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Figures

This section provides background information on the Sacramento/San Joaquin Delta and Suisun Marsh. The early subsections below draw heavily on the document *"Status and Trends of Delta-Suisun Services,"* developed as a foundation for DRMS and the Delta Vision initiative (URS 2007).

2.1 LOCATION

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 (Figures 2-1, 2-2, and 2-3). Unlike the Mississippi River Delta and other river deltas that form where rivers drop their sediments as they enter the ocean, the Sacramento-San Joaquin Delta is an interior delta whose western side lies about 50 miles upstream from the Golden Gate. The major rivers entering the Delta are the Sacramento River flowing from the north, the San Joaquin River from the south, and the Cosumnes, Mokelumne, and Calaveras Rivers from the east.

The Delta and Suisun Marsh, together with the greater San Francisco Bay, make up the largest estuary on the west coast of North America. The Delta and Suisun Marsh together cover about 1,315 square miles in portions of six California counties. Although the Delta and Suisun Marsh cover only about 1 percent of California's area, the region is at the heart of critical California water supply issues. Many users compete for freshwater from the Delta. These users include the many water agencies/contractors and their customers in Northern and Southern California, the San Joaquin Valley agricultural industry, local in-Delta agriculture, and the Delta ecosystem. The competition for freshwater from the Delta becomes exacerbated during summer, when the inflows of freshwater into the Delta are low.

2.2 HISTORICAL PERSPECTIVE

About 20,000 years ago, sea levels were about 400 feet lower than they are today and the coastline was near the Farallon Islands, about 30 miles west of the Golden Gate and about 80 miles west of the present Delta. About 130,000 years ago, sea levels were as much as 10 feet higher than they are today. During these dramatic swings in sea level, the Delta would have existed in its current location only at times when sea level was near the present level.

The rich organic peat soils in the Delta and Suisun Marsh built up over about the last 5,000 years as the sea level rose and as marsh 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 organic soil.

The Delta and Suisun Marsh consisted of hundreds of miles of tidally influenced sloughs and channels, and hundreds of thousands of acres of marsh and overflow land. The braided channels surrounded many natural islands. The river systems accommodated large populations of anadromous fish that passed through and spent parts of their lives in the Delta. The region once supported large mammal species such as the grizzly bear, tule elk, and gray wolf. Native Americans hunted, fished, and foraged for food.

During the gold rush beginning in 1849, the Delta waterways were used to transport supplies and prospectors to the gold fields. Figure 2-2 is an historical illustrative map showing the Delta area in the mid-1800s, before agricultural development and levee construction began. In the 1850s, farmers began to recognize the great potential of the rich Delta soils. Natural levees existed along some river channels where sediments had been deposited when high water overflowed the channel banks. Farmers began to reclaim the land areas to grow crops by building small levees, 3 to 5 feet high, on the tops of the natural levees. High water periodically caused these levees to fail, and some were rebuilt only to fail again.

Large-scale reclamation of the Delta for agriculture began in 1868. Levee building became more aggressive, accomplished with both hand labor and mechanical equipment. Large-scale land development companies were formed, with one firm accumulating 250,000 acres. This period of development ended around 1900. By this time, most of the lands with mineral-organic soils had been reclaimed. With the exception of Bouldin Island, lands with organic soils in the central Delta were generally not reclaimed.

The final period of Delta reclamation occurred between 1900 and 1920 on lands in the Delta's interior. These lands contain mostly organic soils, which make levee construction difficult because of their high organic matter. Figure 2-4 shows which islands and tracts were reclaimed in decade-long periods from 1868 through 1921. The result of these reclamation efforts is largely what is seen as the Delta today – approximately 700 miles of meandering waterways with levees protecting over 538,000 acres of farmland, homes, and other structures. Many of the levees are considered relatively fragile with respect to today's design and construction standards.

With the construction of levees and draining for agriculture, the organic soils were exposed to the atmosphere since most agricultural practices require an aerated root zone. Some soil has blown away with the wind, some has burned as part of an agricultural process, but the major portion has simply decomposed, producing land subsidence. The aerobic (oxygen-rich) condition favors microbial oxidation, which consumes the organic soils. Most of the carbon loss is emitted as carbon-dioxide gas to the atmosphere. In addition, large volumes of organic soil were used for levee construction. Over the past 150 years, as much as half of the original soil volume that accumulated over 5,000 years has disappeared, placing much of the Delta land surface 15 feet or more below sea level. Many of the Delta islands and tracts have flooded multiple times. Since 1900, levee failures have flooded Delta islands and tracts 166 times (see Figure 2-5 for historical island flooding since 1900). Some, like Franks Tract, were never recovered.

Significant diversion and modification of stream flows in Delta watersheds began during the gold

History of Delta Conflict Up to the 1994 Delta Accord

Throughout the 1970s, 1980s, and 1990s, as both in-Delta and export 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 creation of the CALFED Bay-Delta Program.

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. It 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.

Because of the importance of the Delta levee system, the CALFED Record of Decision in 2000 called for preparation of a Delta Risk Management Strategy. This report summarizes Phase 1 of DRMS.

rush to facilitate placer and, later, hydraulic mining. The upstream mining sent large volumes of sediment into the rivers that flow to the Delta. Sediment that migrated to the Delta reduced channel capacity and contributed to flooding. The federal government passed the Caminetti Act of 1893 that led to the creation of the Yolo bypass and prescribed Delta levee heights. In 1960, the Sacramento River Flood Control Project was completed by the USACE, improving flood protection for much of the Sacramento Valley and a portion of the Delta. About a third of the Delta levees are part of the Sacramento River Flood Control Project and eligible for USACE's support for rehabilitation. The remaining levees are not part of a state/federal flood control project. Local landowners, reclamation companies, and reclamation districts constructed the majority of these non-project (local) levees.

In the 1970s, the California Legislature recognized that the Delta levee system benefits many segments and interests of the public, and approved a preservation plan. The Delta Levee Maintenance Subventions Program (Subventions Program) was established in 1973 and amended by the Delta Flood Protection Act of 1988. The Delta Flood Protection Fund was created to provide for local assistance under the subventions Program and for Special Delta Flood Protection Projects (Special Projects) to protect services such as roads and utilities, urbanized areas, water quality, and recreation.

Water development has significantly shaped the inflows to the Delta and changed its hydrodynamics. Construction of upstream dams has lowered peak flows and raised dry weather flows to the Delta, significantly changing the inflow pattern to the Delta. In 1921 the California legislature authorized development of a comprehensive water plan for the state. This plan was largely complete in 1932 and identified Delta salinity control as an issue for northern water users and Delta facilities as a major component of the plan.

By 1939 the federal government had initiated construction on the Central Valley Project's (CVP) Friant, Shasta, and Contra Costa (Delta) Divisions. A portion of the water for the Delta Division was to be exported to San Joaquin River users in exchange for their existing San Joaquin River rights. This arrangement was necessary for two reasons: (1) to allow San Joaquin River water to be exported south and (2) because it was acknowledged that sufficient flow was needed at Antioch and Pittsburg to repel seawater.

Work continued on the CVP for many years, with Trinity Dam completed in 1962. San Luis reservoir was completed in 1967, while New Melones reservoir was not completed until 1978.

In 1957, the State of California released Bulletin 3, The California Water Plan. Bulletin 3 called for the construction of dams, canals, pipelines, and significant alteration of northern streams to meet expected water demands south of the Delta. The 1957 State Plan proposed immediate construction of the Oroville Dam and reservoir project on the Feather River. This reservoir was completed in 1967 and is the major storage reservoir for the State Water Project (SWP). Figure 2-6 shows the major features of the federal, state, and local projects in California.

Construction of the state's Delta facilities began in 1963 and included Clifton Court Forebay, the Harvey O. Banks pumping plant, and San Luis Reservoir (jointly with the federal project). The initial capacity of the Banks pumping plant was 6,400 cubic feet per second (cfs), later expanded to 10,300 cfs in 1991, although diversion into Clifton Court Forebay is still limited to 6,400 cfs.

Today, the Delta is managed as a freshwater system to support in-Delta agriculture and export water supplies. The changes in hydrodynamics (flow and salinity) have contributed to a significantly altered ecosystem, as compared with 150 years ago. Today, about one fourth of the urban water used in California is diverted from the Delta; about two thirds of Californians get some portion of their drinking water from the Delta. Also, about 3 million acres of agricultural lands receive some irrigation water from the Delta.

2.3 STATUS OF THE DELTA AND SUISUN MARSH

Most of the Delta is agricultural land and most of Suisun Marsh is managed wetlands and other lands managed for waterfowl hunting and conservation. Out of almost 840,000 acres, the 2004 land use consisted of about 9 percent urban, 67 percent agricultural, 14 percent conservation and other open lands, and 10 percent water. In 1992, the Delta Protection Act defined the Primary Zone of the Delta, with stringent protection against further urban development. The Secondary Zone contains the rest of the legal Delta with less stringent protection. The zones are illustrated on Figure 2-2. Small, unincorporated communities and historic towns (Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove), within the Delta's Primary Zone (see Figure 2-3), serve as social and service centers for surrounding farms. A small portion of Rio Vista lies within the Primary Zone. The incorporated city of Isleton and portions of Stockton, Pittsburg, Antioch, Oakley, Elk Grove, Tracy, Lathrop, Sacramento, and West Sacramento are within or just outside the Delta's Secondary Zone (see Figure 2-3). The expanding cities of Fairfield and Suisun City are encroaching on the edges of Suisun Marsh secondary management area, creating population pressures on all services.

About 65 major islands and tracts in the Delta rely on the levee system. The levee system generally provides low levels of protection for adjoining lands. Most levees have been locally built and maintained. All of the existing services provided by the Delta and Suisun Marsh rely on the existing levee system. The *Status and Trends of Delta-Suisun Services* (URS 2007) provides information on nine key services (bullet list below). The following provides some observations on the status of the key services:

- Land use (agricultural, urban, and conservation)
  - The Delta includes about one-half million acres of highly productive farmland.
  - Since 1990, about 40,000 acres of farmland have been converted to urban and conservation uses.
  - About 165,000 dwellings and a population of about 470,000 are within the area protected by Delta and Suisun Marsh levees (2000 census); Delta islands and tracts house only about 26,000 people. These islands and tracts include nearly all of the Primary Zone and a portion of the Secondary Zone.
  - The region is surrounded by some of the areas where population is growing at the fastest rates in California
- Flood management
  - Land subsidence on the interior of islands and tracts has created large areas below sea level; some areas are as much as 25 feet below sea level.
  - Levee failures and flooding are possible at any time since the levees hold back water 365 days per year.

  - Levee failures during times of moderate to low Delta inflow can result in saltwater from Suisun Bay flowing upstream into the Delta as islands flood.
  - Land subsidence in some areas continues at the rate of 0.5 to 1.5 inches of soil loss per year.
- Ecosystem
  - The region provides unique habitat for hundreds of species of resident and migratory fish, birds, plants, mammals, and insects, some listed as federally threatened or endangered species.
  - The region is very different from the historical ecosystem in which the native organisms evolved.
  - The ecosystem is subject to rapid change.
  - More than 10 percent of California's remaining wetlands are in Suisun Marsh.
  - Biomass in benthic samples typically is 95 percent or more from nonnative species.
  - The decline of pelagic (open water) organisms, such as Delta smelt and longfin smelt, has increased concern over the sustainability of the Delta ecosystem.
- Water supply
  - The Delta channels serve as water conveyance for millions of acre-feet of export water per year.
  - The Delta is one of few estuaries in the world used as a major drinking water source.
- Water quality management and discharges
  - About 42,500 square miles drain to Delta.
  - 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 the state or nation (highways, shipping channels, and rail).
  - Pipelines crossing the Delta deliver gasoline, diesel and aviation fuel to Northern California, northern Nevada and the Central Valley.
  - Transportation within the Delta and Suisun Marsh follows more of a maze pattern than a straight corridor.
  - Bridges and auto ferries connect Delta islands.
- Utilities
  - A wide variety of utilities (electrical transmission, natural gas pipelines and wells, and water pipelines) cross the area.
  - Most utilities serve large areas of the state.

- Recreation/tourism
  - Recreation is focused on water-based activities.
  - Private land ownership limits land-based recreation.
  - The Delta and Suisun Marsh support a wide range of activities including boating, fishing, waterfowl and upland game bird hunting, wildlife viewing, bird watching, sightseeing, and photography.
- Local and state economics
  - The asset value protected by Delta levees is about $56 billion.
  - Areas protected by Delta levees provide more than 205,000 jobs.
  - The Delta contributes to the statewide economy, especially through water exports.

2.4 TRENDS FOR THE DELTA AND SUISUN MARSH

The Delta and Suisun Marsh levees and 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. A number of influences or “drivers,” most beyond direct human control, may change the Delta-Suisun Marsh and its vulnerability to levee failures in the future (see textbox).

Drivers of Change

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

Key observations about future trends from *Status and Trends of Delta-Suisun Services* (URS 2007) include:

- Land subsidence will continue where organic soils are 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 will be exerted on levees from continued sea-level rise by at least 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.
- Sea-level rise will increase salinities in the Delta, unless additional freshwater inflows to the Delta are provided to prevent this.
- More winter precipitation will fall in the mountains as rain rather than snow (decreasing mountain snow pack by as much as 25 percent by 2050).
- Average winter flood flows to the Delta will likely become larger.
- Natural summer flows will likely be lower, adding to dry season water supply and quality problems.

- About a two out of three chance exists of at least one magnitude 6.7 or greater earthquake in the Bay Area before 2032. Such an event has the potential to cause multiple Delta islands to flood from levee failures.
- Some islands may remain permanently flooded after a levee failure.
- Species known to be problems in other regions, such as northern pike, zebra mussel, and various aquatic plants, are likely to invade the Delta and Suisun Marsh.
- Over the next decade, projections indicate that 130,000 new homes will be built within the Delta and Suisun Marsh protected area.
- Under the present approach to land use planning, urbanization of available land within the Secondary Zone could add 600,000 to 900,000 people.
- Population growth and urbanization are expected to place more demand on the Delta and Suisun Marsh's services (recreation, transportation, utilities, water supply, and urban runoff).
- Urbanization is expected to place more pressure on agriculture and other open space uses.
- Expected urbanization will cover more land and reduce options for future management choices for other resources.

2.5 RECENT GROWTH OF CONCERN

Recognition of the importance of the Delta and Suisun Marsh as a changing, dynamic system is growing. Within the past several years, the Delta and Suisun Marsh areas have gained an unprecedented level of political, public, and funding support.

The California Bay-Delta Authority Program (referred to as CALFED) environmental documentation culminated in the Record of Decision (ROD) in 2000 (CALFED 2000a). The ROD laid out a program to simultaneously meet objectives for water supply reliability, ecosystem, water quality, and levee system integrity. The ROD specifically recognized the need to prepare DRMS. The preferred alternative called for a through-Delta conveyance alternative based on the existing Delta configuration with some modifications and seven other program elements: a long-term levee protection plan, a water quality program, an ecosystem restoration program, a water use efficiency program, a water transfers program, a watershed program, and new groundwater and surface water storage.

Since the CALFED ROD was issued, billions of dollars have been spent towards achieving the four objectives, although only about 20 percent of the funds identified for maintaining and improving Delta levees during the 2000–2007 period were actually made available.

Several events in recent years have heightened concern over the sustainability of the Delta in its current form:

- Many people associate potential levee failures with high winter flood flows in the rivers. That is the most common type of failure but, by contrast, seven Delta levees have failed during low flow periods. Thus, the June 2004 failure of a Jones Tract levee provided a reminder that the Delta levees have water against them 365 days per year and failures at any time are possible. This one island failure resulted in nearly $100 million in repair, recovery, and damage costs. The levee failure did not significantly affect the Delta water exports, but highlighted the risks of such impacts if islands flood in other locations or if multiple islands flood at the same time.

- News of Hurricane Katrina and the resulting damage to the Gulf Coast, and especially flooding in New Orleans, was on the front pages of newspapers and on television news programs for weeks during August and September 2005. The public, politicians, and scientists and engineers became concerned about parallels between levee failures and flooding in New Orleans and the potential for similar occurrences in the Delta. While this lesson wasn't necessarily new, it was a vivid reminder about the vulnerability of Delta levees and the possible statewide and national impacts of catastrophic levee failures.
- 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 already documented changes in California's climate during the latter half of the 20th century. By the end of the current century, depending on future heat-trapping gas emissions, statewide average temperatures are expected to rise between 3 and 10.5 °F. Estimates indicate that more winter flooding will occur and that sea levels will continue to rise. Both of these pose significant threats to the Delta levees.
- On the basis of research conducted since the 1989 Loma Prieta earthquake, the U.S. Geological Survey (USGS) and other scientists conclude that a 62 percent probability exists of at least one magnitude 6.7 or greater quake, capable of causing widespread damage, striking the San Francisco Bay region before 2032 (USGS Open-File Report 03-214). 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 not as tall as they are now. The last 100 years of land subsidence has made the Delta islands deeper and resulted in building the levees higher. These levees now are more susceptible to failure during an earthquake than they were in 1906 as has been confirmed by the analyses described in subsequent sections.
- Preliminary estimates by DWR (JBA 2006a, 2006b) indicate the potential for $30 to $40 billion statewide loss from a large earthquake causing significant levee failures and island flooding. Such an event could lead to multiyear disruptions in water supply, water quality degradation, and permanent flooding of multiple islands. Much of this cost comes from the realization that a significant portion of the state's water supply would be vulnerable to massive levee failures.
- Since the CALFED ROD was issued for the 2000 Programmatic Environmental Impact Statement/Report, a continued pelagic organism decline has occurred in the Delta. These are open-water organisms such as Delta smelt and longfin smelt.
- The varied successes of implementation of the CALFED Bay-Delta Program have caused some to question whether it is possible to achieve all four CALFED objectives at the same time. The four interrelated CALFED objectives are:
  - **Levee System Integrity –** Reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

- **Ecosystem –** Improve and increase aquatic and terrestrial habitats, and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.
- **Water Supply Reliability** – Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system.
- **Water Quality –** Provide good water quality for all beneficial uses.

- CALFED is currently reevaluating its program after the first 7 years of implementation and considering whether the preferred alternative identified during 2000 in its programmatic EIR/EIS and ROD is capable of meeting all four objectives (CALFED 2007).
- Recognition is also growing that prior Delta planning efforts have been too narrowly focused on a few resources and haven't adequately included the full range of Delta uses and resources.
- In AB 1200, the Legislature found and declared the following:

  (a) Substantial water supplies are derived from the Sacramento-San Joaquin Delta for the greater Silicon Valley area, Alameda County, eastern Contra Costa County, Napa County, Solano County, the San Joaquin Valley, and southern California.

  (b) In a document entitled "Seismic Stability of Delta Levees," the DWR estimated that a single 100-year earthquake would result in 3 to 10 Delta levee breaks and that a single 1,000-year earthquake would result in 18 to 82 Delta levee breaks. A 100-year earthquake is defined as having a mean annual frequency of occurring or being exceeded equal to 0.01 (or 1 percent). Similarly, a 1,000-year earthquake would have a mean annual frequency of occurring or being exceeded of 0.001 (or 0.1 percent).

  (c) A report to the California Bay-Delta Authority Independent Science Board estimated that sea-level rise caused by climate change, continuing subsidence of Delta lands, floods, and earthquakes, have a 64 percent probability of resulting in catastrophic flooding of Delta islands over the next 50 years. The state's economy, and the governmental programs that are dependent on a healthy economy and a healthy environment, cannot afford a catastrophic disruption of the water supplies derived from the Delta (Mount et al. 2006).

All of these concerns have combined to prompt new action on making the Delta more sustainable into the future. 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. Some of the actions that have been taken to address these concerns within the past few years include:

- In November 2006, California voters entrusted DWR with about $5 billion in new bond funds for flood management, a portion of which will be available for the Delta.
- DRMS work was initiated to evaluate the risks associated with levees in the Delta and Suisun Marsh and evaluate ways to mitigate that risk.
- The Delta Vision initiative was initiated to devise a strategy for the Delta and Suisun Marsh sustainability that considers all services.

- The Public Policy Institute of California (2007) evaluated nine alternatives and concluded that several promising alternatives deserve more study; all are different than the current system.

2.6 ASSESSING THE RISK OF DELTA LEVEE FAILURES

A comprehensive and thorough probabilistic risk analysis of Delta levees has not been performed previously. The following previous work addressed portions of the risk question and advanced some ideas on risk management. This provides important background and a starting point for the present DRMS effort to prepare the first comprehensive, quantitative assessment of Delta levee risks.

Although the risks of Delta levee failures are obvious and have been recognized for quite some time, efforts to quantitatively assess the likelihood and consequences of levee failures have occurred only infrequently. Most early efforts simply recognized the risks and concentrated on how to best respond to such an adverse event when it occurred (e.g., DWR 1986). Recently, however, it has been recognized that there is an advantage to a quantitative understanding of levee failure likelihood and consequences. With such information, more rational consideration can be given to actions that can be taken to reduce failure likelihoods and consequences.

2.6.1 CALFED Levee Seismic Vulnerability

In response to the CALFED objective of levee system integrity, a first assessment of Delta levee seismic vulnerability was performed (CALFED 2000b). This effort looked only at the possibility of failures due to earthquakes and it characterized the scale of a failure event by the number of simultaneous breaches that might occur. This restricted the interpretation of consequences because it was not stated how many islands were flooded or what impacts would be expected to result from a given number of simultaneous levee breaches. Still, this effort provided an initial estimate of seismic failure likelihood, as illustrated by Figure 2-7.

Note that, in 50 years of exposure, the common benchmark of a 1 percent annual frequency of exceedance event would have about a 39.5 percent probability of exceedance. The common example of this magnitude event is the 1 percent flood, frequently called the "100-year flood." Thus, the figure indicates that the 1 percent annual earthquake would result in four or five levee breaches and can be expected to occur or be exceeded with 39.5 percent probability in a 50-year exposure period under current conditions. More severe events might cause 70 to 90 breaches.

2.6.2 JBA Preliminary Seismic Risk Analysis

As an extension of the CALFED work already described, Jack R. Benjamin & Associates (JBA 2005) analyzed the potential extent of flooding, the water quality impacts, and the economic consequences of seismically induced levee failures. The JBA analysis used the CALFED (2000b) results as input, selected an example earthquake that would lead to levee breaches and used those levee breaches to define flooded islands, repair time and costs, salinity intrusion and persistence, duration of water export pumping disruption, and widespread economic impacts due to water export disruption. The results were then interpolated and extrapolated to estimate similar results for other earthquakes.

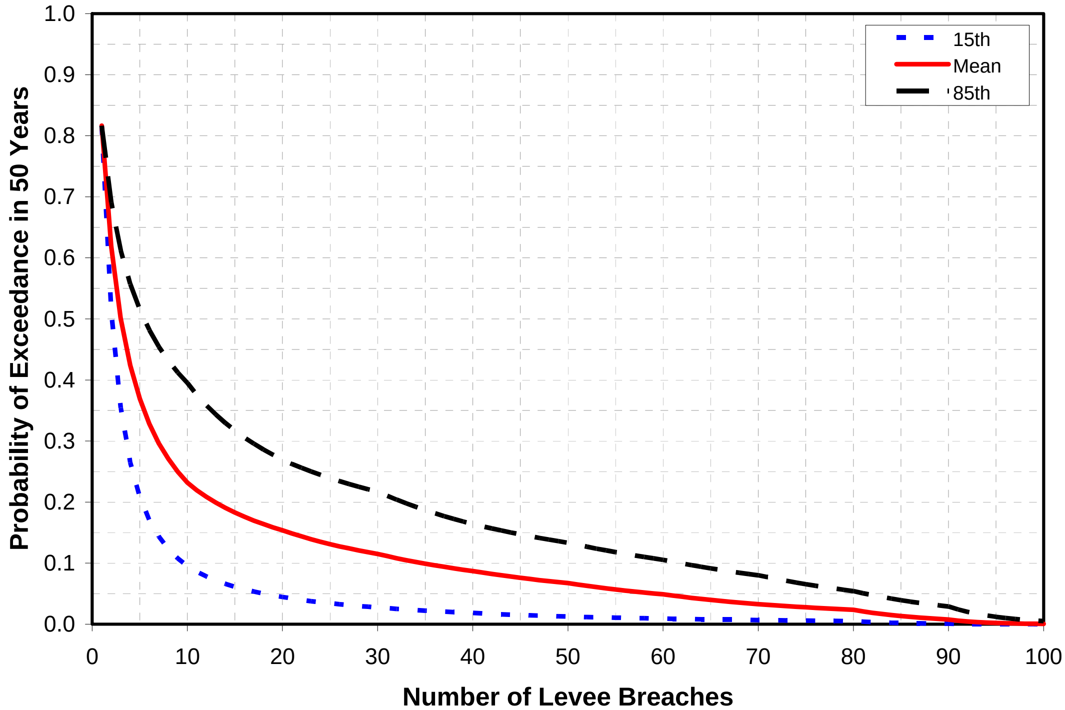


Figure 2-7 Probability distribution on the number of seismically initiated simultaneous levee breaches in the Delta for an exposure period of 50 years under current conditions (scaled from Fig. 5-3 [CALFED 2000a]).

The results were recognized as preliminary, with a need to extend to other hazards (e.g., floods), update the seismic input information, develop a broader set of earthquakes for analysis of impacts, and generally improve the robustness of the analytical approach used. However, the analysis did provide an initial quantification of risk in terms of the likelihood of an important consequence – the economic impact to the state – as illustrated in Figure 2-8.

Note that, in 50 years of exposure, the common benchmark of a 1 percent annual frequency of exceedance event would still have about a 39.5 percent probability of exceedance. Thus, the figure indicates that the 1 percent annual earthquake would result in $1 to $2 billion of economic impact and can be expected to occur or be exceeded with 39.5 percent probability in a 50-year exposure period under current conditions. More severe events might cause $20 to $30 billion worth of impacts to the state's economy.

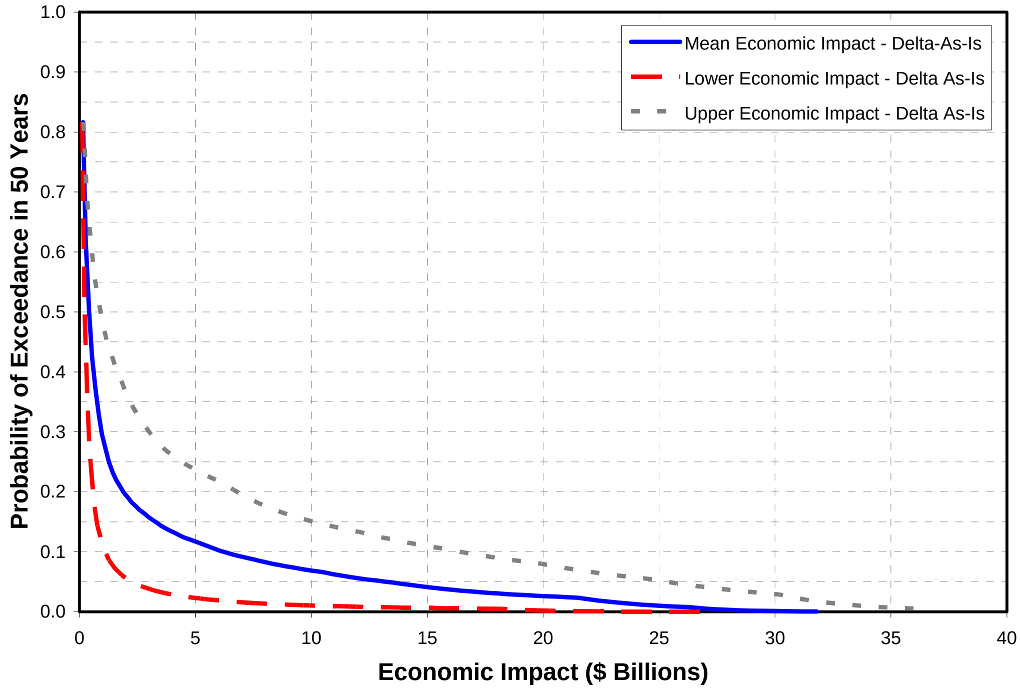


Figure 2-8 Probability distribution on the economic impact to the state as a result of seismically initiated levee failures in the Delta as it currently exists, assuming an exposure period of 50 years (JBA 2005).

2.6.3 Mount and Twiss

As part of their work for the California Bay-Delta Authority (CALFED) Independent Science Board assessment of significant scientific issues relative to Delta management, Mount and Twiss (2005) focused on “Accommodation Space” and a “Levee Force Index” to call attention to the risks associated with potential Delta levee failures. “Accommodation Space” is the volume of Delta space between land surface and sea level. It is physically situated to accommodate flood water in event of levee failures. Accommodation space is substantial and increasing due to both continuing subsidence and sea-level rise. The “Levee Force Index” is proportional to the square of the hydraulic head (the difference between the water surface elevation and the behind the levee land surface elevation), which is the nature of the formula for calculating the water force on levees. The force index is also substantial and increasing due to subsidence and sea-level rise.

Mount and Twiss point out the hazard posed by earthquakes and floods that may cause multiple levee failures. They use the CALFED (2000b) seismic results and FEMA National Flood Insurance Maps to observe that substantial flooding of islands in the Delta should be expected due to either the 100-year flood or major earthquake, and that at least one or the other has about a 64 percent probability of occurrence in a 50-year time frame. Although this provides a reasonable, first-order estimate of risk, the magnitudes of potential consequences are not addressed.

2.6.4 Summary

The DRMS project team developed initial characterizations of risk for portions of the hazards faced by Delta levees. Prior to the DRMS effort, there was not a comprehensive, quantitative characterization of risk associated with Delta levees. To reduce the likelihood of failures and their consequences, such an effort would need to address all hazards, levee failure consequences, and both present and future conditions. That is the scope established for DRMS and detailed in Section 3.

Figures

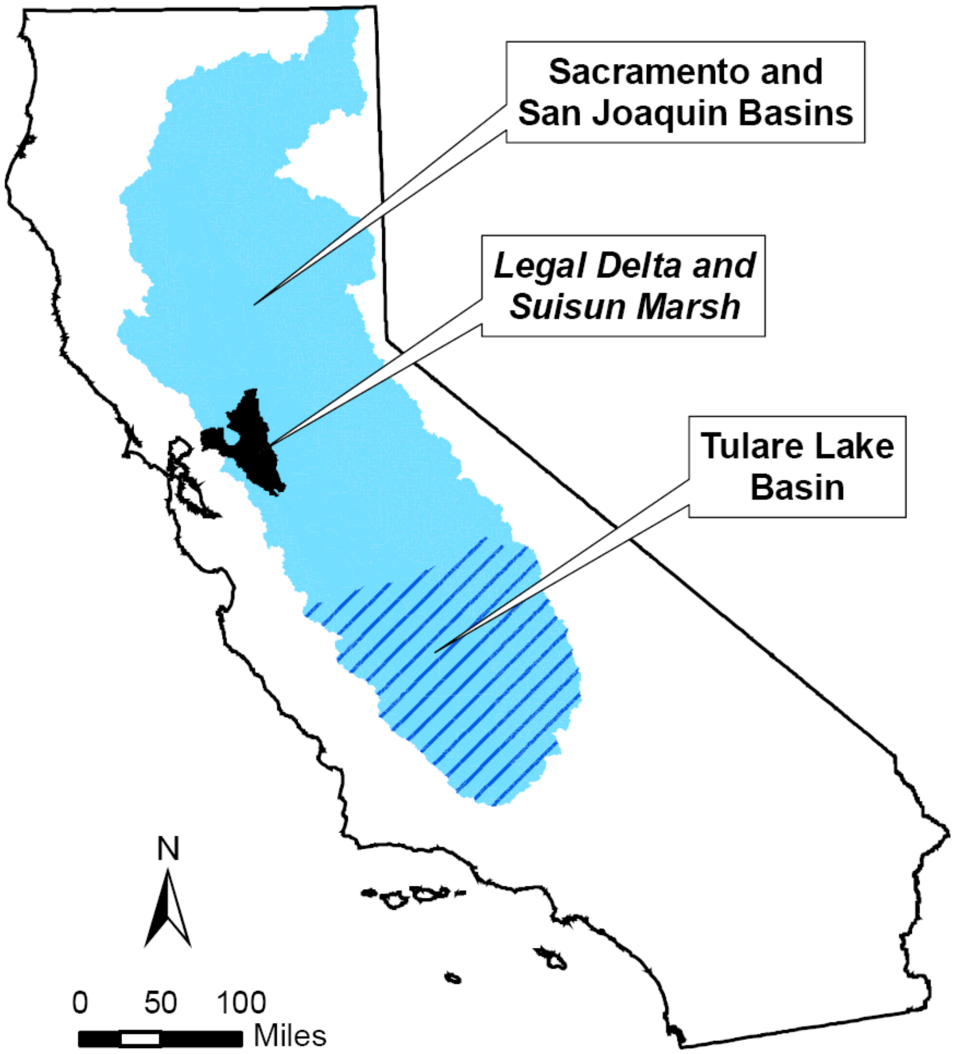
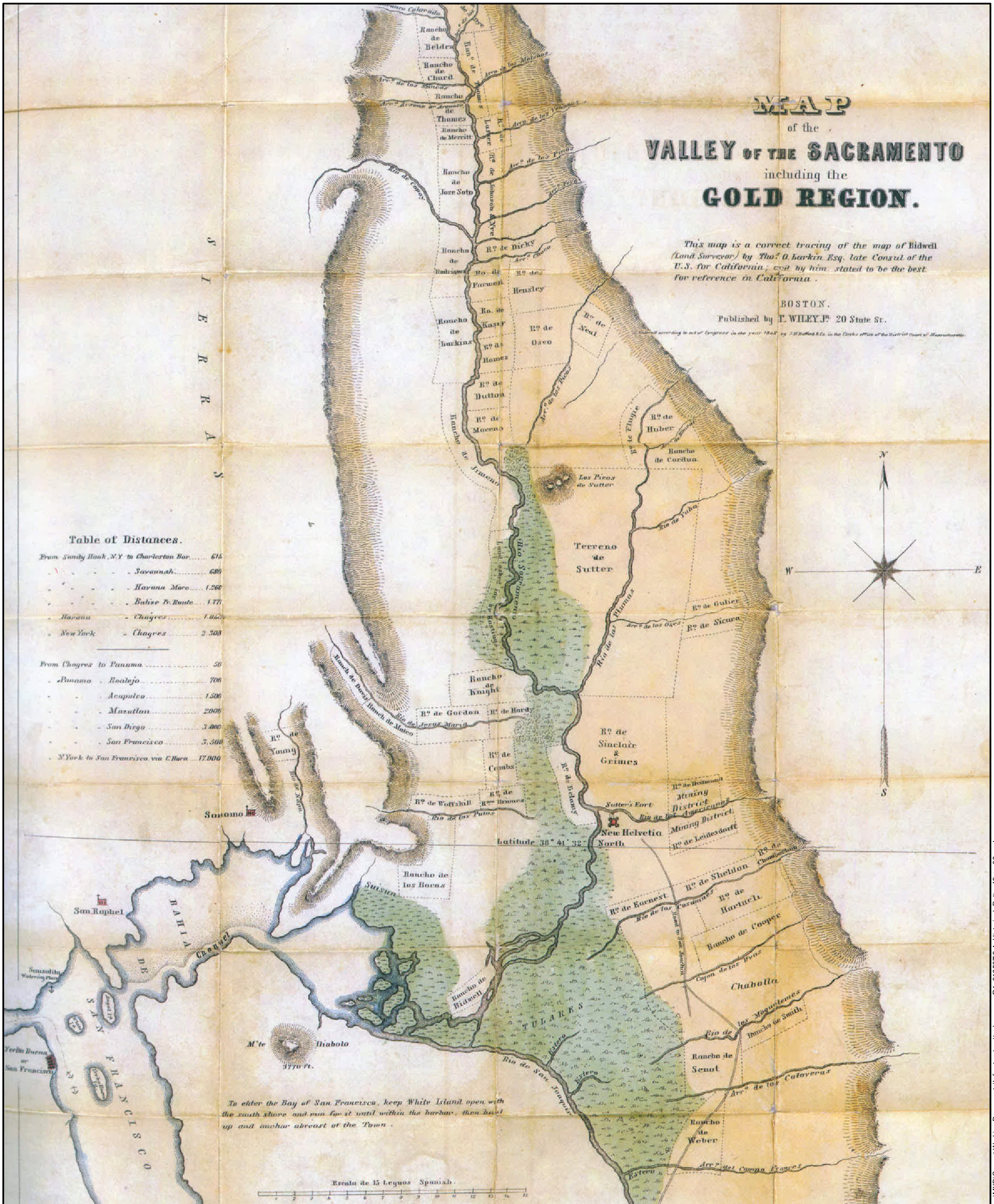


Figure 2-1 Watershed for Delta and Suisun Marsh



Source: Hayes, 2007

URS	DRMS	Sacramento Delta Region Map from mid-1800s	Figure 2-2
	26815431		

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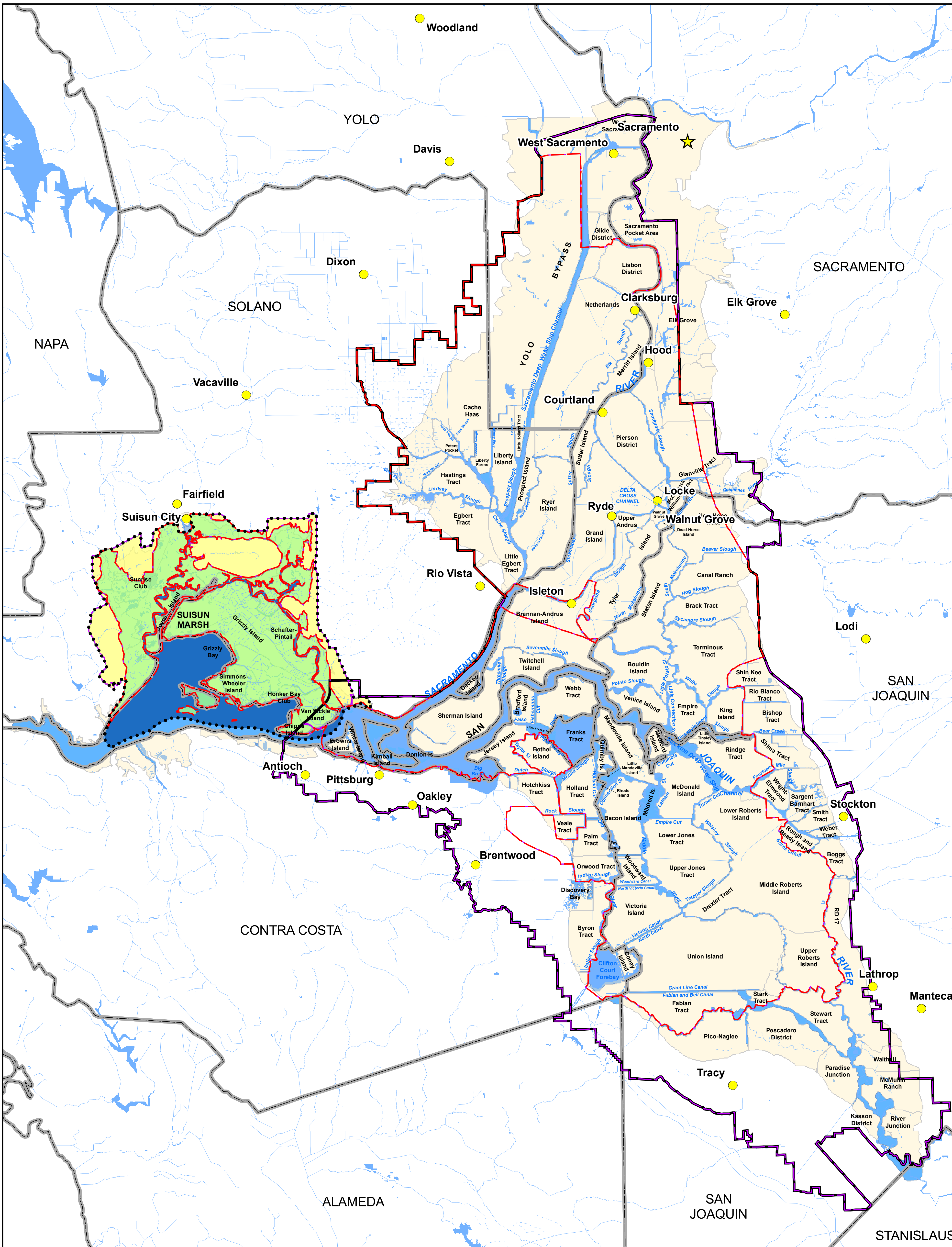


County boundary
Legal Delta
Suisun Marsh
Intermittent waterway
Perennial waterway
Water
Primary Zone boundary
Secondary Zone boundary

Suisun Marsh

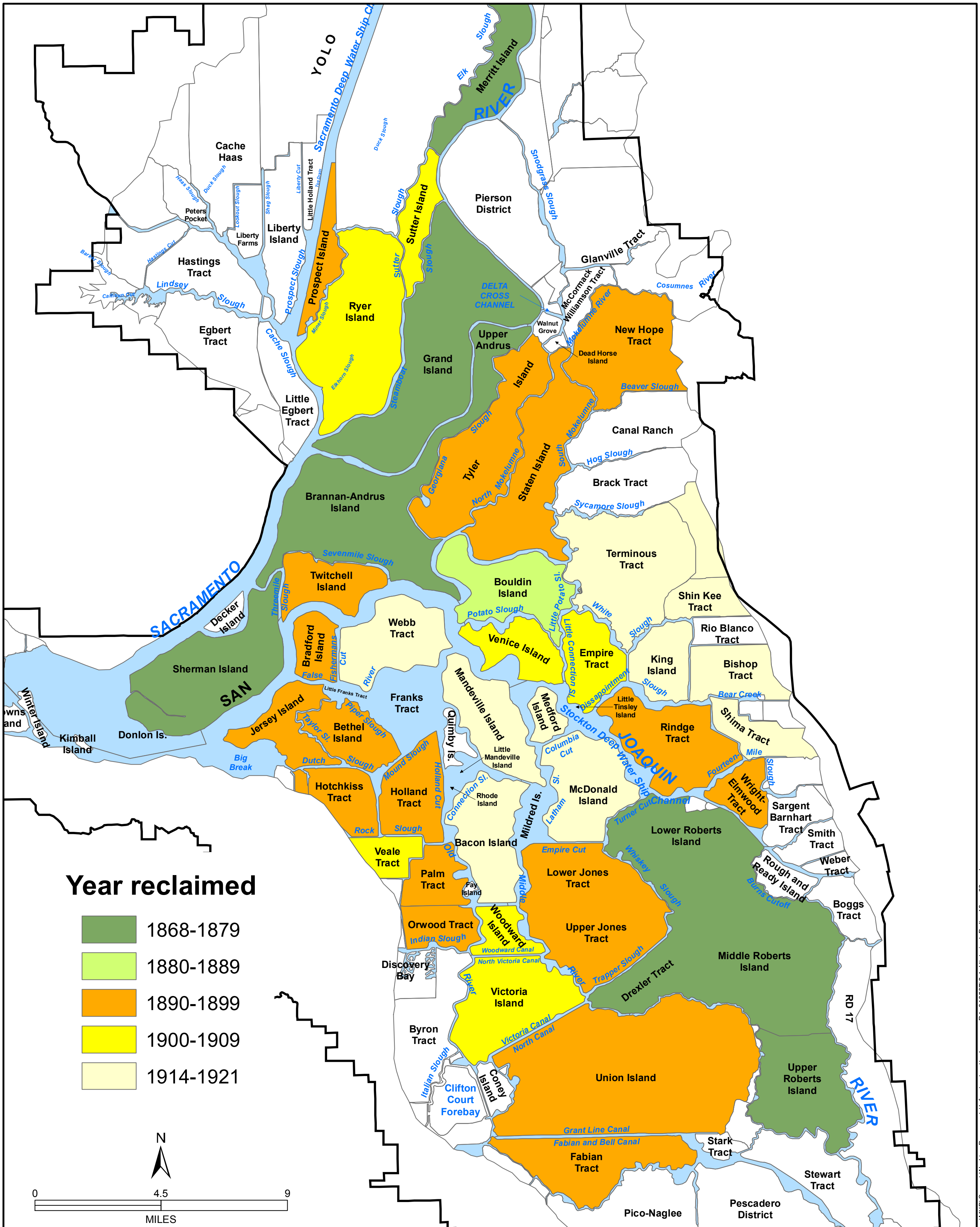
Primary Management Area
Primary Management Area - Water
Secondary Management Area

0 5 10
Miles

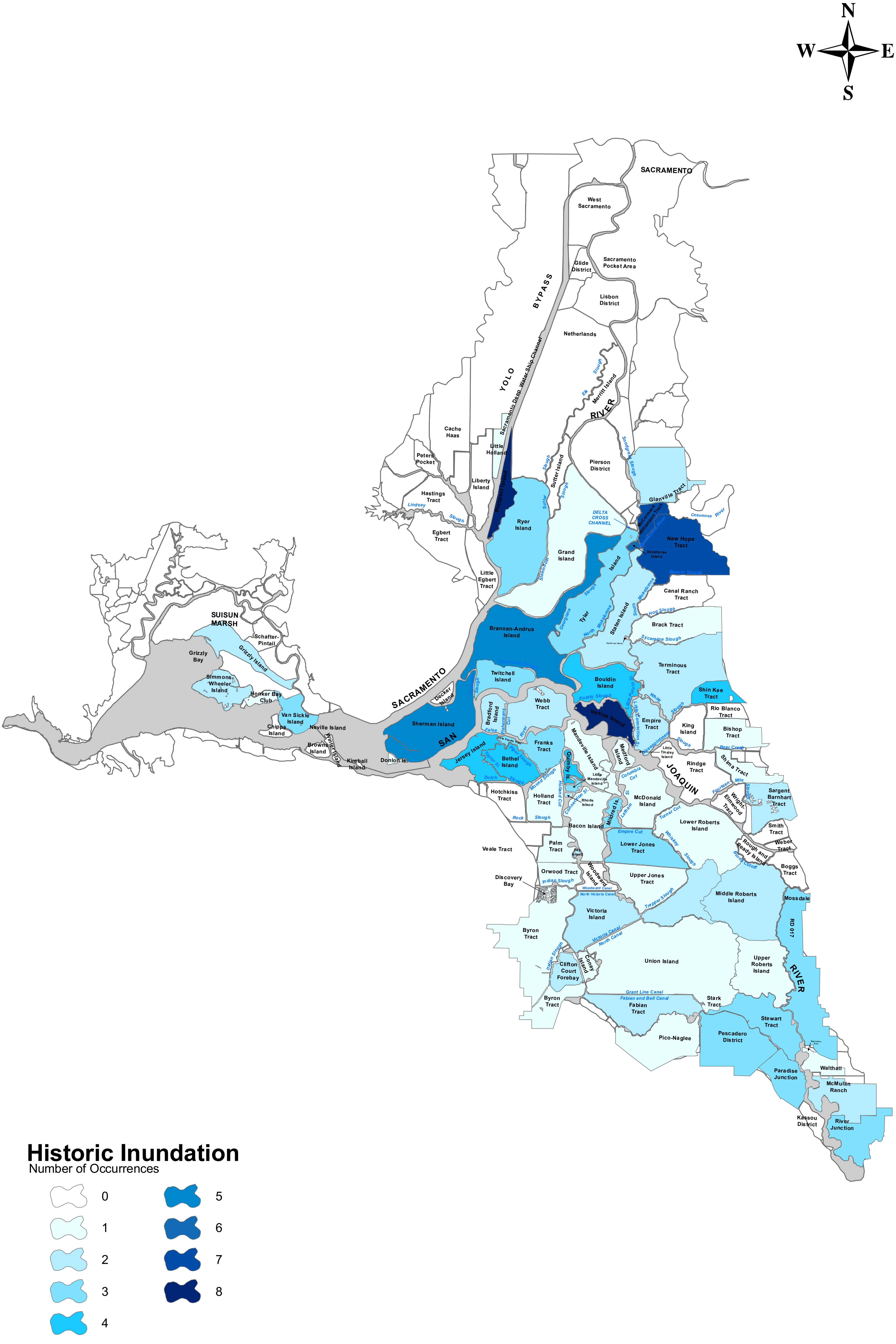
N

URS	DRMS 26815431	Delta Islands and Sloughs	Figure 2-3

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_010507\2-1 delta islands and sloughs.mxd Date: 1/5/2007 9:14:10 AM Name: smlewis0



URS	DRMS 26815431	Year of Initial Drainage	Figure 2-4



URS	DRMS	Historic Island Flooding in the Delta and Suisun Marsh Since 1900	Figure 2-5
	26815431		

URS	DRMS	Federal, State, and Local Projects in California	Figure 2-6
	26815431		

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