Colorado College

The Sacramento-San Joaquin Delta

History, Risks, and The Bay Delta Conservation Plan

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1. Abstract

Located at the confluence of the Sacramento and San Joaquin Rivers, the Sacramento-San Joaquin River Delta forms an expansive inland river delta and the largest estuary in the western United States. The Delta formed as sea level rose after the last glaciation period and, as a result of its constricted spill point, accumulated deep layers of sediment as it expanded in the upstream direction (Blach, et al., 2006).

Over the past 175 years, the construction of levees and drainage canals for farming purposes has negatively impacted native plant and animal species and has resulted in widespread subsidence. Diversions from the Delta by state and federal water projects provide water for about 25 million people and 3 million acres of farmland. Reported in the Delta Risk Management Strategy, levee failure as a result of earthquakes, high water, or during dry conditions would severely disrupt both Delta agriculture and California's water supply system (CDOWR, 2009).

The recently proposed Bay Delta Conservation Plan (BDCP) attempts to find a balance between sustaining the human and ecological needs of the Delta through the construction of a twin tunnel water conveyance system and the implementation of an extensive habitat restoration project. Failure of the BDCP to specify exactly how much water would be diverted from the Delta after its implementation has created widespread skepticism of this $24.54 billion dollar project. Implementation of the Bay Delta Conservation Plan is, however, the right choice for a healthy Delta (Vogel, 2014).

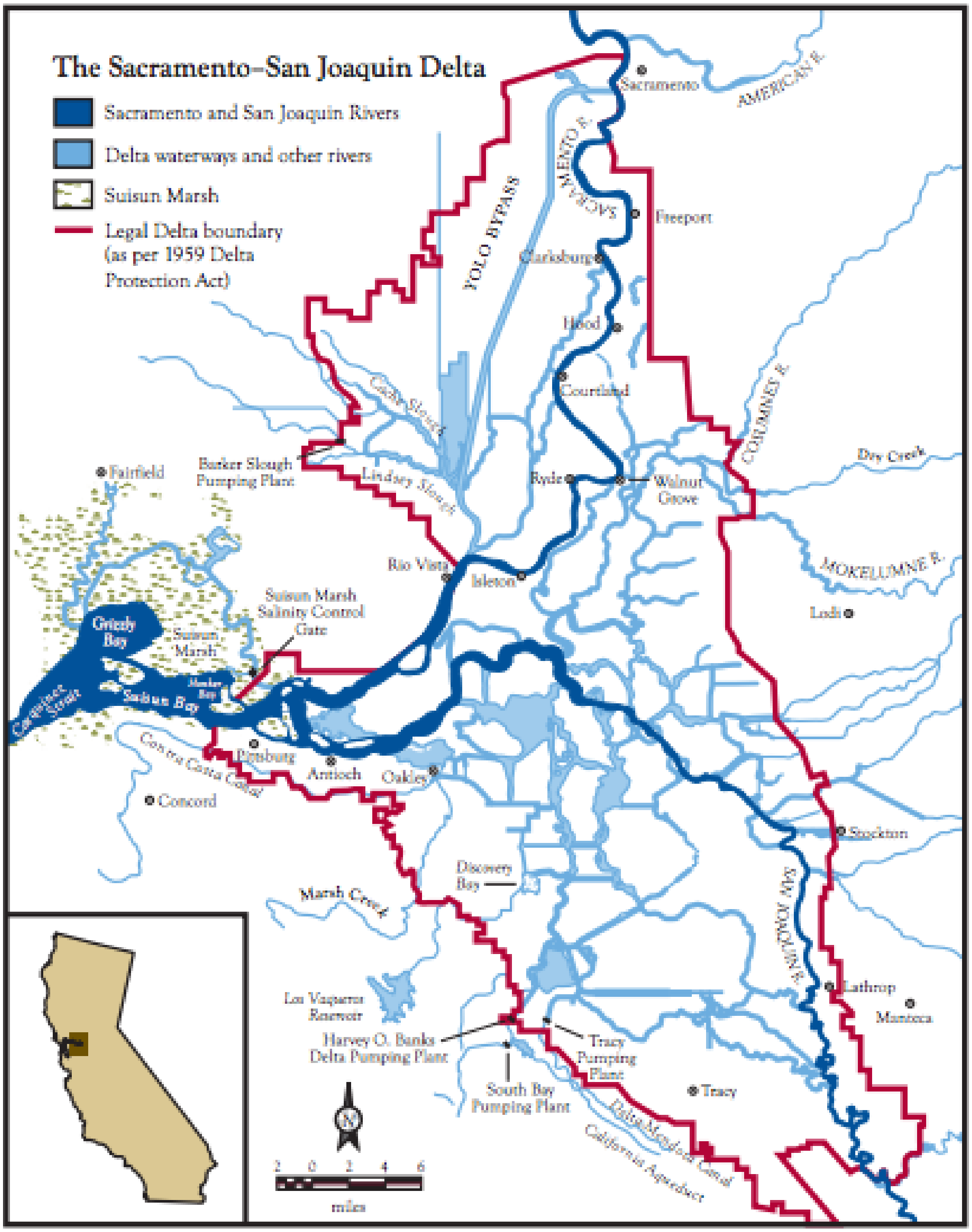

Figure 1: Map of the Sacramento-San Joaquin Delta region with the red line making up the legal Delta boundary as of 1959 (Hanak, et al., 2007)

Introduction

The Sacramento-San Joaquin Delta is home to over a dozen endangered plant and animal species, 520,000 acres of farmland (Blach et al., 2006), and is the hub of California's water supply system (Hanak, et al., 2007). Sustained alteration of the Delta landscape by humans over the past 150 years has resulted in widespread subsidence and the introduction of numerous invasive species (Mount and Twist, 2005). In order to meet long-term human and ecological needs, there must be change in how people use Delta resources. The recently proposed Bay Delta Conservation Plan (BDCP) attempts to find a balance between sustaining both the human and ecological needs of the Delta (Vogel, 2014).

2. Geologic History

The current Delta landscape is, geologically speaking, relatively young. Uplift of the Sierra and Coast Ranges produced two rivers, the Sacramento and San Joaquin, which flowed roughly parallel to the coastline and converged at a large inland sea at the base of the Central Valley. Roughly 5,600 years ago, water penetrated the mountains and carved out the constricted spill point of the Carquinez Strait and the San Francisco Bay (Mann, 2013). The drainage of such large quantities of water through a narrow notch in bedrock has resulted in the Delta narrowing as it approaches the sea while widening in the upstream direction. Due to this pattern of growth, most sediments are deposited in the Delta, rather than downstream in the San Francisco Bay (Blach, et al., 2006).

After the breach of the Carquinez Strait during the Pleistocene, the Central Valley was drained by rivers flowing through the Delta, San Francisco Bay, and Golden Gate. As sea level began to rise after the last glaciation period, water filled the San Francisco Bay and created a large freshwater marsh in the Delta. As sea level continued to rise, marshes, augmented by sediment from upstream, kept pace with rising waters (Herbold, et al., 1989). Eventually, the marshes were growing on top of deep layers of peat formed from the decomposition of wetland organisms and vegetation over thousands of years (Blach et al., 2006).

3. Reclamation

When Spanish explorers first viewed the Delta from the top of Mount Diablo in 1772, they reported a vast landscape of tule and reed marshes that were periodically submerged underwater. Next to prominent stream channels, natural levees supported areas of riparian forest. After closer inspection, these explorers were shocked to discover that fresh water was abundant in the interior of this vast tidal wetland (Ingebritsen and Marti, 1999).

The current Delta landscape looks very different than that of the 16th century due to a reclamation effort beginning in the mid 1800s. After 1800, the Delta shifted from a hunting and fishing site for Native Americans to a transportation network for explorers and settlers. These European settlers saw potential for agriculture in the rich organic soils of the Delta and, in the mid 1800s, began to drain Delta islands to create new farmland from the once submerged fertile soils. Their efforts were encouraged by the Arkansas Act of 1850, which ceded federal swampland to the states who in turn sold it to settlers for a dollar per acre (Hanak, et al, 2007). To safeguard against seasonal flooding, settlers constructed a vast network of levees surrounding the drained areas. Hydraulic mining in the Sierra Nevada Mountain Range activities during the late 1800s led to tons of mineral and organic soil deposits, resulting in the development of numerous flood control channels to flush out the inflow of new sediments (Blach, et al., 2006).

Today, 1,700 kilometers of levees hold the highly altered delta together and allow for the existence of 520,000 acres of farmland, which generate $500 million annually (Blach, et al., 2006). Two major categories of levees can be found in the Delta region. Project Levees are built by the U.S Army Corps of Engineers (USACE) and are constructed and maintained according to specifications of the USACE. Non-project levees are built and maintained with no standards and account for 75% of the levees in the Delta (Herbold, et al, 1989).

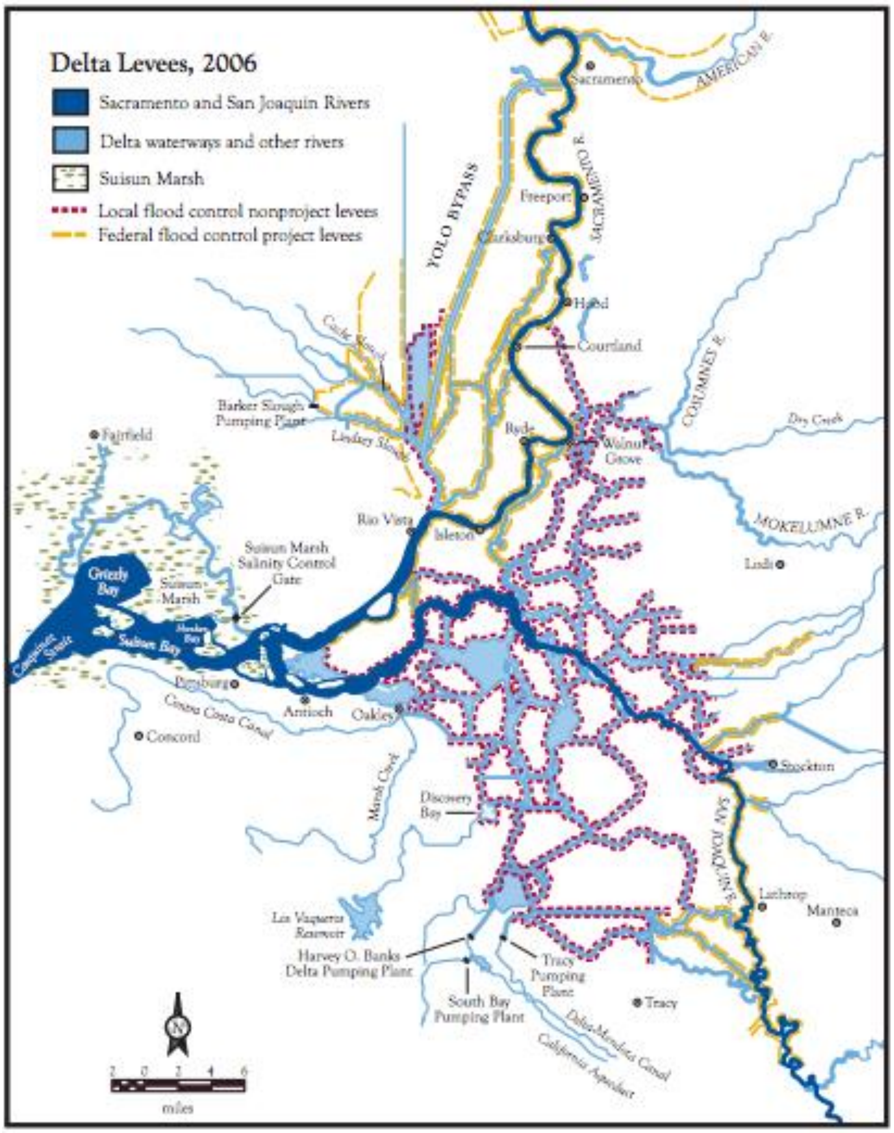

Figure 2: Map showing the distribution of Project and Non-Project levees as of 2006 (Hanak, et al., 2007)

4. Subsidence

As a consequence of the drainage of marshland and the construction of levees, widespread subsidence has occurred. Absence of water results in exposure of surface soil particles to oxygen, allowing microbes to aerobically decompose organic material. High amounts of carbon are oxidized and released into the atmosphere as CO2 (Blach, et al., 2006). Oxidation of carbon accounts for about 75% of subsidence in the Delta (Mount and Twiss, 2005). Around 25% of subsidence is due to compression of subsurface saturated soils as well as the erosion, burning, and shrinkage of organic soils above the water table (Blach, et al., 2006).

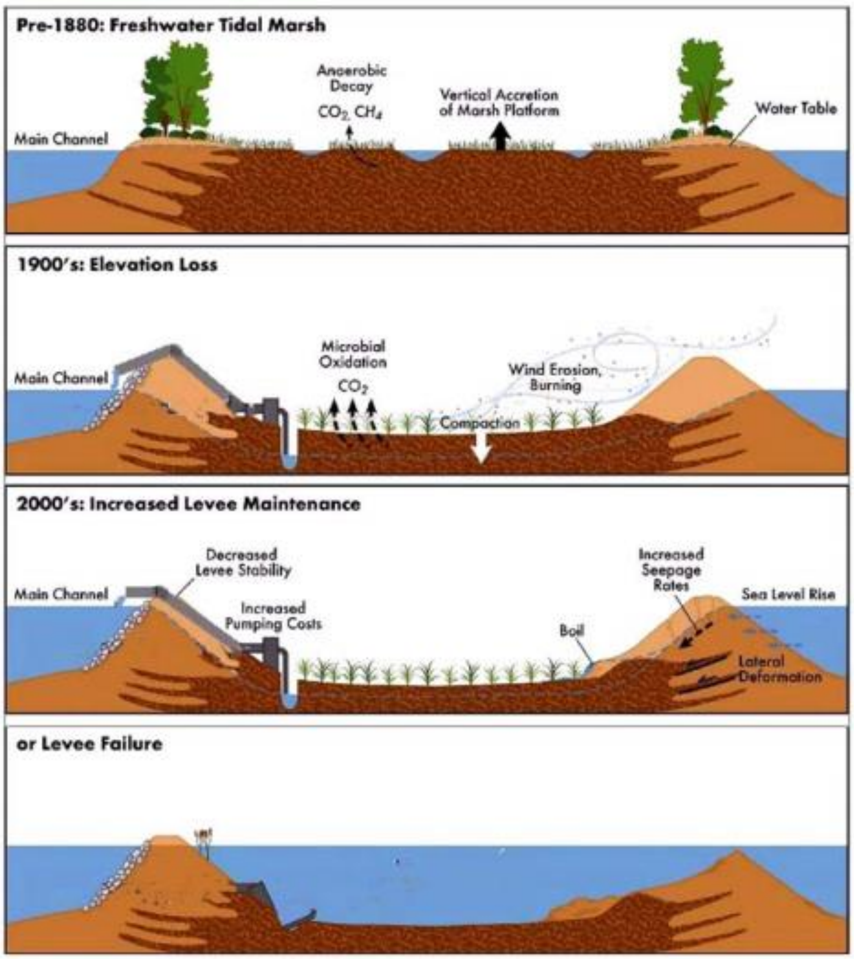

Figure 3: Diagram depicting the progression of Delta islands due to levee construction and subsidence (Mount and Twist, 2005)

Mount and Twiss (2005) refer to the space in the Delta that is below sea level and filled with neither sediment nor water as anthropogenic accommodation space. In natural geologic systems, this space would have been filled with water or sediment long ago but, due to the construction of levees and drainage canals, large areas of land below sea level persist in the Delta. Prior to conversion of the Delta to farmland, accommodation space, formed by gradual sea level rise, was checked by sedimentation and thus a tidal marsh continued to grow. Subsidence over the past 100 years has created approximately 2.5 billion cubic meters of anthropogenic accommodation space. Island elevations in the west and central Delta are locally more than 8 meters below mean sea level. Annual deposition across the Delta is approximately 1.7 cubic meters, which is only 7% of the rate of the current anthropogenic accommodation annual growth. If sea level stayed unchanged and subsidence was stopped, it would take 1470 years to restore the Delta to mean sea level (Mount and Twiss, 2005). A Delta environment returned to sea level, therefore, is out of the question.

Subsidence is dangerous because it diminishes the integrity of levees. Unlike most levees, which protect against the occasional flooding of rivers, Delta levees are subjected to constant pressure from the changing tides. Subsidence reduces shear resistance and lateral support by facilitating the settling of peat layers (Blach, et al., 2006). Pores created by the compression of peat soils can affect capillary flow and result in a greater pull on water than on uncompressed particles. This increased pull on water has a negative affect on drainage and ultimately results in the slumping, spreading, and cracking of levees (Blach, et al., 2006). Levee failure, and subsequent salt-water intrusion into the Delta, would mean millions of dollars in losses for Delta farmers and could pose a huge threat to California water supply.

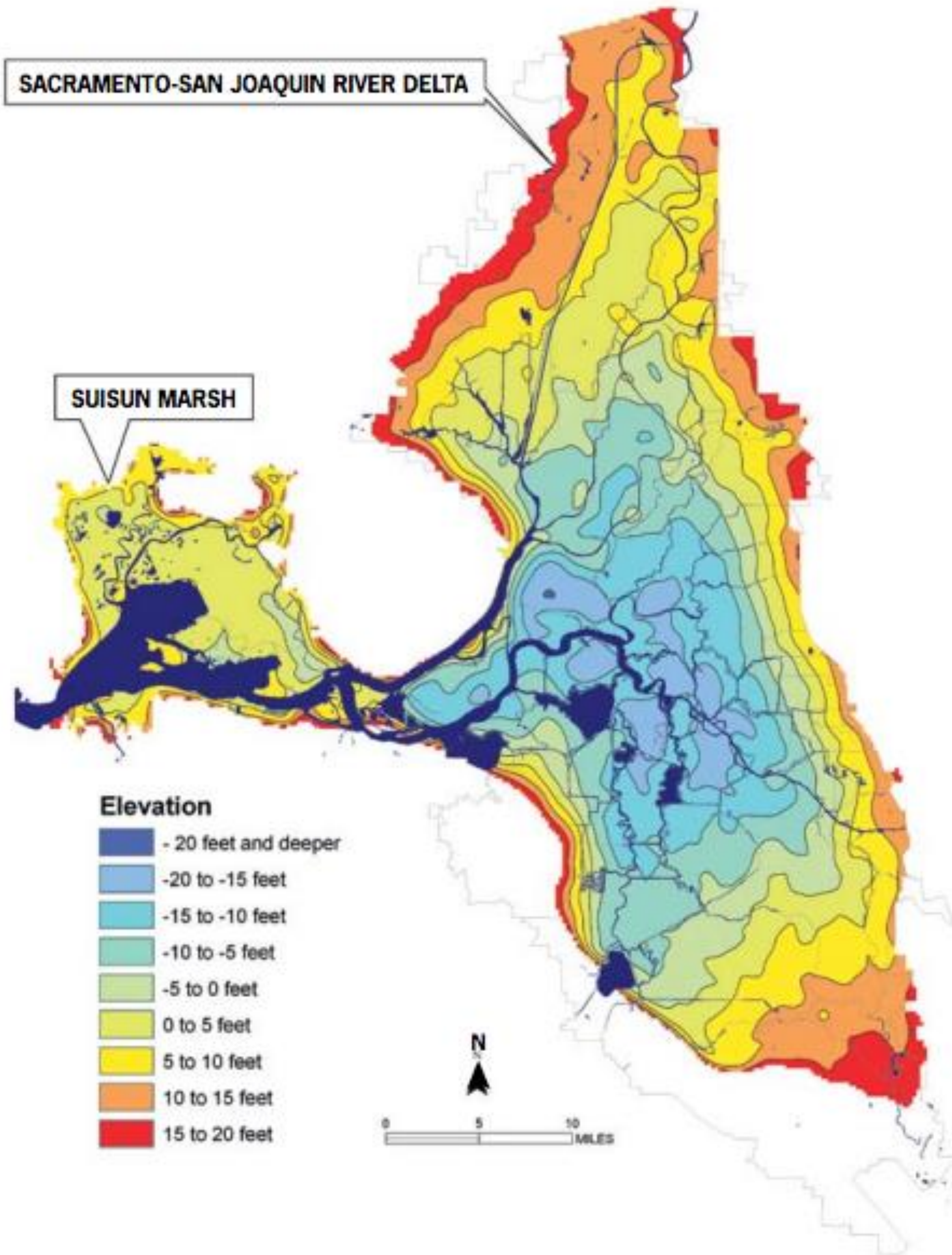

Figure 4: Surface elevation map of the Delta region (CDOWR, 2009)

5. California's Water Supply System

During Delta reclamation, early settlers recognized the prospect of diverting surplus water from the Sacramento and San Joaquin Rivers to the dry, but potentially productive Central Valley (Hanak, et al., 2007). Years later, in the midst of the Great Depression, the federal government took on the Central Valley Project (CVP), which included the construction of the Shasta and Friant Dams as well as the Delta Mendota Canal. The CVP was successful in its main goals of getting rid of salt water from the Delta through controlled releases from the Shasta and Friant reservoirs and in supplying fresh water to irrigators and some urban users in the San Joaquin Valley and areas west of the Delta via the Delta Mendota Canal (Mount and Twiss, 2005). The Tracy Pumping Plant at the southern end of the Delta lifts the water into the Delta Mendota Canal, which in turn delivers water to CVP contractors and exchange contractors in the Central and San Joaquin Valleys. (Project Details- CVP, 2013).

By the mid 20th century, it became clear that the local water supplies would not meet the needs of many of the growing urban communities in California. State leaders proposed the State Water Project to divert water from the relatively wet northern part of the state to the arid southern part. For decades, the project was bombarded with setbacks. Southern Californians wanted to make sure that the north could not rescind water rights, while the north wanted to make sure waterways would stay open. Today, the Sate Water Project is the biggest state-built water delivery system in the nation. Water flows down the Sacramento River into the Delta and is drawn south across the Delta by the Banks Pumping Plant near Tracy, which pumps water into the 444-mile-long California Aqueduct (California State Water Project history, 2014).

Today, the Central Valley and State Water Projects work side by side to fulfill contacts for up to 7.5 million acre-feet of water to be diverted from the Delta watershed per year from the two adjacent pumping stations. Around 83% of this water is used for agriculture, while the remainder is put towards providing some or all of the drinking water for two-thirds of California residents. The Delta receives runoff from about 40% of California land area and about 50% of California total stream flow (Ingebritsen and Marti, 1999). Generally water is held upstream in dams and, when needed, it is released into the Delta to aqueducts and then to its desired location (Blach, et al., 2006). The Sacramento River provides most of the Delta's water, with quantities varying greatly, from about 5 to 35 million acre-feet annually. The San Joaquin River contributes less than 20% to Delta waters and annual flow is even more variable. During peak discharge, flows are usually downstream into the western Delta. Through late spring to early fall, the pumping plants in Tracy divert more water than comes in from the San Joaquin River, resulting in a cross channel opening up between the lower Mokelumne River and the Sacramento River. During this time, Sacramento River water is drawn upstream (Herbold, et al, 1989).

1,700 kilometers of mostly poorly constructed levees hold the Delta together (Blach, et al., 2006). California's water supply system was built on what many consider to be "arm of the ocean," reliant on only a fragile network of levees for protection.

6. Delta Risk Management Strategy

Only relatively recently has the concern of levee failure in a delta below sea level prompted official response. In 2009, the California Department of Water Resources published the Delta Risk Management Strategy: a compressive evaluation of levee failure due to earthquakes, high water conditions, climate change, subsidence, and dry weather events. It considered the consequences to the economy, public safety, and the environment. Findings from the Delta Risk Management Strategy resulted in the conclusion that "business as usual" practices in the Delta are unsustainable (CDOWR, 2009).

6.1 Earthquake Risk

The Delta Risk Management Strategy targeted earthquakes as having the potential to alter the Delta landscape most out of the three major risks. Located in close proximity to the Hayward, Calaveras, and San Andreas Faults, the Sacramento-San Joaquin Delta is in an area of moderate to high seismic risk. The United States Geologic Survey estimates that an earthquake of magnitude 6.7 or greater has a 62% chance of occurring in the San Francisco Bay region between 2003 and 2032. An earthquake of this magnitude has a 40% probability of causing 27 or more islands to flood. If 20 islands were flooded as a result of a major earthquake, export of fresh water from the Delta could be disrupted for a year. Water supply losses would be around 8 million-acre feet, resulting in fiscal losses of $22 billion or more. Methylmercury, from mercury due to gold mining run off, could potentially form if water flooded the islands (CDOWR, 2009). Approximately 400 miles of oil and hazardous liquid pipelines run alongside or across the Delta and, because the density of oil is less than water, the pipes could rise and fracture when soil is liquefied (Blach et al., 2006). In a major earthquake, there is a 40% probability of 90 or more fatalities in the Delta region (CDOWR, 2009).

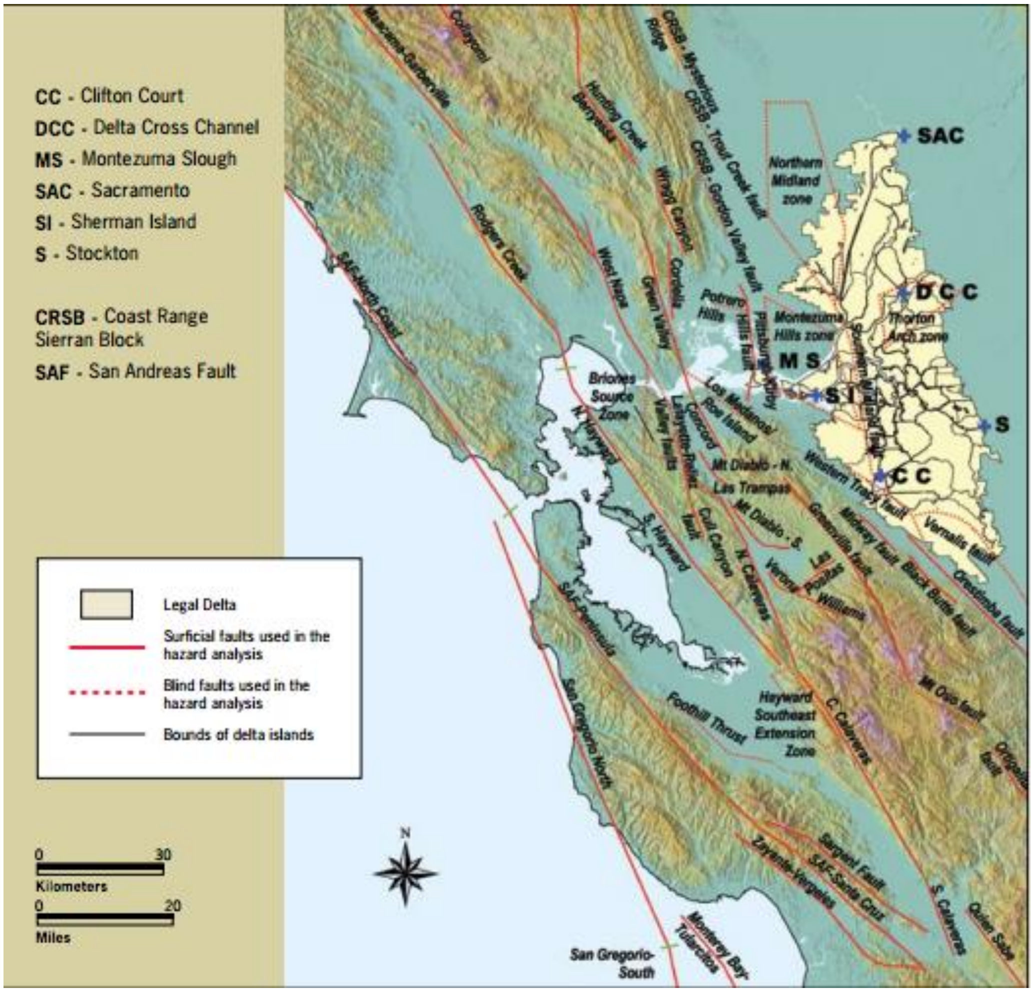

Figure 5: Faults near the Delta region (CDOWR, 2009)

As time goes on without seismic activity, risk will only continue to increase. The risk of levee failure will increase 35% over next 50 years and 93% over next 100 years. The consequences of levee failure will continue to rise over time as long as the demand for water in California continues to increase (CDOWR, 2009).

6.2 High Water Risk

Although levee failure due to high surface water will increase as a result of sea level rise, findings from The Delta Risk Management Strategy indicate minimal damage compared to failure due to a large earthquake. High surface water elevation as a result of high ocean tides or high river inflows increases the hydrostatic pressure on levees and their foundations, and thus increases the risk of through and under levee seepage as well as over levee flooding. Due to the rise in sea level, 140 levee failures as the result of high water are expected to occur over next 100 years. High water levee failures occur in contained regions, resulting in a lower repair cost than that of seismic levee failure. Levee failure due to high water would pose minimal risk to the state water supply because the Delta would likely be receiving substantial fresh water inflow (CDOWR, 2009).

6.3 Dry Weather Risk

Levee failure in dry weather conditions, although less likely than failure due to high water or earthquakes, could have devastating consequences. Levee failure in dry weather conditions can occur because of burrowing animals, preexisting weaknesses in levees and their foundation, or slow deterioration of levees over time. On average, dry levee failures occur once every 7 years. If a levee failure were to occur during a time of less fresh water inflow, it would result in salt-water moving upstream into the Delta from Suisun Marsh. Waters would become salty and could not be used for in Delta irrigation. Significant salt-water intrusion could result in water supply losses for up to two-thirds of California residents. The cost to repair a single island due to dry-weather failure is over $50 million (CDOWR, 2009).

Findings of the Delta Risk Management Strategy have made it clear that the Delta will not exist in its current state for much longer. With constant hydrostatic pressure acting upon them, all levees in the Delta are bound to fail eventually. High water, dry weather, and seismic risk only increase likelihood of failure in the near future. Action must be taken to change the current structure of the Delta to reduce the potential costs of inevitable levee failure.

7. Delta Futures

When looking towards a future for the Sacramento-San Joaquin Delta, it is essential to first consider what would make up a healthy Delta. Ideally, the Delta would continue to meet state needs for agriculture and water supply, while also housing a healthy ecosystem. To obtain a healthy ecosystem, the Delta must include largely native species. In its original, unaltered state, a diverse range of habitats existed in the Delta, allowing many different native species to thrive (Hanak, et al., 2007).

Today, the Delta is a huge resource to California residents because it maintains a freshwater environment. The leveed islands in the Delta help to protect the pumping facilities from salt-water intrusion by displacing salt water and maintaining a gradient favorable to fresh water (Ingebritsen and Marti, 1999). Calculated releases of fresh water maintain a fresh water environment favorable to Delta farmers that rely on this water to irrigate. Salt-water intrusion of the Delta would be devastating for Delta famers and state water supply (CDOWR, 2009), yet the homogenous Delta environment has proven devastating to its ecology. A healthy Delta must fluctuate in salinity (Hanak, et al., 2007).

Prior to human alteration, as much as 60% of the Delta was submerged by daily tides and seasonal flooding from the rivers was common. The Delta was mostly fresh water at the interior, but occasional salt-water intrusion occurred during dry periods. It was a dynamic and constantly changing system, thus species native to the region need a range of habitats in order to thrive. A healthier Delta would contain a productive, brackish, open-water habitat, a brackish tidal marsh, a seasonal floodplain, freshwater wetlands, an upland terrestrial habitat, and open river channels (Hanak, et al., 2007).

Nurse Slough in Suisun Marsh is an excellent example of what more of the Delta should look like. Nurse Slough is a healthy brackish tidal marsh. It is cool (< 20ºC), shallow (< 2 m at high tide), turbid (transparency < 35 cm), and complex in structure, with a substantial tidal influence and few nonnative species. A habitat such as this is essential for raising desirable fish, especially the Splittail, juvenile Striped Bass, and juvenile Chinook salmon (Hanak, et al., 2007).

The seasonally flooded, freshwater habitat just above the Delta is important for the spawning of Splittail as well as a place for juvenile Chinook to grow. Currently, there are numerous freshwater wetlands in the Delta, but more must be dedicated to wildlife rather than agriculture (Hanak, et al., 2007).

An upland terrestrial habitat (now used for corn and rice) must be maintained. These habitats support raptors and migratory waterfowl. Delta channels leading to flowing rivers are key migratory passageways for Chinook salmon, Lamprey, Splittail, Steelhead, and Delta smelt (Hanak, et al., 2007). Entanglement in pumps in the southern Delta has been a significant problem, so this issue must be eliminated in order to create a healthy system (Mount and Twiss, 2005). Furthermore, flow patterns of channels should be more dendritic and reverse flows must be reduced so not to confuse migratory fish (Hanak, et al., 2007).

8. The Bay Delta Conservation Plan

The proposed Bay Delta Conservation Plan would incorporate this fluctuating delta alternative to meet the dual goals of ecosystem restoration and fulfilling the state water supply needs. This plan involves the construction of new intakes in the north Delta along the Sacramento River about 35 miles north of the existing pumping plants in the southern Delta. A set of twin tunnels would transport the water underground to these pumping plants. (Vogel, 2013). These tunnels would minimize environmentally harmful reverse flows in the south Delta and, periodic releases of fresh water into the Delta from the tunnels, would allow most agriculture and recreation to remain intact. Furthermore, under the BDCP, the Yolo Bypass and Cache Slough area would be managed to create a larger fish-raising habitat (Hanak, et al., 2007).

The Bay Delta Conservation Plan is not a perfect proposal. Over its 50-year permit term, the BDCP would cost California $24.54 billion in undiscounted 2012 dollars (Estimated Cost to implement BDCP, 2013). California is currently faced with billions of dollars of debt. With a deficit so large, many argue that is unwise to take on such an expensive project. Additionally, the Bay Delta Conservation Plan fails to ensure that enough water would be diverted to the Delta to sustain a healthy ecosystem, leaving some people worried that the BDCP would result in only fiscal and environmental losses to the state (Vogel, 2014).

When considering whether the BDCP is a good solution to fix the Delta's problems, it is important to first examine possible alternatives. Although other proposals for managing the Delta have been published, the BDCP is the only plan with government backing. The only current alternative to the BDCP, therefore, is to do nothing and allow "business and usual practices to continue in the Delta. The probability of levee failure is extremely high and will continue to rise, deeming the second alternative unwise and dangerous.

9. Conclusion

The Bay Delta Conservation Plan does not solve all of the Delta's problems, but it does call for some key changes to take place. Levee failure due to seismic, high water, and dry weather risks pose a huge threat to California's water supply, while the current homogenous structure of the Delta threatens native species. The twin tunnels of the BDCP would ensure that state water needs are met when levee failure occurs. Further specifications in the BDCP to confirm that enough water would flow into the Delta to sustain a healthy ecosystem would make it a proposal worth putting to action.

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