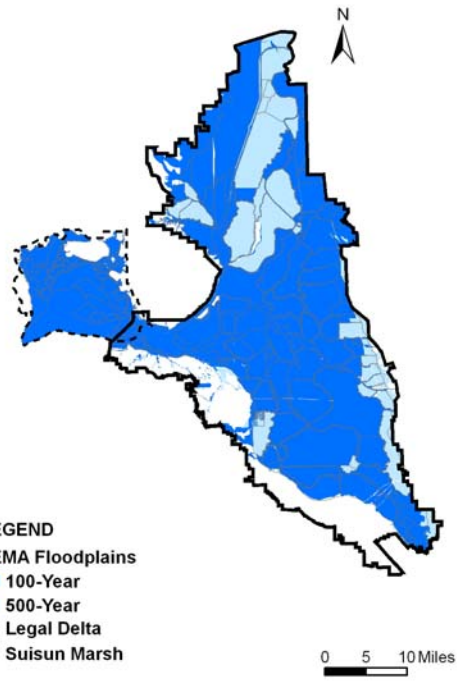
The Delta-Suisun is the natural drain to a 42,500 square mile watershed that includes the Central Valley and the western slope of the Sierra Nevada from Fresno to Mount Shasta. Existing flood management and water supply facilities (dams, levees, and bypasses) throughout the watershed influence floodflows to the Delta.

Flood management begins with the Delta-Suisun levees, but also includes levees, bypasses, and dams in the upstream watershed. Most of the Delta-Suisun does not meet the Federal Emergency Management Agency's definition for 100-year flood protection. What role should the Delta levees play in the future when considering sea level rise or weather changes?

By the 1850s, settlers had begun to farm the rich lands of the Delta. They built low levees to allow land to be drained for farming. Most of these levees were built before modern engineering techniques, and many rest on peat foundations that have settled with the added weight. The levees have been periodically widened and raised to keep pace with subsidence on Delta islands.

The main flood management facilities in the Delta-Suisun are the Yolo Bypass, about 1,100 miles levees in the Delta and about 230 miles of levees in the Suisun Marsh. Most levees are maintained by local reclamation districts. The Yolo Bypass, about 500,000 cubic feet per second (cfs) capacity, was designed to occasionally flood to relieve high flood stages on the Sacramento River. Easements held by the Reclamation Board provide the right to inundate the land, including some islands like Liberty Island, with floodwaters. The lower Sacramento and the Stockton ship channels provide some flood carrying capability. Dredging to enlarge Delta channels used to be an important element of flood management.

FEMA Flood Zones



Most of the Delta is within the FEMA 100-year floodplain

Because it is an estuary with so much land below sea level, water is constantly exerting pressure against the levees. Therefore, levees can fail at any time for various reasons, including increased water pressure caused by island subsidence, the burrowing activities of animals, long-term erosion (high flows events, wind-induced waves, and boat wakes), deferred maintenance, seepage through sand layers underlying levee foundations, and other causes not yet well understood. A levee on Jones Tract failed from unknown reasons during the summer of 2004.

Delta-Suisun levees face risk of overtopping during the wet season (winter and spring), particularly when large storms coincide with high tide events. Storms contribute to levee overtopping risk by creating high water levels in the rivers, by wind-induced waves, and because the low barometric pressures associated with large storms raise water surface levels in Delta and Suisun Marsh channels. The levees generally do not provide 100-year flood protection to the adjacent lands (see map).

Most Delta islands have flooded at least once. Since 1900, there have been 166 Delta levee failures leading to island inundations (see map). Six "sunny day" failures occurred during summer low-flow times. In many cases, the flooding of the islands has been costly to both local residents and farmers and to the state as a whole. The Delta experienced multi-island failures during 26 years since 1900. As many as 19 islands and tracts flooded in 1907 and 11 flooded in 1997. Although records are not complete, levee failures in the Suisun Marsh have also occurred with significant impacts to local and statewide interests. In February 1998, 11 exterior levee breaches in the Suisun Marsh resulted in the inundation of more than 22,000 acres and threatened both the State Water Project (SWP) and Central Valley Project (CVP) facilities with increased salinity.

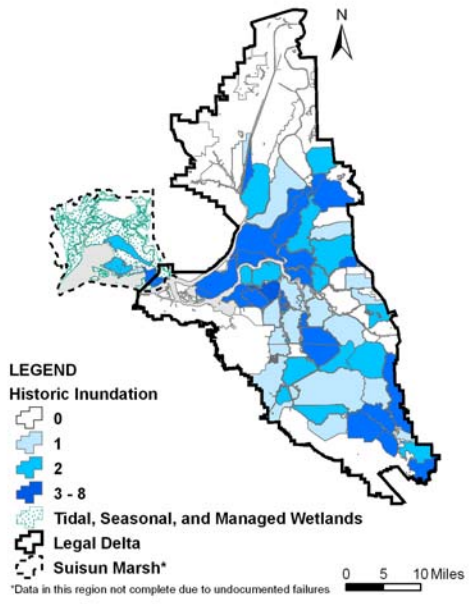
Jones Tract levee failure, repair in progress, in the summer of 2004 is a reminder that Delta levees occasionally fail during low river flows

The California Department of Water Resources (DWR) has primary responsibility for flood management throughout the Central Valley on "project levees" which are part of an authorized federal flood control project. More than 700 miles, or 65 percent, of Delta levees are classified as "non-project" because they are not part of an authorized federal flood control project. These flood control structures have been built and maintained by landowners or reclamation districts to protect agricultural lands. Frequently, they are not as durable as the project levees.

In general, the levee work by reclamation districts is financed by the owners of the lands within the levees. During approximately the last 30 years, the State of California has provided supplemental financing for levee maintenance and emergency response through DWR's Subventions Program. In addition, DWR provides technical assistance to reclamation districts and coordinates flood fights when islands are threatened. Funding for these programs has been intermittent and unreliable.

Fewer than 20 miles (between Van Sickle Island and the mouth of Montezuma Slough) of Suisun Marsh exterior levees are eligible for levee maintenance assistance under the Subventions Program. Maintenance and improvement of the Suisun Marsh levee system, including interior levees, is the responsibility of local reclamation districts, private wetland managers, California Department of Fish and Game (as manager of Grizzly Island wildlife area complex), DWR and USBR.

Island Inundation from Levee Failures Since 1900



Most Delta islands and tracts have flooded at least once

See Chapter 5 for references

Ecosystem

The Delta-Suisun is subject to rapid change. The historic loss of habitat, together with alteration of hydrology, species composition, and water quality, have had severe negative effects on many desirable species.

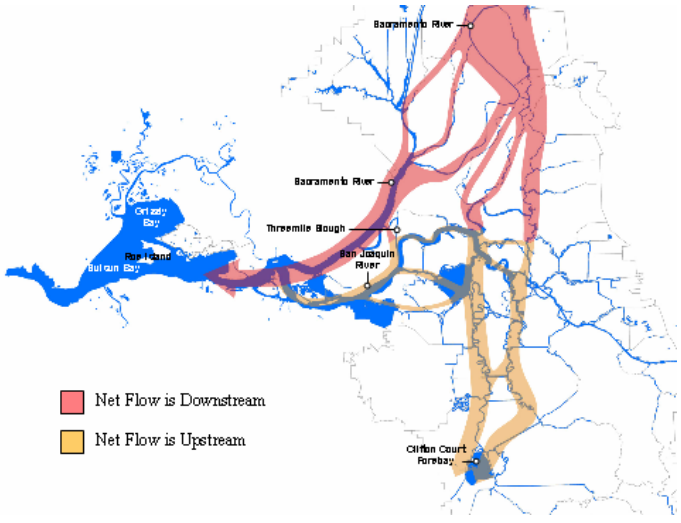
Species indigenous to the Delta-Suisun evolved within an ecosystem that was much different than today's. Many of the indigenous species have declined because of loss of habitat, changes in hydrologic processes or other changes to the system. Some of these ecosystem changes over the past 150 years include:

- Loss of access to upstream habitat for anadromous fish through construction of dams
- Diking and draining of Delta-Suisun lands to convert marshes to farms
- Urbanization
- Canalization and levee construction that separated rivers from their floodplains and eliminated channel meandering
- Invasion by non-native species
- Alterations in hydrology, particularly seasonal flow patterns
- Reduction in seasonal and annual variability in salinity
- Introduction of numerous toxic substances

The Delta Meadows may be the best remaining representation of how some parts of the Delta looked before its conversion to farming

Flow patterns in the Delta are governed by inflows, diversions, and tidal flows. The relative importance of these flows varies with season and location. In general, Delta inflows have been reduced in winter-spring through impoundment behind dams and increased in summer through flow releases to support export pumping and control salinity in the Delta. That change in seasonal pattern has reduced the big floodflows that used to deliver sediment and rearrange the channel configuration (bathymetry) and has decreased salinity in the summer. This has made the water in the area fresher for longer periods, which favors introduced species, such as the waterweed *Egeria densa*, overbite clam, and largemouth bass.

Net, tidally averaged, flows depend on inflows from the rivers and export flows in the southern Delta. Sometimes, the combination of inflows and exports causes "reverse flow", or a situation when flow moves upstream rather than downstream. These flows cause large numbers of young fish, including eggs and larvae, to be sent to the export facilities. In addition, some entrainment of these young fish, eggs, and larvae occur even when the net flow is in the downstream direction.



Sometimes, net flow in the South Delta channels is in the upstream direction

The Delta-Suisun provide substantial habitat for resident and migratory waterfowl and shorebirds. Abundance of these birds declined precipitously in the Delta because of land reclamation, but changes in cropping patterns have allowed for increasing populations. The Suisun Marsh encompasses more than 10 percent of California's remaining wetlands. It is an important wintering and nesting area for waterfowl of the Pacific Flyway, and is the largest contiguous estuarine brackish water wetland remaining on the west coast of North America. The Marsh, together with wetlands managed for 150 waterfowl hunting clubs, serves as resting and feeding ground for thousands of migrating waterfowl. In addition, the Marsh provides habitat for more than 221 bird species, 45 mammal species, and 16 reptile and amphibian species. It is the critical link between the Delta and bay for anadromous fish and is considered an important nursery for fish.

The Delta-Suisun supports approximately 55 fish species, about half of which are natives. Many of the native species have declined in abundance and in range, leading to the listing of several species under the California and/or Federal Endangered Species Acts (ESA). Early species declines were caused by loss or isolation of physical habitat when the Delta islands were drained. Species declines that have occurred since monitoring began in the 1960s-1980s have been attributed to a variety of causes including changing climate, effects of toxic substances, alteration of habitat, introduction of species that consume, compete with, or alter the habitat of natives, and changes in hydrology.

Threatened and Endangered (USFWS) Species in the Delta and Suisun Marsh

Chinook salmon – winter run
Chinook salmon – spring run
Central Valley Steelhead trout
Delta smelt
Southern Green sturgeon
Giant garter snake
Salt marsh harvest mouse
California clapper rail
Valley elderberry longhorn beetle
Delta green ground beetle
Suisun Thistle
Soft birds beak

The condition of the upstream river system affects the fish that reside year-round in the Delta-Suisun and the anadromous fish that spend a portion of their lives in the estuary. For example, the planned restoration of the San Joaquin River will include rehabilitation of the riverbed and release of water from Friant Dam to provide a river flow all the way to the Delta; portions of the river have carried little more than agricultural drain water since about 1950. The restoration is expected to restore anadromous fish runs to the river. Based on current plans, the restoration will be completed by 2016.

Environmental Water Account

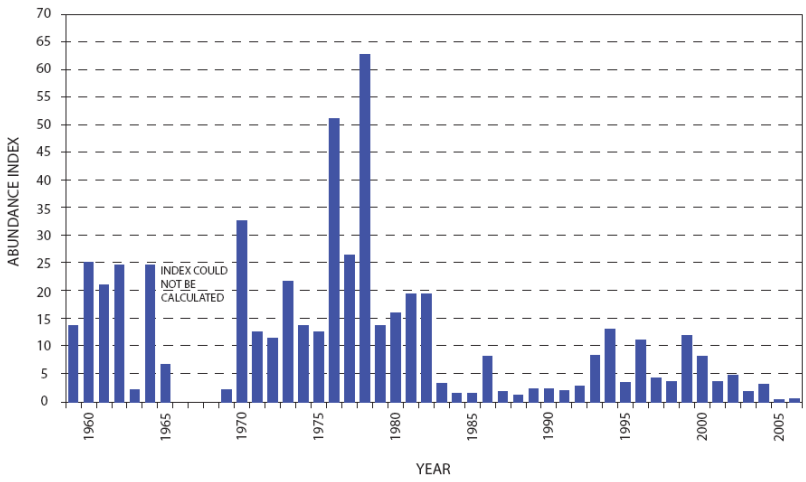
The Environmental Water Account (EWA) was established in 2000 as a tool for protecting fish by flexibly managing the timing of exports from the Delta. This “real-time” operation allowed the SWP and CVP export pumps to be shut down when fish were present in the area and to operate when the fish were not in danger. The EWA was designed for flexible pumping operations without reducing total water exports.

After six years of operating the EWA, it is not yet possible to say whether this program has provided a substantial benefit to fish species.

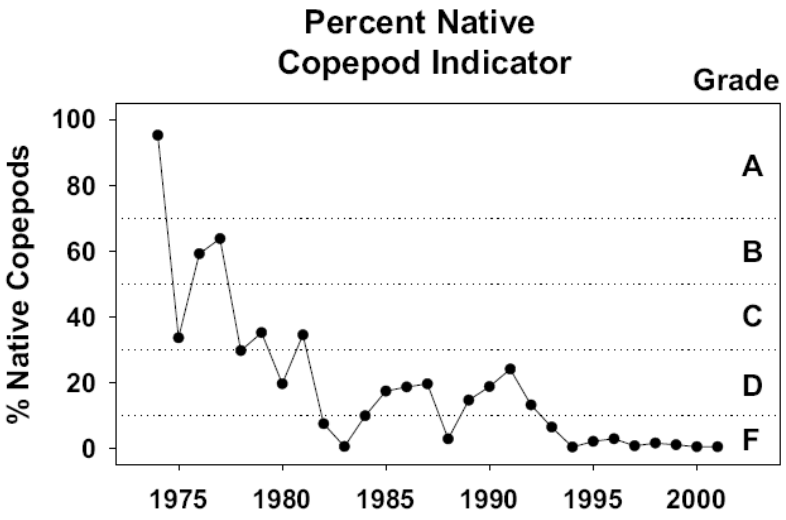
Many other restoration activities are under way and aimed at species sustainability in the Delta and its watershed. For example, the Central Valley Project Improvement Act (1992) included many actions to improve conditions for Central Valley fish including dedication of 800,000 acre-feet of project yield for ecosystem uses. CALFED ecosystem restoration activities have included habitat, water, and operational improvements such as the Environmental Water Account. Several non-governmental organizations are also involved in conserving land and restoring the ecosystem.

There are many other operational requirements aimed at protecting fish and wildlife of the Delta-Suisun. Some of the operational requirements include biological opinions of the fishery agencies,

incidental take limits for special status species that warn (yellow light) and stop (red light) Delta export pumps, export limits, export/inflow ratios, minimum Delta outflow, minimum river flows, pulse flows, Delta Cross Channel Gate setting, San Joaquin River salinity, Suisun Marsh salinity, position of 2 parts per thousand salinity in the estuary, and water quality total maximum daily load (TMDL) requirements. Still, problems with the ecosystem are evident.



Delta smelt have shown a precipitous decline in recent years



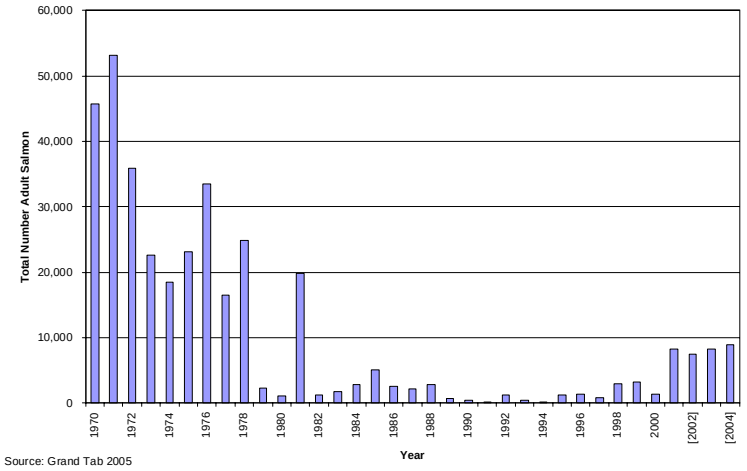
In 2001, Suisun Bay native copepod individuals were less than 1 percent of mean 1974-1970 values (The Bay Institute, April 2004)

In the last few years several pelagic (open water) fish species inhabiting the Delta-Suisun, such as delta smelt and longfin smelt, have declined in abundance to record-low levels (see graphs). The reasons for pelagic organism decline (POD) are multiple and are the subject of intense investigation. Pelagic species of the Delta seem to be squeezed between poor conditions for food and water quality, losses to export pumping, and possibly other negative influences, such as toxins.

At the same time, winter and spring Chinook salmon populations have been increasing after many years of decline (see graph). These increases in salmon population have been attributed to changes in operation of Red Bluff Diversion Dam, temperature control at Shasta Dam, improvement of fish passage on tributaries, favorable hydrologic conditions, and reductions in ocean harvest. Fall Chinook in the San Joaquin River have not fared as well, possibly because of poor conditions for passage of juveniles through the Delta in late spring.

Long-term trends for the ecosystem depend on the severity of climate change and what happens to the physical structure and salinity of the Delta. Current trends for increasing temperature and a shift to an earlier runoff peak will favor some species over others. Chinook salmon, steelhead, and delta smelt are among those likely to suffer negative impacts of these changes. The planktonic species at the base of the foodweb are unlikely to be strongly affected by these changes. However, some species may be strongly affected by the trend toward clearer water in the Delta and by changes in the abundance and distribution of introduced clams and waterweed.

Exhibit



Source: Grand Tab 2005

Some salmon populations have rebounded in recent years

Because the Delta and Suisun Marsh are part of one of the most intensively studied estuaries in the world, it is possible to make reasonable predictions of their future states under different future management regimes. Processes are now underway to make better predictions than in the past (DRMS, Delta Vision initiative, IEP, and others).

Interagency Ecological Program

The IEP goal is to provide data and information about factors that affect ecological resources in the Sacramento-San Joaquin Estuary for more efficient management of the estuary.

The IEP publishes a quarterly report to summarize ongoing data collection, monitoring, and research.

Find more information about the IEP at www.iep.ca.gov/.

See Chapter 5 for references

Water Supply

Flows that enter and leave the Delta-Suisun vary dramatically from year to year. Before construction of reservoirs within the watershed, flow fluctuations between years were even more dramatic.

Aided by flexible operations provided by the Environmental Water Account, Delta exports have reached record levels in recent years. However, sea level rise and seismic hazards put the Delta water supply system at extreme risk.

Water supply includes not only the water used by farms, cities, and businesses, but the flows in the rivers and channels that support the ecosystem. Some of the water entering the Delta-Suisun is diverted out of channels for use within the Delta-Suisun, a larger portion is exported for uses in areas outside the Delta-Suisun region, and most flows to the San Francisco Bay and the ocean.

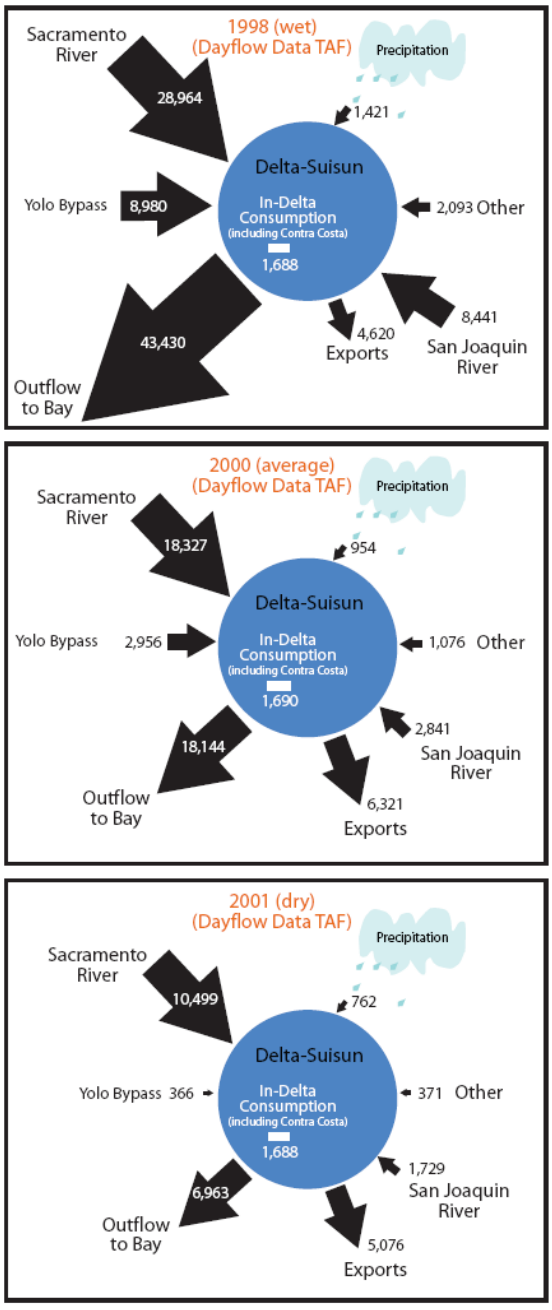
A water balance is a good way to get an overview of the major flows in the system. Three recent years—1998, 2000, and 2001—can help demonstrate typical fluctuations in Delta-Suisun flows among years with different rainfall (see adjoining water balance). During this period, the water system was generally operated under the same rules as today. Some observations that can be made by looking at a wet year (1998), an average year (2000), and a dry year (2001) are:

- In-Delta consumptive use is similar most years
- Water export quantities show more variability but still are in a relatively narrow range
- The widest variability from year to year occurs in the outflow from the Delta. Net outflow to the bay/ocean in a wet year can be many times the outflow during a dry year.
- Water diversions and exports are a larger portion of the Delta inflow during a dry year

The historical records show even larger flow ranges than represented in the water balance. For example, during water year 1983 (October 1982 through September 1983), more than 60 million acre-feet (maf) of water passed through the Delta to the San Francisco Bay. During water year 1977, only about 5 maf of water passed through the Delta to the bay.

Water diversions for in-Delta uses are quite different in number and size from those for export use outside the Delta (see map of diversions). Irrigation water for use in the Delta is taken directly from the channels and sloughs through approximately 1,800 diversions, which together divert up to 5,000 cfs during peak summer months. Most of these diversions are not screened to exclude fish and consist of pipes that pass over the levees.

Delta Water Balance



Flows vary significantly from year to year

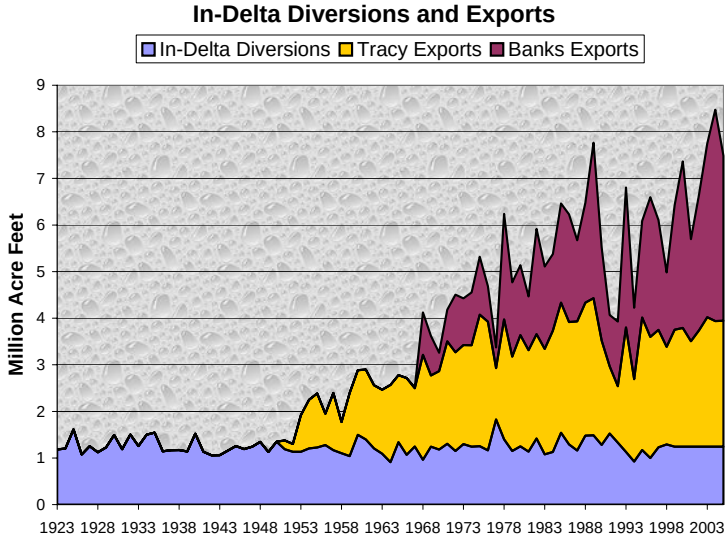
Power plants at Antioch and Pittsburg are cooled with water diverted from the Delta. The diversions are not screened to exclude fish. Combined, the two power plants pumps can divert 3,240 cfs.

The SWP's North Bay Aqueduct and the CVP's Contra Costa Canal are often considered in-Delta diversions, but are mostly exports to the Bay Area cities. In-Delta residential water is generally drawn through private wells or provided through community public water systems, such as the Contra Costa Water District. Groundwater supplies within the Delta are continually recharged due to flows in Delta channels and the soft, deep soils of Delta islands. The water table is relatively shallow, especially because many of the islands have subsided.

Delta Water Supply

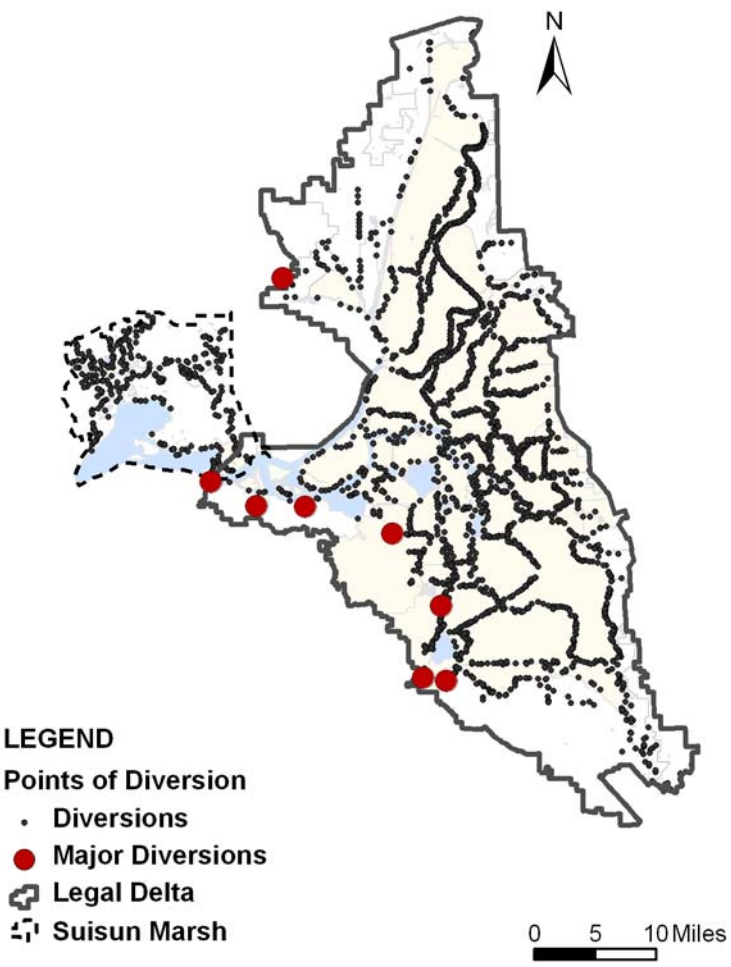
- About 3 million acres of land are irrigated with Delta water
- About 23 million people, 2/3 of Californians, get some of their drinking water from the Delta
- Outflow from the Delta provides the largest freshwater flow to the San Francisco Bay
- The system is governed by many operational requirements

The federal C.W. "Bill" Jones Pumping Plant (formerly the Tracy Pumping Plant) can export about 4,600 cfs, primarily to CVP agricultural land south of the Delta. It also supplies some water to urban areas and to wildlife refuges. The SWP's Banks Pumping Plant has a physical export capacity of 10,500 cfs, but is currently permitted to generally divert only up to 6,680 cfs from the Delta into the pumping plant's Clifton Court Forebay. The fish protective facilities at these state and federal pumping plants are not state-of-the-art. The SWP provides export water primarily to urban areas, but also supplies some water for agricultural uses. The CVP has contracts to divert 3.3 maf annually from the Delta. The SWP has contracts to divert 4.2 maf annually. The projects generally are not able to deliver their full contract amounts because the projects are also operated for Delta water quality requirements and fish protections. On average, the projects together export about 5 maf annually.



Delta diversions/exports have grown over time

In-Delta and Export Diversion Points



Over 1,800 in-Delta diversions remove water from Delta channels

Irrigated Agricultural Lands Dependent on the Delta

California agriculture is the world's fifth largest supplier of food and agricultural commodities. It produces everything from world-renowned wines to specialty items such as almonds and strawberries. California agriculture is the nation's sole producer of almonds, artichokes, clingstone peaches, dried plums, figs, olives, persimmons, pistachios, pomegranates, raisins, sweet rice, and walnuts. It is the leading dairy state, producing nearly a quarter of the nation's milk and dairy products. It is also the leading producer of 75 other crops including apricots, asparagus, avocados, broccoli, carrots, cauliflower, celery, flowers, and ornamental plants, garlic, wine and table grapes, kiwifruit, lemons, lettuce, melons, onions, pears, peppers, safflower, spinach, and processing tomatoes.

Source: California Department of Food and Agriculture, Internal Memo

Out of California's 8.5 million acres of irrigated farmland that produce this bounty that feeds the nation and the world, about 3 million acres are irrigated with Delta water supply. This includes irrigation supplies provided by the CVP, the SWP, and farmland in the Delta that draws water directly from Delta channels.

Source: DWR

See Chapter 5 for references

Water Quality Management and Discharges

Because the Delta-Suisun drains the Sacramento River and San Joaquin River watersheds, storm runoff and waste discharges from upstream and adjacent areas enter into the Delta-Suisun waterways and cause water quality problems. Low flow years generally carry higher concentrations of waste discharges and agricultural runoff and drainage than do wet years.

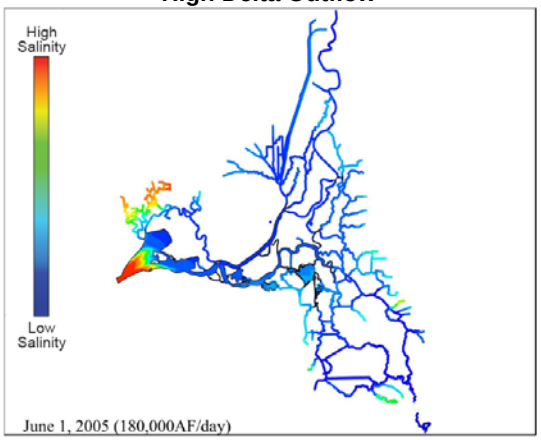
Water quality is affected by upstream runoff, waste discharges, and seawater intrusion.

Some treated urban wastewater, untreated urban storm water, and agricultural runoff and drainage enter directly to the Delta-Suisun. Other urban and agricultural discharges from upstream in the watershed enter the Delta-Suisun along with the river flows. Seepage onto Delta islands from adjacent channels and drainage from the agricultural lands are released back to the Delta channels at hundreds of locations. Data on existing urban storm runoff and discharges to the Delta-Suisun have not been compiled into usable GIS layers for this report. Therefore, the Delta Atlas map on Agricultural Drainage Returns is included to illustrate one aspect of the drainage return issue.

The Central Valley Regional Water Quality Control Board has identified the Delta as impaired by a number of pollutants including pesticides, low dissolved oxygen, electrical conductivity, and mercury. Delta fish have elevated levels of methylmercury, which poses a risk to humans and wildlife that eat the fish on a regular basis. The Board has adopted a TMDL for dissolved oxygen and is developing a TMDL for mercury in the Delta.

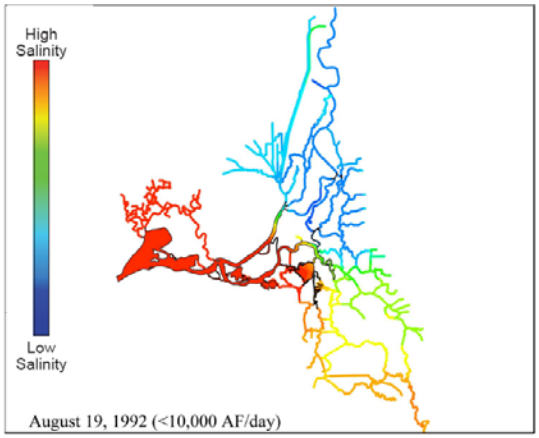
The daily tidal cycles and the San Joaquin River contribute most of the salinity to the Delta. During periods of high Delta inflows, salinity is low; during periods of low Delta inflows, the salinity level rises (see figure). Salinity in the Delta is managed by a mix of releases from upstream reservoirs, Cross Channel gate operations, Delta outflow, and exports from the Delta. The Delta is governed by water quality standards for municipal and industrial uses, agricultural uses, and for fish and wildlife. The combination of organic matter (decaying vegetation), bromide in the sea water, and disinfectants used in water treatment plants produce disinfection byproducts that have been linked to human heath problems. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts for which regulations have been established include trihalomethanes, haloacetic acids, bromate, and chlorite.

High Delta Outflow



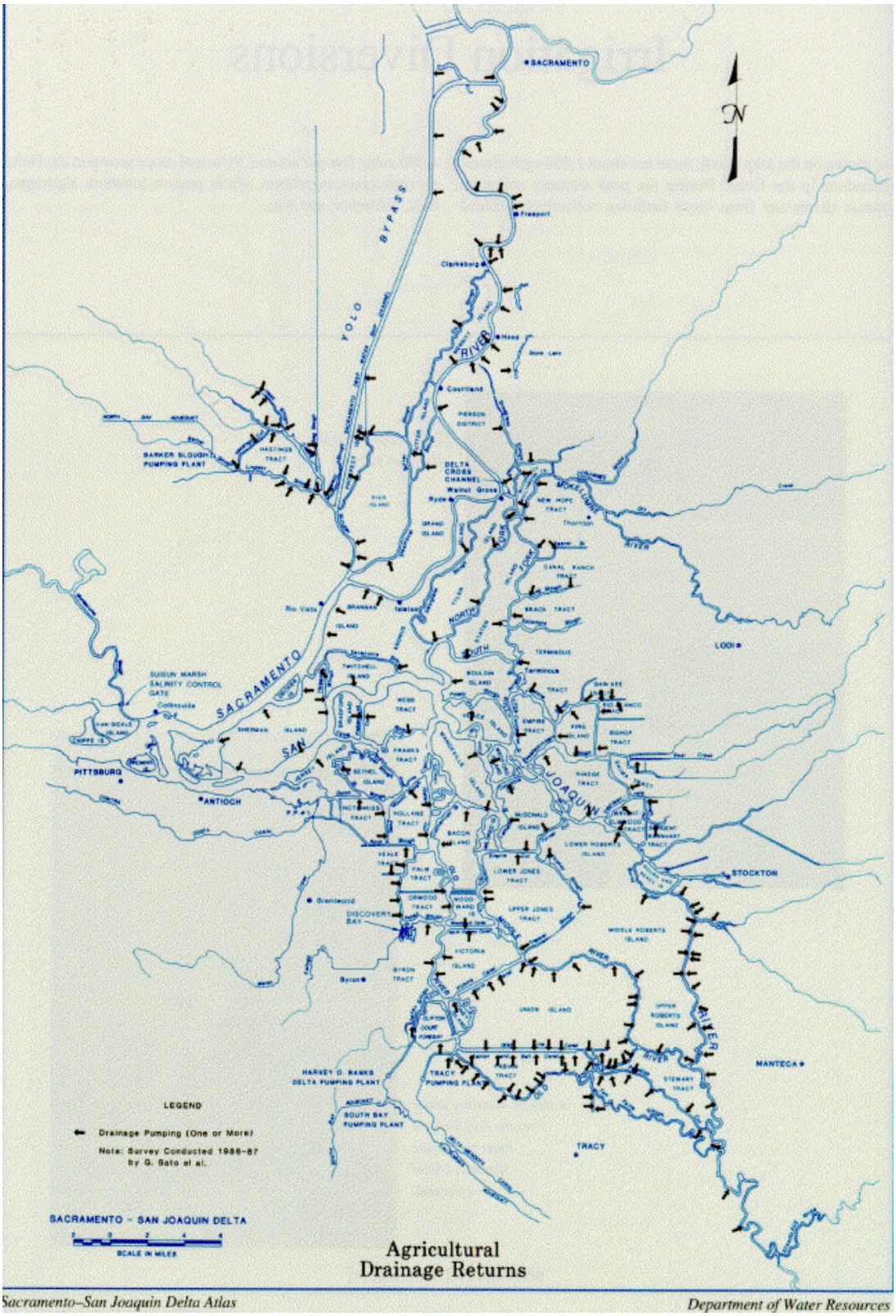
Low salinity through most of the Della

Low Delta Outflow



Higher salinity extends further into the Della

Agricultural Drainage Returns



Agricultural drainage returns discharge directly into Delta channels
(From Sacramento-San Joaquin Delta Atlas)

Water Quality
Ecosystem, Agricultural, and Urban Needs are Not Always the Same

Salinity enters the Delta from the tides and from return flows from agricultural lands, principally in the San Joaquin Valley. Prior to the construction of today's water supply and flood control facilities, salinities were lower in the winter and spring and higher in the summer and fall. Though mandated by water quality control regulations, some evidence indicates that the current (less variable) salinity regime may favor invasive species to the detriment of native species. Small amounts of salt in urban supplies can negatively affect consumer perception and acceptance of tap water. Slightly higher salinities decrease crop yields. Increasing salinity in both agricultural and urban water decreases how the water can be used and at too high a level can make the water unusable. While the ecosystem would benefit from more variability in the salinity, the water diversions for agricultural and urban uses require a more constant low level salinity. The bromide in sea water is one contributor to disinfection byproducts in treated drinking water.

Mercury can be found throughout the Delta as a result of natural occurrence in the Coast Range and historical upstream mining activities. It accumulates in the food chain. The entire Delta is on the State Water Resources Control Board (SWRCB) list for impaired water bodies for mercury.

Pesticides and Herbicides, including insecticides, fungicides, and other substances used to prevent, destroy, repel, or prevent pests have widespread use in the Delta and its watersheds and are being investigated as possible contributors to the Pelagic Organism Decline (POD).

Dissolved Oxygen depletion on the San Joaquin River near Stockton may impede passage of fall-run salmon migrating upstream to spawn. Relatively low river flows, algae growth fueled by high nutrient concentrations, waste discharges, and the configuration of the Stockton Deep Water Ship Channel all contribute to episodes of oxygen depletion in this part of the Delta. Seasonal discharges from managed wetland and possibly other sources have been associated with harm to aquatic resources in the tidal waters of Suisun Marsh, due to its low dissolved oxygen and high biological oxygen demand levels, commonly referred to as blackwater. Blackwater has also been associated with elevated methylmercury levels. A study sponsored by the SWRCB will evaluate a range of modified managed wetland practices aimed at reducing blackwater discharge.

Organic Carbon is essential for aquatic life. However, some of the disinfection practices used to kill harmful pathogens in drinking water treatment plants can react with some forms of organic carbon to produce potentially carcinogenic byproducts. This may lead to conflicts between ecosystem restoration and drinking water quality objectives.

Microcystis aeruginosa, a toxin-producing blue-green algae has been found in the Delta. CALFED and the IEP are studying these algae because it has been identified as a possible contributor to the recent POD. The toxins it produces may affect human and animal health, as well as ecosystem structure and function. DWR found no microcysitin toxins during five months of weekly monitoring at Banks Pumping Plant in 2006.

See Chapter 5 for references

Transportation

All modes of transportation can be found in the Delta-Suisun. Transportation corridors are relatively direct for those passing through the Delta-Suisun between population centers outside the area. Local transportation routes within the Delta-Suisun are more maze-like. See the adjoining figure for transportation facilities.

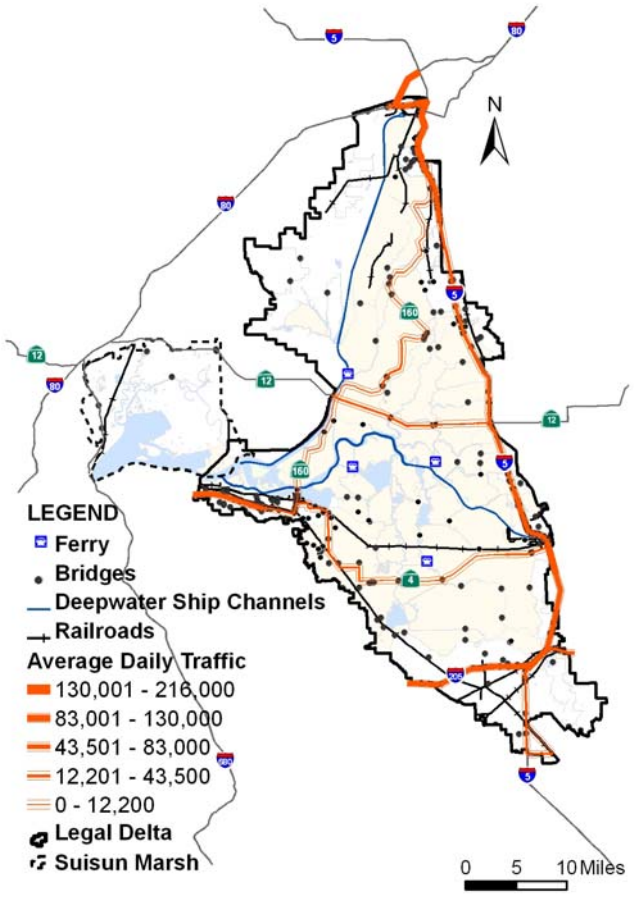
Highway and rail corridors serve growing areas outside of the Delta-Suisun. Island failures can sever critical cross-Delta highway and rail routes. There is no coordinated plan for rapid response or long-term risk reduction.

Highways – Four interstate freeways (I-5, I-80, I-580, and I-680) are major transportation and trucking routes that pass the periphery of the Delta-Suisun. The three major state highways (SR 4, SR 12, and SR 160) are typically two-lane, sometimes built on top of levees. Originally meant for lower traffic volumes at moderate speeds, the state highways are now heavily used for regional trucking, recreational access, and commuting. County roads generally follow the levees. There are five ferries in the Delta that allow public access, but three of them lead to islands that are private property. There are more than 50 bridges, approximately 30 of which are drawbridges, spanning the navigable channels in the Delta.

Evidence suggests that traffic within the Delta is growing disproportionately to population growth in surrounding counties due to congestion on existing freeways and increased Bay Area port commerce. Traffic count data taken on Highways 4, 12, and 160 and on I-5 showed a 14 to 97 percent increase between 1992 and 2004, with an average increase of 30 percent. In comparison, the population of the 6 Delta counties grew between 13 and 20 percent between 1990 and 2000, with an average growth of 17 percent.

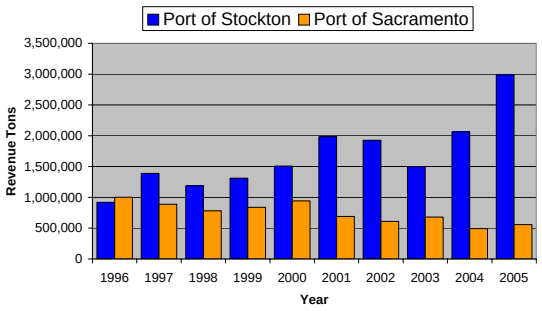
With additional urban development in the Central Valley, there will be more demand on the Delta's road network. Likely candidates for expansion to handle future traffic include Highways 160, 12, and 4, which link the Delta-Suisun to outside regions. Many of the bridges throughout the Delta need to be upgraded to meet current capacity standards. Local cities, counties, and Caltrans are investigating a bypass to the I-80 and I-680 interchange that is likely to pass through the north-western portion of Suisun Marsh.

Transportation in the Delta-Suisun



Major transportation corridors pass through the area

Railroads – Three major railways cross through or near the Delta-Suisun. While most trains carry freight, commuter use has been expanding. In 2006, more than 1.3 million riders rode the Amtrak *Capitol Corridor* route, which crosses Suisun Marsh, along the Union Pacific railway between San Jose, Oakland, Sacramento, and Auburn, making it the third-busiest corridor in the country. The *San Joaquin* route from Bakersfield to Sacramento/Oakland, which crosses the Delta, had nearly 800,000 riders that same year. In addition, companies such as the Sierra Northern Railway use existing short-line tracks for inter-regional freight and passenger services. There are no plans to expand the existing rail system through the Delta. However, the Solano Transportation Authority has adopted long range plans that include the expansion of the use of the *Capital Corridor* to reduce traffic volume on I-80.



Stockton shipping has increased while Sacramento shipping had decreased

Shipping – The Stockton and Sacramento Deep Water Ship Channels were originally constructed in 1927 and 1963, respectively. The Stockton channel is 35 feet deep and can handle 55,000-ton class vessels with full loads. More than 300 ships and barges used the channel in 2005. The Sacramento ship channel is 30 feet deep. Both ports are likely to expand in the future, which would result in an increase in ship and barge traffic through the Delta. The DPC supports the continued maintenance and improvement of the channels to meet modern shipping needs. It also recommends exploring expanded use of barges as an alternative to hauling freight on the highways.

Even ocean-going ships use Delta channels on their way to Stockton and Sacramento

Aviation – One general aviation airport is located in the Secondary Zone of the Delta, and several small private and commercial strips are located within the Primary Zone. Air transportation within the Delta-Suisun is not expected to grow considerably and may even decline depending on shifts in population growth or shifts to other modes of transportation. DPC policy supports air transportation to serve Delta residents and agriculture, but states that the Primary Zone is not appropriate for new or expanded general aviation airports.

Local roads and bridges

See Chapter 5 for references

Utilities

The Delta-Suisun's flat, largely unpopulated, terrain is a valuable site for regional utility corridors such as water pipelines, natural gas pipelines and underground natural gas storage areas, and electricity transmission lines. Along with these regional lines, local lines serve the population residing within the legal Delta boundaries.

Utilities serve large areas of the state. Should facilities be hardened individually, or are there opportunities for shared corridors that would serve both transportation safety and co-located resources such as gas storage fields?

Pacific Gas & Electric, Sacramento Municipal Utility District, and Western Area Power Administration oversee most of the transmission lines and provide local electric service within the Delta-Suisun. The regional lines carry power within California as well as between regions of the western United States. There are more than 500 miles of transmission lines and more than 60 substations within the Delta boundaries. Several electrical peaking plants surrounding the Delta-Suisun depend on these transmission lines. Power plants at Antioch and Pittsburg are cooled with water from the estuary.

There were approximately 240 operating natural gas wells in 2004. Natural gas pipelines serve local gas fields and regional pipelines. PG&E's underground natural gas storage area under McDonald Island provides up to one-third of the peak natural gas supply for its service area. The Suisun Marsh includes several natural gas fields in operation as well as numerous sites under exploration. Kinder Morgan pipelines cross Suisun Marsh on their way to deliver fuel from the Bay Area to the Travis Air Force Base, Sacramento, and on to Reno. Pipelines that carry gasoline and aviation fuel across the Delta-Suisun from Bay Area refineries to depots in Sacramento and Stockton for distribution to Northern California and Nevada provide approximately 50 percent of transportation fuel used in that region.

Water pipelines for the East Bay Municipal Utility District crosses the Delta

The California Energy Commission predicts that total natural gas demand in California will grow from 6.5-billion cubic feet per day in 2006 to slightly less than 7-billion cubic feet per day in 2016. Increased demand in the residential and commercial sectors are predicted to be slightly offset by declining demand in the industrial sector and slower growth in the power-generating sector. The California Energy Commission predicts that statewide electric demand will increase by 42,470 gegawatt hours (GWH) from 2004 to 2016.

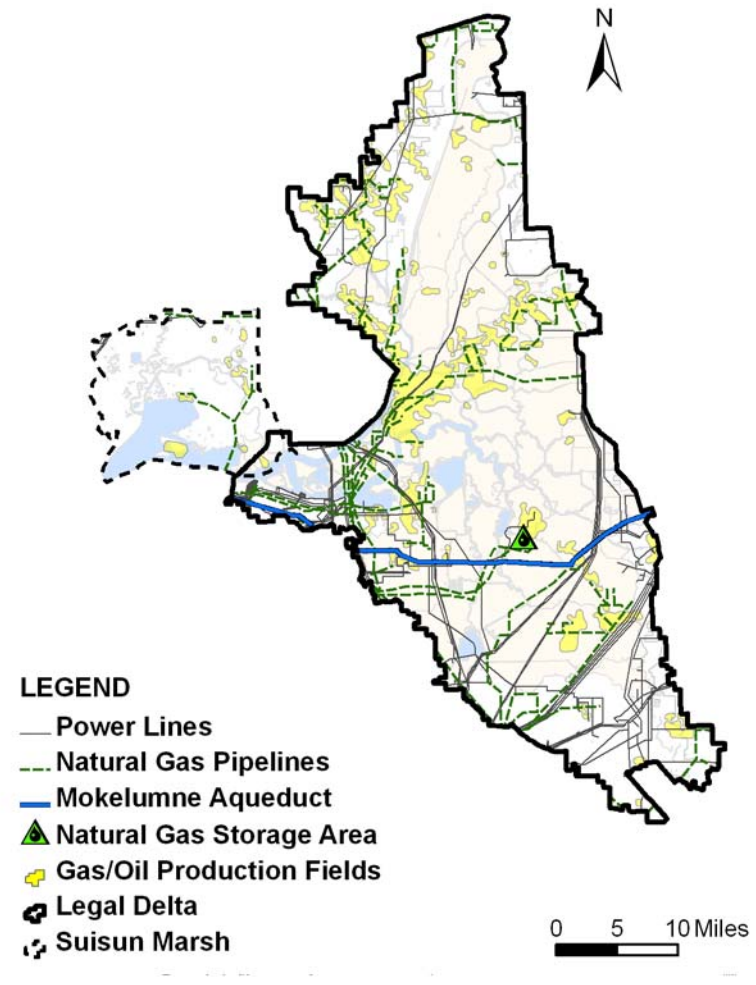
The Mokelumne Aqueduct, consisting of three pipelines, is the main municipal water conveyance facility for 1.3 million people in the East Bay Municipal Utility District. The aqueduct crosses five Delta islands/tracts (Orwood Tract, Woodward Island, Jones Tract, Roberts Island, and Sargent-Barnhart Tract) protected by levees.

Information on future expansion of utilities is unavailable as utility companies generally guard such information. With the exception of natural gas exploration, the utilities have no current plans to increase infrastructure investment in the Delta-Suisun and, given the rapidly changing technologies in the energy industry, the outlook for future investments is unclear.

Power transmission tower

Power plant near western side of Delta

Utilities



Major utilities reside in and cross the Delta-Suisun

See Chapter 5 for references

Recreation/Tourism

The Delta-Suisun annually attracts millions of people interested in a variety of both water and land-based recreation.

The majority of the land within the Delta-Suisun is privately owned, which reduces the availability of land-based recreation. Navigational waterways in the Delta-Suisun are available for public access and make up the majority of recreational opportunities. There are over 6.4-million boating visitor days annually, composed of 2.13-million annual boat trips in the Delta-Suisun. The DPC estimated that in 1998 people spent about $378 million for Delta oriented boating and fishing recreation.

Common Recreation/Tourism Activities in the Delta-Suisun

Land-based recreation	*Water-based recreation*
Hunting (from land)	Fishing (boat and shore)
Camping	Sailing
Picnicking	Water skiing
Hiking	Personal watercraft
Biking	Cruising
Viewing/photographing wildlife	Canoeing/kayaking
Sightseeing (driving)	Swimming
Attending special events	Boat camping
Visiting cultural/historical sites	House boating
Visiting wineries	Windsurfing
	Hunting (from boat)

Many value the recreational opportunities in the Delta-Suisun because the area is so different than the surrounding urbanizing areas. Wide expanses of open land, interlaced waterways, historic towns, and the feeling of a slower pace of life make the Delta-Suisun attractive to many visitors. The area provides unique viewing opportunities. An estimated 7,000 sandhill cranes make Delta agricultural fields their seasonal home. With more than 700 miles of waterways, boaters can often find secluded areas.

The Suisun Marsh includes over 18,000 acres publicly owned by Department of Fish and Game, Solano Land Trust, and Suisun Resource Conservation District, the majority of which is open for public access. Suisun City along the Marsh's northern border includes a marina, and Solano County has a fishing access and boat launching facility at Beldon's Landing along Montezuma Slough. The recreation values of the Marsh, particularly for waterfowl hunting, have been a significant factor in its preservation. The Suisun Marsh supports 150 waterfowl hunting clubs.

Most planning organizations acknowledge the need to preserve and enhance recreation within their sphere of control in the Delta-Suisun. However, no single governing body can steer recreation planning in the area. Therefore, it is difficult to forecast the supply of recreational facilities within the Delta-Suisun.

The newly created Aquatic Recreation Component of the Delta Recreation Strategy Plan by the DPC forecasts demand for boating recreation through 2020 and identifies a deficit of facilities based on current inventory and trends in increasing local population. The plan predicts a 27 percent increase in annual boating visitor days from 6.4 million to 8.1 million. Current

Numbers of Delta Recreational Facilities excluding the Suisun Marsh

	Hunting access (hunting by land)	*Trails & bike paths*	*Camping areas*	*Marinas*	*Boat slips*
Total	33 hunting clubs/ 52,000 acres	25	43	95	11,680

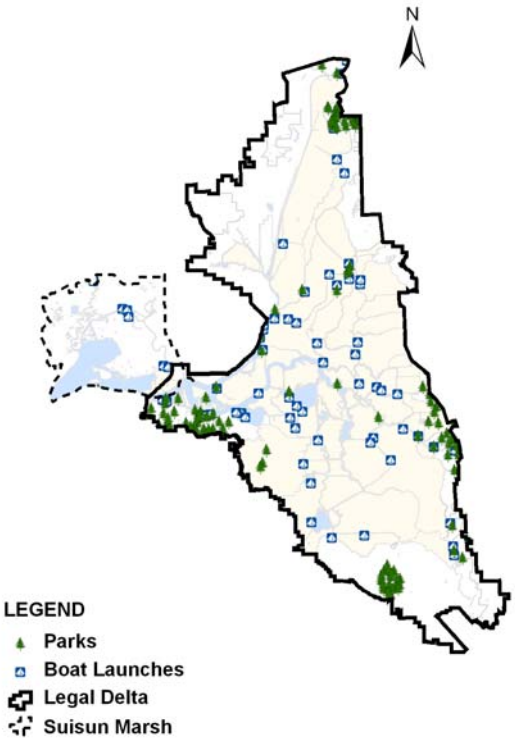
Data from Delta Protection Commission1997

facilities and businesses cannot accommodate this increased demand.

Although little information on future demand for land-based recreation is available, a proposal for a Land Based Recreation Component of the Delta Recreation Strategy Plan is awaiting funding approval. The report is expected to give a good indication of future demands for land-based recreation facilities within the Delta-Suisun and around its historic towns and emerging vineyards and wineries.

Historic Delta towns draw tourists

Senate Bill 1556, signed by the Governor in September 2006, creates a California Delta Trail and requires the DPC to create a plan for designing, constructing, and maintaining this trail. The California Delta Trail will be a bike and pedestrian trail system and recreation corridor along more than 1,000 miles of Delta waterfront in Contra Costa, San Joaquin, Sacramento, Yolo, and Solano Counties. The trail will connect with the 450-mile San Francisco Bay Trail and will provide more land access to the Delta. The trail could increase demand for Delta-related land-based facilities like campsites, picnic areas, and restrooms.



Some Delta-Suisun recreational facilities (map is incomplete as datasets are not up-to-date)

See Chapter 5 for references

Local and State Economics

The Delta-Suisun is important to the local, state, and national economies. Regions outside the Delta-Suisun relay on water exports and utilities that cross its terrain.

The DPC reports that the Delta economy in 1994 represented 1.5 percent ($10.6 billion) of personal income in California and 1.8 percent of employment (249,000 jobs). The entire Delta generated $21.2 billion in output in 1994. Manufacturing is the largest sector, producing $4.5-billion worth of goods. This is followed by trade (wholesale and retail), which generates $3-billion in output, and services, which create $2.9 billion in output. In-Delta agriculture contributes a little less than $1 billion annually to the region. Exports of goods from the region are $5.6 billion, and intermediate sales to local industries are $4.8 billion. More current information is expected from the DRMS investigations in spring 2007.

When considering the value of the services provided beyond the boundaries of the Delta-Suisun, contribution to the state economy is much higher. The Delta Mendota Canal and the California Aqueduct carry millions of acre-feet of water for use south of the Delta. Southern California cities rely on this water as an important portion of their water supplies. Likewise, the North Bay Aqueduct and the Contra Costa Canal deliver water to Bay Area cities. DWR has estimated that a temporary disruption of these water exports due to major levee failures in the Delta could cause $30 billion to $40 billion loss to the state economy. During a temporary loss of water supply, other sources of short-term water, such as surface and groundwater storage, can help keep the losses from growing much higher.

The Delta Mendota Canal and the California Aqueduct are two facilities that carry Delta water ($) to other areas

California is now the sixth largest economy in the world, at about $1.5 trillion. Water exported from the Delta plays a major role in sustaining the California economy. Utilities and transportation that pass through the Delta-Suisun also contribute to the statewide economy.

The asset value of the Delta-Suisun that is below Mean Higher High Water (MHHW) is approximately $4.5 billion. The asset value of the Delta-Suisun that is within the 100-year floodplain is approximately $35.4 billion. This excludes value of crops, electrical transmission lines, cell towers, sewage treatment facilities, pumping plants, natural gas wells, diversion points, hospitals, prisons, chemical storage areas, and solid waste facilities.

See Chapter 5 for references

(Page intentionally blank)

3. Existing Regulatory and Management Practices

The Delta-Suisun is influenced by today's regulatory and management practices. Most of these practices were established at a time when the system was viewed as relatively static. Many entities recognize that the Delta-Suisun area is a dynamic, constantly changing system which requires regional management.

The existing regulatory and management practices are the basis for predicting the trends for the Delta-Suisun services into the future.

Planning and management for the area are spread among state, federal, regional, and local agencies and with numerous non-governmental organizations, businesses, and landowners. The DPC, established to provide broad oversight in the Delta, has partial authority over land use and resource management of the Delta. The BCDC has similar jurisdiction over the Suisun Marsh. Within the last year, the Delta-Suisun area has gained an unprecedented level of political and funding support. Still, there is no program in place for long-term funding and management.

Jurisdictions and Interests

In addition to the usual arrangement of multiple jurisdictions, the Delta-Suisun has a remarkable number of additional jurisdictions and interests that must coordinate and work together efficiently. The Delta-Suisun spans six counties and includes incorporated cities and unincorporated communities.

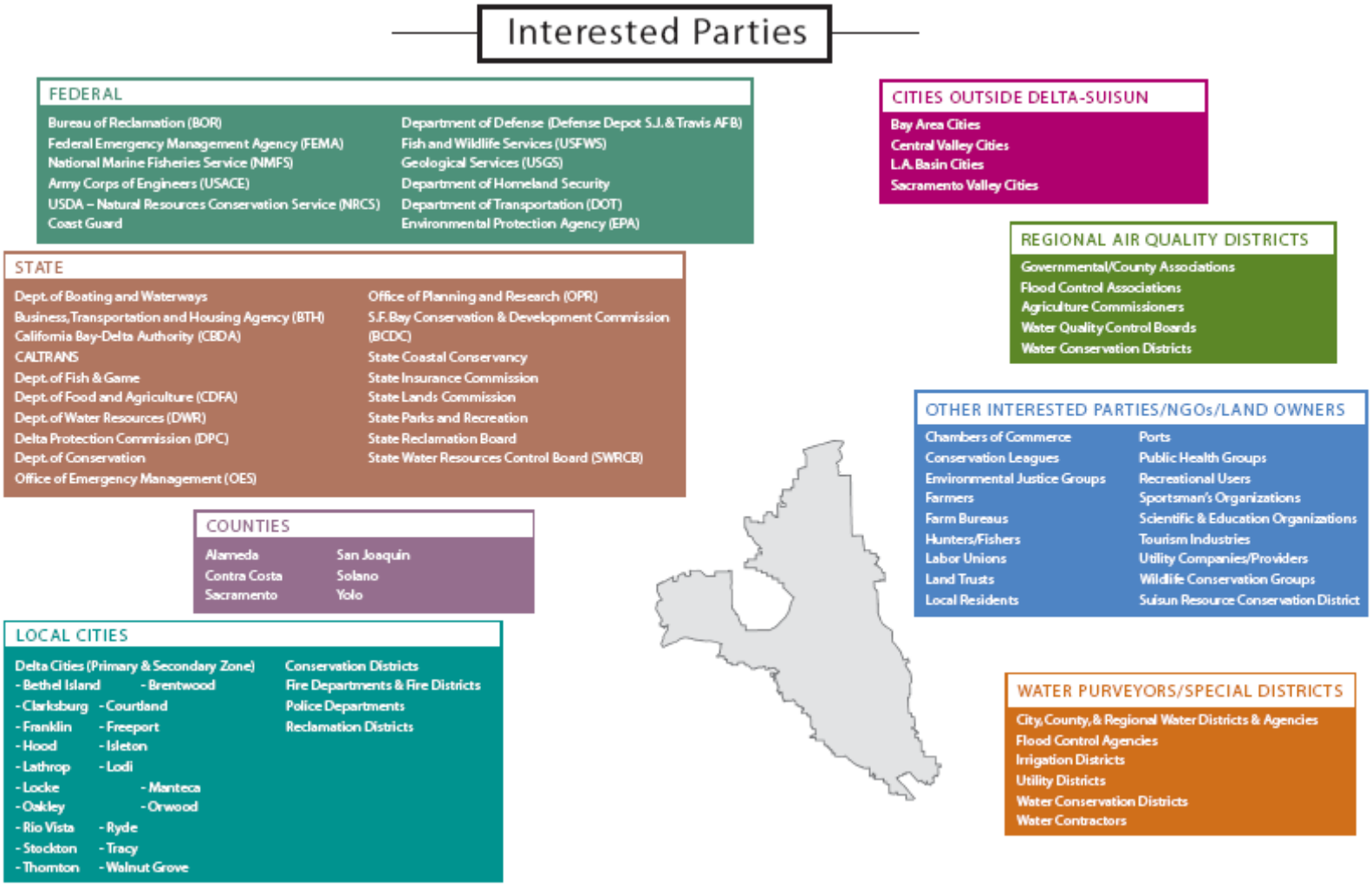
No single entity has responsibility for the Delta-Suisun. The responsibility is spread between state, federal, regional, and local agencies, and with numerous non-governmental organizations, businesses, and landowners. With this fragmented governance, efficient coordination is extremely difficult.

How can all these jurisdictions efficiently coordinate for the best interest of the Delta-Suisun and those who depend on its services given the extremely complex, dynamic, and highly managed nature of the system? It is difficult for all these entities to coordinate efforts, and not all jurisdictions have the same mission or standards.

The figure on the next page shows a sampling of the jurisdictions and interests for the Delta-Suisun. A more complete list and description of these jurisdictions and interests can be found on the CD.

See Chapter 5 for references

Sampling of Delta-Suisun Jurisdictions and Interests



A remarkable number of jurisdictions and interests have influence over the Delta-Suisun

Emergency Response

Emergency response in the Delta-Suisun area is shared among many different entities. The area is served by at least 14 fire districts and at least 14 sheriff and police departments.

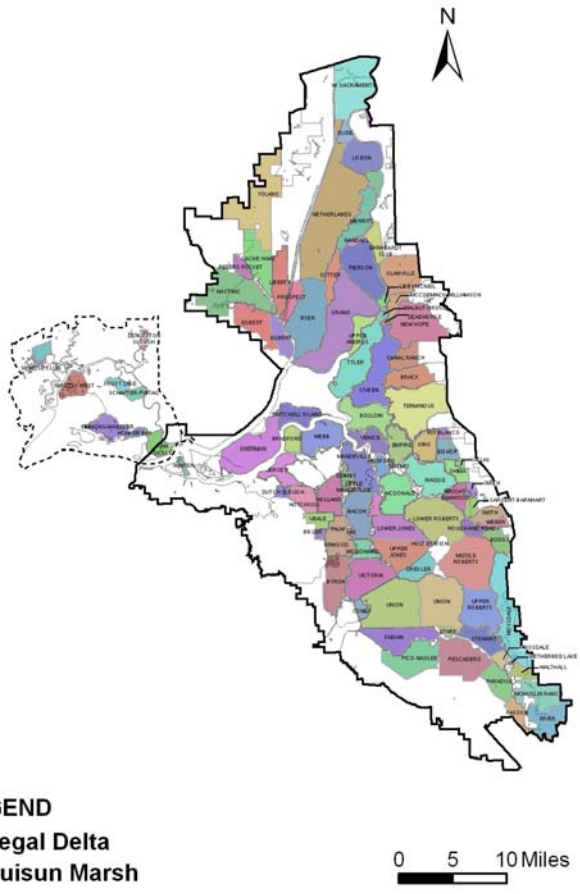
During times of high water, each reclamation district directs flood fights for its own island. DWR provides some uniformity by participating in flood fights throughout the Delta. The U.S. Army Corps of Engineers also participates through its PL 84-99 authority for levees that meet its standards.

In-Delta residents and businesses have tenuous connections to police and fire stations as well as hospitals. Questions regarding emergency response and evacuation remain unanswered.

Access to reach a levee breach for repair can be difficult. Roads in the Delta-Suisun do not always follow a direct path. Most are built on top of levees. Traveling these roads may require crossing bridges and using auto ferries. One may need to cross several islands to get to a destination, which could be a major problem with a levee failure. Children may go to school on a different island than where they live. Given these logistics, individual families may have trouble formulating their own emergency response plans.

If an island floods, major damage can occur to its interior because the inside of the levees are not protected from wave action. Islands next to a flooded island are at increased risk of failure from seepage and wave action from the flooded island. A common statement among Delta-Suisun interests is the lack of equipment that would be available for repairs in the event of large multiple island failures. Most Delta levees do not meet PL 84-99 standards, which are minimum levee cross section requirements to gain Corps of Engineers participation for emergency response and disaster assistance.

Reclamation Districts



Separate reclamation districts maintain local levees

January 2006 Flood

DWR participated in flood fights during high water in the Delta during January 2006. While some small levees failed in the Suisun Marsh, the flood fights prevented failures in the Delta. DWR reports that personnel and other resources were taxed to the maximum during this moderately sized flood, only about a 1-in-10 year event.

See Chapter 5 for references

Sustained Support – Political and Funding

Funding and political support for the Delta-Suisun comes and goes and varies by the type of service. Ecosystem and water supply have generally received more consistent support in recent decades than other services. During the state's fiscal crisis in the early 2000s, funding was cut for many flood management activities. Even the Sacramento – San Joaquin Comprehensive Study, a joint flood and ecosystem restoration study in 2002 by the U.S. Army Corps of Engineers and DWR, did not include the Delta in the analyses.

Today, the Delta-Suisun enjoys a level of political and funding support that it has never seen. Still, there is no comprehensive program in place for leveraging existing resources and there is no plan for adequate and long-term funding into the future.

Since Hurricane Katrina struck the Gulf Coast including New Orleans in August 2005, political and public support for flood management has increased along with the public's awareness of the potential consequences of flooding. In November 2006, California voters entrusted DWR with almost $5 billion in new flood management bond funds, a portion of which will be available for the levee improvements in the Delta. While the new bond funds provide money for capital improvements, they do not provide money for long-term maintenance and anticipated future changes like sea level rise.

In November 2005, federal legislators directed the U.S. Army Corps of Engineers Sacramento District to identify and prioritize potential levee stability projects in the Delta and to devise a strategy for investing an authorized $90 million within the next 5 years. The Corps received 54 proposals totaling more than $1 billion in estimated costs.

Most levees in the Delta-Suisun are maintained by assessments on privately owned land. Since 1973, state government has assisted in funding maintenance and levee improvement projects on local levees through DWR's Subventions and Special Projects programs. Delta reclamation districts that are eligible and choose to participate, submit applications for reimbursement every year. The districts request an average of $50 million every year, but the state awards only $6 million to $8 million per year. Another inconsistency is that not all reclamation districts can raise their cost share for the maintenance. Some islands and tracts have higher value properties that provide more assessment dollars for maintenance. Only a portion of one reclamation district in Suisun Marsh is eligible to participate under the Subventions Program. Only 20 miles of exterior levees are eligible to participate in the Special Projects, resulting in nearly 200 miles of Suisun Marsh exterior levees without any public financial assistance for levee maintenance and repairs.

CALFED, mostly through state funding, has provided funds for a range of Delta levee investigations. There currently is no source of long-term funding for many of the Delta-Suisun services. Other services like transportation and recreation also need governmental funding. The opportunity to identify and build future support is taking hold in the Delta Vision.

Wind waves during flood and high tide

Protecting inside of levee of a flooded island

See Chapter 5 for references

Land Use Planning

Land use planning resides with six counties and several incorporated cities. The DPC has authority to review and comment on urban development in the Delta. The DPC has appeal authority for projects approved in the Primary Zone.

Six counties have general plans that govern their land use authority within the Delta and Suisun Marsh: Alameda (Secondary Zone only), Contra Costa, Sacramento, San Joaquin, Solano, and Yolo. Incorporated local towns and cities also have their own land use plans. The DPC has authority to review appeals for development within the Primary Zone of the Delta. The BCDC is the state agency with authority to permit projects in the primary management area and to review appeal to development for the secondary management area of Suisun Marsh. Given the number of entities that plan for land use in the Delta-Suisun, there is inadequate coordination and limited consistency among the plans.

The DPC was established to develop a Land Use and Resource Management Plan for the Primary Zone, last updated in 2002. DPC reviews county and local government plans to ensure consistency with the Resource Management Plan policies for protection of the environmental and agricultural uses in the Delta. These policies encourage the continuation of agriculture as the primary land use in the Primary Zone. The policies also direct new non-agricultural development to existing communities where support infrastructure and flood protection are already provided.

The Resource Management Plan does not supersede the authority of local governments within the Secondary Zone. However, the plan recommends that development in the Secondary Zone should include an appropriate buffer zone to prevent development impacts on the lands in the Primary Zone and local governments should consider needs of agriculture in determining such a buffer. Because the Primary Zone and the Secondary Zone share a common boundary, the land use on one side of the boundary is often in stark contrast to the land use on the other side of the boundary. The current management often results in no buffer or transition between urban development and open space.

Secondary Zone development directly next to the Primary Zone

The counties' general plans and zoning ordinances all designate the Delta Primary Zone for agriculture, with open space, recreation, wildlife habitat, and nature preserves allowed. The counties have established minimum parcel sizes of 5 to 160 acres in order to retain land in agricultural use, with most parcels between 20 and 80 acres. The counties set parcel sizes based on their own criteria, such as soil type or "farmable unit," which contributes to inconsistent zoning among jurisdictions. These requirements may be inconsistent with the DPC Resource Management Plan and may be changed by the county board of supervisors for specific projects. As a result, growth in the Primary Zone occurs in those jurisdictions that accommodate development.

The Suisun Marsh Preservation Act of 1974 directs the BCDC and the Department of Fish and Game to prepare the Suisun Marsh Protection Plan "to preserve the integrity and assure continued wildlife use" of the Suisun Marsh. The Protection Plan includes enforceable standards for development with the primary goal of protecting the resources. The BCDC has land use and development permitting authority in the primary management area. The county and city development actions within the Marsh must be consistent with the local protection plan that is in alignment with the state plan. Any action by a local government on an application for development in the secondary management area may be appealed to BCDC which may issue the local permit if it finds the proposed development is consistent with the local protection program. The Act also incorporates the management program prepared by the Suisun Resource Conservation District designed to preserve, protect, and enhance the plant and wildlife communities within the primary management area of the Marsh, including, but not limited to, enforceable standards for diking, flooding, draining, filling, and dredging of sloughs, managed wetlands, and marshes.

Three associations of governments, the Association of Bay Area Governments (ABAG), the Sacramento Area Council of Governments (SACOG) and San Joaquin Council of Governments (SJCOG) assist with planning between the counties in their respective jurisdictions. These councils of governments function as municipal planning organizations for federal transportation purposes.

Although many communities are required to have comprehensive land use plans, they are not required to plan regionally nor are they required to meet performance measures for their goals and policies. While there are many planning tools available, including local tax sharing, many land use jurisdictions do not have adequate planning mechanisms in place to manage rapid growth and urban development while protecting natural resources.

A Development Test Case for Suisun Marsh?

The existing Potrero Hills Landfill has an estimated closure date of 2011. BCDC is hearing appeals over Solono County's decision to allow the landfill to increase the height from 230 feet to 310 feet. A separate proposal would expand the landfill area from 320 acres to 580 acres, adding 35 years to its lifespan. The Potrero Hills are part of the buffer zone that was set aside to protect the marsh. The Suisun Marsh Protection Plan allows for the landfill if it does not significantly hurt the marsh. BCDC has established an independent science panel to analyze the potential environmental impacts of the proposed expansion on habitat and associated wildlife and adequacy of the proposed mitigation.

A Development Test Case for the Delta?

The Old Sugar Mill housing development is a proposed development within the boundaries of the Delta Primary Zone. The project won approval from the Yolo County Board of Supervisors on October 24, 2006, to build 162 homes at the 105-acre site in Clarksburg. Project opponents say that the development violates the Delta Protection Act. Project proponents point out that no farmland or habitat will be developed because the site is a former industrial site and that the development will help vitalize Clarksburg. A key point of contention is whether the Sugar Mill site lies within the Delta's Primary Zone. Yolo County and the developer maintain the act excludes previously urbanized areas such as Clarksburg.

The Delta Protection Commission has heard appeals regarding the proposed development. The Commission determined that the development is within the Delta's Primary Zone and that it is inconsistent with the Resource Management Plan. The Commission referred the project back to Yolo County which now has three choices:

- Address the Commission's findings and return with a revised project
- Deny the project based on the Commission's findings
- Challenge the Commission's findings in court

Both sides see the outcome as an important test of the Delta Protection Commission's authority as urban development encroaches on the Delta from all sides.

See Chapter 5 for references

4. Trends – Drivers of Future Change

There are several factors, or drivers of change, that will affect future conditions in the Delta-Suisun. These are factors like forces of nature over which there is little human control, such as earthquakes, or factors like urbanization for which there is no single oversight given existing regulatory and management practices. The Delta-Suisun is facing changes that may be gradual or sudden. These drivers of change include:

- Subsidence
- Global Climate Change – Sea Level Rise
- Regional Climate Change – More Winter Flooding
- Seismic Activity
- Introduced Species
- Population Growth and Urbanization

The Delta's waterways are a complex network. Water volumes, velocities, salinity and pollutants all affect the ecosystem, agriculture, and drinking water supply. Changes in one area can have effects not only locally, but at great distances up and down the system.

Trends are based on the continuation of existing management practices in light of the drivers of change.

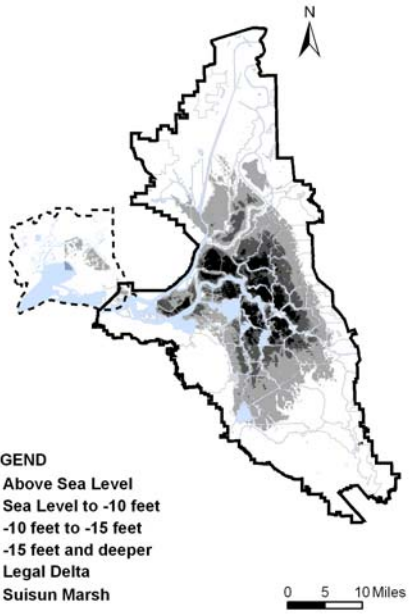
Subsidence

The rich organic peat soils in the Delta-Suisun built up over thousands of years as plants grew and died in the swampy environment. Because the land was waterlogged and anaerobic (devoid of oxygen), organic soils accumulated faster than they could decompose, forming large expanses of peat soil. With the construction of levees and draining for agriculture, the peat soils were exposed to the atmosphere. Some soil has blown away with the wind, but the major portion has simply decomposed (see figure). The aerobic (oxygen rich) condition favors microbial oxidation, which consumes the peat soils. Most of the carbon loss is emitted as carbon-dioxide gas to the atmosphere. About one-half of the peat soil that accumulated over 5,000 years has disappeared during the last 150 years.

Land subsidence, mainly through oxidation of peat soils, has placed most of the Delta land below sea level. With current land uses, subsidence will continue into the future.

Land subsidence has placed most of the Delta land below sea level. Subsidence varies with location, but rates of 0.5 to 1.5 inches of soil loss per year are common in the Delta. This historical subsidence has left multiple islands with average land elevations as much as 15 feet or more below mean sea level (see map). Several islands have areas as great as 25 feet below sea level. The dramatic reduction of land elevation on Delta islands has increased the differential between land and the water surface elevations in the channels. Continued subsidence will increase levee vulnerability. Investigations for DRMS estimate as much as 9 feet of additional subsidence in portions of the central Delta by 2100.

Land Elevation



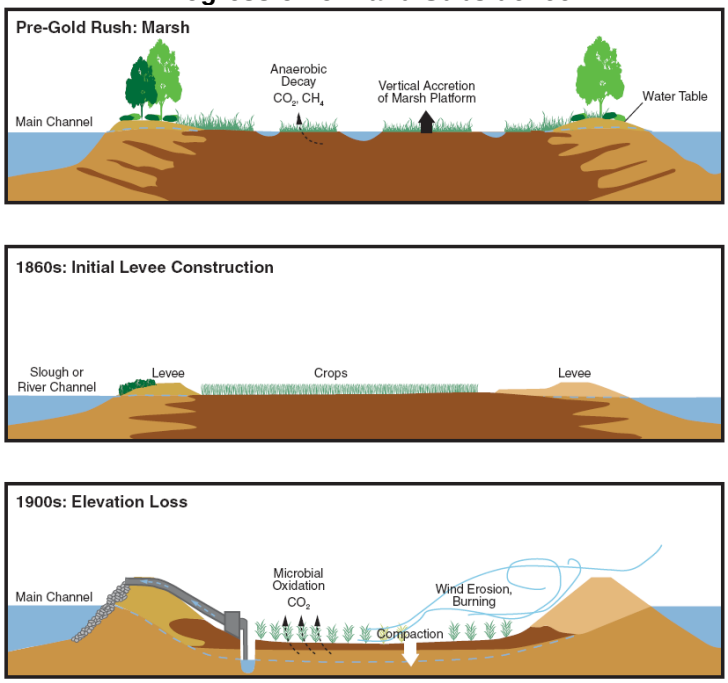
Much of the Delta-Suisun is below sea level

Over the next 200 years, some areas could subside by another 18 feet from existing land levels if current land use practices continue.

Historically, Delta levees have been widened and raised to keep up with subsidence. Where peat soils remain, subsidence is predicted to continue at historic rates where the soils continue to be farmed.

In the Suisun Marsh, subsidence is also occurring, but less information is available about rates and processes affecting rates. The land use for much of the Suisun Marsh is managed seasonal wetlands, which as reduced subsidence compared with the Delta. Investigations for DRMS show that rates of about 0.5 inch per year were common during the past 50 years. Some areas appear to have subsided up to 1 inch per year.

Progression of Land Subsidence

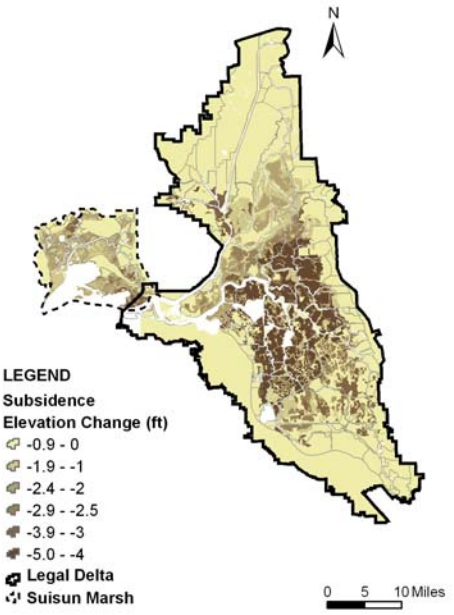


Subsidence has changed the character of much of the Delta-Suisun
(Based on Mount &Twiss 2006)

The map shows the potential future subsidence by 2050. Future subsidence depends on the depth of peat soils remaining, the amount of soil organic matter, and land use practices. Current Delta agricultural practices require an aerated root zone for crop production and therefore promote subsidence. Subsidence slows as the soil organic matter is depleted and will stop once an island land surface reaches the underlying mineral soils. Land uses such as permanently flooded wetlands or flooded agricultural lands can stop subsidence and even begin to rebuild the soil.

The potential consequence of levee failures and catastrophic island flooding has major implications for management of the Delta. The lower land surface provides more room for inflowing salt water when a levee failure occurs. Currently, the Delta provides a hole below sea level of about 1.9 maf. By 2100, the hole is expected to grow to about 3.5 maf.

Estimated Additional Subsidence 2000-2050



Land will continue to subside with existing management practices

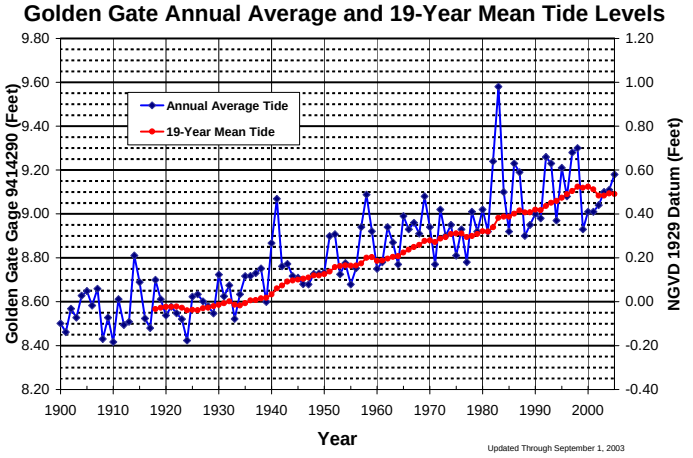
See Chapter 5 for references

Global Climate Change – Sea Level Rise

Except for the range of daily tidal fluctuations, sea level is often viewed as static, with little or no long-term change. However, over the last 100 years, the sea level at California's Golden Gate has been rising by an average rate of about 0.08 inches per year. Mean sea level now sits about 0.6-foot higher than it did in 1920.

Sea level at the Golden Gate is about 0.6 foot higher today than it was in 1920. Studies indicate that sea level will continue to rise by 0.6 to 1.9 feet over the next 100 years and even more beyond. Will society be able to afford the change in Delta facilities, especially the levees, needed to ward off this inevitable rise?

The geologic record shows very significant changes in sea level occurring over thousands of years. During the past 130,000 years, sea level has been as much as 400 feet lower and as much as 10 feet higher than today's level. From about 6,000 years ago to present, the average rate of sea level rise was about 0.02 inches per year.



Records show a 0.6 foot rise in sea level since 1920

Recent scientific evidence suggests the trend to warmer global temperatures will accelerate melting of glaciers, which will release more water into the oceans. In addition, warmer ocean temperatures cause the water to expand, further raising the sea level. Different assumptions about future greenhouse gas emissions and use of different models lead to different estimates of likely sea level rise in the 21st Century. Current estimates by the Intergovernmental Panel on Climate Change indicate that sea level will rise by about 0.6 foot to 1.9 feet over the next 100 years, with a possible added 0.5 foot if the rate of Greenland ice melt increases.

Some estimates, which include ice-dynamic changes in the West Antarctic and Greenland ice sheets and growing amounts of greenhouse gases, show even more dramatic sea level rise of about 10 feet by the year 2100. However, there is a great deal of uncertainty regarding predictions of the extent and rate of ice sheet melting.

Short-term and episodic increases in water levels in the Delta-Suisun include high river flows, ocean/atmosphere phenomena such as El Niño, storm surge, barometric high tides, and high astronomical tides. When combined with longer-term sea level rise described above, the Delta-Suisun could be overwhelmed.

Before reclamation, the Delta-Suisun could naturally expand and contract to adjust to sea level changes. In its current configuration, the Delta-Suisun is unable to self-adapt to sea level rise because its levees have fixed the channel and island locations in place. The rise in sea level will also increase the flooding potential on all the tributaries entering the Delta-Suisun by raising upstream levels. There has been relatively little scientific assessment of the regional impact of sea level rise on the Delta-Suisun. Because the Delta-Suisun is tidally influenced, water will become saltier, especially in the Suisun Marsh and western Delta.

See Chapter 5 for references

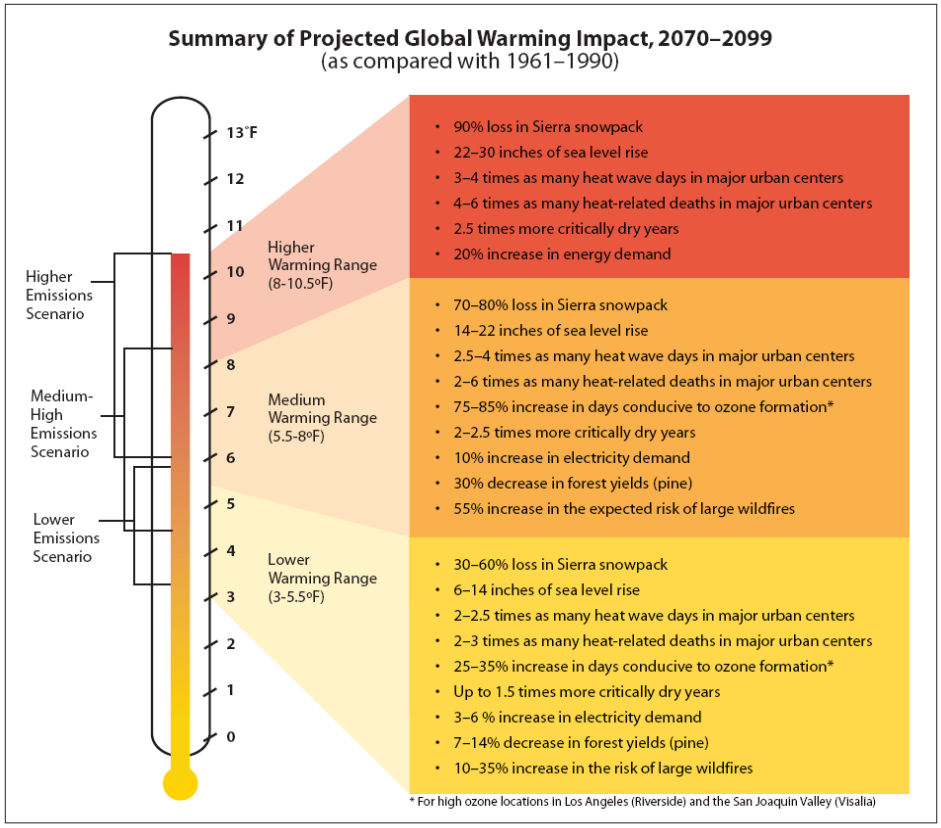
Regional Climate Change – More Winter Flooding

Although climate change is not a new concept, it has received wide attention since the turn of the century. California's climate is expected to become warmer during this century. Climatologists have documented changes in California's climate during the latter half of the 20th century.

Increased winter storm runoff from the mountains will increase river flows. Warmer regional temperatures will have impacts on the ecosystem.

Some climate models indicate that warming will be greater in summer than in winter, which would have widespread effects on ecosystem health, agricultural production, water use and availability, and energy demand. By the end of the century, depending on future heat trapping emissions, statewide average temperatures are expected to rise between 3 and 10.5 °F.

On average, the predictions show little change in total annual precipitation in California, but the models do not show a consistent trend. Three climate warming scenarios prepared by the California Climate Change Center (see graphic) predict slightly wetter winters with less winter snowpack.



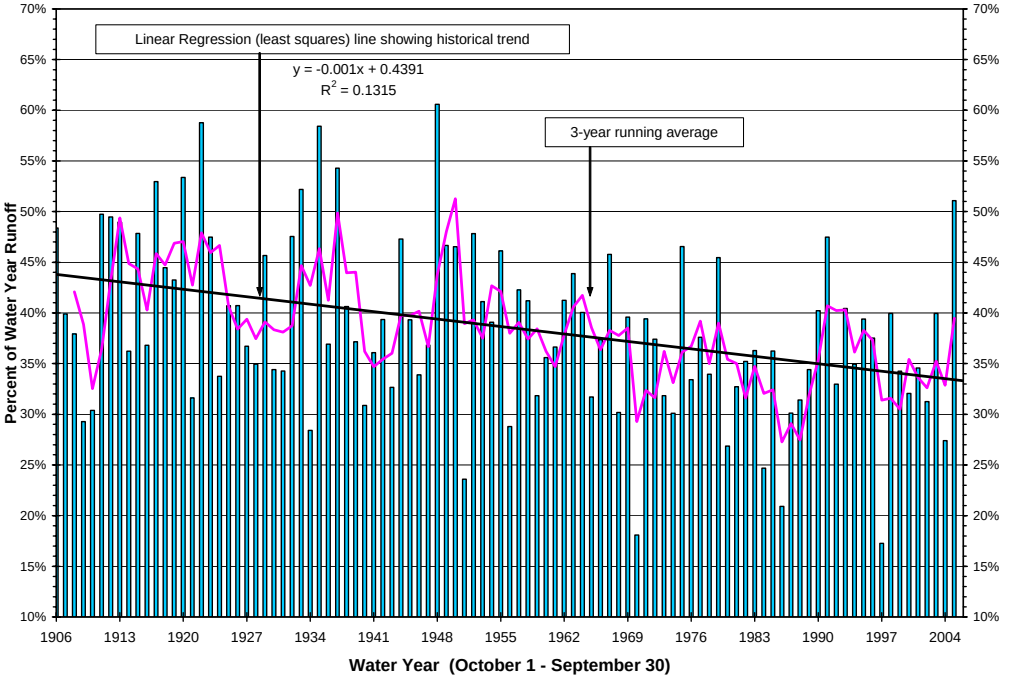
Three climate change scenarios all show a trend for less winter snowpack
(California Climate Change Center, 2006)

See Chapter 5 for references

Storms are likely to become somewhat more intense with higher snow lines causing more winter precipitation falling in the mountains as rain rather than snow. Average winter floodflows to the Delta are likely to become larger in the future.

The change in rain/snow mix, particularly in the northern Sierra Nevada, is predicted to shift the timing of peak runoff in the Central Valley earlier toward the winter. This would potentially lead to declines in spring and summer inflows and Delta water quality:

- Increasing salinity, most notably in the western Delta
- Producing more concentrated agricultural return flows and urban wastewater discharges, particularly if there are lower summer flows in the San Joaquin River



Spring runoff, an indication of snowpack, has been decreasing for years (DWR)

Based on current trends, the biggest risk to the agricultural and urban water diversions comes from sea level rise and the resulting increase in salinity in addition to increased risk of levee failures from continued subsidence, seismic events, and flooding from more severe storms. If there is an effort to maintain current water quality standards, more flushing water will be required from upstream reservoirs, leaving less water for water supply. In addition, increased storm intensity from climate change may require adjustments to flood control reservations. The changes in reservoir operations and the reduced snowmelt could reduce water supply reliability. Increases in water temperature may hurt spawning and recruitment success of native fishes.

See Chapter 5 for references

Seismic Activity

The Delta-Suisun lies near six major faults that are capable of generating moderate to strong ground shaking, particularly in the western Delta. The U.S. Geological Survey estimates a roughly 2-in-3 probability that the Bay Area will experience a large magnitude quake most likely along one of these faults within the next 26 years.

Faults near the Delta have been quiet for at least the past 100 years, but this may mean that stress is building, with risk increasing year by year. None of the existing Delta levees and none of the engineering standards (such as the PL 84-99 "One hundred year flood" standard) address seismic risk.

It can be noted that no Delta levee has ever failed from an earthquake. However, the current network of levees has not experienced a large earthquake. While the 1906 magnitude 7.8 San Francisco earthquake was a significant event, levees were much lower then now. The last 100 years of land subsidence has made the Delta islands deeper and required building the levees higher. These levees now are more susceptible to failure during an earthquake than they were in 1906. Although levees in Suisun Marsh are not as high as those in the Delta, they are much closer to several fault lines.

Potential of Major Bay Area Earthquake

On the basis of research conducted since the 1989 Loma Prieta earthquake, the U.S. Geological Survey (USGS) and other scientists conclude that there is a 62 percent probability of at least one magnitude 6.7 or greater quake, capable of causing widespread damage, striking the San Francisco Bay region before 2032.

U.S. Geological Survey Open-File Report 02-214

The hydrologic, ecologic, and economic consequence of strong earthquake ground shaking in the Delta-Suisun has not been extensively studied. This is a focus of DRMS being led by DWR, the Department of Fish and Game and U.S. Army Corps of Engineers, with results anticipated in 2007.

Potential Consequences of Major Earthquake in Bay-Delta region

With six major faults in the Bay Area, DWR and CALFED estimated the consequences of a major seismic event:

- Water exports cease and do not resume for the foreseeable future
- 30 levee breaks and 20 islands flooded
- 200 miles of levee weakened by slumping, cracking, and increased seepage
- Mokelumne Aqueduct failure
- Highways and utilities flooded, disrupting service and contributing to hazardous spills and clean up
- Shipping channels are blocked
- 85,000 acres of agricultural land and crops flooded
- 3,000 homes flooded
- Levee repairs could take 15 months or longer
- $30-$40 billion loss to California's economy over 5 years
- Job losses exceed 30,000

Preliminary estimates by DWR and CALFED indicate potential $30 billion to $40 billion statewide loss from a large earthquake causing significant levee failures and island flooding. Such an event could lead to multi-year disruptions in water supply, water quality degradation, and permanent flooding of multiple islands.

It is likely that an earthquake leading to multi-island flooding will occur within the western Delta during this century. Some of the islands could remain permanently flooded because it may not be practical to recover all islands. All preliminary modeling indicates that Delta flooding will lead to salt water intrusion into the Delta during seasonal low inflows. Multiple flooded islands and increased seasonal salinities will significantly alter the distribution, type, and quality of habitat along with abandonment of certain land use activities and infrastructure and change in water supply reliability.

See Chapter 5 for references

Introduced Species

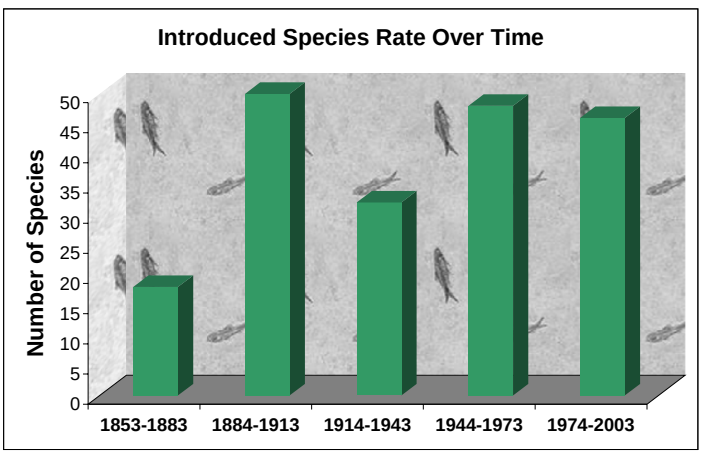
All aspects of the ecology of the Delta have been significantly and, in most cases, irrevocably altered by introduced (non-native) species. Recent reports show 193 introduced species (69 plants, 89 invertebrates, and 35 vertebrates) now dominate most habitats within the Delta-Suisun. For example, 88 percent of the fish captured in 2003 during juvenile fish surveys were introduced species. Sampling of a wide variety of habitats in the south Delta from 1992 through 1999 revealed fewer than 5 percent native individuals. In benthic sampling throughout the Delta, typically 95 percent or more of the biomass consists of introduced species.

There are 193 known introduced species in the Delta. These species dominate many Delta biological communities in both number and biomass.

Introduced waterweed can overwhelm low velocity channels

The effects of most introduced species on the Delta ecosystem are unknown. Some introduced species are also invasive: they spread rapidly, take over habitats, and displace natives. Among the introduced species of the Delta, the most visible is the aquatic weed *Egeria*, which can choke low-velocity channels in the central and southern Delta. Two clams from Asia dominate the benthos of the Delta: *Corbicula* is most abundant in fresh water, and the overbite clam *Corbula* is abundant in brackish to saline water. These clams have substantial effects on the pelagic foodweb. Among the fish, threadfin shad and inland silversides can probably be considered invasive, although shad abundance has apparently decreased in recent years. Striped bass and largemouth bass, both deliberate introductions, are not only among the most abundant fish of pelagic and nearshore habitats, they are also predatory and probably have significant negative effects on natives.

Native species evolved in the Delta and Suisun Marsh under naturally variable flow and salinity conditions. There is a growing sense among scientists that the more uniform present day conditions may benefit introduced species at the expense of natives.



The rate of new introductions has been relatively constant for over a century

The average rate of species introductions into the Delta has not changed much since the 1880s. During the last 30 years, about half the new non-native species introduced into the Delta were probably from ballast water offloaded from ships. Regulations now require at-sea exchange of ballast water before ships can enter the San Francisco

Estuary, but it is too early to tell if this actually reduces the rate of introductions. Other vectors such as release of aquarium or bait organisms continue unabated.

The likelihood of continued introductions of new species represents a significant source of uncertainty about the future of the Delta aquatic ecosystem. Successful introductions usually take advantage of disturbed habitat, so future introductions are certain. Species known to be problems in other regions, such as northern pike, zebra mussel, and various aquarium plants, are likely to invade the Delta-Suisun. The possibility of another harmful species being introduced is too high to ignore. Such introductions could eliminate gains occurring through restoration or improved management.

One Invasive Species:
Has It Run Its Course?

The Chinese mitten crab was first discovered in the Delta in 1996. The crab has been associated with:

- Clogging up water intake facilities
- Degrading levees due to burrowing
- Threatening native fish and other species
- Increasing erosion of tidal lands
- Damage to agricultural crops
- Acting as a vector for disease

At the peak, 25,000 crabs per day were collected at the screening facilities for the south Delta export facilities and hauled away in dump trucks. Since 2003, the population has significantly decreased. Scientists do not know why the decline occurred, or whether another population explosion will occur.

Zebra mussels can create a maintenance headache at water intakes

(Great Lakes Environmental Research Laboratory)

Another Invasive Species:
Is It on Its Way to the Delta-Suisun?

Zebra mussels can clog water systems and become the dominant consumer of plankton, meaning they are a threat to a water body's food chain. Introduced to the Great Lakes in the late 1980s, the mussels have spread rapidly in the Midwest. A cousin of the zebra mussel, Quagga mussel, was found in Lake Mead in January 2007. This mussel is larger than the zebra mussel, but has many of the same impacts.

The thumbnail-sized zebra mussels can lay and fertilize millions of eggs, which quickly turn to larvae that spread wherever the current takes them. They can also be carried on boat hulls transported overland on trailers. Mature mussels mass together, and as many as 700,000 per square yard have been found at some intake valves in the Great Lakes.

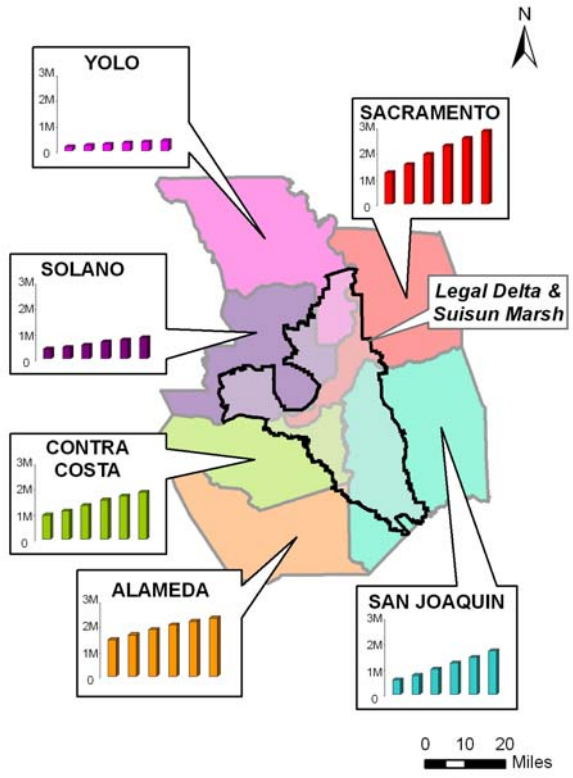
See Chapter 5 for references

Population Growth and Urbanization

Population forecasts indicate that California's population may reach 90 million residents by 2100. As noted in the *California Water Plan Update 2005*, this growth in population will change the nature and timing of demand for water resources, directly and indirectly influencing the future of the Delta. The California Department of Finance estimates that the combined population of the 6 Delta-Suisun counties will grow from about 3.3 million in 2000 to about 7.7 million in 2050, an increase of more than 130 percent.

Urbanization not only removes land from open space uses, but places more demand on the Delta-Suisun's services. We look beyond the boundaries of the Delta-Suisun for the impacts that urbanization may cause during this century.

Projected County Population Growth (2000-2050)



Delta-Suisun counties are growing rapidly, which will place more demand on Delta-Suisun services

The 2000 population of the Delta-Suisun was about 470,000. As with many regions of California, the periphery of the Delta-Suisun is undergoing rapid urbanization. Present and future population growth increases the demand for land for development, particularly in areas near the Bay Area, Stockton, and Sacramento. This demand results in conversion of open space, primarily agricultural land, to residential and commercial use. Estimates prepared by staff for the California State Reclamation Board indicate that as many as 130,000 new homes could be construction within the legal Delta just in the next decade.

Population growth within the Delta-Suisun, in the surrounding area, and in the state will place more demands on the Delta-Suisun services. More people will mean more need for recreation, transportation, utilities, water supply, and urban runoff as examples. Urbanization not only removes land from agriculture and other open space uses, but limits future management options in the Delta-Suisun. Ongoing urban encroachment and levee improvements along the southern and eastern margins of the Delta limit the opportunity for future adjustments to Delta management strategies needed for the changing conditions.

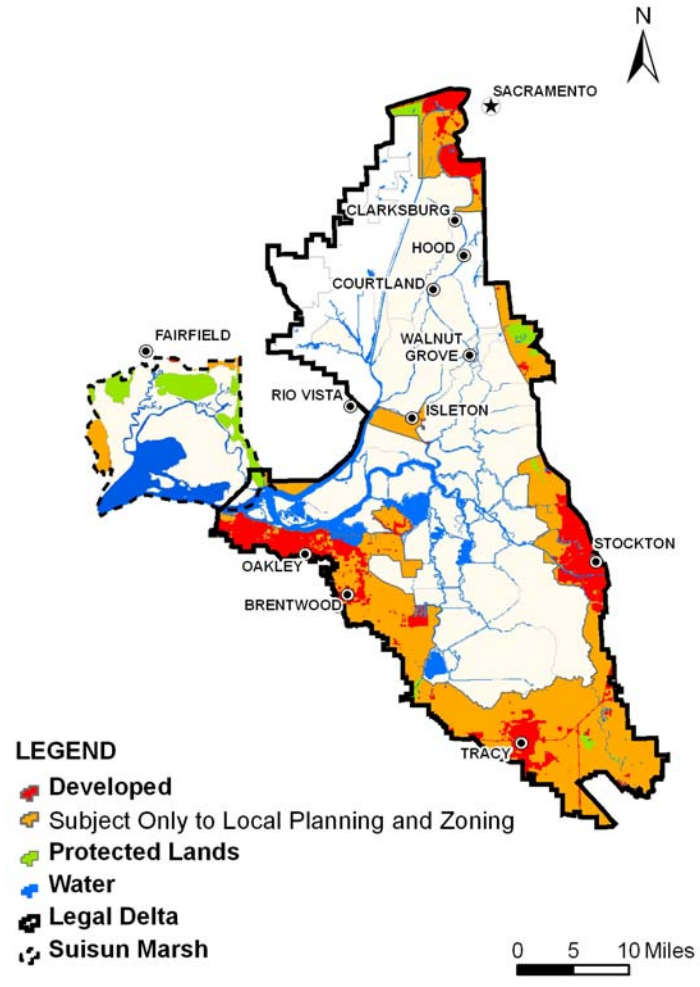
Ongoing and future urbanization may be largely irreversible based on current practices. As demonstrated repeatedly throughout the Central Valley, urbanization leads to increased land values in adjacent farm areas. This, in turn, increases the supply of developable agricultural land which further expands the zone of urbanization. Some people are fearful that urbanization could potentially shift political and funding support from Delta water supply, water quality, ecosystem issues to improving transportation corridors and other necessary infrastructure for the urban areas.

The Delta currently supplies a portion of the water supply to about two-thirds of the people in California. Although projections for future water demand vary, few are predicting a decline in the combined demand for drinking water and irrigation in the future. *California Water Plan Update 2005* recognizes that demand for Delta water will continue at roughly current or higher levels until 2030 and beyond.

The population on Delta islands and tracts is expected to grow from about 26,000 in 2000 to about 67,000 in 2030. While this will be a large growth, most of the future population growth in the Delta-Suisun will occur outside the islands and tracts. Based on current trends, the Secondary Zone of the Delta and a portion of the secondary management area of the Suisun Marsh could become completely built out from expanding metropolitan areas.

The map shows area (orange portion) that could potentially be developed. Excluding land already developed or land set aside for conservation, approximately 160,000 acres of additional land within the Delta-Suisun could be urbanized. Depending on the density of the development, this could increase Delta-Suisun population over 2000 population by 600,000 to 900,000 people. This estimate is in line with Department of Finance data that project a Delta-Suisun population increase of about 600,000 people by 2050.

Potential Urbanization in Delta-Suisun



About 160,000 acres of the Delta-Suisun could urbanize, adding 600,000 to 900,000 people

See Chapter 5 for references

5. References

A CD (or DVD), in the back pocket of this report, is provided as a reference guide. It contains:

- A PDF version of the Status and Trends of Delta-Suisun Services with links to references and page size maps
- Reference list with links to select web pages
- Copies of select references arranged by topic
- Maps

The reference list from the CD is duplicated below:

General

Association of Bay Area Governments (ABAG). Projections 2005 - Forecasts for the San Francisco Bay Area to the Year 2030.

----. December 2006. Demographic Research Unit, Report E-7. California Population Estimates, with Components of Change and Crude Rates, July 1, 1990-2006.

----. Demographic Research Unit, Population Projections by Race / Ethnicity for California and Its Counties 2000 - 2050, May 2004.

California Department of Water Resources. Delta Atlas. 1997. http://rubicon.water.ca.gov/delta_atlas.fdr/datp.html (accessed 11 December 2006)

----. Chapter 12 of Volume 3, California Water Plan Update 2005. 2006.

----. Delta Vision. http://www.deltavision.ca.gov/ (accessed 7 February 2007)

----. June 2006. Delta Vision Projects and Activities.

----. 2007. Delta-Suisun Jurisdictions and Interests. Internal paper.

----. February 2007. DWR staff using block level data from Census 2000.

Delta Protection Commission. Annual Report to the Governor and the Legislature on the Significant Accomplishments of the Delta Protection Commission for the Year 2005.

Mount, J.F. and R. Twiss, 2005. Subsidence, Sea Level Rise, Seismicity in the Sacramento-San Joaquin Delta: San Francisco Estuary and Watershed Science, v. 3, Article 5. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art5 (accessed 11 February 2007)

Mount, J., Twiss, R., and Adams, R.M. 2006. The role of science in the Delta visioning process: a report of the Delta Science Panel of the CALFED Science Program.

Sacramento Area Council of Governments (SACOG). SACOG Projections, Adopted by Board of Director's 12-16-04.

San Joaquin Council of Governments. Research and Forecasting Center Population Projections.

State Lands Commission. Historical Evaluation of the Delta Waterways, Final Report. December 1978.

United States Bureau of the Census, 1850 through 1890 decennial censuses.

----. Census 2000.

Land Use

Association of Bay Area Governments (ABAG). http://www.abag.ca.gov/index.html# (accessed 11 February 2007)

California Department of Justice. November 2006. Old Sugar Mill Specific Plan Appeals – Determination of Delta Protection Commission Jurisdiction and Appealable Issue.

California Department of Food and Agriculture. California Agricultural Directory 2005. http://www.cdfa.ca.gov/card/pdfs/agresdirentire05.pdf (accessed 11 February 2007)

California Department of Conservation. Farmland Mapping and Monitoring Program. http://www.consrv.ca.gov/dlrp/fmmp/index.htm (accessed 11 February 2007)

California Department of Water Resources. August 2006. The Value of the Agricultural Output of the California Delta.

Delta Protection Commission. Land Use and Resource Management Plan for the Primary Zone of the Delta. Adopted February 23, 1995, reprinted May 2002. http://www.delta.ca.gov/plan.asp (accessed 19 December 2006)

----. Projects Memo and Pending Projects List. December 2006

----. January 1994. Background Report on Land Use and Development. Reprinted January 2001.

----. Update on Land Use in the Delta Primary Zone, 1993-2004). Agenda Item # 10, January 14, 2005.

Sacramento Area Council of Governments (SACOG). http://www.sacog.org/ (accessed 11 February 2007)

San Francisco Bay Conservation and Development Commission (BCDC). The Suisun Marsh Protection Plan. http://www.bcdc.ca.gov/index.php?p=79&more=1&page=1 (accessed 1 January 2007)

San Joaquin Council of Governments. http://www.sjcog.org/ (accessed 11 February 2007)

Flood Management

California Department of Water Resources. Delta Risk Management Strategy. http://www.drms.water.ca.gov/ (accessed 11 February 2007)

----. DWR Bay-Delta Office, Delta Levees Program. http://baydeltaoffice.water.ca.gov/ndelta/levees/components.html (accessed 11 February 2007)

The Center for Collaborative Policy. August 2005.The Lower Yolo Bypass Stakeholder Process Feasibility Assessment.

Ecosystem

Bennett, W. A., 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California: San Francisco Estuary and Watershed Science, v. 3, Issue 2, Article 1.

Brown, L.R. 2003. An Introduction to the San Francisco Estuary Tidal Wetlands Restoration Series In: Larry R. Brown, editor. Issues in San Francisco Estuary Tidal Wetlands Restoration. San Francisco Estuary and Watershed Science. Vol. 1, Issue 1 (October 2003), Article 1. http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art1 (accessed 11 February 2007)

Jassby, A.D., Cloern, J.E., and Cole, B.E., 2002. Annual Primary Production: Patterns and Mechanisms of Change in a Nutrient-rich Tidal Ecosystem: Limnology and Oceanography, v. 47, p. 698-712.

Jones, C. G., Lawton, J.H., and Shachak, M. 1994. Organisms as Ecosystem Engineers. Oikos 69:373–386.

Kimmerer, WJ. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. San Francisco Estuary and Watershed Science [online serial].v. 2, Issue 1, Article 1. http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1 (accessed 11 February 2007)

Knowles, N., and Cayan, D., 2004. Elevational Dependence of Projected Hydrologic

Lopez, C.B., Cloern, J.E., Schraga, T.S., Little, A.J., Lucas, L.V., Thompson, J.K., and Burau, J.R., 2006. Ecological Values of Shallow-water Habitats: Implications for the Restoration of Disturbed Ecosystems: Ecosystems, v. 9, p. 422-440.

Nobriga, M.L., Feyrer, F., Baxter, R.D., and Chotkowski, M. 2005. Fish Community Ecology in an Altered River Delta: Spatial Patterns in Species Composition, Life History Strategies, and Biomass.

The Bay Institute. San Francisco Bay (Suisun Bay) Food Web Index. April 6, 2004.

Water Supply

Association of California Water Agencies. No Time to Waste, A Blueprint for California Water. May 2005.

CALFED. Interim Update of the CALFED Bay-Delta Program Surface Storage Investigations, Interim Common Model Package, Modeling Protocol and Assumptions, Technical Memorandum. May 2005.

California Department of Water Resources. Bulletin 132-04, Management of the California State Water Project, Covers Activities during Calendar Year 2003. September 2005.

----. California Water Plan Update 2005: A Framework for Action. Bulletin 160-05.

----. The State Water Project Delivery Reliability Report 2005, Final. April 2006.

Delta Protection Commission. February 1994. Background Report on Delta Water Issues. Reprinted October 2000.

Stockton Record. January 21, 2007. Delta Collapse Also May Hurt East Bay. http://www.recordnet.com/apps/pbcs.dll/article?AID=/20070121/A_NEWS/701210321/-1/A_NEWS14 (accessed 11 February 2007)

Water Quality Management and Discharges

Central Valley Regional Water Quality Control Board. Sacramento-San Joaquin Delta Methylmercury TMDL. http://www.swrcb.ca.gov/rwqcb5/programs/tmdl/deltahg.html (accessed 11 February 2007)

Lee, et. al. June 2004. Overview of Sacramento-San Joaquin Water Quality Issues.

Transportation

Amtrak. Amtrak Fact Sheet, Fiscal Year 2004, State of California.

California Delta Chambers and Visitors Bureau. Ferries of the Delta. http://www.californiadelta.org/ferries.htm (accessed 7 January 2007).

California Department of Boating and Waterways. Safe Boating Hints for the Delta. http://www.dbw.ca.gov/Pubs/Delta/SBHDelta.pdf (accessed 7 January 2007).

Caltrans. February 2006. State Route 12 (SR 12) Comprehensive Transportation Corridor Study – Rio Vista Bridge to SR 99, Final Report. http://www.dot.ca.gov/dist10/media/docs/SR12%20Final%20Report.pdf (accessed 11 February 2007)

ContraCostaTimes.com and wire service sources. Study Bolsters Port of Oakland Plan to Swap Trucks for Barges. October 29, 2006 http://www.contracostatimes.com/mld/cctimes/2006/10/29/news/15878766.htm (accessed 7, February, 2007)

Lauritzen Yacht Harbor. Delta Drawbridge Regulations. http://lauritzens.com/underway/Bridges.asp (accessed 7 January 2007)

Pacific Maritime Association. Annual Reports for years 1994 through 2005. http://www.pmanet.org/docs/index.cfm/id_subcat/18 (accessed 11, February 2007)

Utilities

California Energy Commission. June 2005. Preliminary Reference Case in Support of the 2005 Natural Gas Market Assessment. Staff Report

----. June 2005. Electicity Demand Forecast Comparison Report. Staff Report.

----. September 2005. California Energy Demand 2006-2016, Staff Energy Demand Forecast, Revised September 2005. Staff Final Reprot.

Delta Protection Commission. January 1994. Background Report on Utilities and Infrastructure. Reprinted June 1996.

Recreation/Tourism

California Department of Parks and Recreation. Summary of the Sacramento-San Joaquin Delta Recreation Survey prepared by the for the Delta Protection Commission and the Department of Boating and Waterways. 1997. http://www.delta.ca.gov/recsur.asp#_chapI (accessed 11 February 2007)

Delta Protection Commission. March 2006. Aquatic Recreation Component of the Delta Recreation Strategy Plan, Draft.

----. July 1994. Delta Protection Commission Recreation and Access Study.

Local and State Economics

California Department of Finance. 2005. California Statistical Abstract.

Delta Protection Commission. Economic Impact of Recreational Boating and Fishing in the Delta. 1998. http://www.delta.ca.gov/delta.asp#_C2 (accessed 11 February 2007)

----. The Economy of the Delta Region. 1998. http://www.delta.ca.gov/delta.asp#_C2 (accessed 11 February 2007)

Existing Regulatory and Management Practices

Delta Protection Commission. Land Use and Resource Management Plan for the Primary Zone of the Delta. February 1995. http://www.delta.ca.gov/plan.asp#_land-use (accessed 11 February 2007)

San Francisco Bay Conservation and Development Commission. The Suisun Marsh Preservation Act. http://www.bcdc.ca.gov/index.php?p=80&more=1&page=1 (accessed 11 February 2007)

State Water Resources Control Board. Draft Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. September 2006.

Subsidence

Deverel, S.J., and Rojstaczer, S. 1996. Subsidence of Agricultural Lands in the Sacramento-San Joaquin Delta, California: Role of Aqueous and Gaseous Carbon Fluxes. Water Resources Research 32:2359-2367.

Ingebritsen, S.E., Ikehara, M.E., Galloway, D.L., Jones, D.R. 2000. Delta Subsidence in California: the Snking Heart of the State. U.S. Geological Survey FS-005-00. 4 p.

U.S. Geological Survey. Delta Subsidence in California. FS-005-00. April 2000.

Global Climate Change – Sea Level Rise

Church, J.A., and Gregory, J.M., 2001. Changes in Sea Level, in Houghton and Others (eds.), Climate Change 2001: The Scientific Basis: Cambridge University Press, 639-693.

California Climate Change Center. Projecting Future Sea Level. March 2006.

----. Our Changing Climate: Assessing the Risks to California. July 2006.

Kerr, R. A., 2006. A Worrying Trend of Less Ice, Higher Seas: Science, v. 311, p. 1698-1701.

Orr, M., Crooks, S., Williams, P.B. 2003. Will Restored Tidal Marshes be Sustainable? In: Brown, LR, editor. Issues in San Francisco Estuary Tidal Wetlands Restoration. San Francisco Estuary and Watershed Science: v 1, Article 5. http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art5/ (accessed 11 February 2007)

Otto-Bliesner, B.L., Marshall, S.J., Overpeck, J.T., Miller, G.H., and Hu, A. 2006 Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation. Science, 311(5768):1751-1753.

Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B., and Kiehl, J.T. 2006. Paleoclimatic Evidence for Future Ice-sheet Iinstability and Rapid Sea-level Rise. Science, 311(5768):1742-1750.

Ryan, H., H. Gibbons, J.W. Hendley II, and P.H. Stauffer, 1999. El Nino Sea-level Rise Wreaks Havoc in California's San Francisco Bay Region: USGS Fact Sheet 175-99.

Regional Climate Change – More Winter Flooding

ABAG Earthquake and Hazards Program. 2006. Natural Hazards and Climate Change – Risk Management and Public Policy Opportunities. http://quake.abag.ca.gov/mitigation/PR-Climate.pdf (accessed 7 February 2007)

California Climate Change Center. July 2006. Our Changing Climate: Assessing the Risks to California. CEC-500-2006-077.

California Department of Water Resources. July 2006. Progress on Incorporating Climate Change into Management of California's Water Resources: A Technical Memorandum Report.

Dettinger, M.D., 2005. From Climate-change Spaghetti to Climate-change Distributions for 21st Century California: San Francisco Estuary and Watershed Science, v. 3, Article 4. http://repositories.cdlib.org/jmie/sfews/vol3/iss1/art4 (accessed 11 February 2007)

Dettinger, M.D., D.R. Cayan, M.K. Meyer, A.E. Jeton, 2004. Simulated Hydrologic Responses to Climate Variations and Change in the Merced, Carson and American River Basins, Sierra Nevada, California, 1900-2099: Climatic Change, v. 62, p. 283-317.

Hayhoe, K., Cayan, D. and others, 2004. Emissions Pathways, Climate Change, and Impacts on California: Proceedings of the National Academy of Sciences, v. 101: p. 12422-12427

IPCC (Intergovernmental Panel on Climate Change), 2001. Climate Change 2001: The Scientific Basis. *In*: IPCC Third Assessment Report: Climate Change 2001. Cambridge University Press, 881 p.

----. February 2007. Climate Change 2007: The Physical Science Basis, Summary for Policymakers.

Jain, S., M. Hoerling, and J. Eischeid, 2005. Decreasing Reliability and Increasing Synchroneity of Western North American streamflow: Journal of Climate, v. 18, p. 613-618.

Kim, J., 2005. A Projection of the Effects of the Climate Change Induced by Increased CO2 on Extreme Hydrologic Events in the Western U.S.: Climatic Change, v. 68, p. 153-168.

Knowles, N., and Cayan, D., 2004. Elevational Dependence of Projected Hydrologic Changes in the San Francisco Estuary and Watershed: Climatic Change, v. 62, p. 319-336.

Lund, J.R., R.E. Howitt, M.W. Jenkins, T. Zhu, S.K. Tnaka, M. Pulido, M. Tauber, R. Ritzema, and I. Ferriera, 2003. Climate Warming and California's Water Future: UC Davis Center for Environmental and Water Resource Engineering Report 03-1. Available at: http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/ReportCEC/CECReport2003.PDF (accessed 11 February 2007)

VanRheenan, N.T., A.W. Wood, R.N. Palmer, D.P. Lettenmaier, 2004. Potential Implications of PCM Climate Change Scenarios for Sacramento-San Joaquin river Basin Hydrology and Water Resources. Climate Change, v. 62, p. 257-281.

Stewart, I., D.R. Cayan, M.D. Dettinger, 2004. Changes in Snowmelt Runoff Timing in Western North America Under a "Business as Usual" Climate Change Scenario: Climate Change, v. 62: 217-232.

Seismic Activity

CALFED (California Bay-Delta Program), 2000. Levees and Channels Technical Team, Levees Seismic Vulnerability Sub-Team, *Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees,* April 2000.

----. 2005. Preliminary Seismic Risk Analysis Associated with Levee Failures, Sacramento-San Joaquin Delta: Report prepared for the California Bay-Delta Authority and California Department of Water Resources, Jack Benjamin and Associates, Inc., 50 p.

Torres RA, et al. 2000. Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees. Report of Levees and Channels Technical Team, Seismic Vulnerability Sub-team to CALFED Bay-Delta Program. 30 p.

Wakabayashi, and Smith, 1994. Evaluation of Recurrence Intervals, Characteristic Earthquakes, and Slip Rates Associated with Thrusting along the Coast Range – Central Valley California, Geomorphic Boundary, Bulletin of the Seismological Society of America, Vol. 84, No. 6, pp. 1960-1970, December 1994.

Working Group for California Earthquake Probabilities. Earthquake Probabilities for the San Francisco Bay area: 2002-2031: U.S. Geological Survey Open-File Report 02-214. 2003

Introduced Species

Bryant, M. 2003. Summer Townet Survey. IEP Newsletter 16(4):3.

Cohen, A.N., and J.T. Carlton, 1998. Accelerating Invasion Rate in a Highly Invaded Estuary: Science, v. 279, p. 555-557.

Feyrer, F. and M.P. Healy. 2003. Fish Community Structure and Environmental Correlates in the Highly Altered Southern Sacramento-San Joaquin Delta. Environmental Biology of Fishes. 66:123-132.

Light, T., T. Grosholz and P. Moyle. 2005. Delta Ecological Survey (Phase I): Nonindigenous Aquatic Species in the Sacramento-San Joaquin Delta, a Literature Review. UC Davis. Final Report for Agreement DCN #113322J011. U.S. Fish and Wildlife Service. Stockton. Ca.

U.S. Geological Survey. http://cars.er.usgs.gov/Nonindigenous_Species/ZM_Progression/zm_progression.html (accessed on 10 January 2007

Population Growth and Urbanization

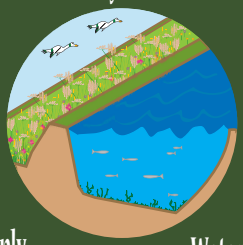
The National Archives. California Indian Acorn Culture http://www.archives.gov/pacific/education/curriculum/4th-grade/acorn.html (accessed 7 February 2007)

Services

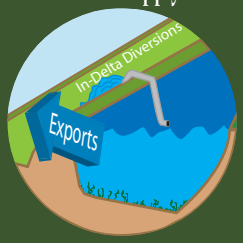
Flood Management

Land Use

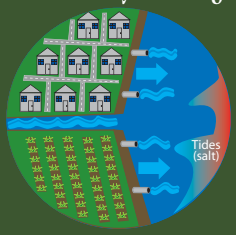
Ecosystem



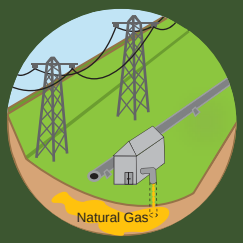
Water Supply



Water Quality / Discharges



Utilities



Transportation

Economy

Recreation / Tourism