LEVEE FAILURES IN THE SACRAMENTO-SAN JOAQUIN RIVER DELTA:

CHARACTERISTICS AND PERSPECTIVES

A Dissertation

by

FRANK HOPF

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2011

Major Subject: Geography

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Approved by:

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	Douglas J. Sherman
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	John Vitek
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ABSTRACT

Levee Failures in the Sacramento – San Joaquin River Delta:

Characteristics and Perspectives. (December 2011)

Frank Hopf, B.S., Lafayette College;

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Co-chairs of Advisory Committee: Dr. Christian Brannstrom
Dr. Douglas J. Sherman

Between 1850 and 1922, agriculturalists built 1,700 kilometers of levees to convert 250,000 hectares of tidal marsh to farmland where the San Joaquin and Sacramento Rivers enter the San Francisco Bay (the Delta). Drained, farmed and isolated from the water channels, the organic soils behind the levees subsided to elevations as low as 8 meters below sea level, turning "levees" into "dams" that hold back water constantly. Engineers built water transfer projects in the mid-20th century, transferring water from the south Delta to 25 million Californians who now rely on the "dams" accidentally converted into supply channels. In 1972, however, a levee failure caused a salt-water intrusion into the Delta, raising the prominence of the polemic Peripheral Canal which, if built would replace the levees in the trans-Delta water transport role. Levee failures in 2004 (the Delta) and 2005 (New Orleans) have re-ignited the debate, fueled by comments made by public officials who warned that the Delta levees posed more risk of failure than did the pre-Katina Louisiana levees. This background motivates two research questions: What are the social perspectives regarding levee failures of the experts managing the Delta; and what is the history of levee failures that might support their perspectives?

The research employed Q-Method to identify and describe four social perspectives: Delta Sustainers, Abandon the Levees, Levee Pragmatists, and Multi-Purpose Levee Advocates. A critical element underlying differences among the perspectives revolved around the perceived history of failures of Delta levees. This dissertation employed semi-structured interviews, archival record searches, and historic map and aerial photograph comparisons to compile a history of 265 levee failures since 1868, many of which are referenced to location, segment, and levee type. In addition, the dissertation compiled a list of emergency repairs and successful flood-fights. The history of failures indicates that important levees of the Delta have performed significantly better than previously identified. Sharing these social perspectives and research results among the key actors addressing Delta issues may lead to improved consensus decisions.

DEDICATION

The dissertation is dedicated to all of those who have accepted responsibilities to balance the societal risks associated with our very complex modifications of the natural world. May you always be effective and enjoy good fortune.

ACKNOWLEDGEMENTS

I am not sure I ever accomplished anything alone in my life, I owe much to many for helping me fulfill this lifelong dream of earning a doctorate in Geography. I owe the dream itself and the will to achieve it from my late parents, Frank and Ida Hopf, and my fourth grade teacher, Mrs Phillippi. They all gave me a lot of love and support, and opened my eyes to the fascinating world worth learning more about. I am thankful that I could share those lessons with my brother Dave during our childhood. We lost Dave during the writing of this dissertation and I miss him. I could not finish this memorial section of my acknowledgements without honoring my wife's parents, Allan and Ann Noroian, who always gave me much love and support also.

I must thank my good friend Professor C. Allen Williams of Sam Houston State for helping me get back into academic geography and his support along the way. And of course I very much appreciate Professors Doug Sherman and Jonathan Smith of Texas A&M University for supporting me through a very tough time in my life. I will always be grateful for that support. The credit for the hard work of helping me become knowledgeable enough to write this document goes to the faculty and graduate students of the Geography Department at Texas A&M and the larger University. Special credit and all my thanks go to my advisory committee, headed by Professors Christian Brannstrom and Professor Douglas Sherman, who co-chaired the committee, members Professor Vatche Tchakerian and Professor Jack Vitek. I also want to thank Professors Dave Cairns and Professor Billy Edge who served on the committee along the way. I appreciate the opportunity to have worked with Christian, Doug, Vatche, Jack, David, and Billy on this and other projects over the last seven years. They are all excellent scholars, councilors, administrators, and human beings. It has been a great honor to be permitted to associate with each of them. I cannot thank them enough for their help.

Another group I would like to thank for their help on this project is the 36 men and women, all very deeply involved in trying to solve the problems in the Delta, who gave valuable time from their busy schedules to share their knowledge and passion for the Delta with me. Their dedication and knowledge, regardless of which social perspective they loaded on, was truly outstanding. I only wish I could thank them individually and by name for they deserve all much credit and thanks for helping me. Unfortunately, the terms of my institutional research restrictions will not permit that. However, you know who you are, and I thank you. I can thank Roy and Diane and their staff at Rogelio's Dine and Sleep Inn in Isleton for making my away from home during my field research so comfortable. I can also thank Phil Pezzaglia at the Rio Vista Historical Museum; and Jeff Hart (Delta Eco-Tours) and the crew of the *Tule Queen II* for their help in exploring the Delta.

I want to thank also the California Department of Boating and Waterways for the financial support they gave me on earlier erosion research work that got me hooked on the Delta.

Moreover, last and perhaps most, I want to thank my friends and family for their support through all of this. Brian and Judy Bochner deserve special thanks for helping me type the paper and proofread. I want to thank Jack Vitek for his helping in proofreading drafts; it is great to have a long time journal editor as a neighbor and friend. The effort might have collapsed of its own weight and my lack of clerical skills without Judy, Brian, and Jack.

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I owe the most thanks, however, to my wife of many years, Gail. Putting up with my sometimes-crazy idea and sacrificing so much for another's dream has not being easy or natural. I tell those who ask, that most of my financial support for this research came from the Gail Noroian Hopf Foundation for Geographic Research. However, Gail's financial sacrifices are only a small part of why I could never have done this without her, and why she means so much to me.

There are many other friends, teachers, professors, and fellow students who helped me on this journey but the effort to make the list complete might match the effort of writing the dissertation, but I do thank them all.

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NOMENCLATURE

af or acre-feet	Volume of water covering one acre to a depth of one foot
CALFED	California – Federal Initiative for San Francisco Bay and the Delta
CVP	US Bureau of Reclamation Central Valley Project
DF&G	California Department of Fish and Game
DRMS	Delta Risk Management Study
DSC	Delta Stewardship Council
DWR	California Department of Water Resources
ESA	Endangered Species Act (Federal)
SWP	California State Water Project
SRCD	Suisun Resource Conservation District
SWRC	State Water Resources Council
RD	Reclamation District
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey

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PROLOGUE TO DISSERTATION

Johann Wolfgang von Goethe (1749-1832), the German poet and amateur geomorphologist/geologist closed his classic work *Faust Part 2* with the disjointed discussion of the future of marsh reclamation involving the hero Faust and Mephistopheles. The region of marsh reclamation remains undefined but the similarities with the Sacramento- San Joaquin Delta of today makes it an appropriate prologue to this dissertation. Goethe left Faust Part 2 to be published after his death.

"A swamp there by the mountain lies,
Infecting everything attained;
If that foul pool could once be drained,
The feat would outstrip every prize.
For many millions I shall open spaces
Where they, not safe but active-free, have dwelling places.
Verdant the fields and fruitful; man and beast
Alike upon that newest earth well pleased,
Shall settle soon the mighty strength of hill
Raised by a bold and busy people's will,
And here inside, a land like Paradise,
The let the outer flood to dike's rim rise,
And as it eats and seeks to crush by force,
The common will rush to stem its course.
To this opinion I am given wholly
And this is wisdom's final say:
Freedom and life belong to that man solely
Who must reconquer them every day.
Thus child and man and old man will live here
Beset by peril year on busy year."

– Dr. Faust on his deathbed to Mephistopheles (the Devil).

"*And yet all your activity*
Serves us, with dam and dike creation;
For Neptune the great water devil
You are preparing one big revel.
You all are lost in every wise
The elements are our allies,
And things head for annihilation."

- Mephistopheles' preemptive response directed to the audience, not Faust.

CHAPTER I

INTRODUCTION

Governor Schwarzenegger's Blue Ribbon Panel declared, "The California Delta is the heart of our state, at once a water supply, an ecosystem, and a place that is indispensable to modern California" (Delta Vision Blue Ribbon Panel 2008, 1). If the Sacramento – San Joaquin River Delta (hereafter "Delta") represents the heart of California, its levees form its arteries. Over the last 160 years, farmers, developers, and the Corps of Engineers have widened, heightened, extended, and transformed the natural levees in the Delta into an artificial levee system that now comprises more than 1760 km (1110 miles) of tidal shoreline, a length longer than the open Pacific coastline of California. The builders modified the geomorphic features to permit farming of the rich organic soils of the Delta, now a $650 million a year agribusiness. Later, engineers took advantage of the access to dry land and flood-protection provided by the levees and built highways, railroads, pipelines (fuels and water), gas production and storage wells, and telecommunication facilities across the Delta.

About half of the total runoff (from 40% of the total area) in California flows between the Delta levees, with water diversions supplying water to 25 million Californians as far away as San Diego and irrigating over 3 million acres of prime farmland that was once arid scrubland. Delta levees are critical to preventing the intrusion of salt water and absorption of organic carbon (TOC) in route to pump intakes inconveniently located at the southwest

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This dissertation follows the style of *The Annals of the Association of American Geographers.*

corner of the Delta. At the same time, the levee-defined Delta ecosystem provides haven for over 750 plant and animal species (USACE 2006, 4).

Delta levees are a critical geomorphic feature of the human-modified Delta socio-ecosystem that is now in crisis (Isenberg 2008a, 1). The presence of levees supports ongoing subsidence, soil oxidation, and wind erosion that continue to lower elevations of the Delta islands. Some spots have already dropped to as much as 8 meters below sea level, increasing the constant hydrostatic pressure across the levees and forcing them to function as “dams,” not true “levees” (USACE 1994, USACE 2000). This exacerbates the concerns over the vulnerability of levees that have been attributed to questionable designs, weak foundations, and heterogeneous soils generally not suitable for levee or dam construction. Rising sea level will add to these woes, as will projected increases in the frequency, size and duration of Delta floods because of climate change in the watershed (Florsheim and Dettinger 2007). Whereas no record of seismic-related damage exists for Delta levees, the potential of multiple, simultaneous levee collapses caused by an earthquake (DWR 1980, DSC 2010b, Benjamin J.R., and Associates 2005, URS 2008a) haunts the residents of the Delta and managers of the water supply system dependent on it. Loss of a single levee at Jones Tract in 2004 halted deliveries of water to a thirsty state for a few days. The 20-island flood, theorized under an earthquake scenario, could stop downstate water deliveries for years, at a cost to the California economy in the hundreds of billions of dollars (RMA 2005; Jack R. Benjamin &Associates 2005; Lund *et al*. 2008; Fleenor *et al*. 2008). Meanwhile, several pelagic and anadromous fish species headline the list of native species of wildlife and vegetation that the accumulation of human activities in the Delta are suspected of having driven onto the state and federal endangered and threatened lists.

Little disagreement exists that the Delta socio-ecosystem is in crisis. As one expert put it, the Delta is "…oversubscribed in every way imaginable" (Interview 120-2009). The question of how to establish a governance process that will help create a sustainable Delta socio-system has consumed much time and energy in California politics since at least 1972. In 1994, California Governor Wilson directed the various state agencies to join federal counterparts in what would become the 25-member CALFED (short for CALifornia – FEDeral) initiative. CALFED had four objectives: to improve quality of the water, increase the quantity of water available for export, improve the viability and sustainability of the ecosystem, and strengthen the integrity of the levees (flood-control), in the Delta. By early 2000, Delta scientific research had been advanced but establishment of goals agreeable to all remained elusive, prompting many of the stakeholders to rename it "Cal fail" (Hundley 2001, 418). Attempting to restore creditability and effectiveness of CALFED, California Governor Davis and U. S. Interior Secretary Babbitt ordered that CALFED cancel the public meetings with stakeholders until the agency representatives could identify the most critical water problems of the state and present an action plan (Hundley 2001, 419). This step excluded from the process more than 80 Delta reclamation districts (RDs) who for 150 years have held first responsibility for integrity of Delta levees. As one reclamation district representative complained, the agencies continually refer to the RDs as "*interested stakeholders* rather than as their *partners,* and we do consider that we are *partners* in maintaining the levees" (Interview 102-2009, 44:18).

CALFED issued its plan in June 2000 and received lukewarm support from many stakeholders (Hundley 2001). President Bush, after 2001, and California Governor Schwarzenegger, after 2003, failed to support the CALFED collaborative effort. Whereas

CALFED drew praise from scholars for its effort to rely on best science in creating policy and for developing innovative solutions, it failed to create timely results (Lejano and Ingram 2009; Owen 2009; Hanemann and Dyckman 2009; Kallis, Kiparsky and Norgaard 2009). The inability of CALFED to successfully involve all stakeholders and to develop consensus by 2005 resulted in excluded groups like the California Farm Bureau Federation, the Central Delta Water Agency, and the Regional Council of Rural Counties suing. These groups obtained a district court ruling throwing out much of the plan created by CALFED because the analysis did not consider the alternative action of reducing or eliminating exports of water. Endangered-fish counts were collapsing, biological options were forcing reductions in water exports, plus the June 2004 unexpected "sunny-day" levee failure at Upper Jones Tract all raised questions about the effectiveness of CALFED. The governor and legislature authorized an independent "Little Hoover Commission" review of CALFED. The commission report (Alpert 2005) condemned CALFED because of lack of leadership and effective public participation. Therefore, in June 2008, when the California Supreme Court overturned the lower court decision and reinstated the plan adopted by CALFED (Abbott 2008), Governor Schwarzenegger had already effectively replaced CALFED by an Executive Order dated 17 September 2006 that created the Delta Vision process directed by the Blue Ribbon Task Force. The order charged this "independent" group of leaders, selected from all over California, with creating a long-term vision for the Delta and developing an implementation plan for that Vision by December 31, 2008. The Vision the Task Force developed pictured a Delta "managed for the coequal goals of reliable water supply and a sustainable Delta ecosystem, while recognizing that the "California Delta is a unique and valued area, warranting recognition and special legal status from the State of California"

(Isenberg *et al.* 2008, 1). In December 2009, the legislature created the Delta Stewardship Council (hereafter DSC) and charged it to carry out the recommendations of the Delta Vision and create a detailed plan for the future of the Delta by January of 2012.

In its condemnation of CALFED, the Little Hoover Commission singled out the lack of leadership to "engage stakeholders in a renewed effort to resolve conflicts" and that "interest groups and stakeholders need more effective ways to understand and influence government decisions" (Alpert 2005, 2). The Blue Ribbon Panel's transmittal letter of the Delta Vision plan acknowledges that "consensus on improving the existing Delta water export system remains elusive" (Isenberg 2008a, 2). Unfortunately, the Delta Vision plan fails to suggest that understanding the underlying nature of the conflicts and social perspective of the leaders and experts of the various stakeholders and agencies should be a priority and an early step to help create consensus.

Therefore, this dissertation will investigate the social perspectives held by the experts of the Delta levee system so that the critical differences and the areas of near agreement can be better understood. In this effort I have followed the lead of other scholars in employing the Q-method to help understand conflicts in science and resource management that hinder effective policy making (Raadgever, Mostert, and van de Giesen 2008; Focht 2002; Bischof 2010; Barry and Proops 1999; Ellis, Barry, and Robinson 2007). These researchers have found that the social perspectives of experts dominate scientific knowledge when uncertainty must be overcome to permit forecasting and policy creation. Review of recent studies on the Delta levees and public comments on those studies (URS 2008a) suggest that forecasting and policy decisions must be made in the face of uncertainty about the probability of an earthquake damaging levees and the stability of the levees as demonstrated by the history of levee failures. The probabilities of damage to levees from earthquakes may always remain "unknowable" but historical geography and remote sensing methods or approaches can help develop a better knowledge base of the history and experience of failures of Delta levees. Therefore, to understand a potential source of divergent social perspectives, this dissertation will create and analyze a concise and rigorous record of failures of Delta levees. This effort will add to the work of Thompson (1957; 1962; 1996; 2006) by adding the historic record temporally, providing more detail and completeness, and by locating the exact failure locations critical to improving empirically based models of levee failures. The data collected have been housed in an Access database and the locations mapped in an ARCMAP GIS system with the intent of eventually making them accessible to all interested stakeholders and experts.

Empirical study of the discourses of Delta levee science and an improved record of the failures of Delta levees may lead to better understanding between and among Delta experts and enhance the opportunity to work to consensus. It can also help identify critical areas where additional research might provide the most value. I constructed a database and analyzed recent failures of the levees to narrow the uncertainty among views underlying all perspectives of levee performance, again to help move toward a consensus discourse. The concern remains that without addressing the items critical to all social perspectives, the resulting policies and solutions will be sub-optimal and subject to resistance, to the disadvantage of all parties.

This dissertation is organized as follows: Chapter II identifies and limits the spatial extent of the study, defines the nature of the "levees" in the study region, describes the understanding of perspectives on Delta levees from the political arena, and describes the scholarship that underpins this dissertation and to which this dissertation will contribute. The chapter also identifies the information gaps that this dissertation works to close. Chapter III provides background information on Delta levees. Chapter IV summarizes the history of changing governance and governing processes influencing Delta levees and the current social perspectives of the key actors in the Delta levees. Chapter V identifies the methods that will be employed to close the information gaps, centered on the Q-Method to identify the social perspectives and the variety of approaches used to obtain input for the levee failure database. Chapter VI identifies and describes the four social perspectives or factors of Delta levee experts concerning the meaning of the failures (and successes) of Delta levees. Chapter VII introduces the database of levee failures and the GIS mapping tool and reviews the differences with published histories of levee failure. Chapter VIII discusses the meanings of the findings of the two parts of this dissertation, highlighting particularly the interaction of the social perspectives with the findings of the historical record. Chapter IX summarizes the effort, provides findings based on this work, and identifies areas of additional research to continue to close the knowledge gaps. The Appendix includes detailed data about the Q-Method and representative examples of reports available from the database of levee failures.

CHAPTER II

STUDY REGION, KNOWLEDGE GAPS, AND CONTRIBUTION OF THE DISSERTATION

STUDY REGION

Humans have built levees around marshes and wetlands, and then drained and "reclaimed" them for agriculture since at least as far back as the civilization at Ur in Mesopotamia in the fourth millennium B.C.E. (Wagret 1968). The Frisians built the first Dutch polders in the ninth century A.D. (Wagret 1968) and the English started developing the peat marsh of the Fens in 1529, led at times by the likes of King Henry VIII and Queen Elizabeth I (Darby 1940). In 1850, just after the discovery of gold in California, the United States government gave the states under the Arkansas Act, title to the almost worthless "swamp and overflowed lands" to develop and earn revenue selling them. The marsh of the Sacramento-San Joaquin Delta was among the first of these lands reclaimed in California. After several false starts, the California legislature authorized establishment of locally organized reclamation districts (RDs) to build the levees and keep the land dry and productive. The legislature empowered the districts to elect boards of directors to govern and raise taxes, and build and maintain levees and pumps to convert marsh to farmland. By 1922, the reclamation districts had completed building the Delta levees with their "unique machinery and modern methods (had) brought about the settlement and agricultural productivity which set this delta apart from all other deltas of the world" as Thompson concluded (1957, 445).

Whereas the “unique” machinery may help set the development of Study Area apart from that of other reclaimed wetlands of the world, they did not spare the Delta from sharing the inherent problems farming former marsh. Darby’s (1940) classic study of the reclamation of the English “Fens,” a former tidal freshwater marsh about the same size as the Delta, concludes by identifying that after over 400 years of development, the Fens in 1939 had survived as an agricultural area with a legacy of four major problems. These included 1) continued lowering of the peat land surface; 2) the constant care required to maintain the banks (levees) built with inadequate materials, particularly against seepage; 3) the constant danger posed by high water levels produced by “a combination of adverse pressure and wind conditions, a high spring tide, and heavy land floods” (Darby 1940, 254); and 4) the complexity of the involvement of multiple agencies that even collectively have limited resources. Darby could have been discussing the Sacramento-San Joaquin River Delta if he had just mentioned two other issues, the stress of being the hub of water distribution (Mitchell 1993) for the 25 million people and one of the largest economies in the world, and the risk of devastation triggered by earthquakes.

In 1959, the California Legislature would take the step of providing special recognition and protection for the Delta as described as the Legal Delta in Section 12220 of the Water Code, otherwise known as the Delta Protection Act (DWR 1992). This act outlined the Legal Delta as shown on Figure 2.1. The act represented the first official recognition that the Delta and its levees would play a major role in water deliveries of the State Water Project (SWP). It passed at the same time as the Burns-Porter Act which authorized a statewide bond issue to build the State Water Project (SWP), a bond issue that the voters approved in 1960 (DWR 1992).

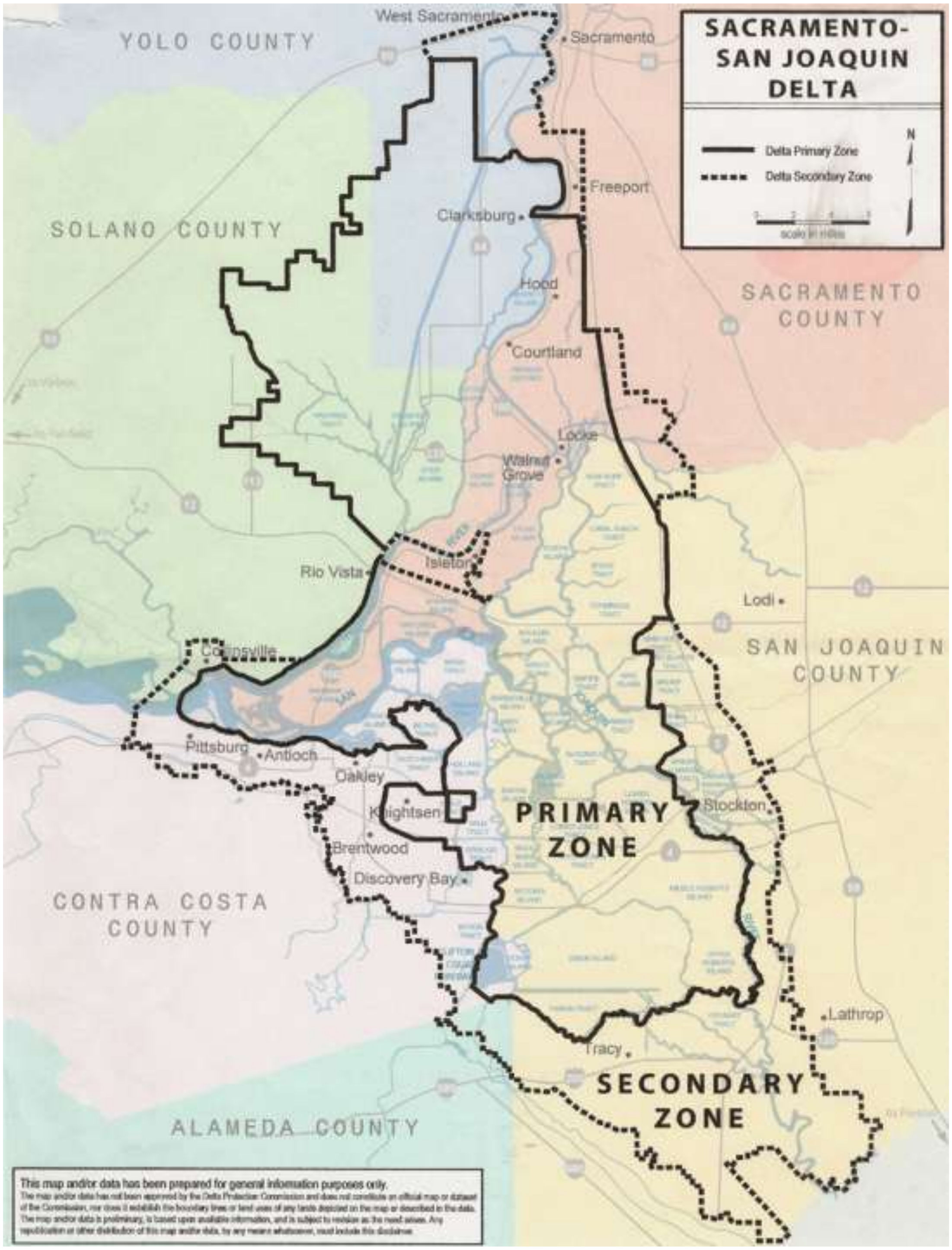

Figure 2.1 - Map of the Legal Delta and Dissertation Scope (DPC Undated)

The Study Region of this dissertation is the "Legal Delta", which includes two major sections, the Uplands or Secondary Zone above elevation +5' and the Lowlands or Primary Zone which sits below the +5' contour line. In the Primary Zone, economic activities are limited by law to agriculture. Certain areas below the 5' contour such as around the City of Isleton and have been designated as part of the Secondary Zone to permit some commercial and other non-farming activities. The boundaries of the Study Area were first defined by the legislature in the state Water Code in 1959. In 1982, this body took the additional step to establish in state law, (the Water Code, Section 12961) a special status of the Study Area because of the statewide significance of this unusual area of meandering waterways and island that support productive agriculture, varied recreational opportunities, and special habitat for wildlife. The law established that the state of California believes that the "physical characteristics of the delta should be preserved essentially in their present form, and that the key to preserving the delta's physical characteristics is the system of levees defining the waterways and producing the adjacent islands" (California 1982, 56). It is fitting, therefore, to focus on the levee to understand the Study Area.

LEVEES OF THE STUDY AREA

The "system of levees" of the Study Region includes four functional types of structures that are all called "levees" and all should include an appropriate adjective in technical discussion:

1) Natural levees – Fluvial overbank depositional features which constrain all but the highest flows to the channel.
2) Enhanced levees – natural levees augmented by humans to increase area that is not inundated during floods. These were important in the pre-clamshell dredge

(pre-1870) including potentially the pre-Eurasian settlement period but are no longer significant, if any remain.

3) Flood control levees – structures built in the floodplain at locations not limited to the tops of the natural levees that are built to constrain flood waters to a certain area larger than the channel itself, to protect the remainder of the flood plain from inundation only during flood. Whereas most of the levees in the Sacramento-San Joaquin watershed and the nation as a whole meet this definition, less than 10% of Delta levees do, all in the Secondary Zone.
4) Levee-dams – human structures along a river or bayhead delta which hold back water continuously or nearly so. Levee dams can start as human enhanced natural levees or levees first constructed for flood control, which later must function as a levee-dam because of lowering of the land surface of the isolated part of the flood plain or an increase in the normal water level. These represent at least 90% of Delta levees, including all of the levees in the Primary Zone. Nationwide, I have only found them in the greater New Orleans area, the Skagit and Snohomish River Deltas of Washington state, and the Delta.

The surfaces of most of the islands or tracts of the Study Region were originally saturated peat, some places up to 12 meters thick. Reclamation has led to subsidence of this peat-dominated surface by as much as 8 meters, leaving the land surfaces well below normal water levels in the channels. They remain dry exclusively because of the levee-dams and pumps. As suggested by Lund *et al*. (2008), these features should more properly be called the Dutch term “polder.” Unfortunately, this term has historically been used in the study area to describe proposals to construct dams across channels to combine multiple islands into fewer, larger ones. For this reason, the dissertation uses the generic term "island" to describe dry land surrounded by water regardless of relative elevations. The terms "island" and "tract" are used interchangeably; the "islands" typically started out as marsh surrounded by river channels and the "tracts" started as peninsulas in the marsh with a land connection to the upland areas. Many of the peninsulas were converted to islands by the construction of back levees with water-filled borrow areas, making them truly islands, but the title "tract" sticks.

This dissertation does not focus on urban levees, or on urbanization in the Delta. It instead focuses on the levees that continue to protect primarily agricultural lands, wetland recreation and habitat lands, and the small legacy communities of Isleton, Walnut Grove, Courtland, Hood, Thornton, Ryde, Terminous, and Clarksburg. Mitchell (1993) reviews the conversion of agricultural land to residential use that took place on Bethel Island and adjacent Hotchkiss Tract where the Pleistocene sand dunes restricted peat formation and the agricultural value of the land played out quickly and led the landowners to turn to residential (waterfront) development starting in the 1950s. Mitchell (1993) also reviews the development of the Discovery Bay on Byron Tract, residential-commercial development near Tracy in the southeast corner of the Delta Secondary Zone, the entire Stockton-Manteca development in the Secondary Zone east of the San Joaquin, and the Stone Lakes and Elk Grove residential expansion of Sacramento to the south toward the Secondary Zone.

Pressure to urbanize parts of the Delta continues to increase; notwithstanding the 1992 Delta Protection Act intended to eliminate additional urbanization in the Primarily Zone and to restrict it in the Secondary Zone (Eisenstein, Kondolf and Cain 2007). Ludy (2009), in her study of the Spanos Park West Development on Delta tracts Bishop and Atlas in northwestern Stockton, argues that the 1971 National Flood Insurance Act has encouraged urbanization in the Delta while masking the risks to those urbanites moving into areas supposedly protected by levees. The degree and location of urbanization of the Secondary Zone of the Legal Delta is a very important issue but it one that is outside the scope of this dissertation. Any references to and discussion of levees in the Study Area, except as explicitly noted, relates purely to levees protecting agricultural lands, wetland habitat and hunting areas, and the legacy communities.

KNOWLEDGE GAPS AND WHAT IS "KNOWN" ABOUT SOCIAL PERSPECTIVES AND THE HISTORY OF DELTA LEVEES FAILURES

Knowledge Gaps

Introduction

As indicated in Chapter I, this dissertation will close two gaps in the knowledge of the levees in the Study Area defined as the "Legal Delta" of California. It will first identify and describe the social perspectives of the experts on the Delta levees relative to the meaning of the history of failures of the levees. Second, it will establish a database on the suspected cause, exact location, and type of levee failures or near misses (the emergency repairs and successful flood fights that prevented levee failures) experienced in the Delta.

Political discourses and social perspectives on Delta Levees

A review of the literature indicates that scholars have not identified the social perspectives of Delta levee experts on these levee failures and near misses. Three major

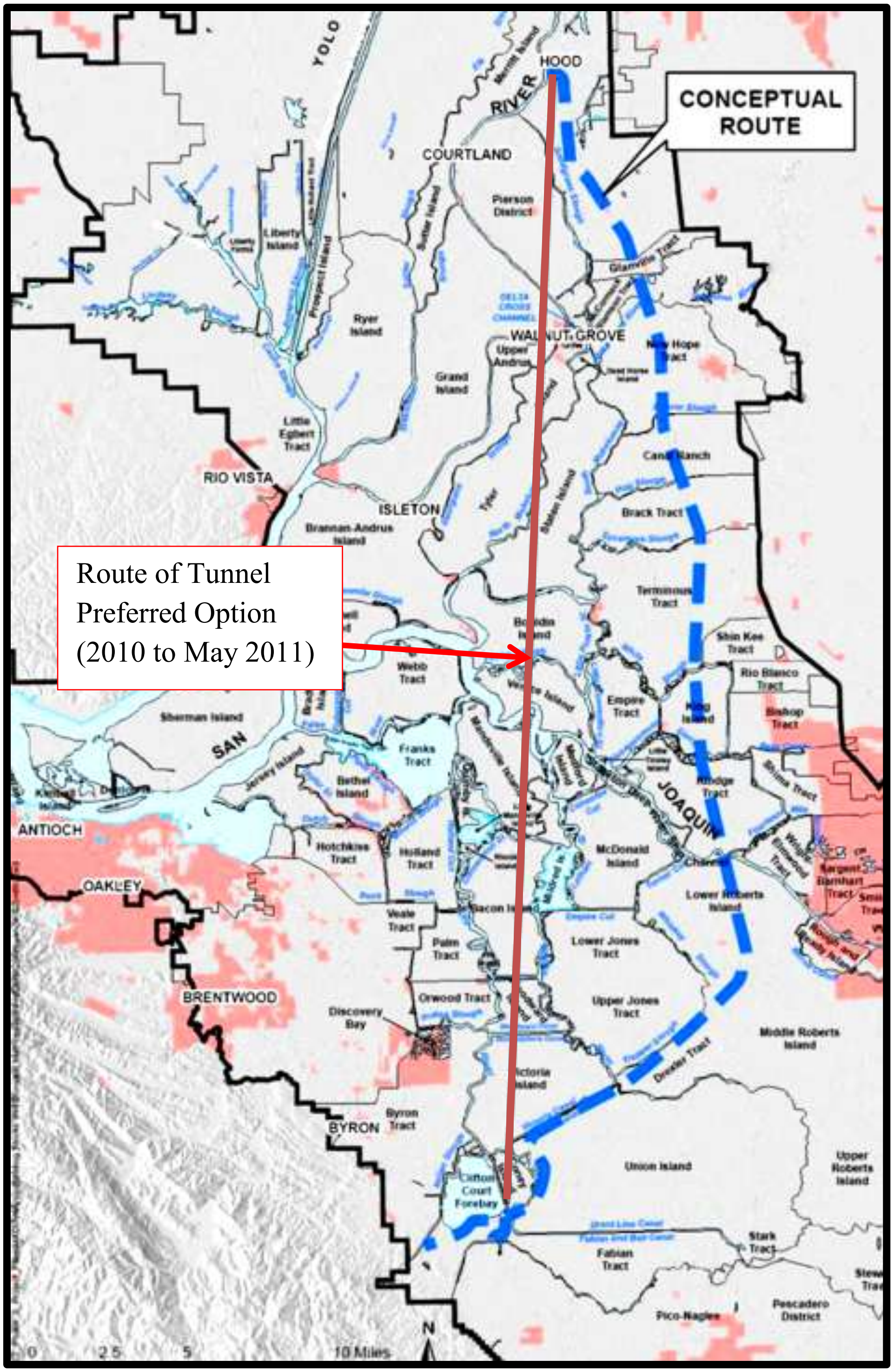

Figure 2.2- Conceptual Route of Peripheral Canal and the Often Discussed Tunnel Route also Marked (DWR 2007)

political discourses, however, currently dominate the public discussion ongoing about the Delta, its levees and its future. Since 1972, political discussion about the Delta deals with the idea of extending the two great water export systems, the SWP and CVP, around, or potentially under, the Delta, to directly access to the primary source of fresh water, the Sacramento River. Figure 2.2 shows the possible route for the Peripheral Canal option for this extension and the alternate tunnel route.

Table 2.1 outlines the characteristics of the three dominant or at least most frequently heard opinions about the Delta when this research started. The first discourse emphasizes, quoting the website (http://restorethedelta.org/ accessed 6/28/2011) the importance of protecting "the economic interests of the Sacramento-San Joaquin Delta, including but not limited to fishing, farming, recreation, and tourism." This perspective further finds it important to establish "a governance system that protects the ecosystem of the Sacramento-San Joaquin Delta defends local Delta water needs" and seeks "the reduction of water exports to restore and sustain the Sacramento-San Joaquin Delta's ecosystem, to protect native and desirable species, to protect public health, and to improve water quality…" The diverse supporters of this perspective have come together to oppose the Peripheral Canal or Tunnel. The supporters have created the "Restore the Delta" organization to advocate the perspective. Members include groups as diverse as the Stockton and the Delta chambers of commerce, the Natural Resources Defense Fund, a real estate developer (Gruppe), two of the three Delta water agencies (essentially the reclamation districts), several fishing and hunting clubs, and the Stockton Catholic Diocese Environmental Justice Project (http://restorethedelta.org/ accessed 6/28/2011).

Table 2.1 - Known Political Perspectives of Delta Levees and the Future of the Delta Itself

Prime Proponent(s)	View Or Perspective	Spatial Scaling Of Issues	Implications For Governance Of Delta	Implications For Delta Levees	Implication For Peripheral Canal	Implications For Environment
Restore the Delta(nonprofit organization) Website: http://restorethedelta.org	Need to protect Delta as a viable economic (agricultural) region and excessive water exports are the primary problem causing the deterioration in the ecosystem	Delta Region Only	Strong local involvement in managing levees and Delta activities	Delta levees protect the economic interest and should be continually improved	Peripheral canal purely a tool for additional water exports – not desired.	Ecosystem will improve when water exports drop to sustainable levels
Public Policy Institute of California (PPIC) (non-profit organization) and Center for Watershed Science – UC Davis (CWS)	Sea-level rise, past and future land subsidence, substandard condition and highly probable earthquake doom existing levees so efforts should be made to prepare for New Delta	At least state-wide	Delta needs a strong state governing agency to make hard decisions and take difficult steps	No additional investment in levees and preplanning required on which levees should be abandoned when they fail.	Required as soon as possible if California water supplies are going to be continued from the Delta	The estuarine endangered fish will do better in a salty-brackish open water Delta. Additional research will be required to help make the transition
Delta Vision – Governor initiated effort to develop consensus political view of future of Delta	California must manage the Delta with two co-equal goals – improve reliability of water exports to rest of state and restore the Delta ecosystem.	California exclusively	Strong plan with wide participation in development executed by single agency	Delta and Delta levees important but secondary to co-equal goals	Necessary to support co-equal goals	Replacing lost habitat and relocation of water export intakes will help endangered species recover.

The second political perspective is a more complicated in its origin, source and supporters but is very well defined in a series of texts that are available in print or online at no cost to the reader (Lund *et al*. 2007; Lund *et al.* 2008; Suddeth, Mount, and Lund 2010; Hanak et al. 2011). The UC Davis Center for Watershed Science (CWS) produced these books and supporting works with an undefined amount of funding for the work coming from the Public Policy Institute of California (PPIC). The CWS defines itself as an interdisciplinary group of engineers, geologists, biologists, and economists. Since at least 2004, the CWS and PPIC have identified, developed, and promoted a new perspective of the Delta that foresees inevitable, dramatic changes for the Delta and its levees, one which given the importance of water exports from the Delta to the California economy, supports the immediate construction of the Peripheral Canal.

Citing concerns about inevitable earthquake damage, sea-level rise, and continued subsidence, Mount and Twiss (2004:2005) first identified the high risk of failure of the Delta levees and identified that the "accommodation space" behind the levees would cause the Delta to look very different once the levees started failing. They defined the "accommodation space" as the missing 2.5 billion cubic meters of eroded and subsided peat soil that has disappeared from behind the levees largely because of agricultural practices. In a series of studies and resulting documents that built on these concerns (Fleenor *et al.* 2008; Lund *et al*. 2007; Lund *et al*. 2008; Moyle 2007; Suddeth, Mount and Lund 2010; and Hanak *et al.* 2011), the CWS proposed a future Delta where fewer and fewer levees would be worth saving and more and more open water space would appear. These papers first suggested that certain levees be issued "do not resuscitate notices," indicating that society should not expend any more energy trying to preserve non-sustainable agricultural levees in the Delta.

Further, they identified that the resulting open water would increase the tidal prism resulting in most of the new open water being brackish or salty. They propose that this environment would be more conducive to the survival of the endangered native estuarine fish and the striped bass than the current socio-ecosystem. The Delta would inevitably become a new salt-water environment, so managers should take action to accommodate these changes as effectively and quickly as possible, including construction of the peripheral canal to secure fresh Sacramento River water for export south before its contamination in the salt water bay. The CWS continued its research and in 2010 argued that few Delta islands are viable to reclaim after levee failure, and that none of the Delta levees are worth upgrading to higher standards to prevent or delay inundation (Suddeth, Mount, and Lund 2010). These findings led to the view that government should discontinue support for Delta levees, including the remaining largely unspent percentage of the $450 million approved by voters for Delta levee enhancements with the 2006 passage of bond propositions E-1 and 84.

The most visible advocates of this perspective, the PPIC, identifies itself as a non-profit, independent public policy research institute that derives its ideas for research topics "from a variety of sources, including policymakers and other leaders, funders, and internal and external experts…covering the range of concerns, such as immigration, education, governance, the environment and economic development." The work with the Center for Watershed Science on the future of the Delta is not the only initiative of the PPIC and no obvious overall worldview connects the PPIC to advocacy of this perspective. The Hewlett Foundation funded the endowment for the PPIC; however, the PPIC reports that "foundations, government entities, and other nonpartisan organizations" (PPIC website accessed 3 May 2011 at www.ppic.org) fund it.

The members of the CWS consist of recognized scholars who have addressed Delta issues for many years. In addition to the PPIC published texts, the group has advocated their perspective almost exclusively in an electronic outlet, the *Journal of San Francisco Estuary & Watershed Science,* which CWS and the CALFED Science Program created in 2003. Edited by UC-Davis professors, the CWS members have been the source of more than half the articles published since the demise of CALFED. The journal masthead identifies it as "peer reviewed"; however, the two editors and eight of the thirty associate editors are members of the CWS. It is not one of the 2,616 American scholarly journals recognized and monitored by the ISI *Web of Science* as of June 28, 2011, however, its articles can be searched in Google Scholar. It is a part of the Directory of Open Access Journals International (DOAJI) where the goals of the *Journal of San Francisco Estuary & Watershed Science* are identified to include providing "a forum for commentary, discussion, and debate on the scientific and management questions and issues pertaining to the science of the Bay-Delta estuary, its watershed and adjacent coastal ocean, and management of their resources," that is "widely discoverable, searchable, and accessible through digital libraries, public Internet services, and other emerging information technologies" (http://escholarship.org/uc/search?entity=jmie_sfews;view=aboutus, last accessed 2 July 2011). This could describe a journal that potentially is a forum for part scientific content, part political advocacy; however, in April of 2011, the editors' took the unusual step of declaring that all articles they had accepted completely avoided "advocacy of specific policies" (Luoma and Muscatine 2011, 1). The journal received over a quarter of million dollars in state funding from the Delta Stewardship Council to operate from July 2011 to June 2012 (Luoma and Muscatine 2011; DSC 2011).

Whereas the first two political perspectives about the Delta and its levees have a degree of grass-roots origin to them, the third, the Delta Vision, clearly developed as an attempt by the executive branch and the leadership of the legislature to establish an official policy perspective of the state government of California toward the Delta and, thereby, the Delta levees. Governor Schwarzenegger established the scale at which the political discourse would be conducted on this issue by appointing leaders from all over California to the task force. The "Sacramento-San Joaquin River Delta" became the "California Delta," which in turn was identified as "the heart of California" (See page 1). The executive order did not include federal agency involvement, establishing that the future of the Delta was primarily a state, not a federal problem.

In late 2008, after holding hearings all over the state, the Task Force identified a perspective or "vision" of a Delta that would be managed so it could produce more reliable and better quality water for export to other parts of the state while the Delta ecosystem would be restored to allow return of the endangered fish species to non-threatened levels. Thus began the often-noted "coequal goals" of the state government (DVC 2008, 1). The Task Force also called for "strategic" levee investments, completion and approval of the Bay Delta Conservation Plan (BDCP) to eliminate the need to shutdown exports when endangered species congregated too close to the export pumps by 2010, and breaking ground on the new water conveyance system (Peripheral Canal) by 2011, among other goals (Isenberg *et al.* 2008; DVC 2008; Isenberg 2008b). The creation of Task Force clearly spelled the doom of CALFED which shrunk to the home of the Science Program by late 2008 when the Task Force issued its 'Vision' of the future California Delta. To oversee this, the Vision identified that a single state agency, originally to be called the California Delta Ecosystem and Water

Council, should be created to take over all the state agency responsibilities in the Delta for governance and governing. Whereas the Delta Vision acknowledges the Water Code commitment to preserving the Delta as "special place," that clearly takes a lower priority to the "coequal" goals.

Three primary political discourses have evolved in the Delta, two advanced by non-profit public interest organizations, and the third, the Delta Vision view, was developed by Governor Schwarzenegger's effort to end the discussions and proceed to some form of action on this issue. Whereas the viewpoints differ, the three political discourses share strong public relations and political campaign elements, complete with electronic newsletters e-mailed to supporters, op-ed piece writers waiting in the wings, rallies, and carefully developed point messages and messengers. The Delta Vision political discourse has the advantage of being delivered by elected and appointed government officials of California from the governor on down, all with honed skills of delivering point messages and the full force of the government websites and other media outlets.

Whereas the three viewpoints represent the dominant political discourses about the Delta and its levees, this dissertation will empirically measure the social perspectives of the experts on the Delta levees regarding failures of Delta levees. In identifying these social perspectives this dissertation will explore the connection and the conflict between the social perspectives of those with expert knowledge of Delta levees, and the scientific claims reflected in the political discussion and final policy. This partially responds to a need identified by Agnew in his Presidential Speech to the AAG (2011, 473), to understand the connections and pathways between the claims of scientists and the policymaking that they purportedly drive. Agnew expressed specific concern for this in water provision while highlighting the California 2009 Water Bill and its proposed funding “of a new management system for the Sacramento Delta” (Agnew 2011, 471).

Records of existing levee failures

In identifying that a full understanding of the history of levee failures in Delta represents an important knowledge gap to fill, this dissertation recognizes that others have attempted to develop lists or count the number of levee failures. In 2010, N. Snard of Ryer Island submitted a chart (Snard 2010) to the Delta Stewardship Council, detailing the results of the numerous summary reports of Delta levee failures produced since 1975. He compiled and submitted this table to the policy makers because these reports, particularly the DRMS report (URS 2008c) were being used to assess the condition and future prospects for Delta levees. Mr. Snard and his neighbors believed the reports were inconsistent and inaccurate, specifically relative to Ryer Island (http:www.ryerisland.com/images/floods/delta_floods. final.pdf, last accessed 30 June 2011). Snard identified the conflicts in the totals but did not note how little detail and documentation of Delta levee failures is available. Some failures have been mapped, as shown in Figure 2.3, but again with few references and little detail. The lack of detail robs the lists of any power to help determine potential causes of failures that would help assess the probability of futures failures, to potentially anticipate, and help prevent those failures. Merely counting the number of “islands that flooded” is insufficient because engineers have designed the levees of several islands and tracts to fail in flood conditions; they are parts of floodways, the formal ones at Liberty Island and Prospect Island in the Yolo By-Pass, and the informal ones at the McCormack-Williamson Tract (MWT) in the North Delta.

The exact locations of the levee failures are important because anyone of a number of levee characteristics vary greatly over the Delta. With more pinpointed locations and details we can begin to determine if relationships exist between the failures and the these characteristics, such as the soil composition of the levee potentially generalized based on the geomorphic feature it was built on, the depth of peat, island elevation, levee geometry and size, levee surface characteristics (rip-rap, vegetated, etc.), nature of the original builder (USACE versus local levee district), wind exposures, potential channel scour, what levee district performs the maintenance, boat and ship traffic exposures, and at some point, the design standard the levee meets. It is not determined which, if any, of these factors influence the risk of levee failure, but until sufficient events and characteristics are mapped in detail, progress is unlikely. To maximize the ability to close the knowledge gap, I have incorporated the database of levee failures database into a GIS system and divided levee segments as finely as differentiable. In such a GIS system, other spatial data such as LIDAR elevation, soils, and levee surface maps; and aerial photography and historic maps can be incorporated. Filling this gap should help scholars attempting empirical studies of the probability of future levee failures to reduce the concern over the inadequacies in the record that Houston, Duncan, and the USACE (1978); Logan (1989; 1990); Burton and Cutter (2008); and URS (2009c) expressed. The DRMS contractor URS (2009c) tried to address this problem in its analysis of future failures based on the empirical record of the past but it was constrained to only using existing records by their contract. They did make requests

Figure 2.3 – DRMS map of levee failures (URS 2008c, Table 3-2)

to several DWR and reclamation district engineers to quickly pull together a table listing of known failures, which they completed within the time constraint as a sidebar to their normal job responsibilities (Interviews 103-2009, 106-2009, and 124-2009). A University of Pacific based proposal to develop a complete history of Delta levee failures would have helped close this important knowledge gap but unfortunately it did not get funded by the Sea Grant Delta Science Program in 2011 (Interview 118- 2010B). Therefore, the gap remains.

Still missing from the latest summaries of levee failures, such as DRMS, are the details. These include the locations, the time and date, river level conditions, known or speculated pre-failure levee conditions; responding agencies; all identified possible causes; repair and damage details; repair costs, damage estimates; speculated causes: and resulting changes in regulation and management, maintenance, and/or construction practices; and public and political reactions to the incidents.

To learn to prevent future failures of the levees we must understand the details of past failures, flood fight and emergency repairs. Petroski (1985) encourages all engineers to first study failures, noting that "no disaster need be repeated, for by talking about and writing about the mistakes that escape us, we learn from them, and by learning from them we can obviate their recurrence" (1985, 227). He also notes, however, just how difficult this is to achieve as he highlights the tremendous problems created because society defaults to the legal system to determine cause and liability, a system poorly structured to render such judgments. Petroski goes so far as to suggest that liability constraints drive those wanting to discuss failure of levees to do so in works of fiction, not professional journals. He suggests that creative writing, where the places and people are fictitious but the circumstances of engineering failure are real, represents a possible way to skirt legal department concerns.

This dissertation will not resort to that tactic but provides the alternative of capturing the confidential reports from the interviews, recorded without attempting to analyze or to assess validity or legal liability.

The database also helps fill a void in the basic information about levee failures in the Delta, created when the DWR indefinitely delayed issuing its annual reports on California flooding. Starting in 1962, DWR issued annually the Bulletin 69 series entitled “California High Water” which provided information on the levee failures and others floods of the previous water year (October 1 to end September). DWR published Bulletin 69-86 covering year 1985-86 in May 1988 and included information about the nature of levee failures for the 1986 water year (DWR 1988), including those in the Delta and large one on the Sacramento Valley System at Linda, California. In 2003, the State of California and DWR lost on appeal a court decision that resulted in a $464 million settlement from the failure of the levee at Linda (LOA, 2005) in 1986. DWR issued the latest issue, and perhaps the last, in 2003 covering water year 1995 (DWR 2003), many years after the events. The reports covering the flooding and levee failures in 1997 and 2004 have not been issued; they appear to have been prepared but have not gotten through legal review to be issued. Since 1996, no levee failure has been officially documented by DWR in the structure of Bulletin 69, apparently because of concerns over the liability of the state (Interview 103-2010A).

Finally, this dissertation attempts to expand the record by documenting with the same level of detail, the near misses, and the successful flood fights. It expands the record and in many cases, as much if not more, can be learned from them as from actual failures. This is particularly true with Delta levee failures where the water rushing down the landside of a failed levee with 5 to 10 meters of differential head (pressure) quickly and completely destroys the evidence of a beaver den, erosion spot, or seepage path, lateral sliding plane or whatever caused the failure. Making information available about near misses to all is important to advance the engineering and understanding of Delta levees.

CONTRIBUTIONS OF THE RESEARCH

This dissertation builds on and contributes to several scholarship streams. First, the database of failures of Delta levees and identification of the social perspectives of Delta levee experts extends temporally and expands Thompson's (1957; 1962; 1982; 1996; 2006) historical geography of the settlement of the Delta. Whereas Thompson's scholarship remains the most recognized on the Delta, his interests were limited to the 1850-1955 period of settlement activity. Thompson's student Mitchell (1993) expanded the study of the Delta to its development as the hub of the California water supply network and to the initiation of urbanization on the Delta fringe.

Thompson focused on Delta farmers and developers efforts to convert worthless swamp and overflowed lands into productive farms, a process promoted and encouraged by the federal and state governments and society of the time. Prince (1997) describes the farmer conversion by artificial drainage of the wetlands of the Midwest to cornfields during the same period (1870 -1920) as Delta farmers were doing the same by building the levees of the Delta. Prince highlight the changes in perceptions of the wetlands first identified by society as wastelands that needed to be made productive, to the current view that values wetlands as important ecosystems, a view confirmed in the 1989 federal executive order mandating no future loss of wetland function. As Prince suggests, for better or worse, the changing and varied mental constructs of nature will determine the future of the wetlands, and by extension, the Delta levees. Prince also believes that in the Midwest society is forcing farmers to reinvent and develop "mixed species communities in which they (the farmers) could continue to have a place to live" (1997, 346). This dissertation will identify how the re-evaluation of wetlands has affected the discourses about the Delta levees.

In addition to wetland reclamation, the Delta levees represent the physical manifestation and focus of the two other great movements in the development of the American West: control of flooding and the irrigation of the arid and semi-arid land that John Wesley Powell first wrote about. The Delta levees stand in the middle of reclamation of wetlands, flood control, and water exports for two-thirds of Californians, a position which limits and defines the discourses about the future. Depending on one's social perspective, Delta levees are now either the tools of or the impediments to the political economy of California, at a scale that has increased greatly since the local farmers finished building the system in the 1920s.

Two scholars, Karen O'Neil (1998; 2006) and Robert Kelley (1989), detail the development of flood control and the history of changing social perspectives and resultant political decisions in the Sacramento River Valley. O'Neill (2006) outlines the development of discourses and political maneuvering that led to the development of the Mississippi and the Sacramento flood control systems, often with locals from each region working together to promote the development of these managed, tamed rivers. O'Neill suggests that society has come to expect that the U.S. government, led by the USACE, will completely engineer the major rivers so they can manage them, in conjunction with the state and local governments. She argues that this challenge now includes responsibility to additionally manage the rivers for economic development, public safety, and environmental protection. She argues that as early as 1930 state, federal, and local flood control interests and agencies were working as a surprisingly seamless team. All those involved in this cooperative endeavor grew more powerful through the interaction. She points out that today society, prodded by environmental NGOs, now also requires a functioning, pleasing environment as well as flood control and water supply, something that ironically must now be "engineered" into the designed river system, including Delta levees. Over time, the federal government has taken a larger role in flood protection, intervening in response to crises, neither a planned takeover by the USACE nor a calculated effort by local elites to shift the cost and responsibilities to others. O'Neill suggests that the working relationships of federal, state and local agencies, river contractors, and the public, as reflected by congressional delegations pressuring at the USACE district level, may have developed a fairly rigid physical and organizational structure that inhibits changes to the system. This inflexibility may make it difficult for the system to effectively incorporate environmental protection and restoration into flood-protection projects. The Delta levees, specifically the 75% of Delta levees that were never reworked by the USACE, present a case not really explored by O'Neill (1998; 2006) where the involvement of state and federal agencies in the flood protecting levees came in at the same time as environmental protection became one of the norms. This dissertation will explore the social perspectives of Delta levee experts on the nature of these working relationships in an area and time unexplored by O'Neill (2006).

Robert Kelley's (1989) *Battling the Inland Sea* addresses the entire history of levees and flood control projects in the Central Valley from the first recorded inundations to the monstrous Central Valley flood of 1986. He concentrates on levee failures and developments upstream of Sacramento so the levee failure database that is part of this dissertation will make the record of Sacramento River flooding more complete temporally and spatially.

Kelley details the background of the hydraulic mining era that helped drag the Corps reluctantly into flood control responsibilities on the Sacramento River. He notes how the flood of 1907 demonstrated the folly of USACE approaches and stopped implementation of what would have been a disastrous plan for the Sacramento based on the previously long held USACE levees-only policy. Kelley traces the USACE involvement in Sacramento River flood control from reluctance to deep involvement and jealousy of their role and resulting power. Kelley concludes that the taming of the Sacramento floods represents the political victory of the "Whig-Republican" philosophy that it is the role of government to help support private economic activities by taking on large infrastructure projects, like flood control levees, navigation projects, and water supply/irrigation schemes. He also characterizes the USACE and the others involved in bringing flood control to the Sacramento Valley as "a people slow to learn" (Kelley 1989, 323) and reluctant to initiate change because of deep psychological and sociological as well as material ties to the status quo. This research will assess Kelley's (1989) conclusions to determine if they can be identified in the social perspectives of Delta levee experts today.

Starting in 1940 the Delta levees also served a major role in moving water to some of the major water transfer and irrigation projects in the West. The history of the development of reclamation effort in the U.S. West, including prominently the CVP and the SWP is laid out in the works of four scholars: Donald Worster's (1985) *Rivers of Empire,* Marc Reisner's (1986) *Cadillac Desert,* Norris Hundley's (2001) *The Great Thirst,* and Donald Pisani's (2002) *Water and American Government.* Each of these emphasizes slightly different spatial and temporal aspect and each reaches a different view of what the great projects tell us about and how they affected the changing relationship of society, government, and the environment.

Worster (1985) provides a critical view of the political economies that have driven development of increasing larger water projects of the U.S. West. He relates a dark story, highlighting the growth of the USBR and the irrigation projects they built, including the CVP. Worster looks for and finds signs in the California projects elements of the Hydraulic Empires as defined in the early work of Karl Wittfogel (Worster 1985, 23). Wittfogel studied the ancient hydraulic empires of China, the Indus, the Euphrates and the Nile where control of the water meant wealth and absolute power for the individuals or bureaucracy who controlled it. As one of these, Assyrian Queen Semiramis, explained to eternity on her tomb: "I constrained the mighty river to flow according to my will and led its water to fertilize lands that had before been barren and without inhabitants" (Worster 1985, 39). She apparently did not sense the need to add that all power and wealth flowed back to her through her bureaucracy that made irrigation and life possible. Rulers of the Hydraulic Empires, like Semiramis, exercised absolute power over their subjects and in their minds over nature itself. In detailing the development of the CVP by the USBR, Worster highlighted the growth of the agency bureaucracy and the development of a hierarchical social structure and capitalist state featured in the areas served by the USBR. He also predicts the eventual collapse of the hydraulic society that exists today in California and the rest of American West, just as the Assyrian hydraulic empire collapsed.

Marc Reisner (1986) similarly questions the sustainability of the culture and society built in the semi-arid and arid areas of California through the great irrigation projects, including the CVP and SWP. He challenges the economics of the federal and state investments in water projects while noting the great wealth it has created for a few beneficiaries of the subsidized water is wealth that translates into power to keep the water and money flowing. Reisner further explores how this accumulation of wealth and power translated into the political maneuvering and corruption he found in the selling of development of CVP, SWP, and other water projects of California and elsewhere in the west. Reisner plays particular attention to the political maneuvering around the 1980-1982 version of the fight over the Peripheral Canal. Reisner identifies the contributions, contradictions and shenanigans of each of the major players in that two year battle to build the one missing piece of what Reisner classifies as "uniquely productive, creative vandalism" (1985, 503), the water projects of the U. S. West. Many of the same participants are back to tangle in the latest attempt to build the canal. The dissertation may allow identification of which, if any, perspectives of Delta levee experts share Reisner's distrust of the political leaders and overall distaste for the large water projects.

Norris Hundley (2001) relates the story of California water use from the earliest Spanish mission to the high water mark of CALFED in 2000 when it issued its Record of Decision or ROD. Hundley quickly dismisses Wittfogel's Hydraulic Empire theory adopted by Worster and proceeds to provide a less negative description of a plethora of fragmented authorities including DWR, USBR, MWD, and the Central Valley corporate agribusinesses and their water districts, which developed the system that accidently made the Delta the hub of a badly managed water supply system. Unlike Worster, Hundley blames the American public, not a strong central power water bureaucracy, for continuing to support giant water projects in the face of evidence that they are damaging nature. Hundley sees tremendous problems with the waterscape that has developed, in the Delta and throughout the West but sees the authority to act too fragmented to effectively act. He concludes that: "Ultimately what seems clearly warranted is a coordinating agency authorized to *take charge*" (italics in original) (Hundley 2001, 553). The challenge he identifies is to make this agency accountable to the people, dismissing the legislature as incapable of solving the problems whereas the issues are unsuitable for resolution in the courts, and too complex for the initiative process. Hundley (2001, 553) may have inspired creation of the Delta Vision Blue Ribbon Task Force he suggested (in 2001) that the complex water problems of California "deserve the attention of the nation's best minds in and out of government: a task force approach." The book also outlined eight years earlier, many of provisions that would be included in the 2009 Water Bill package including creation of the Delta Stewardship Council, attention to groundwater and aquifer storage options, and the need for statewide water conservation, indicative of the insight of Hundley's (2001, 554-558) work. He remained silent on the need for the peripheral canal but this dissertation will potentially find the threads of Hundley views in one or more social perspectives of Delta levee experts.

Donald Pisani (2002) also analyzes Worster's portrayal of a powerful federal agency leading the growth of the hydraulic society that developed in California after the start of the CVP. He looked at the USBR from its establishment in 1902 until it assumed control of the CVP from the state of California (1902-1935). He found that rather than the USBR coming out of Washington as a powerful federal agency able to bestow great wealth on its supporters, the USBR struggled to survive in Congress. Few of its projects were completed and even fewer financially successful for anyone. When Franklin D. Roosevelt looked at the CVP as way to jump-start the New Deal, he selected the USBR over the USACE to run the project, but even then initially only assigning the Friant Dam piece of the project. FDR did not select the USBR to run the Central Valley project because he perceived the USBR would be more effective, he merely used the logic that the USACE should build flood-control or navigation related dams and the USBR would construct hydroelectric and/or irrigation dams. Thus, the USBR, USACE, and (later) the DWR designed and managed dams and reservoirs in the Sacramento and San Joaquin watersheds, with each dam designed for the specific purpose of the particular project and agency. Pisani describes the USBR in these early days as an agency that failed to achieve its original ideal of a top-down social engineering project of populating the dry West with millions of Jeffersonian yeoman farmers. Instead, it accidently created an agricultural elite by providing heavily subsidized water to those willing to take it. The industrial farms of the Central Valley prospered because the USBR had no choice but turn a blind eye to acreage limit violations if it was going to survive as a politically viable agency.

Whereas Pisani (2002, 295) generally agrees with Hundley's views, he does raise a concern, potentially counter to Hundley's desire for "smart" people to take charge, that water resource development in the United States and California has been susceptible to "high modernist technology" as James Scott's *Seeing Like a State* (1998) noted. Scott's book details the failures of several modern authoritarian state attempts to create a new social and economic order, including places like Tanzania, Brazil, and the collective farms in the Soviet Union, where an all-knowing, privileged hegemonic science excluded "the necessary role of local knowledge" or *metis* as Scott refers to it. This dissertation, by determining and describing the major social perspectives of Delta levee experts, will help identify the variety of views of what constitutes the best available science that should be applied in development of Delta levee policies. It will also determine social perspectives on the role of *metis* in what constitutes the best available science relative to Delta levees, and may indicate which if any formulations of best science is hegemonic. This dissertation will identify the major perspectives on what constitutes the best Delta levee science and practice today.

All of these works tell part of the story of the political and social forces that lead to the levee system existing in the Delta today and the roles and interactions of the various actors. Many Delta experts that I interviewed had read Kelley, Worster, Reisner, and Hundley, therefore, their works may play a role in establishing, refining, shaping, or reinforcing the attitudes and social perspectives of their readers. Each of these authors takes a different view or at least emphasis on the interaction and power relations between the government and society, the agencies and individual interest groups.

Hurricane Katrina destroyed New Orleans and heightened concerns of everyone dependent on levees for protection of their safety and well-being. Given the role the Delta levees play in water distribution in California, the well-being of two-thirds of the population of the state depends on them. Craig Colten (2009), in *Perilous Place, Powerful Storms*, reviews the historical development of the Greater New Orleans Hurricane Protection System, over the years since Hurricane Betsy (1965) clobbered south Louisiana badly enough to trigger Congressional approval of the project and the creation of the National Flood Insurance Program (Colten 2009, 36). He emphasizes the human processes that led to the failures in 2005 precipitated by the landfall of Katrina, specifically looking at the complex interrelationships and interactions of the USACE, state and local agencies, environmental groups, and other special interest groups (fishermen, shippers, local businessmen, etc.) that help contribute to the levees failures in 2005. By interviewing the Delta levee experts and determining the social perspectives of the effects of the human interactions on the stability and the security of Delta levees today, this dissertation can lay the groundwork for a similar analysis for the Delta without the backdrop of the catastrophic event. In closing, Colten (2009, 147) dismisses views that precarious places like New Orleans or the Delta should not be inhabited, noting risks lurk everywhere and making decisions to live in the face of risk of levee failure "more typical than lunatic," a perspective that may find support and opposition in the social perspectives uncovered among Delta levee experts.

A survey of the literature suggests that scholars have not determined the social perspectives on any issue in the Delta. The Q literature, to be developed more fully in Chapter III, however, shows at least three research efforts have been directed at understanding the social perspectives of scientists and experts elsewhere (Bischof 2010; Focht 2003; Raadgever, Mostert, and van de Giesen 2008). All of these scholars also used Q to help identify the social perspectives of scientists and experts; Bischof on coral reef science and the other two on water management issues. Focht identified the social perspectives of those working on watershed management issues on the Illinois River in Oklahoma, and Raadgevar on flood control in the Rhine watershed in Europe. This dissertation will extend this approach into the very complex Delta socio-ecosystem for the first time.

As Bischof (2010, 598) suggests, by "deconstructing the subjectivity that is embedded in the statements about the environment, some first steps are made towards extricating the scientific uncertainty and ontological artifacts that generate friction and disagreement." As Bischof did with coral reef science, this dissertation will use the Q-Method to identify and explore the social perspectives of Delta levee experts and managers that help determine the opinions they have about the past and future of failures of Delta levees and the actions they recommend. The identification of the perspectives of the key actors in the Delta in 2009 adds temporally to the work of Prince, Kelley, Pisani, and O'Neill in their exploration of the changing attitudes and roles of society and local, state and the federal government *visa vi* each other, to the exploitation of resources, and the environment. Table 2.2 summarized the works of these scholars and their relevance to Delta levees.

The scholars listed in Table 2.2 and described above have studied and described with differing perspectives and emphasis, much of the history of the public discourses and policy outcomes of the governance of the major environmental and resource use issues still very much at issue in the Delta. These scholars describe much of the underlying attitudes and the history of events that help shape the social perspectives that persist in the discourses that address governance issues of today. Some of these writings have become so well read they may be considered direct influences on one or more of the social perspectives that this dissertation seeks to understand about Delta levees. These scholars in relating their accounts do not attempt to understand the social perspectives behind the governance debates and conflict they detail, and indeed, it would be impossible to do retrospectively. This dissertation contributes back by looking at the social perspectives about one element, the stability of Delta levee, at one point in time that touches the great conflicts of the settlement of the American West, land reclamation, flood control, large state irrigation projects, and environmental restoration.

SUMMARY

The chapter described the defining of the region of interest of this dissertation to be the Legal Delta as defined under the California Water Code since 1959. The legislature defined the Delta as a place requiring special treatment because of its importance as an agricultural producer and gathering point for water transfers between northern California and southern California. The chapter then described the special type of levee that dominates the study area, the Levee-dam, a structure that must protect against flooding even during average or low water levels and compared this requirement to other structures call "levees."

The chapter then identified the pre-dissertation answers to the two research questions. First, it identified three widely heard political perspective on the Delta levees: 1) build the Peripheral Canal before the inevitable collapse of the conversion of the Delta to a salt water bay view; 2) restore the Delta, its levees, and environment by investing a little more in the improving levees while looking to reduce the water exported out of the Delta argument; and 3) build the Peripheral Canal so California can make use of every drop of Delta while restoring the endangered species official position of the State of California.

The chapter identified the pre-dissertation answer to the research question relative to the history of failures of Delta levees as the list of "flooded islands" listed in the State issued DRMS report (URS 2008c). The primary failings of this report was the lack of detail about the incidents and the locations, lack of references, and absence of indication of near-misses, defined as the sum of the successful flood fights and emergency repairs.

The chapter concludes with a discussion of the efforts of scholars whose work provide a significant part of knowledge base for approaching the research questions. Prince (1997), O'Neill (2006), Worster (1985), Reisner (1986), Pisani (2002), and Colten (2009) provide data on the events and discourses that potential influence the social perspectives of today. Thompson (1957, 1962, 1996, and 2006) and Mitchell (1993) provide much of the detail on the early history of failures of Delta levees.

Table 2.2 Summary of Important Scholarship Relative to Delta Levees

Scholar and Work(s)	Emphasis	Time Frame	Major Assertions	Implication for Delta Levees
Thompson (1957, 1962, 1996, 2006)	The Delta	1860-1957	Delta was the first major wetland reclamation effort to be attempted with modern methods and equipment	Listed major flooding events and levees failure through 1957 with an emphasis on those prior to 1930.
Mitchell (1993)	The Delta	1920-1993	Updates Thompson and documents conversion of Delta to water hub and introduces issue of urbanization of Delta	Reviews abandonment of Franks Tract and establishes role of levees in water exports
Prince (1997)	The draining of the wetlands of the Upper Midwest (US)	1850-1920 1970-1990	Societal attitudes towards the wetlands have changed significantly, as mental constructions of Nature have changed.	Attitudes towards the levees and the levee builders have eroded with changing perspective of the value of the wetlands they eliminated.
Kelley (1989)	Development of the flood control system on the Sacramento River (largely upstream of Delta)	1850-1986	The development of the Sacramento River Flood Control System (not necessarily in the 75% of the Delta protected by non-federal levees) was critically shaped by party or at least ideological politics and a USACE that went from an agency reluctant to become involved in flood control, to one jealous of that role.	The significance of party politics in flood-control and the toward property rights, water rights, and the role of government assistance to private economic interests could have major impacts.
O'Neill (2006)	Historic development of the Mississippi and Sacramento River flood protection systems	1803- 1936 (some post 1936 references)	Local interests in the Mississippi and Sacramento River basins worked together and separately to promote USACE involvement with local and state agencies to build the flood control systems. The existing physical and organizational structure inhibits changes to the system.	For the most part Delta levees were not built by the USACE, the working relationships between the local, state, and federal interests in the levees play an important role.
Worster (1985)	The "Hydraulic Empires" of world history, focus on the Central Valley	1847-1985	History teaches that large water distribution systems require strong, dictatorial powers and are doomed to failure	If California has become a hydraulic empire, the only important role the levees will have is as a water conveyance system and little else.

Table 2.2 Continued

Scholar and Work(s)	Emphasis	Time Frame	Major Assertions	Implication for Delta Levees
Mitchell (1993)	The Delta	1920-1993	Updates Thompson and documents conversion of Delta to water hub and introduces issue of urbanization of Delta	Reviews abandonment of Franks Tract and establishes role of levees in water exports
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Table 2.2 Continued

Scholar and Work(s)	Emphasis	Time Frame	Major Assertions	Implication for Delta Levees
Reisner (1986)	The large water projects of the USBR in the Western US, and other major water projects in California	1803-1984 (mostly post -1902)	The water supply and irrigation projects of the US West have been tremendously wasteful of the water resources; they were built largely through political maneuvering and corruption, creating an environment where water flows uphill to money and power.	The financial and political forces and even some of the key actors (Jerry Brown and Jerry Morel for example) have not changed since the last great debate over the Delta and the Peripheral Canal raged in 1982.
Hundley (2001)	The changing waterscape of California from pre-European contact to 2001.	1000-2001	Popular support for large water projects, in spite of knowledge of the problems they helped create, is the reason California has a water mess on its hands. Hundley calls for the best minds to take a task force approach to fix the problems. CALFED was identified (in 2001) as a good approach.	Huntley emphasized the need for stronger political leadership and a better informed electorate to make the hard choices to clean up the water mess in California
Pisani (2002)	The effects of the USBR on the development of the US West and the inability of the American state to shape Western society through large scale irrigation projects.	1902-1940	The Reclamation Act that established the USBR had the makings of a state driven attempt to rework the US West into a large social engineering project. Fortunately it failed because of the weakness of the USBR in a federal system of checks and balances and distributed power. He concludes by suggesting there is still the possibility that per Scott (1998) the potential exist for water projects to entail hegemonic planning that excludes local knowledge and knowhow.	Even in the US, state power has been known to attempt to establish hegemonic scientific discourses, with little or no study or justification, and little or no recognition of local knowledge and experience.
Colten (2009)	The events that lead to the failures in New Orleans due to Hurricane Katrina	1948-2009	The failure of human systems in planning to prevent the failure of the levees during Katrina, the failures of people who knowingly put themselves in harm’s way.	The political, social and economic wrangling can be more difficult to deal with than the complex physical risks that the levees face.

CHAPTER III

BACKGROUND: DELTA LEVEES

OVERVIEW

This chapter will discuss the background on the levees to understand the history of levee failures in the Delta and the reflection of that history in the social perspectives of Delta levee experts. The chapter starts with a short description of the geology and geomorphology of the surfaces on which human constructed the levees, followed by a brief history of the development of these levees by the local reclamation districts for agriculture. The chapter then reviews the involvement of USACE in providing a flood control system for the Sacramento River and then later the San Joaquin River, upland from the Delta, followed by an explanation of the interaction of island subsidence and the Delta levees. The chapter concludes with a short explanation of the modes of levee failures and the design standards that have evolved for the Delta levees.

GEOLOGY AND GEOMORPHOLOGY OF THE DELTA

The Sacramento-San Joaquin River Delta represents the eastern-most inland portion of the San Francisco Bay estuary. Approximately 400,000 years ago, the ancient inland lake covering most of the Central Valley of California (Lake Clyde) overtopped the confining Coast Range and eroded what today is the Carquinez Straits west of the Delta and Suisun Bay. This established the Delta as an area where the Sacramento, San Joaquin, and tributaries that drain about 40% of the modern state of California join and begin westward flow to the sea (Harden 1997, 279). The drainage basin includes the northern two-thirds of the Central Valley, west slopes of the Sierra Nevada, east slope of Coast Ranges, south slope of the Klamath Range and part of the Modoc Plateau. Since the erosion of the Carquinez outlet, sea levels have risen and fallen at least three times. Each time sea level fell, the drainage incised the Delta down to near the lowered sea levels. Each time sedimentation and vegetation rebuilt the land surface of the Delta as the transgressive sea re-flooded the valley, the current re-development starting about 6700 years B.P. (Shlemon 1971; Atwater 1982; Weiss and Goman 1994; Goman and Wells 1999; Drexler *et al.* 2007).

The Delta differs significantly from the typical delta of the world in that it is a bayhead delta (Davis and Fitzgerald 2004), overlain with a bird's foot delta of the Sacramento River (URS 2008b) as it enters the marsh, as shown in Figure 3.1. It does not exhibit the classic form of the advance of fluvial deposition into the sea that has caught the attention of scholars from Herodotus to Syvitski *et al*. (2009) and thus it is rarely discussed as a Delta. As a bayhead delta, it does not discharge directly into the Pacific, but rather it discharges through 80 kilometers of first a constricted outlet (Carquinez Straits) and then through a series of estuarine bays and straits. The land surface reflects deposition of Holocene muds and organics on top of earlier deposits of alluvial and aeolian sediments (Atwater 1982). Atwater and associates (Atwater and Belknap 1980, Atwater *et al*. 1979) and map (Atwater 1982) describe in detail the resulting locations of natural levees, flood basins, and aeolian sand deposits of the Delta itself. The alluvial fans that originate in the Sierra confine the Delta lowlands to the east and the Montezuma formation and hills and the fans originating in the Coast Ranges limit the Delta to the west. Rising tidal water reached the tapered western section of the Delta (where Sherman Island stands today), about 6,000-6,700 years ago when sea level was about 8 - 10 meters below the current levels and tidal waters were just transgressing into the Delta (Atwater and Belknap 1980, 97; Atwater et al. 1979; Goman and

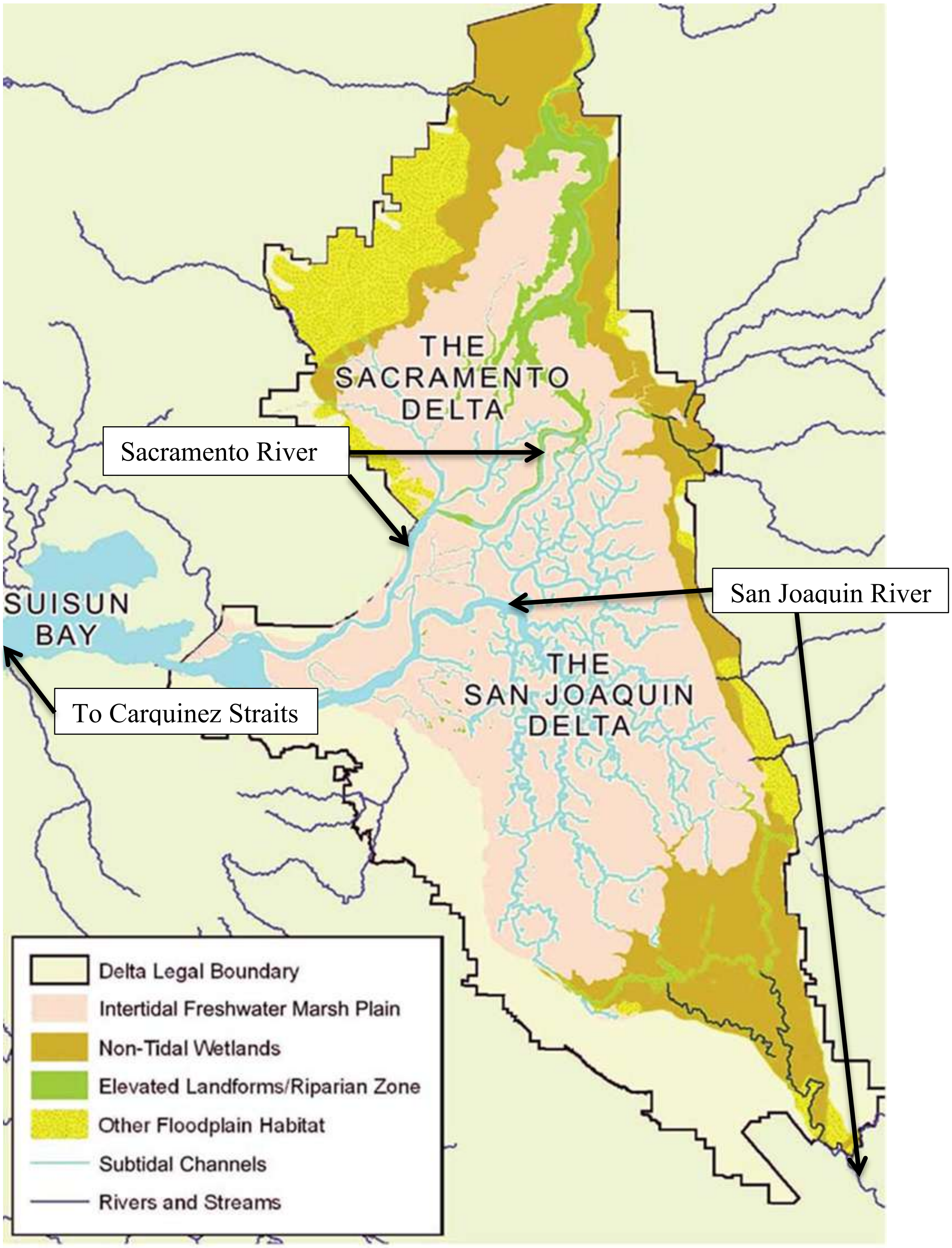


Figure 3.1 – Pre-1850 Delta Showing Channels, Limits of Types of Wetlands, and Legal Limits of the Delta under the California Water Code (URS 2008b)

Wells 1999; URS 2008b; Drexler et al. 2007). The water remained fresh under most circumstances and the Sacramento and San Joaquin Rivers tends to carry the clay sediments entrained in the flow westward where they settled out in the brackish and saline waters of Suisun and San Pablo Bays.

The rapid growth of vegetation adapted to shallow freshwater, particularly the bulrush (*Scirpus acutus*) or "tules," allowed organic rates of sedimentation to keep pace with water levels rising at rates of approximately one plus meter per millennium over the last 6,000 or 7,000 years (URS 2008b). Water and climatic conditions in the Delta allow the tules and associated species to produce 2.5 kg of dry organic material per square meter every year (Atwater and Belknap 1980, 96). With the large roots and rhizomes remaining sub tidal after the winter die off, organic material built up a rate able to match the rate of sea-level rise plus the rate of consolidation and crushing of the organic deposition from previous years. This restricted the increase in the tidal prism as sea-level rose, which helped the water remain fresh in the Delta. Conditions were kept perfect for peat accumulation in the Delta because the water levels and the inundated surface area continued to grow reaching an area of about 1,500 square kilometers by 1850 (Atwater and Belknap 1980, 97) or most of the current Delta peat islands. For the past 5,000-6,700 years, these tule marshes built up the elevation of the surface at an average rate of 1-2 mm per year (Atwater *et al*. 1979; Goman and Wells 2000; URS 2008b), whereas relatively little suspended riverine sediment deposits in the Delta. The rivers transport most of their estimated 1.5 million cubic meters each year of suspended sediment through the Delta to the depositional environment in the brackish mud flats and marshes of Suisun Bay and the rest of the San Francisco Bay, where *Scirpus acutus* and associates did not prosper.

Before the gold seekers poured into the region starting in 1848, the Delta consisted of a large fresh water tidal marsh with 3 to 4 meter tall tule growing over 2 to 12 meter thick beds of Holocene peat. The Sacramento River entered this wetland creating, what some have described as, a classic bird's-foot Delta (URS, 2008b) into the northern part of the "Delta" of channels defined by the natural levees which grew shorter and narrower as the river ran deeper into the tidal marsh. Upstream of the Delta, the river also built natural levees which grew to an elevated position above the flat Central Valley flood plain, such that for hundreds of kilometers, the tops of the confining levees of the river and its tributaries stand high above the floodplain. Wide flood basins running parallel to the river, often on both sides, developed. The natural levees confined the normal flows to the leveed channels. The drainage basin, however, sits in either a Mediterranean or Mountain climate zone and experiences highly variable seasonal and year-to-year precipitation. Floods in the Sacramento River can be 20 times average flows. The capacity of the natural channel of the Sacramento River is limited upstream of the Delta to approximately 3285 cubic meters per second (115,000 cfs), slightly less than the flood capacity of the American River tributary that joins in Sacramento city (Hyatt 1942). In floods, the river overtops its natural levees and sends the excess flow into the wide flood basins that run parallel to the levees, historically creating Kelley's (1989) "inland sea." Floods arrived in the Delta via the Yolo flood basin to the west of the river, and then dumped back into the Sacramento through Cache Slough between Rio Vista and Isleton. Pre-development, the east bank below Sacramento also had a floodway that ran between Interstate 5 and the river, entering the Delta through Snodgrass Slough east of Walnut Grove. In the natural state, floodwaters cut crevasses (holes) in the natural levees to enter these flood basins and natural depositional processes closed them when flood levels dropped. In the 1920s, the USACE flood control system incorporated some of these “holes” as controllable weirs to create an engineered Yolo Floodway that can dump five times the flow of the normal river channel into the Delta. This floodway includes two weirs (floodgates to control flow rates) and confining levees. Land development in south Sacramento precludes intentionally utilizing the natural floodway on the east side of the Sacramento.

The San Joaquin enters the Delta from the south and splits into two main distributaries south of the tule marsh. The Old River runs westerly from the divergence then turns north to run up the western edge of the Delta. The main San Joaquin runs more northerly and enters the historic marsh just south of modern day Stockton. Flows in San Joaquin are much smaller, and sediment supply is less than carried by the Sacramento. Vegetation and sea level rise turned the southern 70% of the Delta into a level, tidal freshwater marsh. The vegetation helping create the marsh included tules or bulrush (*Scirpus* sp.), cattails (*Typha* sp.), and common reed (*Phragmites* sp.) (Atwater and Belknap 1980; URS 2008b).

Restricted by the narrow outlet to Suisun Bay and confined to the east and west by the alluvial fans from the Sierra and the Montezuma formation, Atwater and Belknap (1980) suggest that the Delta channels themselves did not migrate very much over time. This resulted in the Holocene deposits of the Delta dominated by rather simple sequences of tidal-wetland (peat and silty clay) and natural levee facies as shown in Figures 3.2 and 3.3.

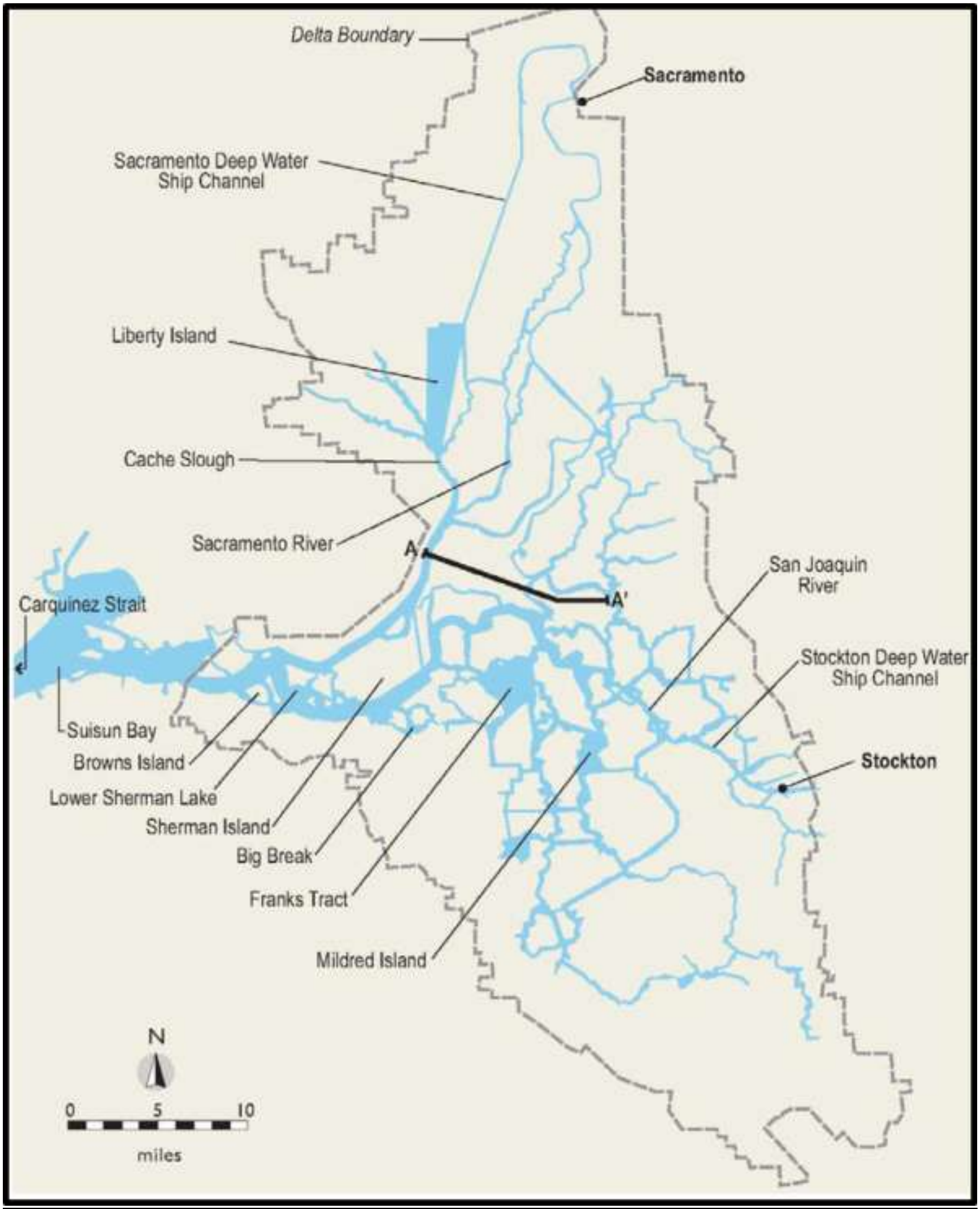


Figure 3.2 – The Modern Delta (URS 2008b, Figure 3. Cross section A-A' shown in Figure 3.3).

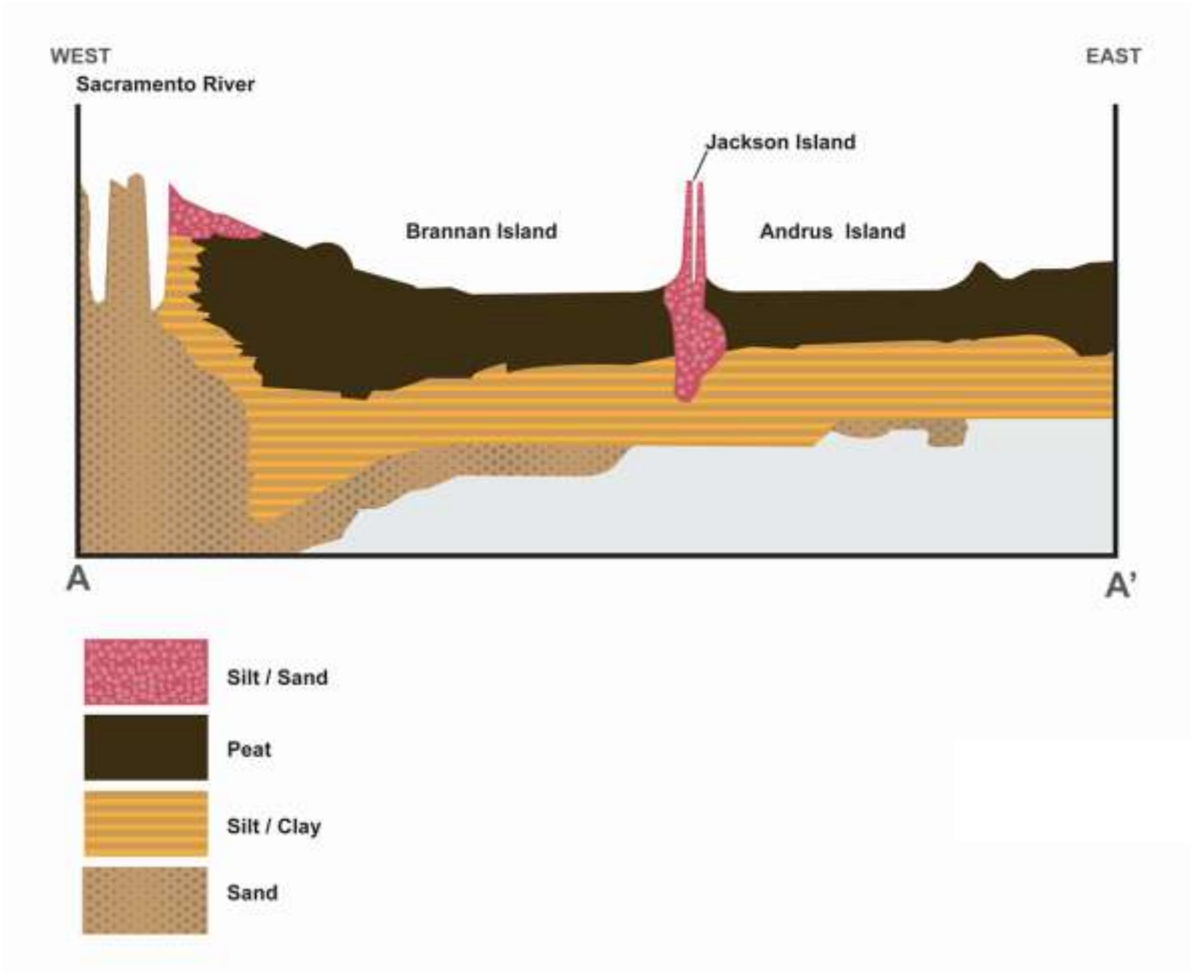


Figure 3.3 – Cross Section A-A' from Figure 3.2

Showing Simplified Delta Stratigraphy (URS 2008b, Figure 4)

CLIMATE AND HIGH WATER EVENTS

As noted above, the Delta and most of the watershed has a Mediterranean climate with moist to wet winters and dry summers. River flows vary significantly during the course of the year into the Delta and the watershed is prone to droughts and large amounts of precipitation over periods of several days (Interview 103-2009). The Sacramento River drains 8,900 square miles (23,050 square kilometers), with an average discharge of 24,670 cfs (699 cubic meters per second). Most runoff generally comes after large amounts of rainfall across the watershed, often combined with rapid snowmelt during December to May.

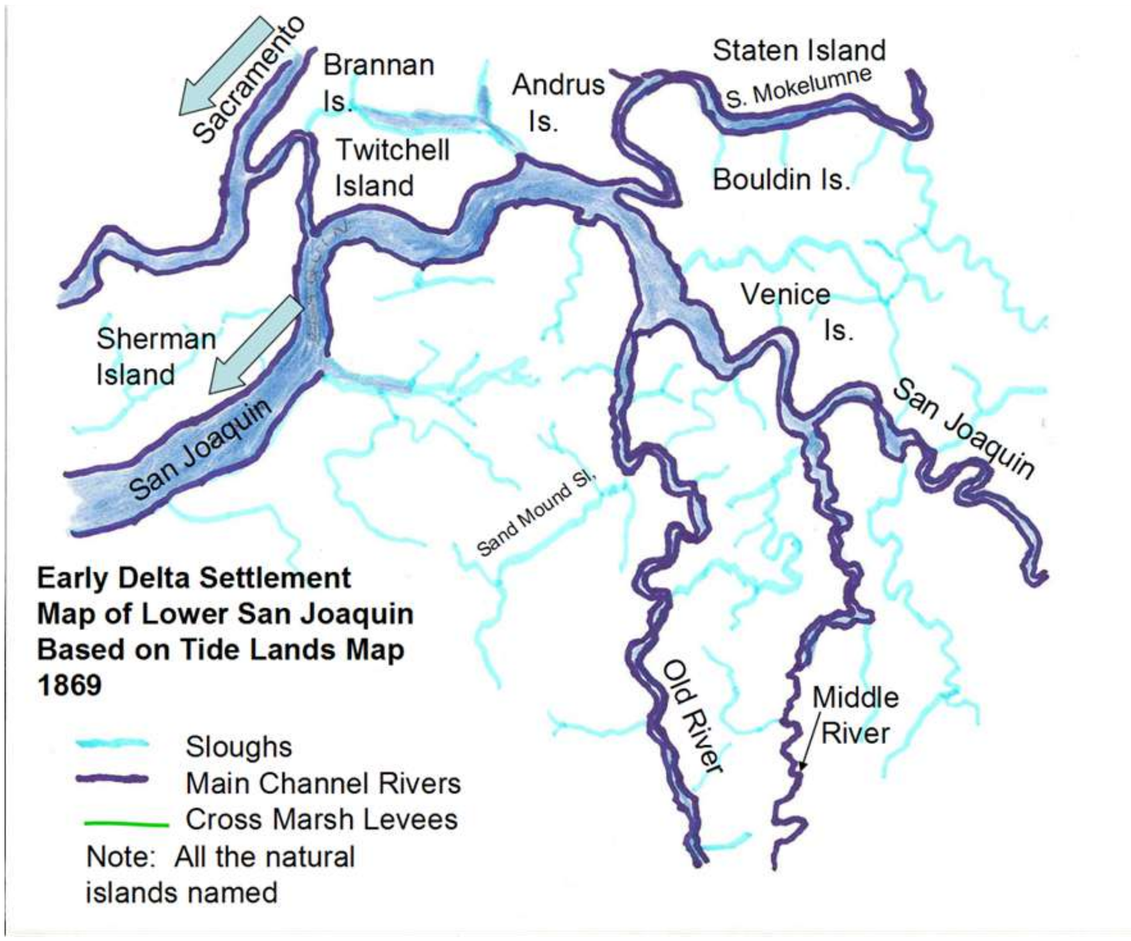


Figure 3.4 – The Natural Channels and Sloughs in the Central Delta on which the Levee System was Constructed (Based on Tidelands 1869)

In the old natural marsh, now termed the "Delta Pool" by residents and regulators, ocean tides dominate water levels and increased riverine flows have the primary effect of backing out some of the volume of tidal water originating at the Golden Gate, with tidal channels and sloughs as shown in Figure 3.4. Delta Pool floods occur during a very high tide in the diurnal cycle of the Delta tides. The highest or springtides occur in conjunction with the direct alignment of the sun-Earth-moon twice a lunar cycle (New moon and Full moon phases). Strong onshore winds and low atmospheric pressures can stack water in the estuary can increase high spring tide levels in the Delta to very high levels. Pacific storms that create the large winter precipitation events (the "Pineapple Expresses") can also produce strong onshore winds and generate very low-pressure readings. When these storms hit during spring tides, Delta pool flooding can occur. Unlike the riverine floods where water levels build for several days and then fall over a similar time frame, Delta pool floods rise with the tide and fall with the tide and result in short periods of predictable risk on a twenty-five hour or so cycle.

BUILDING THE DELTA LEVEES FOR AGRICULTURE

The federal Arkansas Act of 1850 that conveyed swamp and overflowed lands from federal ownership to California and other states, initiated state encouragement of small farmers (initially grants were limited to 320 acres per family) to reclaim swamps and marshes into land with exchange and use values (Thompson 1957; Thompson 2006; Prince 1997). Many emigrants from the American East and Europe recognized that agriculture held more promise for them than the gold mining that originally drew them to California and soon they lined the natural levees downstream of Sacramento with small farms. These farmers built earthen ramparts on top of the natural levees to increase the area they could farm protected from flooding (Thompson 1957; Dillon 1982, 89). Reclamation of the tule-covered back marsh, however, did not occur until potential reclaimers could secure clear title for the land that had to be leveed and drained. It would take until 1861 for California and the US government to resolve which "swamp and overflowed lands" had been conveyed from federal ownership to the state. California created the short-lived Board of Reclamation Commissioners (1861-1866) to promote sales of swampland to small landholders, and to take direct control of reclamation activities. This agency authorized the process of local landowners forming and funding local reclamation districts with taxation powers granted by the state. In 1866, the California legislature eliminated the Board and turned swampland development over to the counties. Within five years, the Contra Costa, San Joaquin, Sacramento, Solano, and Yolo county surveyors had sold of much of the 500,000 acres of state swampland in the Delta. Gone too were the 320 acre limits; indeed, George Roberts, the organizer of the Tide Land Reclamation Company (Thompson and Dutra 1983, 27) ended up controlling about half of the Delta swampland in the early 1870s (Thompson 1957). Figure 3.5, modified from an 1869 map, shows the predevelopment Delta and some of the large landholdings accumulated.

Thompson (1982; 1957; 1962; 2006) details the early successes and failures of early 1870s reclamation of Delta, largely consisting of levees built out of blocks of peat by hand by mostly Chinese immigrant labor. Sherman Island became the first major complete restoration project, finished in April of 1869 and Tidelands enclosed Twitchell Island the same year with hand-built peat levees. Initially, crop returns were excellent but floods that overtopped the levees in 1872, 1875, 1876, 1878 and 1880 destroyed enthusiasm for this type of levee project. Developers abandoned Twitchell after the 1875 flood and Sherman Island returned to marsh after the 1880 levee failure. They remained un-reclaimed until 1893 and

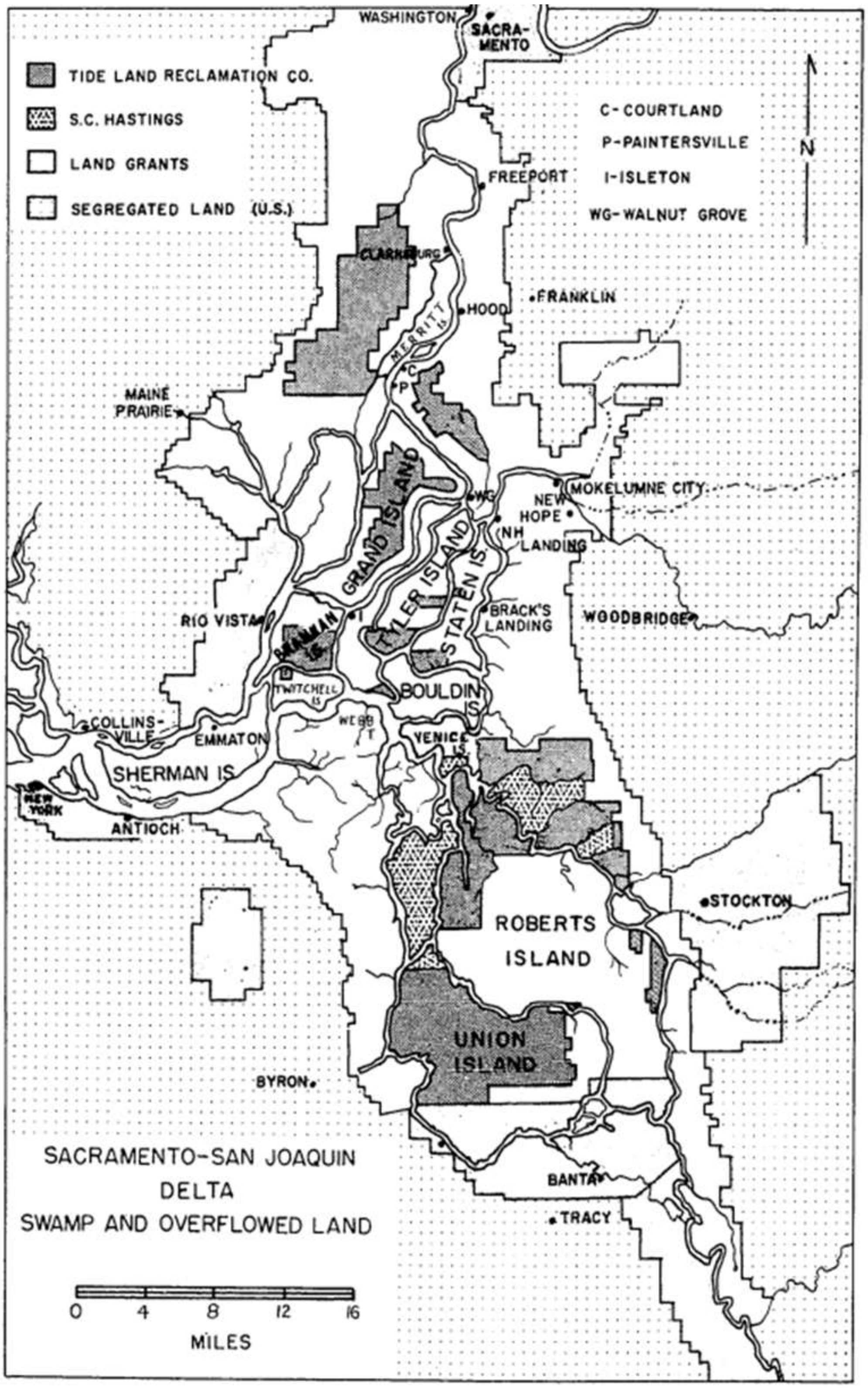


Figure 3.5 – Early Large Landholdings in the Delta (Thompson 1957, 228)

1894, respectively, when levee builders employed clamshell dredge technology to try again to farm the islands (Thompson 1957, 481). The clamshell dredge first saw use in building Delta levees before 1880 and almost immediately, it became the preferred tool and method of levee construction.

The history of nearby Brannan Island reads similarly, with peat levees raised in 1873, failures culminating in an 1881 collapse that led to abandonment until 1894. Whereas the wheelbarrow and shovel built peat levees make an interesting story of human effort, the levees that they created largely washed or floated away during long periods of abandonment, prompting one engineer in 1882 to state that no peat islands had "been successfully reclaimed. Levees made of peat have proven failures in every instance" (Thompson 2006, 29).

The clamshell dredge and other dredges, either developed or perfected in the Delta, would set off the second wave of reclamation. The clamshell dredge first found use in the Delta around 1879; it held the advantage of simplicity coupled with the ability to access materials from the depths of any channel and deliver it relatively dry to a levee surface 15 to 60 meters from the edge of the water. It could also build a levee across a back marsh, floating in on its own ditch and digging as deep as necessary to access better levee construction materials. Thompson and Dutra (1983) discuss in detail the development of the dredging equipment, including hydraulic dredges that subsequently built the Delta levee system. With the help of the new dredges, the independent, self-governing, often clamshell dredge-owning Delta reclamation districts eventually gained some control over the marsh and outlasted major floods in 1893, 1902, 1904, 1906 , 1907, and 1909 that destroyed miles of levees and repeatedly inundated most of the reclaimed land (Thompson 1996). The arrival in the Delta of tons of mining sediment eroded from the Sierra foothills by 30 years of unregulated hydraulic mining exacerbated these floods. Floodwaters transported the sediments out of the foothills and dropped them, clogging river channels in the valley and Delta which added to the flood heights (Gilbert 1917; Thompson 1996; Kelley 1989). Flood prevention pitted the two major economic interests in the state, agriculture, and hydraulic mining, against each other (Isenberg 2005). For the first time the levees of the Delta were placed into the spotlight of political fights between major economic interests. Where the streams entered the valley, floods left the coarser sediments in thick layers on the previously fertile fields. By the time the floodwaters reached the Delta, the less competent Sacramento River deposited thick layers of sediments in the channel bottom and on the growing levees. Shoaling exacerbated flooding but also provided channel bottom sediments (potentially tainted with mercury from the upstream gold extraction activities) for the dredges to add to the heights of the levees. Hydraulic mining would effectively end in California after a court order banned the practice in 1884 and the economics of the method had deteriorated; however, it took several decades for the rivers and streams to transport the bulk of the artificially eroded material through the watershed. During the period of 1850-1915, Gilbert (1917) estimated that the amount of sediment delivered to the Delta jumped almost tenfold from pre-mining levels to 14 million cubic meters per year. This level would decline to about a third of that amount by the late 1950s as the slug of hydraulic mining sediment moved through the Delta (Atwater and Belknap 1976, 1980; URS 2008b).

Farmers and developers built the agricultural levees that remain today between 1897 and 1920 from adjacent soil materials collected by clamshell dredges and in some cases hydraulic dredging equipment. Mormon board scrapers and the locally invented “caterpillar” bulldozer helped shape the levees. Over time, the reclamation districts, several of which owned their own clamshell dredges until the Great Depression , added height and width using the same techniques (Thompson and Dutra 1982).

Materials of construction varied along a levee, depending on the nature of the depositional development and the depth of the excavation. As shown on Figures 3.2 and 3.3, four types of depositional environments dominated the pre-development Delta. The first were the channels of the main rivers, the Sacramento including distributaries Steamboat Slough, Prospect Slough, Georgiana Slough, and 3-Mile Slough; the San Joaquin River, including its two distributaries, the Old and Middle Rivers, and the Mokelumne River (North and South branches). Deposits in these channels tend to be clastic materials originating in the Sierra with the largest sizes, in the Delta, being gravels and sands.

Floodwaters would carry sediments over the levees into the marsh behind, with the largest sediments, mostly sands and larger silts, settling out closest to the riverbanks as water velocity declines when the floodwaters expand out of the channel. This deposition created the natural levees immediately adjacent to the channel, again mostly sand and larger silts fining into the marsh.

The marsh behind the natural levees always experienced the slowest rates of flow, allowing deposition of the finer clastic sediments, mostly clays and fine-grained silts. As discussed earlier, the primary deposition in the Delta marsh over the last 6,000 years has been of the organic roots and stems of the marsh vegetation *spircus* and *pragmatus*.

The last major depositional environment developed in the crevasses and tidal channels, particularly in the tidal pool where twice a day the flood tide overwhelmed low spots in the natural levees and allowed the water to inundate the marsh. These twice-daily flood flows created permanent channels, holes in the natural levees to allow water and some sediment into the marsh and then back out as the tide ebbed. Unlike the main channels that had net positive flows to the sea, the tidal channels mostly had small net negative flows as evaporation rates exceed precipitation over the course of the year; however, they could have significant flood and ebb flows. Deposition in these sloughs would vary with rates of flow but would be similar to the natural levees at the levee "breach" fining further into the marsh. Perhaps as significant, the tidal flows erode away the organic materials and fines clays and silts along the course of the sloughs.

With the clamshell dredge, developers built levees on one of five types of alignments, each of which has implications for the materials of construction of the levees still standing today. The first alignment followed the course of one of the main river channels. The dredge bucket would dig materials from the channel bottom and perhaps the natural banks to build a silt-sand-gravel levee on a similar natural levee foundation. On the fringes of the study area, the natural levees were large, but shrank as the rivers ran further into the tidal pool. At locations where the levee was built across a crevasse or opening of a tidal slough, this hole in the levee had to be filled in with dredged material and a tidal gate would be installed to permit drainage during low tides of any excess precipitation. The dammed slough continued to provide a drainage path even after the island land elevation subsided below the low tide elevation and required a pump to drain the interior of the island, replacing the tidal gate.

Often, ownership issues or the size of the slough would require that the levee builders build along the slough rather than across the slough, creating the second type of levee alignment, simply termed "Slough." Here the levee builder's clamshell bucket would find some sand and silt, but depending on the size of the slough and the distance from the main channel, it could also pick up more clay-peat mix from the marsh. Again, the levee builder would build across and block any side sloughs, and again would install initially tidal gates. Eventually the farmers would be required to install pumps to maintain drainage after subsidence dropped the landside elevation below low tide levels.

In the center of Delta pool, both the main channels, particularly the Old River and

Figure 3.6 – Google Earth Image of Middle River between Jones Tract and Victoria Island Showing the Levees Built to Cut Off the Meander Bends with the Original Channel Marked in Blue

Middle River and the larger sloughs, such as Disappointment and Potato, meandered through the marsh and created large swampy point bars. The levee builders often took their clamshell on straight lines between cutbanks of the river or slough, forming the third and fourth types of levee alignment, the main channel meander and slough meander cutoff alignments. Figure 3.6 shows the original meandering river or slough and the main channel meander and slough meander cutoff alignments, specifically showing the original meandering river and the levees built to reclaim Victoria Island, Upper Jones Tract and Woodward Island, cutting off the

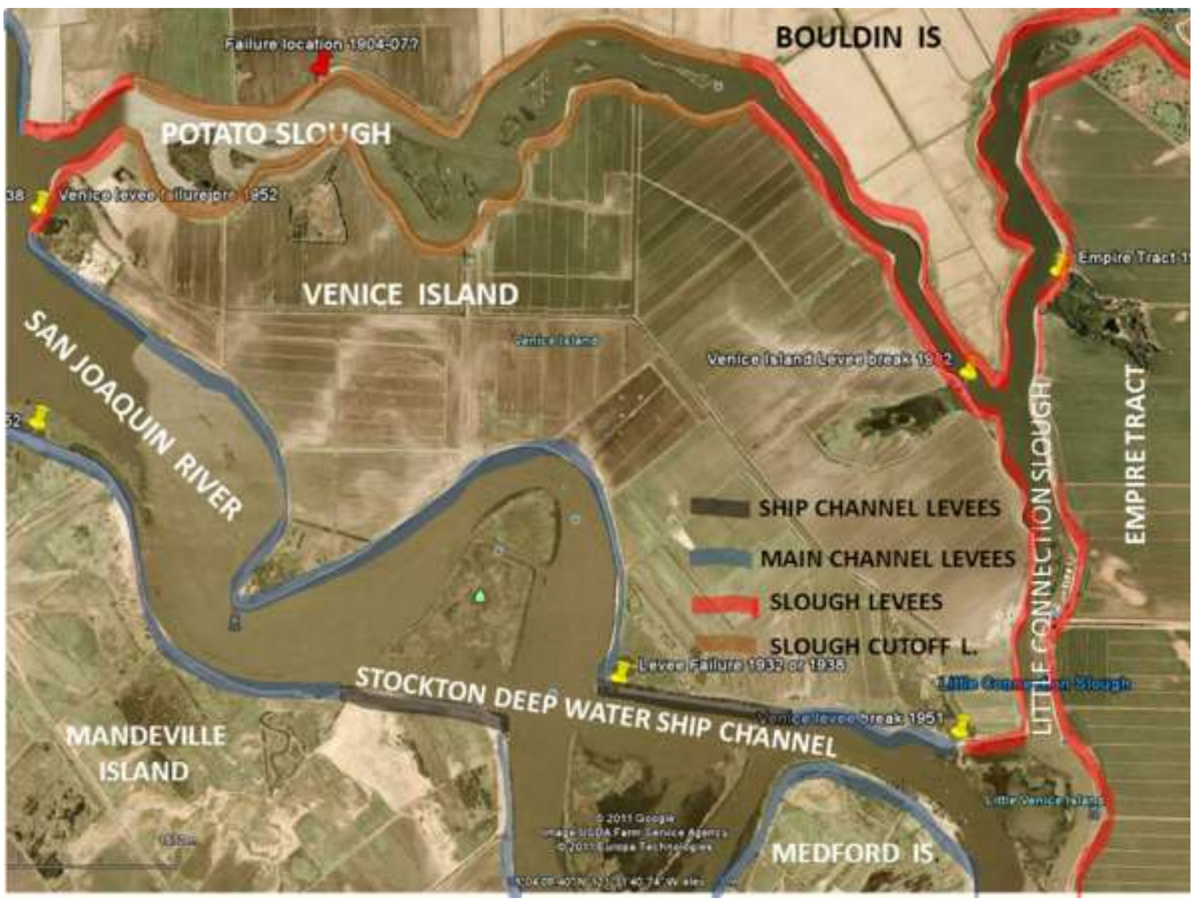


Figure 3.7 - Google Earth Image of Venice Island Marked to Show the Different Types of Levees Alignments Involved in Reclamation of the Delta

bends and leaving behind the mid-channel marsh islands. The dredges building the meander cut-off would find differing materials; such as river channel deposits at the cutbanks, more organic materials, and peat foundations between the bends. The soils materials contacted and used for a meander cutoff levee along a slough, such as the one shown in Figure 3.7 along Potato Slough on both Bouldin and Venice Island sides may have possessed even greater variation than a typical main channel cutoff variety.

Figure 3.8 – Google Earth Image Showing Grant Line Canal and Levees on the South Side of Union Island, one of the Cross-Marsh Levees Built in the Delta by Clamshell Dredges.

The final alignment used by the levee builders went along property lines, which generally required the dredgers to cut across the marshland, building clay-peat soil levees on clay-peat soil foundations, depending on peat thickness at the location. Figure 3.8 shows the Grant-Line/Fabian and Bell Canal, the classic property-line, cross-marsh levees. The alignment dates to a Mexican land grant boundary. By the 1870s, the owner of present day Union Island, George Roberts could not reach agreement on levee protection with his neighbor to the south of the old Mexican land grant line. Roberts built a levee on the "grant line" which formed his south property line, working the dredger across the marsh, floating in, digging the canal in front of them, and creating the Grant Line Canal in the process. As shown in Figure 3.8, the owner of Fabian Tract to the south later built his levee across the marsh immediately south of the property line and of the Grant Line Canal to protect the north side of the Fabian Tract. A thin band of marsh was left between these borrow pits/canals, either to provide spoil material for future levee repairs or to avoid trespass claims. Straight, parallel canal pairs became rather common alignments in the Delta.

Figure 3.9 summarizes identification of the levee types in the Central Delta by reverse engineering the Delta levees known to exist today, identifying what was there initially, and recognizing the technology at the disposal of the levee builders. The record indicates few variations in the techniques used by the levee builders after the development of the clamshell dredge and the type of alignment represents an identifiable "design" factor. The exceptions to building the levees exclusively from immediately adjacent dredge material included the method used to develop Union Island of first constructing parallel peat walls, which the builder then covered with hydraulically dredged deposits (Thompson 1957). Some of the USACE levees built for the Stockton Deep Water Ship Channel shown in Figure 3.7 and marked on Figure 3.9 (Hardeman 1986) were also exceptions in that the USACE and Port of Stockton built these essentially cross-marsh levees in the 1930s by first excavating the

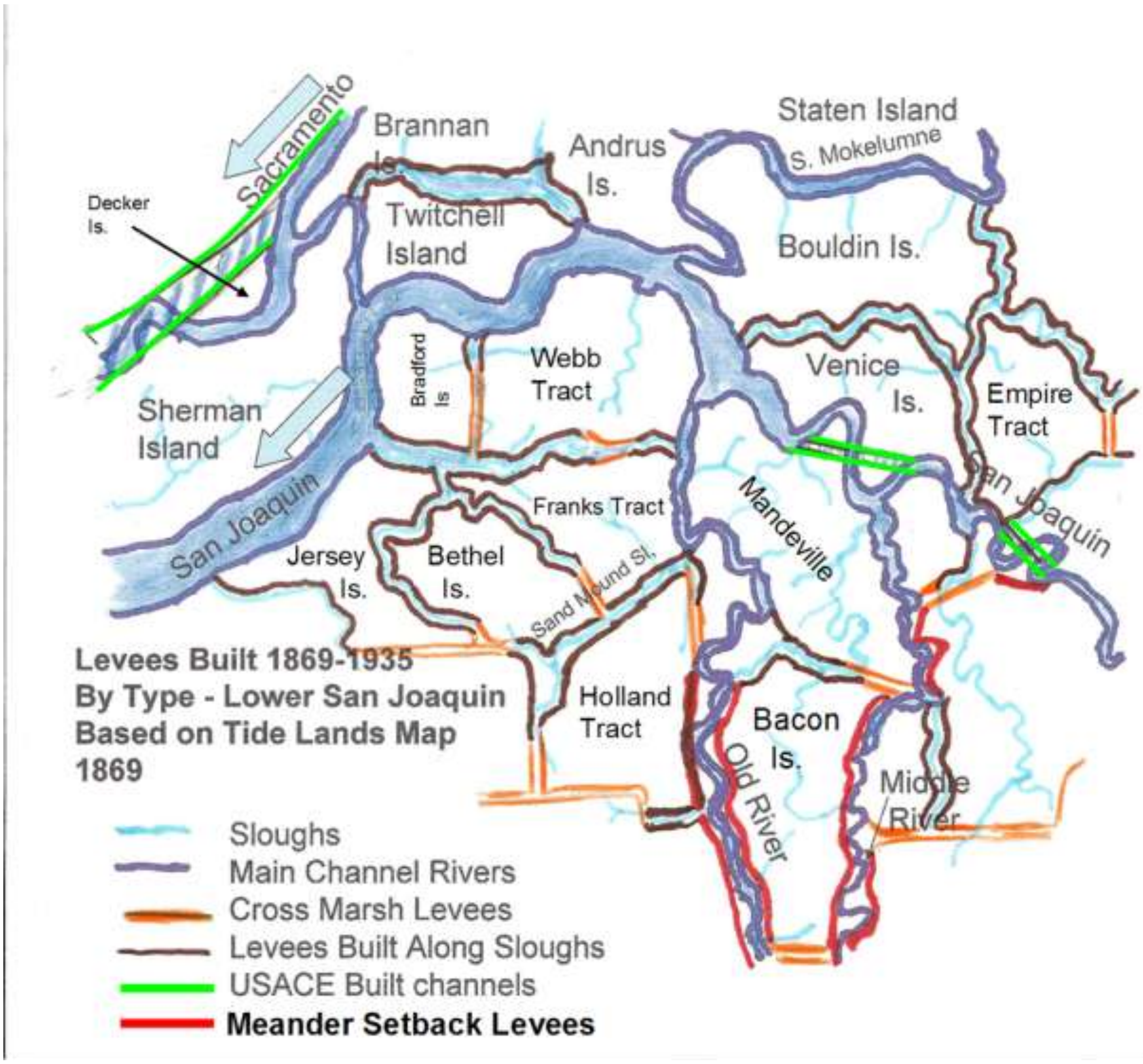


Figure 3.9 – Levees Built 1869-1935, By Type – Lower San Joaquin, Based on Tide Land Map (1869)

organic soils at the base of the levee foundation and replacing them with granular material dredged from the river. They completed the levee with dredged material from the new channel (Hardeman 1986).

SUBSIDENCE OF PEAT ISLANDS

By 1922, reclamation district levees ringed the Delta marsh and converted most of it to farmland. Most agricultural crops do not tolerate saturated soil conditions so farmers had to clear the new land, usually by burning, and drain it. The organic soil material of the former tule marsh, sub-aerial for the first time, oxidized rapidly. Whereas the marsh plants were gone, ending the creation of replacement organic materials, the gradual consolidation, and compression from gravitational loading of the underlying materials continued. Winds eroded the fine oxidized particles and the subsidence of the Delta farmlands commenced, a process that continues to this day and now leaves the islands “bowls” with centers as much as 8 meters below sea level. Today the average elevation in the reclaimed Delta stands about 5 meters below sea level. This subsidence process, first measured by Weir (1950) on Mildred Island, occurs at a rate of 3-6 cm per year and has irreversibly changed the geomorphology of the Delta. Approximately 2.5 billion cubic meters of the peaty soils (Mount and Twiss 2004), that constituted the fresh water marsh of the Delta and developed purely from tules and related vegetation, has oxidized, consolidated, or blown away. Wide spread abandonment of Delta levees would see eventual filling of these holes with water so deep that, as Reed (2002) points out, the fresh water plants that built the marsh cannot grow. If subsidence stopped today, it would take over 500 years to make up for these loses if all the sediment delivered to the Delta deposited on the islands. Whereas the subsidence rate has slowed, the process continues under current farming practices. Approximately 20% of the

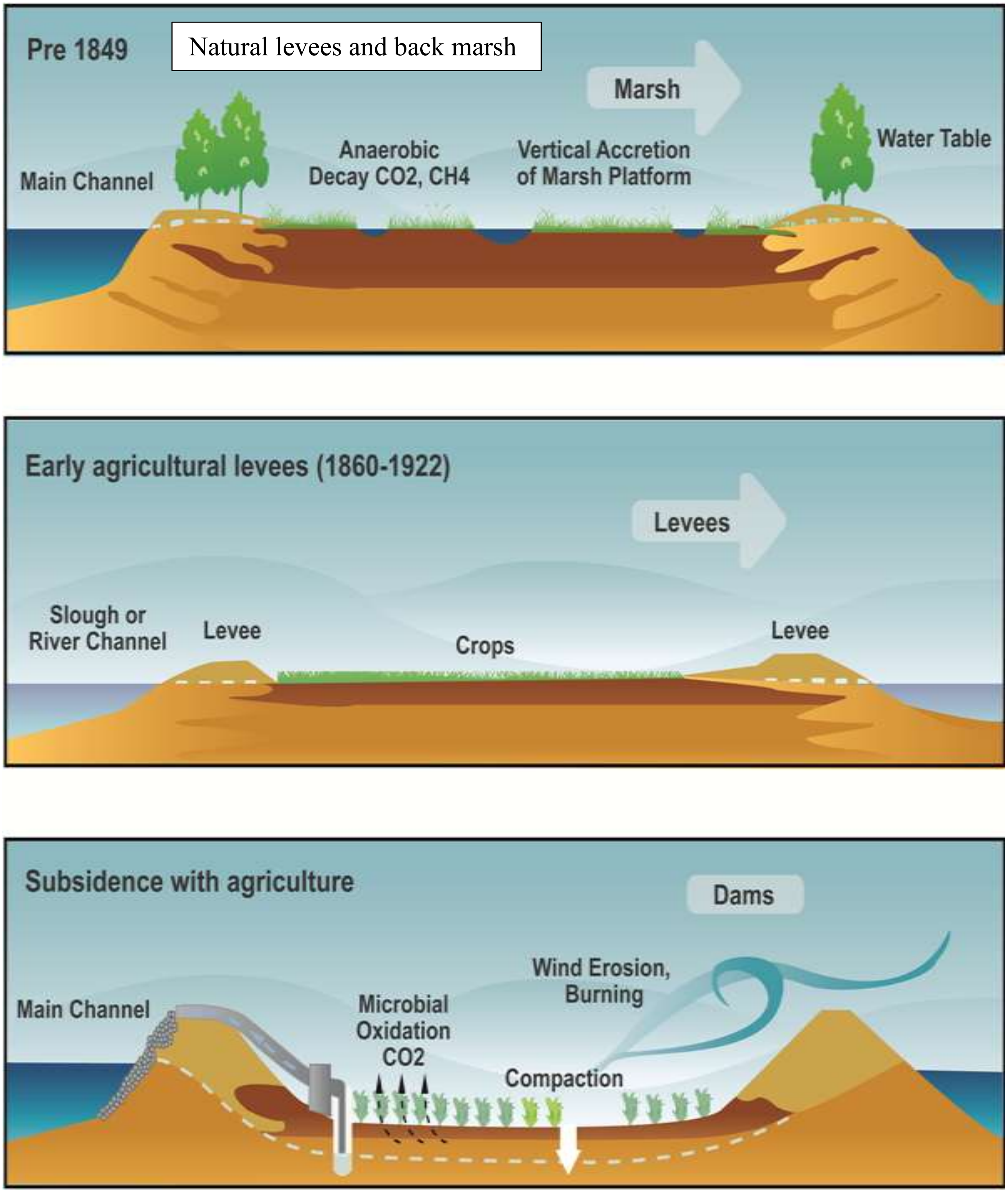


Figure 3.10 – Cartoon Showing the Steps in Land Reclamation and Peat Soil Subsidence in the Delta, that Saw the Marsh Progress to Islands Protected by “Dams” adapted from URS (2007, 39).

sediment delivered to the Delta remains in and along the Delta channels or deposits in the Clifton Court Forebay, the new sub-delta of the Sacramento and San Joaquin. Figure 3.10 shows the stages in this subsidence process.

THE USACE AND FLOOD CONTROL LEVEES

O'Neill (1998; 2006), Kelley (1989), and James and Singer (2008) detail the story of how the debris from hydraulic mining accentuated flooding in the Sacramento Valley and culminated in the devastating flood of March 1907. This flood overtopped most of the levees in the Delta and destroyed most towns and levees north of Sacramento. The flood reached a peak flow rate into Suisun Bay of over 20,880 cubic meters per second, a rate twice what state and federal engineers had estimated to be the absolute maximum possible flood and the one used to define the design basis for the flood control plan the state had proposed in 1906. The 1909 flood would nearly duplicate the 1907 levels, events that finally helped overcome the resistance of the collection of individual reclamation districts, who in the words of the state engineer, were content to continue to protect their properties by waging "a struggle or war, in which the biggest and strongest levee would certainly be the winner" (O'Neill 2006, 115). Some levee owners considered sabotage of others' levees during times of high water. The release of floodwater onto one island would always lower water levels everywhere else in the system.

The reclamation districts all up and down the Central Valley would join the state and similar groups in the Mississippi River valley to press Congress to get the U.S. Army Corps of Engineers (USACE) to help improve flood protection on the Sacramento and the Mississippi Rivers (O'Neill 2006). Prior to 1917, the USACE had resisted working on flood control issues; however, Californians were able to convince Congress that the federal government had greatly benefitted from the hydraulically mined gold and, therefore, should help fix the problems it had created. Congress first created a state – federal agency, the California Debris Commission in 1893 to regulate the debris dams required of mines to keep the tailing out of the river system. Congress would house the federal part of this early federal-state joint agency with the USACE. The Debris Commission would eventually propose a flood control plan for the Sacramento that fortunately deviated from the "levees only" policy the USACE so stubbornly held to on the Mississippi (Davis 2000; Gomez 2000; Kelman 2000; Pubis 2000; Shallat 2000; Colten 2005). The final proposal included a system that would be composed of levees, flood control dams, and flood bypasses. The USACE commenced executing this plan in 1913, officially completed it in the 1960s and it protects the Sacramento Valley today.

As noted above, the USACE, so deeply involved today in the levees and flood control structure of the Delta and the rest of the Central Valley, had long resisted this role, preferring to limit civilian activities to maintaining the navigable waterways of the U.S. The USACE got into the new role slowly, initially starting the part of the total flood control project that involved straightening and widening the Sacramento between Cache Slough where the Yolo Basin re-enters the main river and Suisun Bay. This allowed the USACE to ease into the new role of responsibility for flood control on a project that also helped improve navigation. Congress fully authorized the involvement of the USACE in 1917 with flood control projects in the Sacramento and Mississippi River basins only. Congress would not expand USACE involvement in flood control on the rest of the rest of the rivers of the nation until 1928 (Kelley 1989). From 1917 to the early 1950s, the USACE, with the assistance of the local Reclamation district would re-build about 15% of the Delta levee to provide improved

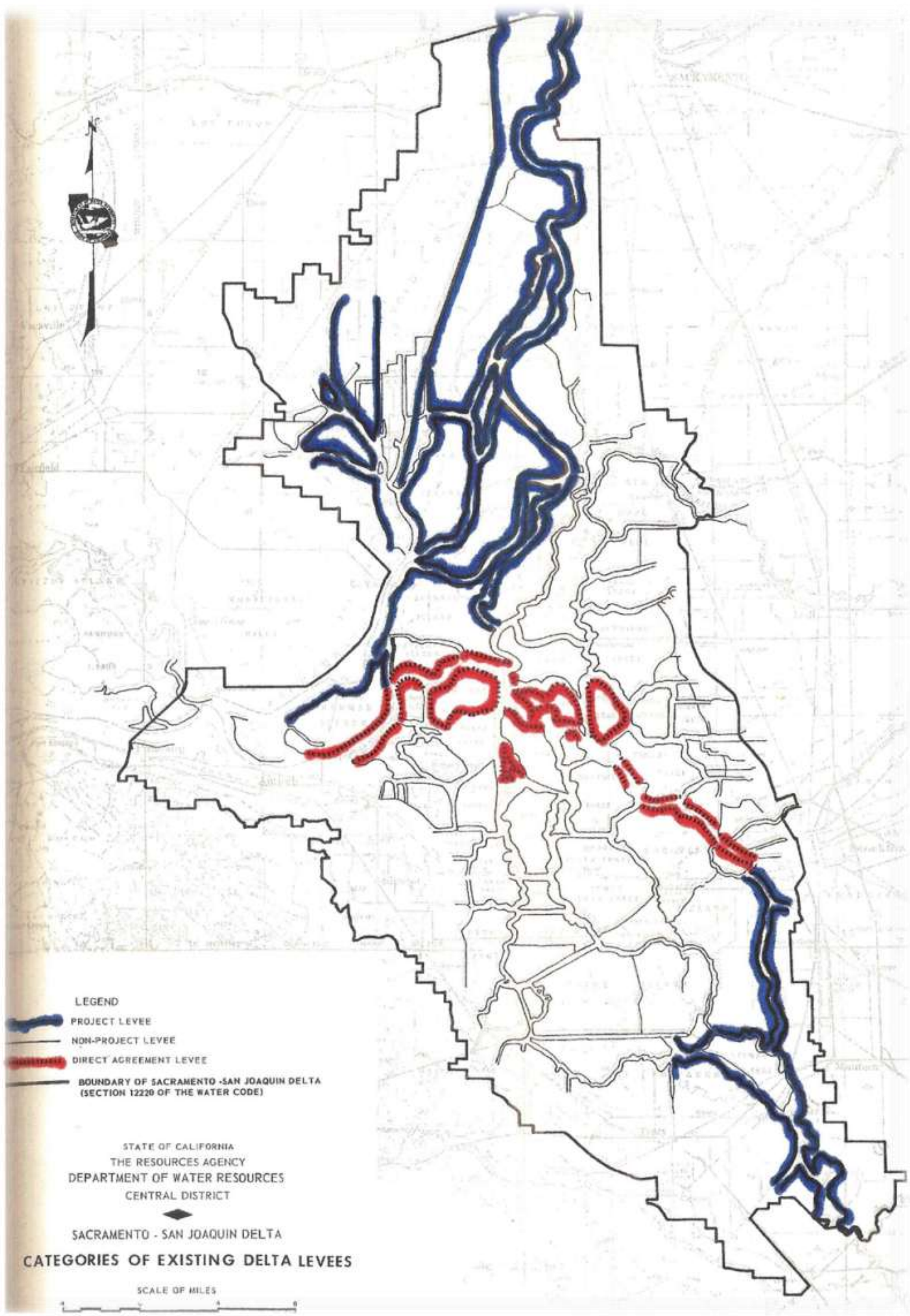


Figure 3.11 – Project, Direct Agreement, and Non-Project Levees in the Legal Delta

flood control for much of the Central Valley. These so called "Project" levees extended along the main Sacramento to its confluence with the San Joaquin along with Steamboat, Georgiana, Cache, and Three-Mile sloughs as shown in Figure 3.11 and established an approximate 100-year flood standard. When completed, the USACE turned the levees over to the State of California who assumed the liability for them. The state then turned the levees back to the local reclamation districts who continued financial responsibility to maintain the levees under their own taxing and borrowing authority, as they had before the USACE rebuilt and strengthened the levees. After damage from flooding on the San Joaquin River in water year 1951, the Central Valley congressional delegation would successfully pressure the USACE to rebuild the levees in and around Stockton and south along the San Joaquin (Interview 124-2009).

Under the 1936 Flood Control Act, federal flood control projects required the states and locals to a) provide the rights of way; b) "hold and save harmless the United States free from damages due to the constructed works; and c) maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army" (Nolan 1984, 538). The so-called "Project" levees are generally assumed to meet the 100-year return flood design standard and are among the strongest in the watershed. Most of the mileage of the Project levees extends outside the Delta, up the Sacramento-Feather to Oroville and Hamilton City and down the San Joaquin to near Fresno. In total, the USACE reworked about 15% of the levees in the Delta as part of the flood control project (Robie 1975).

Several railroad embankments were built to carry the tracks across the Delta, most notably the Santa Fe (now BNSF), constructed in 1899 (Thompson 1957; *San Francisco Call* 1899). This embankment separated the two Jones Tracts and played a significant role in flooding on those island/tracts. Railroad engineers copied the method of constructing the embankments across the marsh from the local levee builders (*San Francisco Call* 1899) and therefore the many of these railroad embankments were constructed as levees and function as levees at times.

The USACE also completed the Stockton Deep-Water Ship Channel between 1923 and 1933 (Hardeman 1986), which involved building and reinforcing levees along the San Joaquin between Antioch and Stockton, as part of their more traditional role of expanding and maintaining navigable waterways. The project deepened the 75-mile waterway to a 39 foot depth and cut off some of the meanders that made the old route torturous (Hardeman 1986). Many of these meander cutoff levees do not directly protect reclaimed land because most of the pieces cut off were too small to justify reclamation. Therefore, they remain as "tule berms" or pieces of semi-natural marsh. In 1963, the USACE completed a 9-meter deep ship channel to West Sacramento. Unlike the Stockton Deep Water Channel that followed the San Joaquin area, the USACE dug a new channel for the Sacramento Ship Channel, starting at Cache Creek where the Yolo Basin reconnects with the Sacramento River. The channel runs on the east side of the Yolo Bypass and spoils from the channel reinforced the confining levees of the Bypass. After construction, the Ports of Stockton and Sacramento assumed responsibility for the levees from the USACE on the ship channel and turned responsibility for them to local reclamation districts. By official terminology, they are named called "Direct Agreement" levees, and they constitute about 10% of the total levees in the Delta.

DELTA LEVEES: STANDARDS

Millions of U.S. residents live, work, farm, go to school, and/or play in places protected from flooding by an estimated 100,000 miles of "levees," including the 14,000 miles in the USACE levee safety program initiated in 2006 (http://www.usace.army.mil /LEVEESAFETY/ACTIVITIES/Pages/act_nldb.aspx, last accessed 12 August 2011). One potential reason why the public, the politicians, the managers and even the engineers and scientists seem to have little grasp of the problems posed by the current flood protection systems, especially those in the Delta, may be rooted in the inconsistent use of the terms that define the components of those systems, by politicians and the general public. The word "levee" is used in general parlance and in government and industry design standards to describe at least three different functional "structures" separating land and water. For example, the USACE who engineered of 25% of the Delta levees and are responsible for 14,000 mile nationwide, provides on the website of the Coastal and Hydraulic Engineering Section, the following definitions for a "levee": "1) an embankment constructed to provide flood protection from seasonal high water; 2) a dike or embankment to protect land from inundation; 3) a ridge or EMBANKMENT of sand and silt, built up by a stream on its flood plain along both banks of its channel; and 4) a large DIKE or artificial EMBANKMENT, often having an access road along the top, which is designed as part of a system to protect land from floods" (upper and lower case usage per original) (USACE, not dated). The third definition clearly fits the natural levees. Artificial levees built for reclamation and flood control purposes fit in first and fourth definitions for those designed to protect only against seasonal flooding, whereas the second definition is not so specific. With respect to the human-built levees, the USACE does not distinguish between the dominant geomorphological forces involved (waves, tides, or fluvial) or whether the protection provided against inundation is constant or only under extreme flood conditions. Terminology does not even permit distinguishing between natural and human-built structures.

This lack of precision lumps the levees in the Delta pool that restrain water in the channel constantly, with those upstream along the San Joaquin with both sides dry except during the occasional flood, under the same name – a levee. When one looks at the detail of the USACE engineering standards, however, distinctions are apparent. The USACE standard EM-1110-2-1913, Design and Construction of Levees (USACE 2000), describes in the "Introduction" that "(1) The term levee as used herein is defined as an embankment whose primary purpose is to furnish flood protection from seasonal high water and which is, therefore, subject to water loading for periods of only a few days or weeks a year. Embankments that are subject to hydraulic loading for prolonged periods (longer than normal flood protection requirements) or permanently, should be designed in accordance with earth dam criteria rather than the levee criteria given herein." Still, the only place where the USACE standards for the I-floodwall levee design that also had to hold back water permanently but failed so tragically in New Orleans is defined is on page 8-14 of the levee standard (USACE 2000). Whereas few, if any, of the levees in Legal Delta primary zone, whether built by the local reclamation districts or the USACE, meet the USACE definition of a "levee," none were designed as "earth dams" per USACE EM-1110-2-2300 (USACE 1994).

The primary differences between what I call the "levee-dams" that hold back water constantly and standard flood control levees, standing high and dry most of the time meeting the standard of EM 1100-2-1913 are that levee dams require "spillway structures" so the structure is not eroded away when overtopped, and they must meet standards for seepage control. No spillways exist in the Delta levee system and what has evolved is a separate, Delta-Specific, less formalized set of engineering standards that have been developed by the USACE, FEMA and DWR exclusively for the Delta levees and applied to levee-dams and flood control levees without differentiation. Cross-sectional geometry requirements represent the primary features of the Delta standards, which gain support from the reclamation districts because those levees not meeting the particular standards are not eligible for federal flood insurance programs and /or post-flood assistance.

Figure 3.12 shows the current levee standards, in reality largely geometry standards, developed in the 1980s after several costly failures of Delta levees. The standards were first initiated by the Federal Emergency Management Agency (FEMA) which had concerns that the lack of standards would lead to repetitive claims against the Federal Flood Insurance Program by properties with clearly substandard protection, and no incentive to improve protection. Working with DWR, FEMA issued the short-term Hazard Mitigation Plan (HMP) standard, which became the minimum standard for work supported by the DWR subventions program after the 1986 floods. FEMA established the requirement that after September 11, 1991, that they would only honor emergency relief claims on properties protected by levees certified meeting the HMP standard (Betchart 2008). The HMP standard was considered a temporary minimum standard with 30.5 cm (one foot) of freeboard required over the 100 year flood and minimum with 3 to 2 slopes on the water side and 2 to 1 on the island side. It also required a minimum crest width of 4.88 meters with an all-weather road on the top to facilitate inspection and repair, a requirement apparently not emphasized

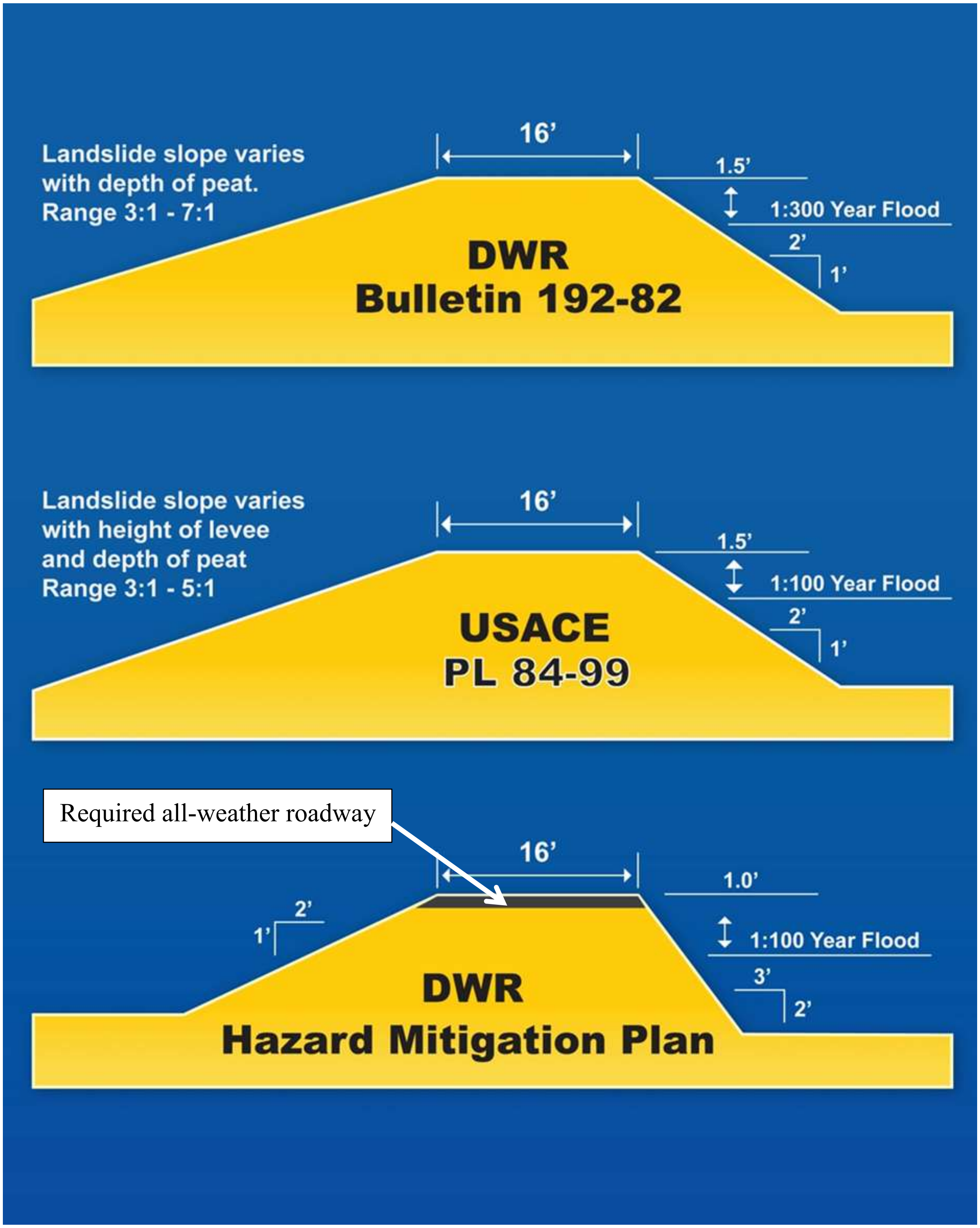


Figure 3.12 – Current Delta Specific Levee Standards for Agricultural Areas

initially by DWR documents. The standard also includes requirements that internal surveys be made for weaknesses in the levee, that any piping or other conduits through the levee be inspected, and vegetation controlled to facilitate inspection (DPC 1994, 20). In September 1990, a year before the deadline, DWR inspected the districts participating in the Subvention Program and declared 22 out of 47 of them 100% HMP compliant. Nearer the deadline, a joint FEMA-California Office of Emergency Management (OEM) team inspected 52 island/tracts and found only Rindge Tract, Tyler Island, Stark Tract, and Glanville Tract to have met all requirements. The list of islands not inspected included Little Mandeville, which subsequently suffered a levee failure and has not been reclaimed (Norris 1996). Many that did not pass met the geometry requirements but apparently lacked an all-weather road. A follow up DWR inspection in 1995 suggested that 31 islands had achieved the standard. Discussions with several Delta experts, interviewed for this dissertation, suggest that many islands and tracts still have not achieved this minimal standard (Interviews 112-2009 and 124-2009) but all are working toward it. Betchart (2008) suggests many of the non-compliant islands/tracts are too small and/or poor to raise the 25% reclamation district cost share under the subvention program to complete the work to meet this standard everywhere in the Delta.

The next more stringent levee standard is the PL84-99, the response of the USACE to the Public Law 84-99 requirement to establish a standard. This standard represents the minimum requirements for the federal flood control project levees (Project levees) although most were built before this standard was established. After the 1997 floods on the San Joaquin broke several USACE levees, the USACE rebuilt them to this standard. It requires a foot and a half freeboard above the 100-year flood, and requires a slope of less than 2 to 1 on the waterside and as gradual as to 7 to 1 on the island side, slope depending on peat content and other soil conditions.

After 1987, non-Project levees certified by the USACE to meet the PL84-99 standard became eligible for 75% federal reimbursement for rehabilitation in the event of failure. In 1995, the USACE Sacramento District office viewed Holland and Byron Tracts as the only two non-Project levee surrounded islands to have achieved the PL84-99 standard at that time (Norris 1996).

In most regards, the DWR 192-82 standard, issued in 1982 represents the most stringent of the current standards for agricultural levees. Nevertheless, compliance has no real legal or financial incentives built in, notwithstanding that from the standpoint of DWR, the HMP standard represents only an interim step in achieving the 192-82 requirements. In agricultural areas, 0.522 meter (one and a half feet) of freeboard above the 300 year reoccurrence flood level is required by 192-82; it maintains the same maximum waterside slope of 2 to 1 as PL84-99, however, the land slopes are expected to range from 3:1 to 7:1, depending on levee height and soil conditions. By 1995, only Webb, Twitchell, Bacon, and Bouldin had achieved or were near achieving the 192-82 standard (Norris 1996) and they were all part of the long delayed Delta Wetlands project described by Mitchell (1993). Webb and Holland Tracts had achieved the standard but subsequent subsidence of the peat foundations dropped them back out of compliance. It is likely that PG&E has helped McDonald Island make the necessary investments to achieve the standard so it could protect its natural gas storage facility since 1995. Most of the other islands still aspire to this standard.

Many of the islands/tracts, particularly those with full or partial enclosure by "Project" levees have obtained FEMA 100 year flood certification for urban use. This means that residents can obtain federally subsidized flood insurance for their homes (Ludy 2009). Whereas this standard requires 91.44 cm (three feet) of freeboard against the 100-year flood, its landside slope requirement only stipulates that an engineer confirm the stability of the levees. FEMA grandfathered as meeting this standard many of the USACE project levees, such as those on Grand Island, Pierson District, Hastings Tract, and urbanized areas like Discovery Bay and Walnut Grove. In 2008, however, FEMA de-certified the grandfathered levees pending re-certification of the levee by a competent engineer (Booth 2008), to the consternation of the residents on the islands.

Betchart (2008) introduced to Delta Vision the concept of a wetlands levee standard for areas like some of the islands in the Suisun Marsh and other areas such as Little Franks; an agriculture and infrastructure standard probably similar to PL84-99; a new urban levee for standard new developments with a 200 year-flood standard; and a standard for the legacy urban areas like Walnut Grove. He also projected the potential need for earthquake resistant and earthquake repairable standards at least for the last three land uses, if the regulators agree on the need for earthquake standards.

None of the published Delta-specific levee standards differentiate requirements based on the normal water level; only 100-year flood levels. Therefore, we still have no difference in the standards in the Delta for what I call "levee-dams" and what I would prefer to call "flood-control or protection levees." Whereas everyone involved would enjoy the limitations on seepage that the "Dam" standard would require (USACE 1994), the fact remains that the Delta levees were constructed out of porous sands, gravels and peats, whatever was available to the bucket of the clamshell. They were built on foundations of similar materials. The reality is that these structures function as levee-dams only with large inputs of labor and expertise to manage the constant and often excessive seepage. This approach has enjoyed relative success in an agricultural Delta.

Delta levees are primarily soil and rock embankments which can fail because of 1) overtopping, 2) erosion (top or of either side), 3) excessive seepage through the levee or its foundation where the fluid velocity exceeds the threshold required to initiate erosion of the material in the levee, causing internal erosion called “piping,” or 4) structural failure. In Delta levees, the USACE holds that most common structural failure takes the form of a horizontal displacement of part of the levee along a surface of inadequate resistance to sliding, such as happened in Wilnes in the Netherlands in 2003 shown in Figure 3.13 (Duncan and Houston 1983; Interview 126-2009, Van Baars 2008). (Note that the picture of a horizontal displacement failure comes from the Netherlands, not from the Delta, because the USACE have never truly proven this type of failure in the Delta. The Vilnes failure took place on a secondary levee, the primary levee held, so that after the failure, pressures quickly equalized and the flow did not last long enough to erode away the plug and start lateral erosion. In the Delta, few such secondary levees exist and the virtually unlimited supply of water attacks and exploits any failure, eroding away the displaced soil, leaving no evidence of the cause.)

Voids (created by rodents, humans, rotting tree trunks, etc. in the levee section can contribute to each of the failure modes. The Tyler Island Reclamation District was one of the first to conduct an internal inspection of their levees, discovering buried pottery, abandoned irrigation water conveyances (including a wooden box channel and pipes of all

Figure 3.13 - Levee failure at Vilnes NL 2004 (van Baars 2008)

types), and in one strange case, a hand-dug cave in the levee (Cavanaugh and Stefani 1984). The purpose and excavators of the cave remain unknown but it was large enough to stand in (Mello 2008). Other mammals represent a more common threat; every levee engineer in the Delta has his or her favorite beaver-den-in-a-levee picture, and many of the pictures of water pouring through a levee break may mark the location of a former rodent burrow.

Whereas different only in velocity, the erosive flow involved in "piping" is not to be confused with normal seepage of water (non-sediment bearing) through the porous levee material lenses. The Delta levees hold back freshwater and the islands siphon or pump in large amounts of irrigation water over the levees routinely; seepage without damage to the levees is manageable. Seepage generally does deteriorate into “piping” and, thus, requires monitoring and in most cases, controls and repair.

EXISTING STUDIES OF DELTA LEVEE FAILURES

As the early Delta farmers built and watched the levees fail, few outside the island that flooded noticed the levee failure. Those who abandoned Sherman, Twitchell, and Bouldin for many years in the late 19th and early 20th centuries and even Franks Tract in 1938 absorbed the tremendous financial losses. Thompson in 1957 detailed the various levee failures and overtopping but did not attempt to analyze them or even catalog them; they were merely part of the human settlement of the region. Efforts to get federal help in flood fighting and recovery came slowly for people in the Delta and in other flood prone areas of the country. The Army sent a small crew to help try to save the levee on Webb and Bradford Tract during the high tides of June 1950. The first case I have uncovered of significant help for non-Project levee failures came at the insistence of Congressman John Baldwin of Rio Vista who pressured the USACE to help repair Thor Kofod’s levees at Quimby Island after they were destroyed around Christmas of 1955 (Delta Herald 1956). The Quimby Island levees remain Special Agreement levees to this day, a tribute to the importance of the friendship of a congressional representative with a key role on the House Subcommittee on Flood Control that controlled the USACE budget. Not until the damage caused by Hurricane Betsy on the Gulf Coast in 1965 made national television news did federal flood insurance gain support to help fill the void of a virtually non-existent private insurance for flooding (Colten 2009, 41: FEMA 2002).

By 1969, the levees, Project, Special Agreement, and Non-Project, as will be developed in the next chapter, were assuming a larger role in the California water supply system, justifying more state and USACE involvement in providing increasingly expensive help to recover from Delta levee failures.

Under contract to the USACE, Duncan and Houston (Houston, Duncan and the USACE 1978; Duncan and Houston 1983) attempted to assess what society could expect out of these unusual levees of the Delta. They determined that data were insufficient to develop theoretic models of the levees, so they elected to employ an "empirical approach to estimating probabilities of failure…" (Duncan and Houston 1983, 268). They first developed a list of levee failures on the 44 major agricultural islands/tracts from 1950 to 1976 so they could compensate for the uncertainties of their assumptions "through adjustment of the results to fit the history of failures" (Duncan and Houston 1983, 268).

A primary assumption Duncan and Houston made was that rates of levee failures on an island/tract basis depended on the original thickness of peat soil. Using the 26-year history of failures they constructed, Duncan and Houston found a strong correlation empirically, identifying that an island that started with 13.7 meters (35 feet) of peat was almost eight times more likely to suffer a levee failure than an island identified as having originally less than 4.6 meters (15 feet). They assumed that a rate of 7.6 cm (3 inches) per year of subsidence would continue everywhere to project into the future and they established four classes of peat thickness (0-15'; 15'-25'; 25'-35'; over 35'). Perhaps because the USACE was involved in the original research (Houston *et al.*, 1978), they assigned a probability near zero that a "Project" levee would fail, regardless the thickness of island peat. On islands like Tyler with Project and Non-levees, the authors assigned the Project levees a length of 0.0 miles whereas in calculating the risk on Grand Island, totally protected by Project levees, they assigned a 2-mile length to the levees instead of the actual distance of 30 miles. The other islands totally protected by Project levees received the same 2 miles worth of assigned risk. Houston and Duncan did not consider the “failures” of the height-restricted levees that are designed to fail at the McCormack-Williamson tract and the ones in the Yolo By-pass in their analysis. Duncan and Houston (1978) estimated that 28 failures of levees would occur across the group of 44 islands/tracts that they considered the major agricultural islands. Individual island/tract failure probabilities were also developed and published for each of the 44 islands/tracts.

Samuel Logan applied a similar approach (Logan 1989; Logan 1990), based on the 15 levee stability failures he found between 1950 and 1986 on the 46 island/tracts he elected to study. Logan based his estimates of future failure rates also on various peat thickness classifications, this time using the map of peat thickness developed by DWR (1976). He established three peat thickness classifications, those with peak thickness in 1976 averaging between 10’ and 20’, those with less than 10’ of peat, and those with more than 20’ of peat. Logan also highlighted that “much of the process of estimation of levee failure probabilities, no matter how sophisticated or rigorous in appearance, must be judgmental” (1989, 9). Logan deviated slightly from Houston and Duncan in that he did include the McCormack-Williamson Tract failures, a height limited floodway levee, in his analysis.

Logan used his part-judgmental and part calculated analysis to determine that in the event of future levee failures it made the state economic sense to reclaim only 13 of the 46 islands studied. Historically this had been a reclamation district or local farmer decision to reclaim after failure and the Franks family had abandoned Franks Tract in 1938 after the second levee failure in two years; owners had abandoned Sherman, Twitchell, and Bouldin Island for many years after levee failures. With increased subsidence, the size and cost of repairing levee breaches and de-watering had grown tremendously and state and federal emergency funds have become very critical in disaster recovery everywhere, including Delta reclaimed islands.

Logan combined economic analysis with empirical failure analysis to focus on determining which islands/tracts made economic sense to restore after levee failure; in other words, which islands/tracts could produce sufficient economic return before a second levee failure to justify repair, de-watering and restoration after the first (next) levee failure. Logan based his financial calculations on failure probabilities for each island/tract with annual probability of failure ranging from a low at Dead Horse of 0.0024 to a high of 0.0347 at Mandeville Island. He determined the annual probability of one of the 46 islands suffering a levee failure as 0.6169.

Starting in March of 2006, the URS Corporation under contract to DWR to perform the legislature-mandated evaluation, based on information already available, of the risk and consequences of Delta levee failures, the Delta Risk Management Study (DRMS). One of the first steps created a list of all levee failure in the Delta and Suisun Marsh for the previous 106 years, going back arbitrarily to 1900. Figure 3.14 is adapted from one published separately in a poster (Gaddie *et al.*, 2008) to summarize and communicate the results of this analysis. DWR did not authorize URS to do new research, contractually limiting URS to compiling and analyzing existing reports and studies. URS explained in the final report, "We observed that not all the details of historical flood events are recorded or available. It is recommended that failures in the Delta be fully documented in a formal and comprehensive way that covers the necessary details to reconstruct the events and verify them numerically. This documentation will provide increased validity to future modeling" (URS 2009c, 7-29). This lack of detail and completeness in the record they were able to identify did not hinder the preparers of the "Executive Summary" of DRMS from declaring that in spite of 25 years

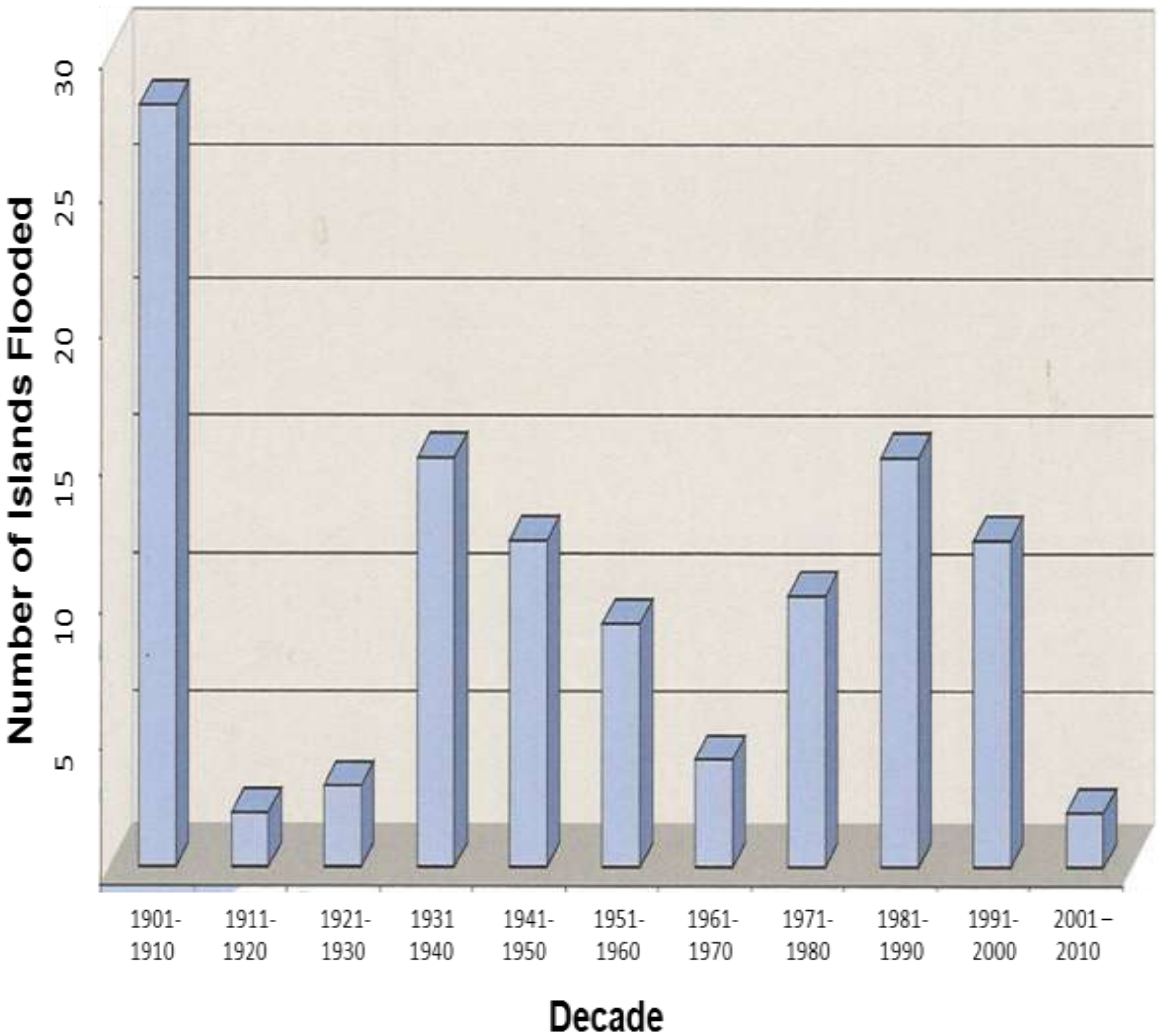


Figure 3.14 – URS Chart of the Number of Delta Islands Flooded by Levee Breach 1900-2008, modified from Gaddie, V., M. Mierzwa, and J. Marr. 2008

of increased state investment in Delta levees, failures continue at an unacceptably high level. To generate a forecast of future levee failures from the two non-earthquake related factors of high water and "Sunny-Day" failures, URS took different approaches. URS researchers created a "Sunny-Day" failure empirical model, taking from the history generated that six such failures had occurred since the first one recorded in 1950 (Webb Tract). They used this to determine that the standard "Sunny-Day" rate of failure would be $1.06x10^{-4}$ per year per levee mile (URS 2008c, 29). Therefore, DRMS forecasts 10 "Sunny-Day" failures in the Delta over the course of the 21st century.

Unlike Houston, Duncan and the USACE (1978) and Logan (1989, 1990), and their own "Sunny Day" failure rate calculation, URS elected to deviate from empirically-based models to forecast failures from high water to a quasi-mechanical model. This model looked at the geometry of typical levee sections based on available data to determine exit gradients across the levees during simulated events of high water. URS also factored meters with an all-weather in peat thickness combined with channel width to establish modifying factors for each of 12 levee classes based on relative resistance to failures. They then relied on expert elicitation of selected Delta levee engineers and scientists to predict the probabilistic relationship of exit gradient to rates of levee failures. The selected experts were invited in and asked to graph, based on their perception, the relationship between exit gradient and probability that the levee would fail for a standard levee section, which they called the "conditional probability of failure function." The model employed an averaged curve of these "expert guesses" to simulate probabilistically failures under exit gradients determined by a Monte Carlo simulation of future water levels at various locations based on historic high Delta inflow events. Actually two "probability of failure functions" were developed, one based on the instructions to the experts to assume no intervention, meaning no human effort to fight flood, and the other assuming the standard flood-fight response.

URS had generated a very detailed model with levee geometries, historic relationships between water level readings during floods, and channel width and peat depth but all resting on the averages perspectives of the levee experts selected to participate. Indicative of the differences in viewpoints of the experts, the standard error of the expert responses was approximately 22% under the no flood-fight regime, with a projected levee water gradient of 1.0 (URS 2009c, Figure 7-71). Indicative of the perceived importance of flood fighting in the Delta, the average expert estimated probability of failure with a gradient of 1.0 falls from 38% to 5% when human intervention was expected.

Section 7 of DRMS (URS 2009c) included a map summarizing the island-by-island forecast of annual probabilities of levee failure (except earthquake related) for the next hundred years. Sherman island, Tyler Island, Venice Island, New Hope Tract, and Sargeant-Barnhardt Tract and most of the Suisun Marsh districts had predicted annual rates of failures of over 7% (84% over the next 25 years); whereas Quimby, Deadhorse, Upper Roberts, Victoria and Coney Islands and several tracts on the edges of the Delta had failure probabilities less than 1% per or 22% cumulative over the 25 years. The total URS estimate came to 140 failures over the 2005 to 2105 period, including the 10 “Sunny-day” failures but not including earthquake related incidents.

SUMMARY

Encouraged by state and federal governments, farmers and developers started to convert the great tule marsh of the Sacramento and San Joaquin River Delta into farms by building levees after 1861. In the first two decades of this effort, the levees were constructed from the land (marsh) side by hand cut and wheel barrowed materials, often blocks of pure peat. Regular flooding, exacerbated by increased silting of the rivers indirectly caused by hydraulic gold mining in the Sierra until 1884, destroyed most of the early hand-built peat levees by around 1882. The Delta might have returned to marsh except for the local development of the clamshell dredge. From about 1879 to 1920, individual districts and developers dredged from the main rivers, some of the many tidal channels, and even worked their way across the open tule marsh on property lines building the 1700 kilometers plus of levee in Delta and established the agricultural islands and tracts of today.

Between 1913 and 1955, the USACE would rework about 25% of these levees to help provide improved flood control for the upstream parts of the Sacramento and San Joaquin River basins and to create deep-water ports in Sacramento and Stockton. About 75% of Delta levees remained the sole work and responsibility of the locally elected reclamation district boards. Most of the levees, those built by the USACE and those built by a local reclamation district, were constructed before the 1930s when modern soils engineering practices were first introduced into the United States. Practical engineering standards have evolved for Delta levees based on what appears to have worked over the years with increasing reliance on engineering principles and judgment. Meanwhile, subsidence of the organic soils now farmed has caused much of the Delta island farmland to sit, 5 meters or more below sea level, placing a constant hydraulic load on most of the Delta levees. Given all the variety and uncertainty of development, scholars have only been able to assess the capability of the Delta levees to continue to perform through empirical models based on histories of levee failures limited by short time frames, limited detail, and collection at the island or tract scale; or with mechanical models forced to rely on expert elicitation to estimate the relationship between forces, form and failure. This dissertation will add detail to the historical record, extend back to the 1860s, and present it at a much finer scale and identify the several social perspectives of Delta levee engineers, scientists, and managers providing expert elicitation.

CHAPTER IV

BACKGROUND: LEVEE DISCOURSES AND GOVERNANCE

OVERVIEW

This chapter provides the necessary background to understand the social perspectives this dissertation analyzes empirically in Chapter VI. This chapter describes the development of an expanded role for the Delta levees beyond wetland reclamation and flood control into a central place in water conveyance for 25 million Californians and 2 million acres of irrigated cropland. Society then began to recognize the damage done to the ecosystem by the exploitation of the soils and waters of the Delta. Thus, new constituencies and discourses about the Delta sprung up, the complexity grew and new governance and governing processes were attempted. These provide the backdrop for the social discourses about Delta levees that this dissertation explores.

Built originally to allow farming in the marsh and to protect the reclaimed land from floods, the role of Delta levees became more complicated after 1940 when they accidently became part of the water delivery system, first to Contra Costa County and then later to the Central Valley Project (CVP) and then the State Water Project (SWP). This chapter provides the background on how that role developed. After the first Earth Day on April 21, 1970, increasingly environmental concerns over the management of Delta levees have been a part of the discourses also. As more groups wanted more from the Delta conflicts developed, sometimes triggering unilateral exercise of power, such as the USACE did in 2007 when it started enforcing long-ignored vegetation-free levee polices which are discussed next. This represents the latest controversy in the Delta and the latest focus of power struggles between the key actors with interests in use of the resources of the Delta (Cowin and McCamman 2010).

The rest of this chapter develops the background on the recent attempts to provide effective governance and governing of the Delta starting with the formation of CALFED, hailed by scholars like Kallis, Kiparsky, and Norgaard (2009, 631) as “the most ambitious experiment in collaborative policy and adaptive management the world has seen to date.” The chapter then provides background on the demise of CALFED and its replacement with the Delta Vision effort and then the Delta Stewardship Council. Some of the attempts to govern, specifically the Delta Risk Management Study (DRMS or “dreams”) and the Bay Delta Conservation Plan (BDCP) are also introduced along with along with some of the elements of the discourses generated in those processes. All along, the element behind most discourses about the Delta and the levees since 1972 has been the desire by some interests to construct an isolated conveyance system to transport export around (the Peripheral Canal) or potentially under (Cross Delta tunnel) the troubled Delta.

DELTA LEVEES BECOME PART OF THE WATER EXPORT SYSTEM

The Sacramento River Flood Control Project encouraged expansion of irrigated agriculture and irrigation water withdrawal upstream of the Delta, which by the 1920s and 1930s, threatened Delta access to fresh water. This competition, coupled with drought, drew salt water deeper into the Delta. Lower flows in the rivers into the Delta meant that during the late summers of several years during the 1920s and 1930s, salty and brackish water often lapped against the levee banks far into the central Delta, rendering irrigation worthless. In March 1922, the State Supreme court denied the claim advanced by the city of Antioch (Jackson and Paterson 1977) that prior use of water established a legal right to “fresh water” before new upstream users could tap the resource. Defeated in the courts, in-Delta water users began looking to engineering solutions to solve the salinity problem. Engineers first advanced the idea of constructing barriers to block seawater from the Golden Gate from entering the Delta during low flows, but eventually the state and federal government would address this problem while solving another problem, the depletion of ground water and resulting subsidence in areas of the Central Valley lacking access to surface water (Jackson and Patterson 1977; Hundley 2001, 239). Dams upstream of the Delta rather than ones downstream would counter the salinity intrusion (Jackson and Patterson 1977).

Much of the fertile land in the Central Valley lacked access to runoff from the streams flowing year round out of the Sierras. By the 1930s, however, agriculturalists had sunk 23,500 wells into a once great aquifer and converted 1,500,000 acres of steppe and desert into a green empire (Reisner 1986, 157). Water levels dropped 100 meters in some wells and experts forecasted that the Central Valley irrigators would mine the entire aquifer dry by 1970 unless surface water became available for irrigation. The Central Valley and State Water Projects have supplied this irrigation water.

California engineers viewed the excess precipitation in the northern part of the state as a solution to the unmet need in the south, so they developed a comprehensive plan to provide surface water for irrigation in the southern Central Valley, as shown on Figure 4.1 and schematically in Figure 4.2. It also included salinity control for the Delta and a new fresh water supply for Antioch and the rest of Contra Costa County. In 1933, the legislature approved the plan, the governor signed it into law, and voters defeated an initiative challenge (Hundley 2001; Jackson and Paterson 1977; Pisani 2002; Reisner 1986). The failure to sell the $170 million bonds in the Depression-racked economy stalled the project, but President

Roosevelt's 1935 executive order directing the Public Works Administration to use un-designated federal budget money got the project going. In Reisner's view (1986, 159) Roosevelt acted to find homes and farmland for a 100,000 farmers displaced by the Dust Bowl. Financially strapped California let the federal government assume full control and funding responsibility for the project with the passage of the River and Harbors Act of 1937 (Jackson and Paterson 1977). The state project, thus, became the Central Valley Project (CVP) of the U.S. Bureau of Reclamation (USBR), which included the large storage of Sacramento River water behind Shasta Dam and the San Joaquin water behind Friant Dam. The Friant Dam allowed the USBR to channel the upper reaches of the San Joaquin into a new artificial river flowing into the Kern River Basin. A canal (Delta-Mendota) with intakes on the south side of the Delta would furnish replacement water for the San Joaquin north of Fresno. Contra Costa County cities and industries would get their new fresh water supply via a canal with an intake also on the southern portion of the Delta at Rock Slough. This put the intakes for the CVP on the Old San Joaquin River upstream of its junction with the much larger and cleaner Sacramento River. Once the lake filled behind the Shasta Dam, the large upstream storage reservoir built by the CVP, the system managers could keep the whole Delta pool fresh by increasing reservoir discharges during periods of low natural flows. This satisfied Delta residents by promising fresh water in the Delta all year. Deliveries on the Contra Costa County supply system out of the Delta started in 1940 and Shasta Dam first closed its gates in 1944.

With 75% to 80% of the water coming into the Delta pool from the north on the Sacramento and all of the exports leaving from southern edge of the pool, the USBR added a short cut from the Sacramento to the San Joaquin when it built the one mile long Cross-Delta

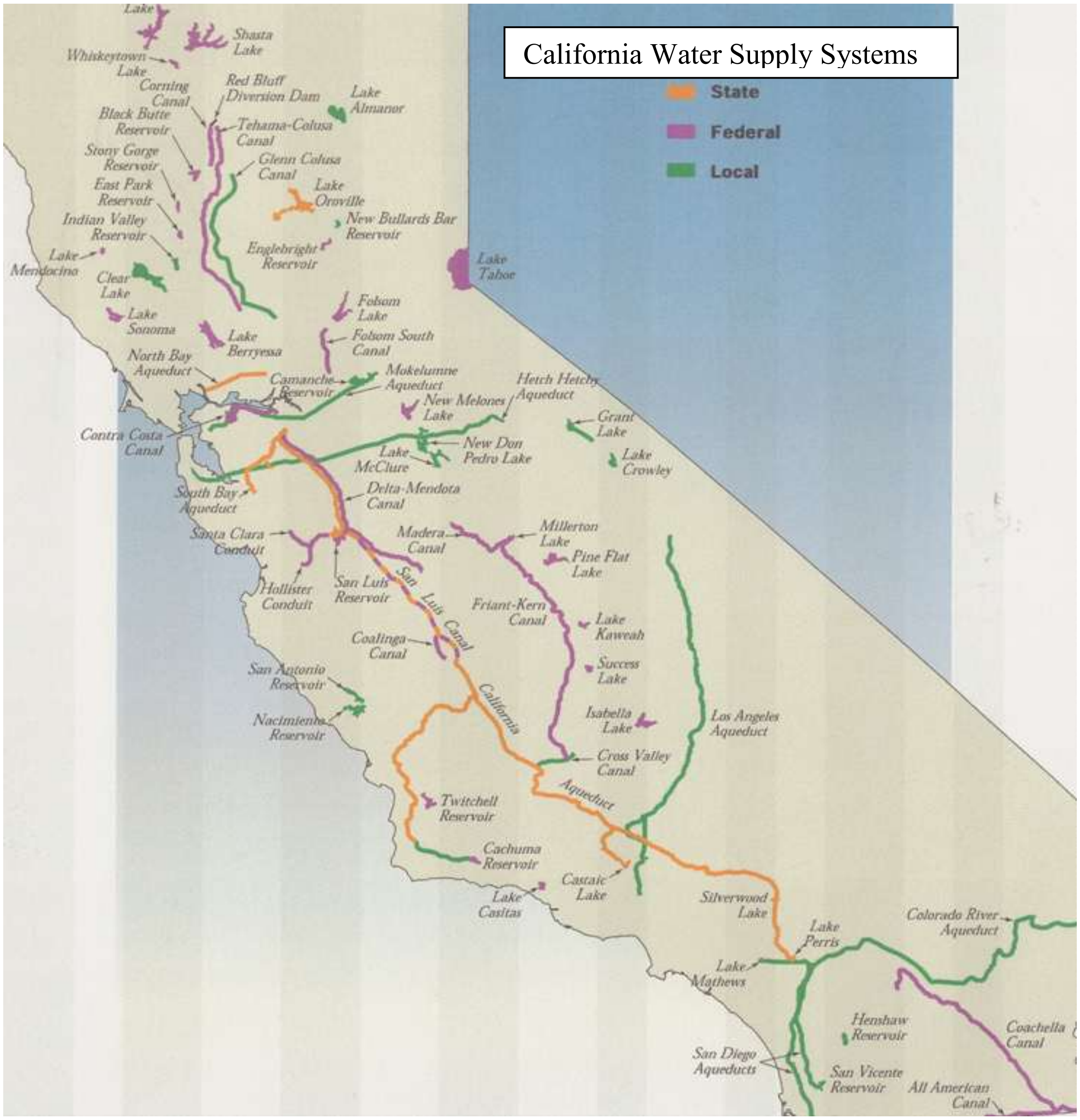


Figure 4.1 – Key Elements of CVP in Purple and SWP in Orange (DWR 1999, ES 3-2).

Channel and Gates at Walnut Grove in 1951. Opening the gates during the summer maximum water delivery times creates an additional flow path for the Sacramento that allows

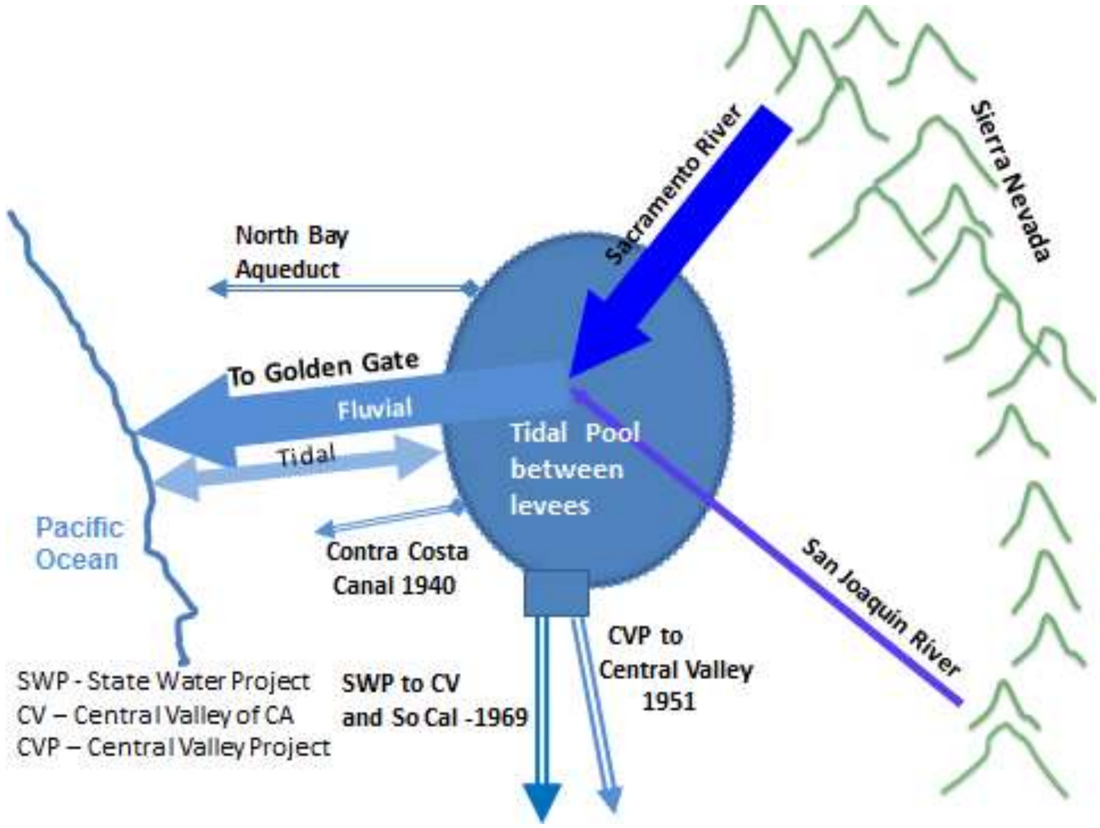


Figure 4.2 - Schematic of Delta as Accidental Hub of California Water Supply

water to move more directly to the intakes "upriver" or "cross pool" on the San Joaquin (Old River). In 1945, buoyed by the success of the CVP, driven by the rapid wartime growth of the California population and economy, and pushed by landowners in the un-served southwest part of the Central Valley, the California legislature created the predecessor to the Department of Water Resources to look into a second water re-distribution scheme of similar scope. Hundley (2001, 277) details the promoters as including some of the largest and most powerful landowners in the state, e.g., the Kern County Land Company; Belridge, Standard (Chevron), Shell, Occidental, Tidewater, and Richfield oil companies; and the Tejon Ranch, itself controlled by the Times Mirror Company that also owned the *Los Angeles Times*

(Hundley 2001, 277). The state plan attracted additional support when the USBR also announced in 1945 plans for a large number of projects for inter-basin water transfer across the West. The thoughts of sending Klamath River water from Oregon to California sounded good but the plan to move American River water to Nevada lacked appeal to Californians. The larger landowners supported a state-owned water project because the USBR could legally only irrigate farms no larger than 160 acres, a requirement that the federal agency did not enforce but remained in the regulations. Southern Californian water interests also feared the USBR plan to send part of the Owens River water to irrigate the Mojave, so they too enthusiastically supported the state role (Hundley 2001, 279). In 1951, the legislature authorized studies of a state water project originating in the Delta. In 1956, a disastrous flood inundated what Hundley (2001, 280) claims was 100,000 square miles of California, including some islands in the Delta, and spurred the legislature to consolidate the 56 state agencies involved in water issues. This created the Department of Water Resources (DWR), which would be large and powerful enough to manage a huge water redistribution project (Hundley 2001).

California voters approved the plan and the $1.75 billion in bonds to finance the project in November 1960, although only 10 (most importantly, Los Angeles) of 58 counties in California approved the measure (Reisner 1986, 367). The Metropolitan Water District (MWD), the giant water supplier to urban areas of southern California, announced support of the plan just days before the vote. The initial reluctance, according to Worster (1985) and Hundley (2001), stemmed from its directors' concerns that access to Sacramento River water would undermine MWD claims to less expensive water from the Colorado River, then under challenge in the U. S. Supreme Court by the state of Arizona. The state project would also provide very expensive water for its customers, water not required by urban customers for many years. Hundley (2001, 284) also suggests MWD had its eyes on an Owens River aqueduct-like project to tap the Eel River in far northwestern California, exclusively for residential and commercial users in the Southland. When environmental opposition to that idea grew, the State Water Project (SWP) looked more attractive than the Eel River.

Governor Edmund “Pat” Brown, the main political driver of the SWP, had understated the cost and/or over contracted water deliveries (Reisner 1986, 364). By the time the money ran out, work on the project came to a halt, and two critical pieces, a system to store and transfer water in from the Eel River watershed, and the so-called Delta facilities, remained unfinished, as they are to this day.

Just weeks after the election victory of the SWP, the fight over the Delta piece started. The SWP needed this piece to facilitate transport of the Sacramento River water around (or through) the Delta to avoid its salty tidal intrusions. The discussion of what the Delta piece should look like started late November 1960, weeks after passage of the State Water Project. Jackson and Paterson (1977, 75-99) outline the original efforts of DWR to consider various options of water barriers, largely variations of the Biemond Plan. None of the barrier plans proved very popular with Delta interests, particularly Contra Costa County looking to use Delta water to drive its own growth. In September 1964, the Interagency Delta Committee, composed of representatives from the DWR, USBR, and USACE would present the project with an alternative. The alternative called for a Peripheral Canal from the Sacramento River south of Sacramento around the Delta to the east and then across the Delta to the pumps on the southwest side of the Delta. This represented a resurrection of an old USBR plan that it scaled back in the late 1940s to the one mile long Delta Cross Channel, a gate controlled connection of the Sacramento between Walnut Grove and Locke to the Mokelumne. The USBR completed this shortcut in 1951. Even though the DWR had representatives on the interagency study group, they formed an internal group of experts not involved in the interagency study to study this issue. The DWR internal study concluded that the interagency report ”does not demonstrate the clear economic advantages of the Peripheral Canal on the basis of tangible benefits, nor does it demonstrate that the greater cost of intangible benefits is justified” (Jackson and Paterson 1977, 97). Demonstrating that more than one social perspective existed then in the hierarchy of the DWR, the Director agreed that tangible benefits were not proven but that intangible benefits justified approval of the concept and DWR moved to proceed with building the Peripheral Canal. The USBR agreed while the USACE remained silent on the project. Moving forward on this jointly funded and operated facility required Congressional approval and state funding. When neither was forthcoming in 1967, California put work on the design of the canal on hold.

By the time DWR-USBR got back to pushing the project again, Californian had elected Reagan governor and the federal National Environmental Protection Act of 1969 had become law. The Sierra Club joined other environmental activists, Contra Costa County, and the Delta water agencies (dominated by the Delta farmers and legacy communities) in objecting to the Canal, while the Environmental Defense Fund sued to require DWR develop an environmental impact statement for the project. Indicative of some of the concerns, an unpublished memo by scientists at the EPA in San Francisco stated that the Peripheral Canal should not be constructed because of environmental issues. It went on to suggest that the Federal government should acquire all 886 islands in the Delta for inclusion in a new national park, showing how opposition to the Peripheral Canal could come from several social perspectives (Jackson and Paterson 1977, 160). The count of 886 islands might be a typographic error or it may reflect a count of the mid-channel islands, mostly tule berms, sand bars, and river bend cut-offs in the Delta, the bits of marsh left surrounded by water by the clamshell dredges reclaiming the larger chunks of peat land.

In October 1971, the pumps built at Clifton Court Forebay on the south edge of the Delta started to feed water to the 80,000 horsepower A. D. Edmonson Pumping Plant south of Bakersfield. This facility boosted the water up over the Tehachapi Range to the L.A. Basin and the project started full operations without the benefit of SWP Delta faculties. This "temporary" operational mode continues 40 years later. The Project, Direct Agreement, and Non-Project levees continued to help deliver water to the largely agricultural interest of the CVP and accidently became part of the water supply system for much of urban southern California. I term the role an accidental one for the levees; farmers developed the levee system to support agriculture years before the idea of water exports from the Delta gained credibility. Since at least 1965, engineers have planned some sort of water conveyance system that would be peripheral to the Delta and its levees, concerned about the Delta levees fulfilling that role (Jackson and Patterson 1977: Hundley 2001; Reisner 1987) but the political leaders have not yet gained full approval and funding and the facilities remain in design phase.

Within a year of the start-up of the water deliveries to Los Angeles, the Delta levees failed in their new role of helping transport quality water to the pumps for the first time when the Direct Agreement levee on the San Joaquin on Brannan-Andrus Island blew out in the middle of the night of June 20-21, 1972. Two state highways flooded and Isleton, the once growing city of 2,200 on the island, evacuated. Figure 4.3 shows the failure location and a flooded Highway 12. The USACE effort to build a cross levee to save the Isleton failed and the town inundated. Previous levee failures had occurred on isolated islands that affected only the few island residents or they occurred during widespread flooding such as the December 25, 1955, failure at Sherman Island. It marked the first time that a levee, working as part of the water conveyance system, failed during low water inflow to the Delta. This triggered the first "Big Gulp," the surge of seawater into the Delta to fill the subsidence created holes that the waters rush to fill when a levee fails. When a levee fails because of high river levels, the so-called "accommodation space" behind the failed levee serves to dampen the flood crest; but in normal and low flow periods, the origin of the water dumping into the space can only be the Golden Gate. The gulp of seawater can throw the entire Delta off specification on salinity as water enters municipal treatment plants and is used for irrigation purposes. At Brannan-Andrus in 1972, with river flow at early summer levels in a dry year, seawater helped provide much of the 17,150 hectare-meters of water that flooded most of Isleton. Six hours after the break, DWR closed the gates at Clifton Court and USBR idled five of the six CVP pumps because of concerns over water quality. The USBR released 24,670 hectare-meters from Shasta Dam and DWR released about half that amount from Oroville to flush salt water out of the Delta. Ten days after the break, the CVP started ramping back up, but DWR and USBR could not restore normal operations on the two water projects until mid- August. The official annual DWR report (DWR 1973a, 42) on the SWP lamented that they could have restored the system to full operation in less than three weeks with the Peripheral Canal in place. Figure 4.4 shows schematically how a Peripheral Canal frees the big water supply systems from dependence on the Delta.

Of course, DWR did not have a Peripheral Canal and the damage to Isleton and the

Figure 4.3 – Photo taken 25 June 1972 of the Brannan-Andrus Island Flood - Picture courtesy of Rio Vista Historical Museum

rest of Brannan-Andrus Island triggered interest in Delta levees far beyond the flooded area. As the USACE was pumping out Brannan-Andrus, DWR issued a report raising the question in its title: “Delta Levees – What is their future?” (DWR 1973b). This report only obliquely acknowledged that Delta levees now served the SWP and CVP while suggesting that California taxpayers should pursue one of three levels of levee improvement. DWR

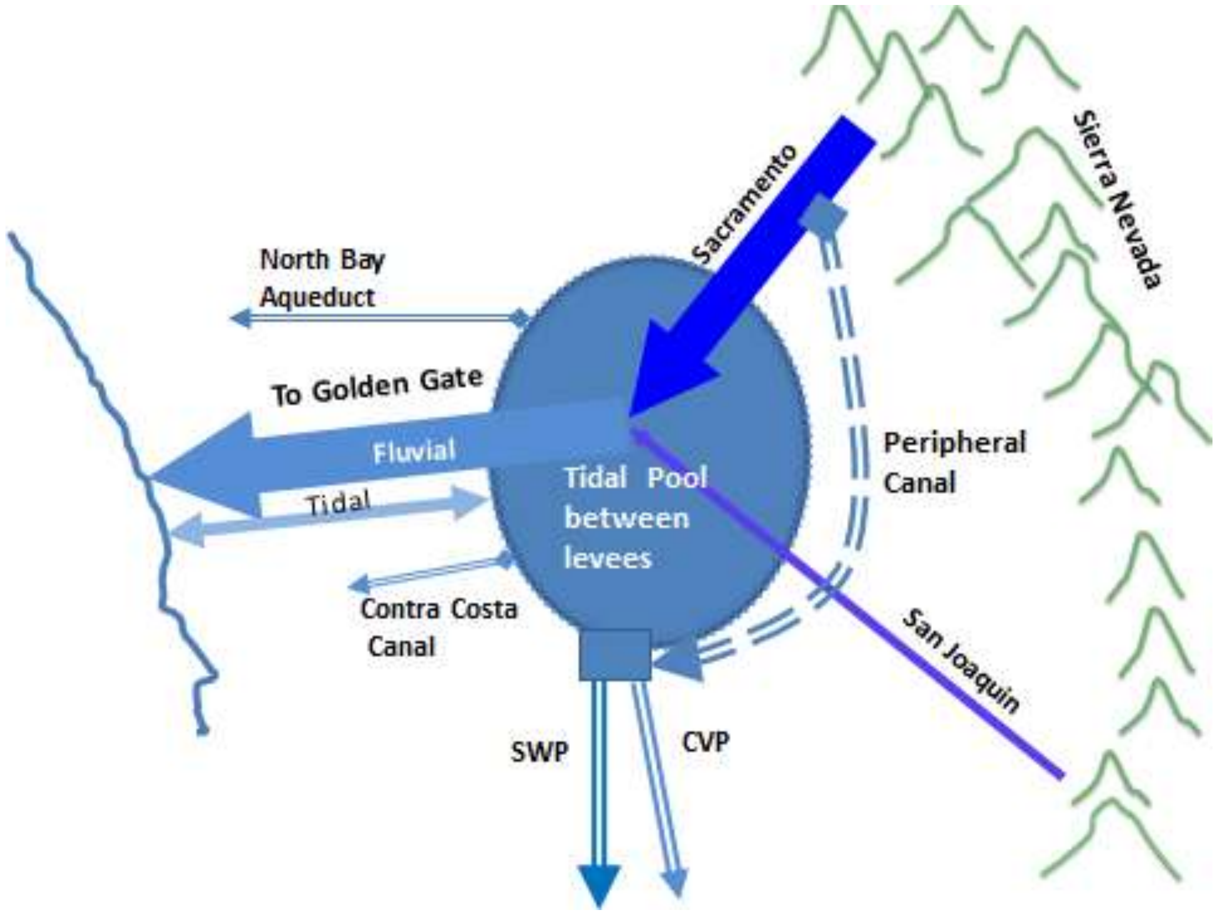


Figure 4.4 – Schematic of Delta Showing Peripheral Canal Allowing SWP and CVP Export Water to Avoid the Delta.

estimated the price of a 100-year return flood protection option at $192 million capital and $7.5 million annual operating expense (1973 dollars). To highlight the concern over the levees and the unplanned and un-designed role in the water delivery system, DWR mapped (DWR 1974) and highlighted 33 levee failures that led to island flooding (including the 1973 failure) in the previous 43 years. Thus, it was that in the wake of the Brannan-Andrus levee failure in 1972 that the California State legislature held two days of hearings (DWR 1972).

These hearings would lead to the Legislature and DWR to formally acknowledge the importance of the Delta levees in the unplanned and unanticipated role of water delivery for the state and the uncertain and potentially fragile condition of the levees. Publication of the DWR report (1973b) introduced several of the issues still dominating discussion in 2011: the proper type, role, and place of vegetation on Delta levees; the condition and failure record of the private levees; the underfunding of the maintenance of the Delta levee maintenance; and the high cost of necessary upgrades and maintenance for the levees. In the last regard, whereas all three options seemed designed to facilitate transport and export of water (one map even shows the flow arrows), the report did not identify CVP and SWP customers as potential financial contributors to better Delta levees. Instead, it identified residents, businesses, utilities, customers of the water lines crossing the Delta, state and county highway departments, environmental funds from state and federal environmental and wildlife agencies, recreational boaters, and the ports as those who benefit and, thus, should contribute to improving the Delta levees. The report also pointed out the importance of Delta levees at the local, state, and national scales.

Meanwhile, the legislative hearings into the Brannan-Andrus levee failure (DWR 1972) resulted in the passage of the Way Bill. Named for the committee chair, this act provided state matching funding for improvements of the Delta levee and maintenance for the first time. Under the legislation, the DWR managed this “subventions” program and the local reclamation districts designed, managed, and provided upfront financing for the work. The legislation essentially called for state reimbursement of 75% authorized expenditures for levee maintenance after the first $1000/mile spent per year. The program depended on the funding levels set by the legislature and the early authorizations were meager, $2000 total for the whole Delta in the first year (Interview 115-2009; Agnew 2011). In practice, reimbursements to reclamation districts have averaged 50% of total expenditures, but with reimbursement made only after completion of all work for the year. The program achieved success in improving the condition of the Delta levees, as evidenced by the annual report on of flooding in California by the DWR (*Bulletin 69* series) for water year 1983. It credited "the millions of dollars spent in recent years by the Corps of Engineers and the Reclamation Districts to fortify Delta levees" (DWR 1984, 58) and the flood-fighting efforts of the California Conservation Corps (CCC) with limiting levee failures in 1983 in spite of record high water levels at Rio Vista and across the Delta pool.

After approving financial support for the reclamation districts that had accidentally become DWR partners in moving water across the Delta to the export pumps, the Reagan administration put the Peripheral Canal on the "deferred list." After his election in 1975, Governor Jerry Brown ordered a reappraisal of the project and evaluation of alternatives. Two years later, with the state in the second year of the worst dry spell on record, Brown did not wait for the formal report and came out in favor of building the Peripheral Canal (Hundley 2001, 323). In 1980, water users in Southern California won a major victory as the legislature and Governor Jerry Brown approved the Canal.

Not quitting the fight, project opponents forced a ballot initiative to reverse the approval of the project. They were able to win the referendum 63% to 37% on an almost pure North-South division of votes (Hundley 2001, 332). Northern Californians and members of the emerging environmental movement led the fight against the canal that would have freed DWR, USBR, and the big water project contractors (Westlands Water District, MWD, etc.) from concerns that a Non-Project Delta levee failure could interrupt supplies by pulling salt water into the supply channels.

During the second political fight over the Peripheral Canal (1980-1982), two Delta levees failed (Lower Jones Tract in September 1980 and McDonald Island in August 1982) under similar circumstances to the June 1972 failure. These were classic "Sunny-day failures" occurring unexpectedly at low summer flow rates, making them nightmare scenarios for water exporters. After precautionary shutdowns and slowdowns of the export pumps, DWR quality sampling showed that the levee failures were not causing the same increases in salinity as the 1972 failure had. Full operations of the water projects were quickly resumed (Rabbon and McCullough 1986).

DWR ran their Bay-Delta hydrodynamic models, which indicated that the "Big Gulp" represented the greatest risk to water quality at the pumps when the one of westernmost islands in the Delta "gulped." Part computer modeling, part DWR expert "intuition," this evaluation led to the identification of Sherman, Bradford, Twitchell, Bethel, and Jersey Islands and Webb, Hotchkiss, and Holland Tracts as areas where levee failure created the greatest risk to Delta exports without a Peripheral Canal (Interview 119-2009). DWR successfully lobbied the legislature to pass AB-34 in 1986, which essentially established that one-half of the available state levee funding would go to "Special Projects" dedicated to the levees of the eight western islands. DWR became directly involved in the maintenance of these levees on the eight islands, particularly on Sherman and Twitchell where state land acquisitions have made DWR the majority landowner and, therefore, the dominant player in these reclamation districts. AB-34 also increased funding levels for the subventions program in the wake of more record Delta water levels in February of 1986 and ensuing failures of levees.

During 1985, critics mounted the first attacks against the provisions in the Water Code that established as public policy of the State of California to preserve the Delta as a "special place." Faced with increased state expenditures on Delta levees, Assemblyman Willie Brown introduced in December 1985, legislation (AB 25) that declared that "continued agricultural use of certain high flood risk islands in the Delta is no longer in the interest of the people of the state…" (Logan 1989, 1). AB 25 did not pass, however, AB 955 was signed into law in 1985 which included the statement that "the Legislature recognizes that it may not be economically justifiable to maintain all Delta islands" (Logan 1989, 1). By 1986, levees were "accidently" a critical part of the water supply for Southern California and Delta residents could no longer rely on the total commitment of the state of California to preserve the Delta islands as a special place.

After 1990, the increased public concern for the environment and the increased activity of environmental non-governmental organizations (ENGOs) began to increase the focus on the health of the Delta ecosystem. The dams and pumps of the water project were playing havoc on the two main classifications of native fish. The CVP and SWP dams upstream reduced or eliminated the spawning and rearing habitat for the most of the anadromous species native to the Delta. Further, re-routing of water across the Delta to the export pumps could confuse salmon trying to find their spawning gravels (Moyle, Israel, and Purdy 2008). Even the "imported" striped bass that arrived on one of the first trains that completed the transcontinental trip across America and had flourished into a great sports fishery in their new home began to decline in number. The numbers of Delta smelt, the primary native pelagic fish of the Delta, plummeted, apparently also suffering loss of habitat attributed in part to the Delta operation of the export pumps and from competition from invasive species (Moyle 2007).

Changes in the Delta levees themselves have also not helped. The reclamation districts and the USACE have steadily placed rip-rap (large boulders) and concrete rubble (now discouraged) up to at least to the high water line to protect against levee erosion from boat wakes and flows of water to the pumps and to the Bay. Sherman *et al*. (2007) noted their detailed mapping of the levee, which revealed that of 1294 km of Delta levees, over 870 kilometers of levees were protected with rock or broken concrete surfacing at he waterline. Unfortunately, this also generally reduces the habitat and routes of safe passage for endangered native species of fish along the levees.

GOVERNANCE, GOVERNING, AND THE CREATION OF CALFED

By the early 1990s, at least 24 state and federal agencies were charged with managing the increasingly taxed and troubled Delta socio-ecosystem, each with responsibilities for parts of the problem, each with its own supporters and detractors. The responsibilities of agencies often conflicted as much as the positions of the constituents of each agency. The state agencies, particularly the Water Resources Control Board (SWRCB), were vulnerable to pressures from California water users to keep more water flowing south. This bothered the Delta interests and fish advocates because the Racanelli decision in 1986 affirmed state board authority over water quality and quantity issues (Hundley 2001, 404) but SWRCB buckled to pressure from Central Valley irrigators and MWD (Hanemann and Dyckman 2009). ENGOs turned to the U.S. Congress and helped get the Central Valley Project Improvement Act passed in 1992 that set aside 98,680 hectare-meters (800,000 acre-feet) of CVP water largely to help save endangered native fish in the river system. The next year the National Marine Fisheries Service and the U. S. EPA challenged the SWRCB water quality regulations for the Delta and the U. S. Fish and Wildlife Service listed the Delta smelt as "Threatened", making the ingestion of smelt into the pumps a federal issue. Agencies were pitted one against another and gridlock loomed. In response, Interior Secretary Babbitt and Governor Wilson created CALFED in 1994, a grouping of initially 15 state and federal agencies that came together as "a collection of federal and state agencies with their own responsibilities and authorities trying to work together to improve efficiency" (Hundley 2001, 407).

CALFED drew the charge of doing four things in the Delta: improving water quality, increasing water quantity for export, improving the sustainability of the ecosystem, and improving levee integrity, in other words, resolving the unaddressed problems accumulating over the previous two plus decades of the socio-ecosystem of the Delta adding the role of water export hub. Collaboration rather than confrontation among the stakeholders initially produced interim water quality standards, the Bay-Delta Accords, and a $400 million plan to achieve them. In 1996, California votes approved a $995 million water bond issue, with two-thirds of the money designated to initiate restoration of the Delta. CALFED floated three alternative plans to do this; two of them relied on improved Delta levees to achieve the goals whereas the third relied on the "Open Channel Isolated Facility," a new name for an old idea, the Peripheral Canal. Each of the three options included additional storage dams upstream and downstream of the Delta (on the water export systems), better fish screens, ecosystem restoration, groundwater storage, groundwater controls (for the first time in California) and each would cost somewhere near $10 billion and thirty years to build (Hundley 2001, 407-425). MWD immediately endorsed the third alternative, the revived peripheral canal, but every other stakeholder in the process had major concerns with one element or another of all alternatives. CALFED bowed to the pressure and in late 1998 announced a new approach that would incorporate adaptive management, starting with a Preferred Program Alternative and essentially only considered an isolated conveyance system (peripheral canal) viable if all else failed. Governor Wilson confirmed the CALFED opinion in December 1998 and put consideration of the peripheral canal on a seven-year freeze.

The collaborative effort of CALFED stood on the brink of collapse in 2000 from too much stakeholder input, inducing incoming Governor Davis and Interior Secretary Babbitt to order CALFED to end public hearings and privately produce a plan to address the big water problems of the state. In June 2000, CALFED issued its new plan, termed the Record of Decision (ROD), that included no canal and no new reservoirs but plans to study both. The ROD did include an array of individual projects to accomplish the four goals of CALFED, including $450 million for improvements of Delta levees. The total estimated seven-year price tag for all four goals would reach $8.7 billion. Hundley (2001, 425) optimistically stated that CALFED would get the proper governance legislation and strengthened leadership to be able to execute the largest "environmental restoration in American history."

Conflict and unexpected setbacks soon engulfed CALFED. The endangered Delta smelt populations collapsed in 2001 (Interview 126-2009) and with their short one-year lifespan, they remain on the verge of swift extinction (Moyle 2007). Other native species followed with dramatic declines of their own and by 2008, most of the native fish species and salmonoids runs (Weiser 2008) had found their way to the endangered species lists, including two kinds of smelt and nine salmonoid runs. In the first 57 years of operation, the CVP had consistently delivered the contracted (except during the 1976-77 severe drought) 863,456 hectare-meters of water from the Sacramento and San Joaquin watersheds south to 250 water contractors irrigating 1.2 million hectares (three million acres) of Central Valley farmland while supplying drinking water to slightly less than two million urban water consumers (DWR 2011). In 1997, however, the streak ended when the 98,680 hectare-meters (800,000 acre-feet) set aside requirement for the environment forced the USBR to cutback allocations to 10% of contract volume to its CVP water contractors (*L.A. Times* 1997). Since then, the DWR and USBR have been forced to curtail water deliveries because, as noted in the 2006 Annual Report of the SWP, "During the last decade, water management issues in the Delta have been complicated by the listing of native species under the federal Endangered Species Act (ESA)… issuance of biological opinions under the ESA; and the implementation of 98,680 hectare-meters (800,0000 acre-feet) of CVP yield for fish and wildlife under the 1992 Central Valley Improvement Act" (Dreher *et al*. 2008). The cutbacks of water deliveries came not from the "Big Gulp," but because of a little fish as the biological opinions forced shutdown of the pumps when the suction screens trapped too many endangered fish.

JONES TRACT, KATRINA, AND THE DEMISE OF CALFED

After 1982, the Delta levees had served as a water conveyance system effectively, the entire levee system held up except during record high floods in 1986 and 1997, preventing the feared "Big Gulp." This 22-year successful run ended in June 2004 when the Jones Tract levee failed along the Middle Fork of the San Joaquin during low water levels. The resulting in rush of water forced closure of the export pumps as a precaution and flooded the farmland at the bottom of the Jones Tract "hole." The flood threatened stability of the BNSF railroad embankment and tracks and eroded out the foundations of some of the pipe supports for the East Bay MUD water pipelines that run through Jones Tract parallel to the railroad (see

Figure 4.5). Newly elected Governor Schwarzenegger flew by helicopter to the site of the levee failure and stunned his Director of the Department of Water Resources (DWR) by announcing to the accompanying TV cameras that the state would repair and restore the tracts (Interviews 103-2009 and 112-2009), a role the in levee failure response the state had not taken on previously. Fortunately, as with earlier sunny-day levee failures deep in the Delta, the quality control shutdowns of the export pumps were short and relatively minor. The cost of levee repairs and dewatering of the islands, however, would cost an estimated $90 million according to official pronouncements (Gaddie, Mierzwa, and Marr 2008), although full accounting has not yet been published and several experts assert that the real cost was less than half of that amount (Interviews 112-2009,124-2010A, and 115-2009).

When Governor Schwarzenegger thrust the DWR into the new role of managing a levee repair, agency officials were still reeling from the decision of the state Supreme Court just three months earlier to let stand an appellate court ruling in the Paterno case. This decision declared that the state bore sole liability for the damage resulting when a flood control levee failed in Yuba County (well out of the Delta itself) some eighteen years before. The USACE built the levee that failed as part of the Sacramento River Flood Control Project but as noted earlier, the Flood Control Act of 1936 required that the levees would be turned over to the state and locals to maintain and the state would hold the U. S. government harmless from any damage claims. The resulting settlement of the Paterno Case would cost DWR and the taxpayers of California $464 million (LAO 2005, B-85) and added an element of "levee paranoia" to the lives of DWR management.

The failure of the Jones Tract levee and its risk to water supply quality and integrity triggered an action-oriented Governor, not enthusiastic about CALFED progress, to fire off a request in June 2005 to the Little Hoover Commission, the independent government "watch

Figure 4.5 – June 2004, Flooded Upper and Lower Jones Tract, and Threatened BSNF Railroad Tracks and EBMUD Water Pipelines (left) (Picture Courtesy of Chris Neudeck)

dog" organization in the state (Alpert 2005), to investigate the effectiveness of CALFED. Two months later, the storm surge from Hurricane Katrina knocked down and poured over the USACE built levee walls in Orleans parish, inundating a city with topography and a physical environment similar to the Delta islands. Pronouncements made by public officials in the Governor's office and DWR, implied that the levees in Delta were built and maintained by farmers and were vulnerable because of age, the materials and methods of construction, increasing hydraulic loadings, earthquake risk, sea-level rise, and the limited resources of the owners. Delta levees were, therefore, at much higher risk than the pre-Katrina New Orleans levees built and maintained by the premier levee builder, the USACE. The governor quickly signed AB-1200 (Laird) into law that directed DWR and the Department of Fish and Game (DF&G) to work with the USACE to assess the potential performance of the Delta levees and the economic, environmental, and health/safety impacts of such failures. It was then to develop Delta Risk Management Strategies (DRMS) to deal with these (URS 2009, 1.2).

In November, the Little Hoover Commission reported back, condemning CALFED, calling for stronger leadership, and praising DWR among other findings (Alpert 2005). When reforms in CALFED did not occur quickly enough, Schwarzenegger issued an executive order dated 17 September 2006 to create the Delta Vision Blue Ribbon Task Force of statewide business, civic and political leaders to envision a future Delta that would maximize water production and ecosystem functionality and then develop a strategy to get there. Delta Vision kicked off while the consultants hired by DWR pushed forward to produce in 13 months what would become the 3000-page DRMS Phase I study (URS 2008). Obeying the legislation that authorized this study, DRMS looked at levee stressors of earthquake, subsidence, climate change, and extreme floods. In late 2007 and early 2008, California had four major Delta initiatives in progress, the DRMS study, the Delta Vision efforts, the Ecosystem Restoration Program (ERP) Conservation Strategy of a wounded CALFED, and the Bay Delta Conservation Plan (BDCP). The BDCP represents an effort by DWR, USBR, and those agencies responsible for protecting endangered species in an effort to provide enhanced habitats and environmental protection to offset and compensate for the environmental damage caused by water exports. Of these initiatives, the Delta Vision would play out as the statewide political discourse on the Delta as reviewed in Chapter II. The Ecosystem Restoration Program appears to have lost momentum with the demise of CALFED, with its 2010-2011 budget identifying its main activity to be support of the Bay Delta Conservation Plan BDCP (ERP 2010). The DRMS study and the BDCP itself, however, would have major impacts on all discourses, social and political, on Delta levees.

THE DRMS REPORT

As noted in Chapter III, after Katrina, the legislature mandated an evaluation, based on information already available, of the risk and consequences of failures of Delta levees. URS would get the contract to complete, under DWR direction, the report called the Delta Risk Management Study (DRMS). This report would attempt to develop a political solution to the problems and conflicts in the Delta, which would make winners and losers among the various social perspectives about levees held by Delta levee experts that this dissertation will identify in Chapter VI. As such, views on the execution, scientific basis, and presentation of DRMS itself became a major part of the discourses about Delta levees. When the draft report hit the internet in June 2007, the findings of its Executive Summary would draw sharp focus on two major areas of underlying differences among the perceptions of Delta levee experts, specifically the inherent fragility of the Delta levees and the degree of risk of multiple levee failures inducted by earthquakes.

Again as noted in Chapter III, the DRMS Executive Summary first highlighted the finding that in spite of 25 years of increased state investment in Delta levees, failures continued at an unacceptably high level. Further, sea-level rise and continued subsidence would render it difficult to improve this performance in the future. The Summary concluded that there would be 140 levee failures over the next 100 years, a very slight improvement over the 158 failures they recorded over the 1900-2006 period used to perform their analysis. This established official public support for key elements of the social perspectives of some Delta levee experts, whereas it rejected the perspective of others. As will be demonstrated in Chapter VI, the DRMS analysis apparently lacked sufficient width and breadth to change the social perspectives of some of Delta levee experts relative to this issue.

In addition to focusing on the 158 islands flooded since 1900 (Figure 3.14) and the islands like Franks Tract that never were restored, the Executive Summary then noted that the Delta levees had "not yet experienced a damaging earthquake." In super bold print, the Executive Summary pointed to the U.S. Geological Survey report indicating a 62% probability of a 6.7 magnitude earthquake hitting the San Francisco Bay area between 2003 and 2032 that could cause multiple levee failures in the Delta and that several closer faults posed an even greater risk to the Delta levees. The DRMS Executive Summary drew attention (URS 2009a) to the finding of the report that between 2003 and 2032, the estimated probability of a simultaneous 20-island levee failure resulting from an earthquake and cost of levee repair at $2.3 billion stood at 40%. Again, on this major indeterminate issue, the DRMS study supported certain social perspectives and rejected others. Chapter VI will identify the social perspective and indicate if the DRMS report provided sufficient evidence to create unity of views by Delta levee experts on this concern. The DWR and others discussed earthquake risk to Delta levees prior to the June 2007 issuance of the DRMS draft report. URS based the actual earthquake risk assessment in DRMS on the 2000 CALFED study (Torres *et al.* 2000). Scholarly studies and interviewed Delta experts agree, with the exception of one questionably documented reference in one paper (Finch 1988), that levees in the Delta remain undamaged by an earthquake or earthquake-related activity. Geologists express concern that tectonic forces have overstressed northern California fault lines, with pressures building on the San Andreas Fault since 1906 and the Hayward Fault since 1866. They have also located or projected faults under or near the Delta that represent a concern regardless of the absence of a surface exposure or record of recent activity.

A 1980 report (DWR 1980) appears initiated concern for seismic damage to the levees of the Delta. It suggested that whereas the 1906 earthquake did not produce a recorded levee failure in the Delta, the levees were not substantial then. The report concluded that risk had become significant and needed investigation. The 1980 report signaled a change in DWR thinking about this subject because the summary report on the Peripheral Canal written in 1974 did not mention risk of earthquake damage in the Delta (DWR 1974). In 1975, the plan published by DWR to improve Delta levees mentions the possibility of liquefaction and the formation of seiches under earthquake conditions, noting that more investigation should be undertaken (DWR 1975, 9). The U.S. Geologic Survey studied this issue (Youd 1982), investigating the six earthquake faults near the Delta, and determining the maximum values of moments for earthquakes originating on those faults. The investigator identified that liquefaction probabilities are a function of the susceptibility of the soils to liquefaction and the intensity of the seismic shaking. He concluded that "although there is a high likelihood of susceptible sediment in the Sacramento-San Joaquin Delta, the opportunity is lower, and thus the liquefaction potential is low" (Youd 1982, 354). Other studies in the 1980s and 1990s disagreed as outlined in the DWR summary report on the DRMS study to the Delta Vision Task Force (DWR 2007, 3), all reporting that Delta "levees are susceptible to liquefaction and could fail in moderate to strong earthquake shaking." Finch (1988) studied Twitchell Island and postulated that one particularily troublesome Project levee on Three Mile Slough could suffer failure of the loose sand toe berm which could lead to levee failure in the event of a maximum credible earthquake on any one of the six nearby faults.

In 2000, CALFED authorized the study on the probability of damaging earthquakes to resolve the differences in perspectives on this issue to hopefully achieve a guide for policy makers (Torres et al 2000). As note above, this study would form a major part of the basis of the DRMS analysis on the earthqauke risk. Torres et al. (2000) produced the charts in Figure 4.6 showing probabilities of the number of levee failures (not number of islands flooded) for a 50 year, 100 year and 200 year return earthquake. The study determined the maximum magnitude of the shaking and the probability of magnitude and frequency of earthquake for each fault shown on Figure 4.7. They then estimated the horizontal gravity reaction force, or Peak Ground Acceleration (y) based on the energy at the source and the distance related attenuation to the various parts of the Delta. The potentials from the various faults were then summed. This generated a seismic hazard curve for each site in the Delta. To get from the hazard curve to probability number of levee failures, the team developed a "levee fragility function". The report notes that adequate geotechnical information for the 600 miles of

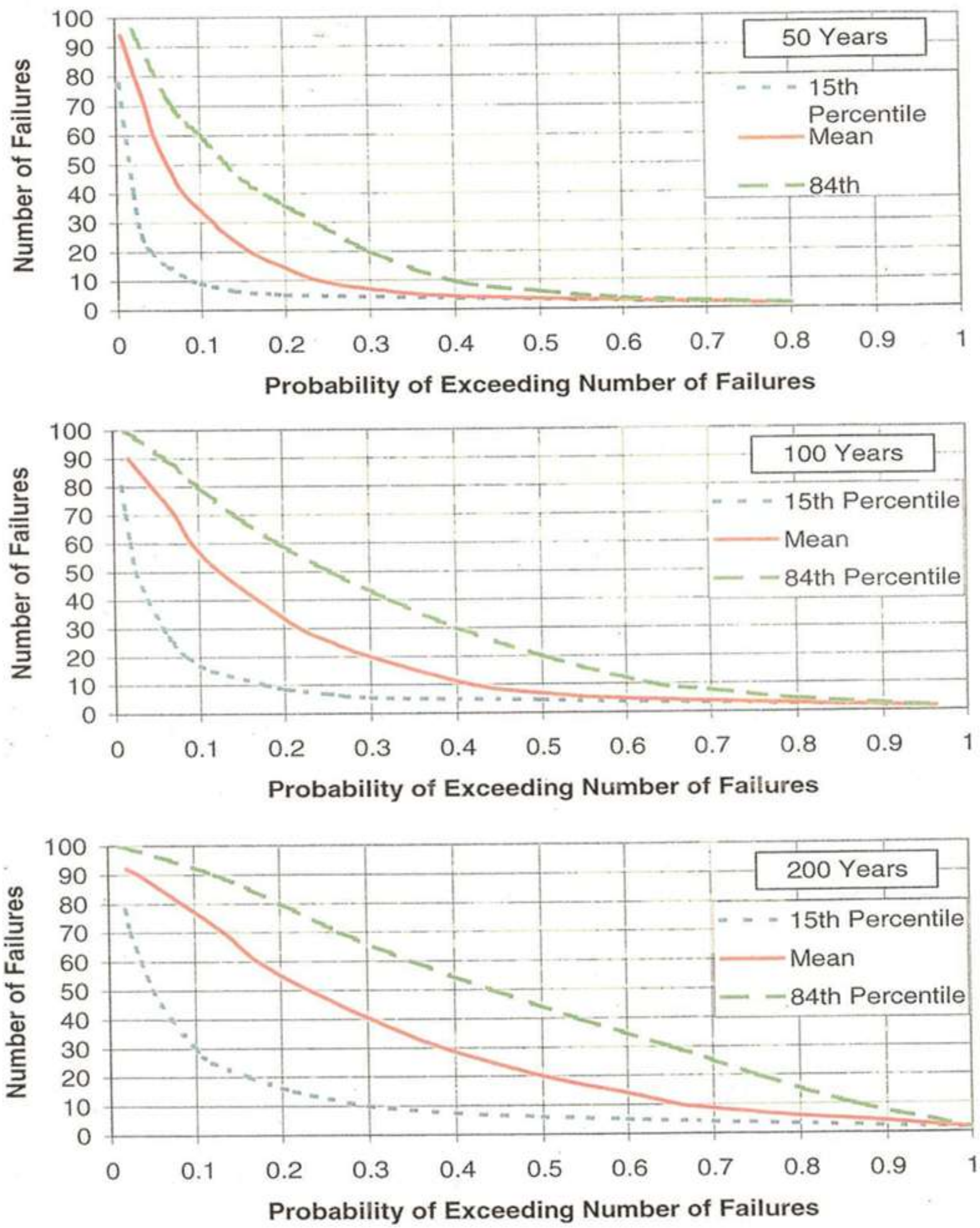


Figure 4.6 – Torres *et al.* (2000) Levee Fragility Function Curves for 50, 100, and 200-year Reoccurrence Earthquakes Base on Expert Elicitation

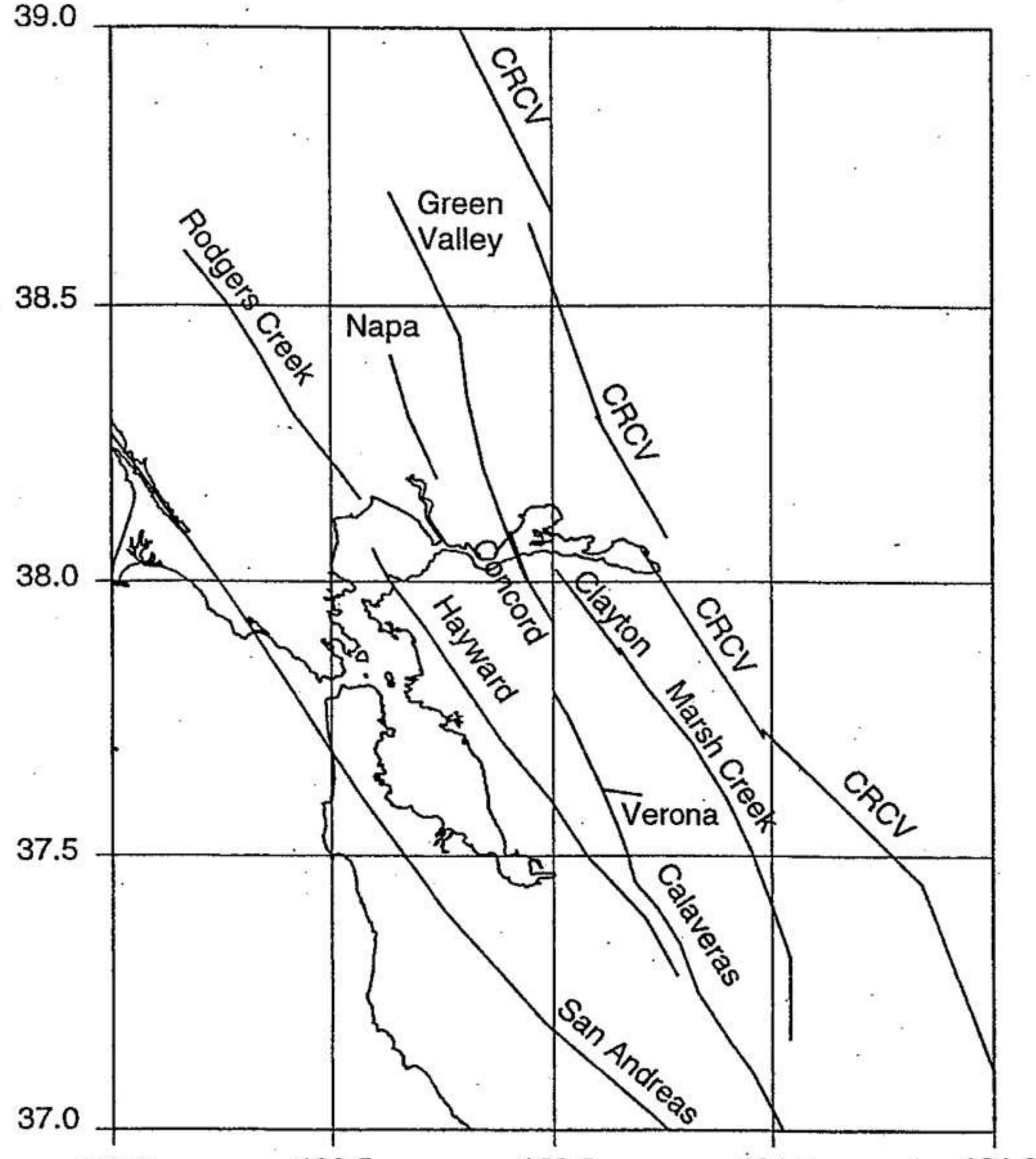


Figure 4.7 - Map of Faults in the Delta Region Investigated in Torres *et al*. (2000, A1)

levees of interest was not available, nor likely to ever be available, to perform true engineering analysis of the resistance of the levees. Therefore, a sub-team of nine Delta levee experts was given the available data (borings, reports, etc.) and ask to prepare an estimate of the frequency of levee failure for different levels of earthquake shaking. The experts then met, reviewed the individual findings, and then developed a single averaged range of values. The width of the range of probability versus number of failures shown in Figure 4-4 a, b, and c reflects the differences in perspectives among the Delta livee experts of how the levees will react to earthquake forces. Whereas the potential intensity of earthquake shaking and the probability of earthquakes are reasonably estimated with widely accepted models, it is the reaction of the levees to the shaking or this "levee fragility function" that remains the unknown and, therefore, again subject to expert elicitation. The DRMS report again tackled the issue of the various faults, active, inactive, and projected, and how often they will shake the Delta and with how much energy, but it did not directly address the issue of vulnerability of Delta levees to damage caused by liquefaction. So again the DRMS report did not, as will be shown in Chapter VI, eliminate any opposing viewpoints. The "levee fragility function" of Torres *et al*. (2000) represents an averaging of viewpoints or social perspectives and not a resolution of differences or consensus.

The DRMS Executive Summary-Phase 1 (URS 2009a) was directed at the general public and attracted attention and readership. DWR hoped to and may have set an established public discourse on Delta levee concerns, specifically that the Delta levees are extremely vulnerable because of inherent weaknesses and the certainty of future damage from earthquakes. Chapter VI will explore the ability of the report to change or influence the social perspectives of the Delta levee experts on these issues. One of the results of the DRMS report is that among the experts, the motivation and execution of DRMS itself became subjects of the discourse and conflict, again as will be the subject of Chapter VI.

The draft report and Phase I heightened the intensity of the debates among Delta levee experts. The Phase II report, on the other hand, got held up with the 2009 California state budget crisis and the focus of the public debates moved elsewhere, to the Delta Vision exercise and its successor, the Delta Stewardship Council and to the development of the Bay Delta Conservation Plan (BDCP). DWR issued the Phase II DRMS on 13 June 2011 with little fanfare and stakeholder reaction.

THE BAY-DELTA CONSERVATION PLAN (BDCP)

The listing of nine Delta fish runs under the Endangered Species Act and the California state equivalent led to court-ordered restrictions on water exports in 2007 and added to the woes of the water exporters. With fish counts and water exports continuing to drop, the DWR, USBR, the major water contractors (Kern Count, Westlands, MWD, Friant, etc.), the state and federal wildlife agencies, the USACE, and several ENGOs were convinced to come together to form a type of expanded, project oriented CALFED team to develop a Bay-Delta Conservation Plan (BDCP). The intent was to obtain a 50-year permit to operate new and existing water and energy projects. The plan calls for agencies enforcing the provisions of the endangered species act (USF&W, the National Marine Fisheries (NMF), and state Depart of Fish and Game (DF&G)) to issue the permits to allow restored operation of the existing CVP and SWP systems. It also calls for streamlining any permits required to build the "identified" ecologically friendly ways "planned to move fresh water through and/or around the Delta" (BDCP 2011). This of course strongly suggests a Peripheral Canal, which plays a critical role in differentiating the social perspectives of the Delta levee interests. A large element of the BDCP requires the creation of more habitats, with the hope that would support an increasing in the number of endangered fish, prospering in new home waters. The improved habitat would more than offset the losses of fish at the export pumps. Eventually the fish species would work their way off the endangered species lists and recover in the restored 65,000 acres of freshwater tidal marsh and 10,000 acres of expanded flood plain created by levee setbacks (SAIC 2011). CALFED funds previously allowed acquisition of properties on and around Liberty Island. USBR had acquired most of Prospect Island and Westlands owned property upstream in the Yolo Basin with the hope that BDCP could convert the lower end of the Yolo By-pass and nearby Prospect Island into tidal marsh habitat. The planners also looked at restoration in the Suisun Marsh and smaller potential areas to restore environments to allow the many endangered species to recover, even in the face of continued fish mortality at the pumps. This of course all involves land use planning which in the Delta means levee planning. Chapter VI will investigate the relationship of these plans and discussions over them on the social perspectives of the Delta levee experts. The involvement of the water contractors in BDCP stems from their interest in reducing or ending the restrictions placed on water exports from the Delta required by the USF&W biological opinion on Delta smelt and one by the NMF that covered salmonoids and sturgeon, all under the federal Endangered Species Act (Huggett 2010). The water contractors and their customers will probability bear much of the cost of the BDCP. Part of the final plan likely will be a peripheral canal or perhaps tunnel, which again potential impacts the Delta levee and drivers for funding levee maintenance. The BDCP premise that approval of the plan will then expedite any permitting and financing required, suggesting that a peripheral canal as part of an approved BDCP would be on its way quickly.

BDCP team lost a financially important member in November of 2010 when the Westlands Water District withdrew from the negotiations when it became clear that execution of the BDCP would not guarantee additional water for agriculture. The State Water Resources Control Board (SWRCB) had not renounced the water-for-fish guideline recommended by an interagency team reporting to the SWRCB and the DSC, which proposed in July 2010 additional limitations on future pumping operations. Under these guidelines for example, exports and net change in upstream storage could not exceed 25% of the unimpaired Sacramento River flow into the Delta from November through June (Hanak *et al*. 2011). In theory, water deliveries out of the Delta are limited to 25% of the average total annual normal flows in or which are those in excess to the needs of the watershed. The CVP and SWP historically captured as much of the winter excess runoff in the reservoirs in the Basin, the proposed guideline will limit capture and use to no more than 25% of the stream flow in any month. In most years, this would limit water exports below historic averages and render additional more storage less valuable from a water supply standpoint. The BDCP project continues and time will determine if Westlands withdrew as a negotiating step, or if not, what effect that their non-participation would have on the results of the effort.

BDCP suffered additional embarrassment when on 5 May 2011, when the National Science Foundation issued a press release headlined by: "California's Draft Bay Delta Conservation Plan incomplete; needs better integration to be scientifically credible" (Walsh 2011), suggesting that the debate over the future of the Delta and its levees will continue.

DELTA VISION AND THE DELTA STEWARDSHIP COUNCIL

As noted in Chapter II, Governor Schwarzenegger created the Delta Vision Blue Ribbon Task Force in 2006 when he recognized that CALFED had not produced a widely accepted public discourse that would solve the water supply, environmental and levee safety crises in the Delta. When the Blue Ribbon Panel presented its results in late 2008, the Governor had what he wanted, a governing plan for the Delta that included emphasis on quickly building the peripheral canal. This would free the water projects from the problems of the Delta, while promising an environmental restoration of the Delta to save the endangered species and keep the environmental community on board with the overall plan. The statewide composition and reputation of the task force members, plus the approach of holding Task Force hearings all over the state help establish the findings as THE California perspective. Just as momentum built for the Delta Vision, the 2008 real estate market crash and recession hit California hard. The real estate markets in the Stockton and Sacramento areas took some of the most significant drops in national valuation and the unemployment rate in Stockton jumped from 6.3% in October 2006, to 8.1% for 2008, then skyrocketed to 15.3% for 2009, and continued climbing to a March 2011 estimate of 18.4% (USDL 2011). The debt service on many billions of dollars of general obligation bonds, many of them for flood control, water supply, or environmental restoration projects, already approved and spent, became difficult to cover in the face of declining tax revenues. The governor and legislature could not work out a budget, the state furloughed its employees, contract work halted, and contractors received state IOUs for work, materials, and services already delivered instead of money. The reclamation districts, first buoyed by additional funding promised by the subventions program through the passage of referendums E-1 and 84 were left with huge, uncovered loans when DWR could not make the promised 75% reimbursement of authorized expenditures for the levee maintenance work completed in

2008. The resulting tension between the DWR managers and the reclamation districts impacted some of the elements of the social perspectives uncovered in Chapter VI.

Schwarzenegger did manage to keep the Delta Vision moving and in November of 2009, the legislature passed the comprehensive statewide water package that included four major water policy bills. Major elements of the bills were requirements to establish statewide groundwater monitoring, to tighten up Delta water diversions, to develop statewide water conservation goals, to established a new governance structure to the Delta (Delta Stewardship Council) and re-structure and realigned some governing structures, and to float a new package of $11.15 billion in water bonds. The bills also re-designated $546 million from bond packages E-1 and Prop 84 approved by the voters in 2006 (DWR 2009), including setting aside $202 million of the 2006 bond money for “flood protection in the Delta to reduce the risk of levee failures that would jeopardize water conveyance” (DWR 2009, 6). The proposed bond issue includes $2.25 billion for “Delta Sustainability” defined as “projects to assist in maintaining and restoring the Delta as an important ecosystem... to reduce the seismic risk to water supplies derived from the Delta, protect drinking water quality, and reduce conflict between water management and environmental protection” (DWR 2009, 7). Much of wording of legislation supports the discourse of the Delta Vision justifying the peripheral canal (or isolated conveyance or water tunnel). The package also included $3.0 billion for unidentified surface and aquifer storage projects designed to overcome the effects of climate change on the system. The rest of the money in the package promised some technological solution for the water issues of every region of the state to help assure statewide voter support.

The bills also established the Delta Stewardship Council (DSC) consisting of seven members with "diverse expertise providing a broad statewide perspective." The legislation charged the DSC to develop a plan by early 2012 that furthers (once again) "the co-equal goals of Delta restoration and water supply reliability" (DWR 2009, 2). DSC will then develop and track performance measures, review state and local governing agencies' projects for consistency with the Delta plan, and act as an appellate body should claims of inconsistency be filed by others. The legislation specifically designed the DSC to review the Bay-Delta Conservation Plan (BDCP). On the governing side, the bills established the Sacramento-San Joaquin Delta Conservancy to manage the ecosystem restoration activities within the Delta. Finally, the Delta Protection Commission (DPC), got streamlined (membership cut from 23 to 15) and responsibilities expanded. The legislation assigned the DPC responsibility to prepare a plan for economic sustainability for the Delta, emphasizing flood protection. The DSC will incorporate the DPC plan in the overall DSC effort. The Legislature established the DSC as the governance process for the Delta. The DSC became the agency charged with listening to and considering for inclusion in public policy, the discourses of the social perspectives identified in Chapter VI. The Q-sorts discussed in Chapters V and VI were conducted very early in the life of this process so little can be gained from them relative to the effectiveness of the DSC in this role.

The governor wasted no time getting the DSC up and running, appointing as chairperson the widely respected Phil Isenberg, former mayor of Sacramento, and the individual who had chaired the Blue Ribbon Panel. By March 2010, the DSC was holding monthly public meetings as the council organized and set to work on its ambitious objectives. The meetings have been open to the public and broadcast live on public television and via the internet. Back at the Capitol, however, public opinion polls were forecasting defeat for the $11.15 billion bond proposition and late in 2010, the popular vote got put on hold until the 2012 elections. In November of 2010, Governor Schwarzenegger could not run for re-election because of term limits and California voters returned Jerry Brown to the governor's mansion. Governor Jerry Brown, of course, served as governor during the 1980-82 second public debate over the Peripheral Canal. As if to prove that nothing had changed in 30 years, Brown appointed Gerald Meral, once an Environmental Defense Fund scientist, in 1980 as Assistant Director of DWR (Reisner 1986, 375) and then 2011 appointed him to a similar position. Meral's primary assignment is to push the BDCP to completion and acceptance by the DSC. As American philosopher Yogi Berra might explain it, in California, water politics can be a case of *déjà vu* all over again.

PUBLIC SAFETY *VERSUS* HABITAT

As if those working to restore habitat in the Delta did not have enough to deal with in February 2007, the USACE surprised DWR and levee owners when it revealed that it was enforcing a heretofore ignored prohibition on vegetation on the levees. This change in enforcement was "announced" by inspectors suddenly issuing failing "grades" to the districts during annual levee inspections when vegetated levees were found. By April 2007, thirty-three California reclamation districts had failed 2007 annual inspections, leaving them all at risk of losing certification under the FEMA National Flood Insurance Program, and more inspections were coming (Weiser 2007a). This created concerns for the DF&G, DWR, USBR, NMF, and USF&W, all of which were trying to create more, not less, "shaded marine habitat" (vegetated levees) to restore the endangered species in the Central Valley and Delta. The reclamation districts faced two problems, not only would they lose flood insurance, but the cost of removing the vegetation would total millions if not billions of dollars (Interview 124 -2010A). In 1993, the Legislature greatly increased the cost of removing vegetation by passing Assembly Bill-360 (AB-360) which required replacement of habitat lost during levee subventions program work on a three for one basis.

The change in enforcement policy came directly from the USACE Headquarters, at least in part in response to the intense criticism over the Katrina levee failures. No indication exists that Headquarters consulted with the local USACE District offices. The policy would require removal of all levee vegetation in the interest of public safety, not a problem elsewhere in the country, but a major issue in the Central Valley of California. The state and USACE had quietly encouraged some vegetation for habitat. For example, the 2006 emergency levee repairs on the Sacramento River levee paid for by California and largely executed by the local USACE District office, incorporated waterline vegetation and woody debris in the design, significantly adding to the project cost.

Even with resistance from the Sacramento District, USACE Headquarters refused to budge. In August of 2007 the Sacramento Area Flood Control Agency (SAFCA), the DWR, the USACE Sacramento District, and the California Reclamation Board sponsored a symposium on the effects of vegetation on levees. Experts from as far away as Holland presented papers, Van Vuren (2007) indicating that bare levees promoted destructive habitation by round squirrel and other burrowing mammals. Sherman *et al.* (2007) presented data showing the wave energy attenuation of vegetation and field erosion data showing the effectiveness of vegetation simulating “bush bundles” in reversing erosion on Delta levees. They also presented a chart showing the extent of vegetated levees in the Delta alone, as expert after expert challenged the wisdom of the USACE vegetation policy in California.

Unimpressed or under impressed, USACE Headquarters refused to withdraw the enforcement edict. A truce developed as the USACE essentially delayed enforcement until 2012; however, the issue still hangs over Delta levees. In April 2010, DWR and DF&G sent a 58 page formal request to USACE Headquarters detailing justifications for major changes in the policy for California (Cowin and McCamman 2010; Interview 124-2010A).

CONCLUSIONS

The accidental role of the Delta levees in the California water supply system has greatly added to the importance of the levees and number of people who are stakeholders in the levees. Once merely the concern of handful of farmers living behind them, miles of Delta levees now are critical to upwards of 25 million Californians dependent on then for adequate domestic water supplies and irrigation water. Also, the levees themselves, the water exports, and other human impacts on the Sacramento – San Joaquin River system have severely taxed the ecosystem and pushed the native fish species to the brink of extinction. About the only thing that most stakeholders agree on is that more is unknown than known about the workings of Delta socio-ecosystem, from the history of levee failures to the habitat needs of the Delta smelt.

Early attempts to provide governing and governance to this over tapped and complex system came through the interactions of single focus government agencies, an approach that by the early 1990 had proved impossible and so federal and state leaders then attempted to manage the Delta through a collaborative effort of agencies called CALFED. Much of CALFED's efforts revolved around attempting to reduce the unknowns and identifying the "best available science" to employ in policies. Unfortunately, efforts to draw the knowledge from all the stakeholders and scientists take a lot of time as a minimum and as Huntley suggested (2002), solving the problems of the Delta will require the best ideas from all involved.

Starting in the 1940s, the stakeholders concerned with water supply for the southern areas of the state have favored drawing water from upstream of the messy, tidal Delta and letting the Delta centric interests deal with their problems. With at least 75 percent of the water coming in on the Sacramento, this means a Peripheral Canal around the Delta to the Sacramento. This solves the problems of water exporter but leaves all of the problems for the Delta interest but potentially reduces the options and resources, primarily water and money, to deal with them. As outlined in this chapter, much of the political discourses about the Delta have focused on this one element since at least June of 1972 when the levee failure at Brannan Island reminded all interests of the central role the levees played in all aspects of the Delta. The 2004 failure at Jones Tract and the destruction of the levees in another American delta by Hurricane Katrina have served as vivid reminders of the vulnerability of levee-dams.

The last two chapters have outlined the events that have shaped the political discourses and the underlying social perspectives of those involved in dealing with the past and future of Delta levees. Chapter VI focus on empirically determining the main social perspectives or factors of the groups most knowledgeable about the Delta levees to better understand the science and logic behind the political rhetoric. It also helps understand the differences in what various social perspectives view as the best available science. As the last two chapters demonstrate, expert elicitation represents the default method of determining the unknowns when time and resource constraints force an answer before sufficient research can be completed. Expert elicitation means tapping into the social perspectives of the experts, the object of Chapter VI.

Table 4.1 summarizes the events and governing and governance processes discussed in the last two chapters that have shaped the four social perspectives or factors of the Delta levee experts. Chapter VI will explore these social perspectives.

Table 4.1- Time Line of Events Contributing to Current Social Perspectives of Delta Levee Experts

Event or Period	**Date (s)**	**Kev actors/ Governance processes**	**Discourses, views, frames supported**	**Impacts focused on Delta Levees**
Arkansas Act	*1850*	US. Congress	Swamp and overflowed lands represent a waste that the state should encourage independent farmers to make them useable.	Established basis of Delta settlement and land title transfer from federal government
Period of identifying lands involved and initial efforts to get reclamation going	1850 - 1866	Surveyors and California legislature	Locally organized reclamation districts should lead the effort with state support	Little progress, acreage limits (320 A) too small to attract capital required, state reinvestment of land sale money also inadequate
Legislature turns overflowed lands development over to counties	1866	County Engineers and Large Investors	Reclamation requires financial resources and risk spreading of large corporations or wealthy individuals.	Acreage limitation quickly dropped
Development of peat levees in Delta	1866 - 1882	Land landowners like Roberts, Chinese and other immigrant laborers and lessees.	Small peat levees can create large profits in Delta but floods can produce ruin	Early levee development, largely a failure.
Hydraulic gold mining in Sierra and resulting deposition of sediments in Sacramento valley streams and farms	1853 - 1884	Mining companies, valley farmers, courts and legislature	Public priority of private extraction of minerals, particularly gold slowly gives way to view that the land and waters also had value that had to be protected for the public good	Sedimentation in the Sacramento limited navigability and increased frequency of levee destroying floods along the Sacramento. In Delta the effects not as great and arrived later than those levees on the floodplain upstream of the Delta.

Table 4.1 Continued

Event or Period	Date (s)	Kev actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
Era of levee construction in Delta with clamshell dredge.	1882 - 1922	Reclamation districts, land developers, and emigrant and immigrant farm lessees, purchasers, and laborers.	Continuing battle to reclaim farmland from marsh against increasing floods. Flooding peaked in 1907 at flow levels twice as high as engineers considered possible.	Constant struggle to keep levees above many floods, Flooding forces abandonment of Sherman, Twitchell, and Bouldin Islands for several years but increasing number and size of clam shell dredges finally permits reclamation of entire Delta by 1922.
San Francisco Earthquake	*April 1906*		Delta levees, such as they existed, were not damaged by large earthquake.	None and it is the largest quake to have been felt by Delta manmade levees.
USACE constructs the Sacramento River flood control project	*1917 to 1953*	USACE, and Sacramento Valley agricultural and navigation interests, U.S. Congress.	Sacramento Valley flooded and navigation harmed because of lingering effects of hydraulic mining sediment transport of which the US government had been the prime beneficiary	While about 15% of Delta levees were reworked to accommodate draining Kelley's "Inland Sea", most of the Delta did not benefit from the great flood control project, except along the Sacramento and its direct distributaries.
City of Antioch loses water rights claim in court	*1922*	City of Antioch, Delta farmers and industrial interests, upstream water users, State Supreme Court	Rights to water determined to not include rights to "fresh water"	Contra Costa County and Delta users needed to find ways to protect their water supply from salinity intrusions
California Legislature approves what will become the CVP	*1933*	Legislature, San Joaquin Valley agricultural interest	Need to move excess water from Sacramento to the Central Valley to replace rapidly depleting Central Valley ground water ssupplies	Beginning of Delta involvement in water distribution

Table 4.1 Continued

Event or Period	Date (s)	Kev actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
USBR takes over and builds CVP	*1937 - 1951*	FDR, Congress, the USBR	The state water project, stalled because of failure of California to sell bonds in Depression becomes part of New Deal job creation effort, hoping to help save some small farmers from additional Dust Bowl conditions.	Project included Shasta Dam which would allow the USBR to wash salinity intrusions out of Delta. Makes Delta part of the CVP, particularly after construction of Cross Delta channel in 1951.
Burns Act passes – establishing State Water project and declaring Delta a "special place deserving protection"	*1959*	Governor E. Brown, DWR, state legislature, Central Valley agricultural interests, MWD.	Need to move additional surplus water from as far north as the Eel River to the Central Valley and South Coastal Region to continue growth and prosperity in California. No acreage limits on water recipients. Established guarantees for Delta farmers	Establishes Legal Delta and promises protections as special place. Further cements Delta's place a center of water distribution System
SWP bond issue passes at $1.75 B	*1960*	Gov. Brown, public relations firms, voters	North - Theft of water and opportunity. South – Water necessary to sustain growth	
Construction of SWP – deciding what kind of salinity barrier to establish in Delta	1961 - 1971	DWR, USBR, Contra Costa County, Delta interests	Physical barrier would hurt Contra Costa county access to fresh water, restrict navigation, but protect Delta and water export access to freshwater. Peripheral Canal proposed to protect water export access to fresh water, potentially at expense of Delta water users	Money ran out before any Delta facility could be built, delaying decision. Water deliveries to LA start in 1971. Delta levees now part and center of large reclamation and water supply project.
National Environmental Protection Act passes	*1969*	Sierra Club and newer environmental NGOs, Congress, national press	Environmental consequence of infrastructure projects need to be considered and ameliorated before projects permitted. Environmental concern raised over Peripheral Cana al	Peripheral Canal would now require environmental review

Table 4.1 Continued

Event or Period	Date (s)	Key actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
Levee Failure –Brannan Island	*June 1972*	Brannan Andrus RD, USACE, DWR	Water exports vulnerable to disruption due to failure of locally built levees. Support for Peripheral Canal and some state financial support for levee maintenance grows.	First real exposure of Delta levees to wide public interest. DWR reminded of need for peripheral canal. Leads to passage of Way Bill giving some support to levee districts.
California Drought	*1976 - 1977*	Gov. J. Brown, water users, water contractors, DWR	Peripheral canal, additional dams, and perhaps connections to other northern California watersheds (Eel) needed to keep California economically viable.	Upstream dam releases keep Delta waters fresh
Revival, approval and voter defeat of Peripheral Canal	*1977 - 1982*	Governor J. Brown, DWR, MWD and other water contractors, large Central Valley landowners, environmental groups, Contra Costa County and other Delta interests, California voters	Peripheral canal needed to support water exports vital to California economy, Eel River however deserved permanent protection. Contra Costa County and Delta users and other northern Californians concerned over another LA water grab. Environmental groups oppose the peripheral canal.	Delta levee districts continued to be concerned about increased salinity in Delta if the Peripheral Canal got built. North Delta Water District signs contract with DWR for water from canal if necessary. Other Delta water Districts refuse to sign such agreements
Jones Tract and McDonald island "sunny day" levee failures	*1980 & 1982*	DWR experts	Issues of salt water intrusion did not develop as severely as expected. hydrodynamic modeling and expert knowledge establish that levee failures on the eight western Delta islands posed the greatest risk to water exports	AB-34 passed in 1986 increases subventions moneys but half were dedicated to the eight western islands as suggested by DWR.

Table 4.1 Continued

Event or Period	Date(s)	Key actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
Wet years in California cause numerous levee failures	*1980-1986*	Reclamation Districts, DWR, FEMA, USACE	Levee failures during floods of 1980, 1982, 1983, 1984 and the record flood of 1986 raise concerns over safety and cost of Delta levees. Rising concern that Burns Act commitment to preserving Delta levees may be too costly. Need for engineering standards for Delta levees identified.	Legislature gets serious about state financial support for Delta levee maintenance passing AB-34 with the caveat noted above. Reclamation Districts also get more serious about levee maintenance especially in light of passage of AB-955 in 1985 that suggested the state might be not able to preserve all Delta island and FEMA ruling that after 9-11-91 levees not meeting the HMP standard (FEMA and DWR established) would not receive emergency relief funding.
Sacramento winter run salmon and Delta Smelt listed as Threatened under NEPA	*1990 &1993 respectively*	USF&W and NMF acting under NEPA	Delta environment for native species deteriorating because of loss of habitat among many other stressors. Congress sets aside 800,000 Acre-ft. for fish under Central Valley Improvement Act in 1993	Riverine habitat on levees becomes more important and leads to changes in 1993 in the Subventions program to require 3 for 1 habitat replacement for levee maintenance work
Formation of CALFED	*1993*	Governor Wilson & Secretary Babbitt		
CALFED era of Delta governance	*1993-2007*	All 24 agencies (federal and state), governors Wilson, Davis, and Schwarzenegger.	Adaptive management, commitment to best available science and collaboration would allow agencies to execute the largest environmental restoration project in history while enhancing water export quality and quantity and provide stronger Delta levees.	CALFED took credit for subventions funding for Delta levees. CALFED not as concerned with Delta levees as other responsibilities

Table 4.1 Continued

Event or Period	Date(s)	Key actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
Jones Tract levee failure and decision in the Paterno lawsuit	*2004*	Governor Schwarzenegger, DWR, BNSF railroad, Upper Jones Tract RD, USACE	Weakness of Delta levees and the problem of relying on them for the water supply system questioned, State liable for not making levees safe or warning residents about dangers of levee weakness. Effectiveness of CALFED questioned.	Cost for repairs and dewatering Jones Tract was very high raising the issue of ability of local levee districts to manage the levees of the state, including the Delta. DWR questions what role it should play in future levee repairs and pump outs
Katrina knocks over New Orleans levees, destroying city	*2005*	USACE, national press. Governor, DWR.	California characterized as having greater risk of levee failure than N.O. pre-Katrina has. Delta levees described as weak, not-engineered, too old, prone to earthquake damage and a greater risk in future because of sea-level risk and continued subsidence.	Governor and DWR spend $50 million with USACE and levee district s on emergency levee repairs, many in Delta, all with vegetation incorporated in design. AB-1200 passes establishing Delta Risk Management Study of Delta levees. E1 and Prop 84 bond issues pass with money for Delta levees.
Little Hoover Commission reports on effectiveness of CALFED	*2005*	Governor, DWR, Little Hoover Commission, CAL-FED	CALFED sound to be ineffective while fish populations and levee safety continued to deteriorate, water quality and water exports also in decline. Stronger leadership structure required to solve problems	CALFED had not paid much attention to Delta levees
Creation of Delta Vision panel	*2006*	Governor Schwarzenegger, the legislature, Blue Ribbon panel	Clear action plan required to save water supply of 24 million Californians and protect salmon and smelt from extinction.	References still made to protecting Delta as unique place but not with same intensity of coequal goals of water supply reliability and ecosystem restoration.

Table 4.1 Continued

Event or Period	**Date(s)**	**Key actors/ Governance processes**	**Discourses, views, frames supported**	**Impacts focused on Delta Levees**
Legal battles in Federal Court (Judge Wanger) over adequacy of NMF and USF&W biological opinion on now Endangered smelt and salmonoids	*2004 to present*	Judge Wanger, USF&W, NMF, DWR, USBR, Environmental NGOs, MWD, various water contractors, Senator Feinstein and others from California congressional delegation.	Discourses over how much pumping of water from south side of Delta was impacting fish survival, discussion of other reasons for ecosystem decline pollution, Judge Wanger rules in 2007 and 2008 that USF&W and NMF (respectively) biological opinions inadequate to protect smelt and salmonoids and orders reduced exports. Court approved biological opinions pending	Peripheral Canal debated as either good or bad for endangered fish. Delta water rights and contributions to pollution of Delta waters questioned along with all other water users.
Bay-Delta Conservation Plan development (BDCP)	*2006 to present*	DF&G, USF&W, NMF, DWR, USBR, Water Contractors, ENGOs	Plan can be developed to restore enough habitat in Delta for endangered species to recover and keep fish away from pumps	Concern over economics of effects on total agricultural support community of taking 75,000 A out of production plus P.C.
Dispute over the USACE enforcement of bare levee policy	*2007 to present*	USACE, DWR, DF&G, reclamation districts	Levees need to be free of vegetation to permit inspection.	Delta and all California levees had long been considered also part habitat, removing vegetation will require millions in expense, a cost increased by the mandated 3 to 1 replacement of habitat removed.
DRMS Phase 1 draft released to internet	*2007 (June)*	URS and other contracted consultants, DWR, DF&G	Executive Summary emphasizes poor and declining performance of Delta levees and the high probability of a multiple levee failures in a likely earthquake that could shutdown water exports for years.	Effectiveness of subvention program and reclamation district efforts questioned. Lends support to PPIC/CWS calls for planned abandonment of most, if not all, Delta levees and construction of peripheral canal.

Table 4.1 Continued

Event or Period	Date(s)	Key actors/ Governance processes	Discourses, views, frames supported	Impacts focused on Delta Levees
Delta Vision Panel Report Released	*2008*	Delta Vision Blue Ribbon Panel members	State need to move quickly to restore the Delta ecosystem and develop statewide water plan to improve reliability of water supply. Isolated conveyance system needed immediately. Established single state agency to oversee all activities in Delta.	Delta Vision clearly establishes Delta and Delta levees a statewide issue, not a local concern
Passage of Statewide Water Policy Act of 2009	*2009 (Nov.)*	California legislature, Delta Vision Blue Ribbon Panel, Governor Schwarzenegger, DWR	Included 4 major water policy acts including recording of groundwater. Creates DSC to develop a plan for the managing the Delta, including review of the BDCP. It included an $11.15 billion bond package for a variety of projects, much of it for water supply and environmental restoration in Delta.	Delta Protection Commission reorganized and given additional authorizes within the overall Delta plan

CHAPTER V

METHODS

OVERVIEW

This chapter describes methods used to achieve the dissertation objectives of 1) understanding the social perspectives of the leaders, scientists, and experts of the various stakeholders and agencies, which establish the policies governing Delta levees; and 2) establishing a concise, widely available and rigorous record of Delta levee failures to better inform those who manage the Delta levees today.

For the first objective, I used the Q-Method to identify and characterize the social perspectives. For the second goal, the dissertation used traditional methods from historical geography and application of GIS and remote sensing techniques to fill in many of the gaps in our understanding of the history of levee failures. This chapter will discuss in some detail the resources and approaches employed. Ethnographic interviewing techniques provided much of the information included in the Q-Method and the history of levee failures, so the process of selecting interviewees, the interview process itself, and the coding processes employed will be reviewed.

UNDERSTANDING DISCOURSES THROUGH Q-METHOD

Q-Methodology (hereafter Q-Method)

Geographers increasingly use the Q-Method to address issues and answer questions about discourse because of its ability to integrate qualitative and quantitative methods (Eden, Donaldson and Walker 2005, 420). This dissertation represents my first opportunity to use Q-Method and I will be extending the use of Q-Method within geography to the relatively unexplored area of identifying the social discourses that guide the science and management of natural resources, following most closely the efforts of Focht (2002), Raadgever, Mostert, and van de Giese (2008) and Bischof (2010). In this section, I provide a quick overview of Q-Method as an approach to understanding the social perspectives of failures of Delta levees. I will then present a short history of the method and trace its recent growth in geography and the environmental sciences. Then I will identify the major steps in the method and trace the development of these since 1980 as Q expanded from psychology. I will then show how my use of Q-Method followed "best practice" in this growing literature. Chapter VI presents the results of the Q-Method study.

History of Q-Method

William Stephenson earned Ph.Ds. in physics and psychology at Oxford and studied under Charles Spearman, the father of factor analysis (Brown 1997). Stephenson introduced the Q-Method concept to study human subjectivity in a letter to the editor of Nature in 1935 (Stephenson 1935a; 1953, 8; Robbins and Krueger 2000; Robbins 2005). Stephenson so that instead of measuring n individuals with m tests (or images, essays, views, or "other measurable materials"); n tests could be measured by m individuals and the result subject to factor analysis (Stephenson 1935b). He presented this to his fellow psychologists and started using the Q-Method terminology to contrast the method with standard factor analysis with its Pearson's r statistic. (Stephenson 1935a; 1936; Webler, Danielson and Tuler 2009). Using Q-Method, Stephenson could correlate individuals rather than tests or views. He also argued that all subjective behaviors can be studied scientifically using Q-Method (Stephenson 1953, 343; Robbins and Krueger 2000).

Stephenson's ontology assumes that individuals reveal their subjectivity through their behavior (Stephenson 1953; Robbins and Krueger 2000, 638). Stephenson defined subjectivity as a measurable internal view of the world in the conscious mind, not the subconscious or unconscious (Robbins and Krueger 2000). As Robbins and Krueger express it, Stephenson viewed subjectivity as "the internal frame of reference one calls upon to make sense of the world around oneself" (2000, 637). Robbins (2005) pinpointed two characteristics of subjectivity that Q-Method can help expose. First, individuals can communicate this form of subjectivity and they possess an innate awareness of the concourse of viewpoints or attitudes about a subject (Stephenson 1980, 884), a property termed "discourse awareness" by Robbins (2005, 210). This allows us to express our viewpoints or understandings. Second, subjectivity is assumed to be operant, or acted upon without external stimulation; self-referent or reflective of the individual point of view; and contextual in that it exists as a consistent part of the individual's totality of attitude toward the world and self (Robbins and Krueger 2000, 63; Robbins 2005, 211). Q-Method does not address any concept of subjectivity as part of a pure mental experience divorced from processing inputs and outputs, or any concept reflective of physical or social attributes such as gender, race, or job title/employer (Robbins and Krueger 2000).

Q-Method helps identify and define subjective perspectives and can do so with relatively small data sets. It does not attempt, however, to determine statistically what portion of a larger population identifies with a particular perspective or factor. The percentage of the participants in a Q-Method study who rank highly; or in Q-Method terminology, "load" on a factor, may but most likely do not, reflect the degree of support for that perspective in any other population other than the limited number of participants, termed “P-sorters” (Ockwell 2008).

Q-Method grew slowly from psychology, hampered within that field by its rejection by Cyril Burt and other giants of British psychology in the mid-20th Century (Brown 1997). Stephenson emigrated to the U.S. after World War II and his method slowly made gains in psychology and started finding homes in other fields, particularly in political science, championed there by Steven Brown (1980). Brown, Stephenson and others promoted the use of Q-Method in a variety of fields, founding in 1977 the scholarly journal *Operant Subjectivity*. In 1989, the Q-Method practitioners, just before the death of Stephenson, established the International Society for the Scientific Study of Subjectivity (ISSSS) and developed the now quarterly journal, *Operant Subjectivity* (Brown 1997). In 1992, ISSSS developed the “PQMethod” freeware package for mainframe computers, later making it available in the PC version used in this dissertation (Schmolck 2002).

Brown (1997) reported that from 1968 to 1997, the Q-Method bibliography had grown from 600 to over 2,500 entries in fields ranging from nursing, public policy, marketing, and religion, to literary interpretation. Brown also noted that Q-Method found applicability in new areas like postmodernism, deconstruction, social construction, feminism and women’s issues, identity theory, narrative analysis, qualitative analysis, and discourse analysis. By the period 1990-2003, Eden *et al.* (2005, 414) found 91 Q-Method papers in the *Web of Science*, about half in the fields of political science and psychology and a few from business and environmental/geography fields.

Robbins and Krueger (2000, 641) encouraged Q-Method use in human geography and lamented that geographers had not tapped its power as a quantitative tool to understand people's knowledge and interpretation of, and feelings toward, the places they inhabit. They specifically noted that Q-Method could effectively serve the increased interest of political ecology in understanding the nature, sources, and power of discourses of environmental knowledge (Robbins and Krueger 2000). The paper also suggested the same for political geography with its interest in understanding the complex interactions of identity, nationalism, and place; along with those exploring the divided and shared human perceptions of the environment and relationship of those perceptions with class, race, and gender.

Robbins and Krueger (2000) provided encouragement and systematic instructions for geographers to explore the Q-Method. Given the relative unfamiliarity of Q-Method to many scholars, Appendix K includes a table entitled "Summary of selected Q-Method Studies in Geography and related Fields 1999-2011." This table summarizes 19 applications of Q-Method as geographers and scholars in related fields have widened the application to areas similar to the issues this dissertation addresses, specifically, the understanding of the subjective attitudes of scientists and other experts that controls and confounds science-based policy development in water resource and environmental management. The table highlights an increasing confidence by geographers that Q-Method can help identify the social perspectives of the experts and key actors, which in turn can help understand the root of policy conflicts. The table also highlights applicable critical lessons learned in the studies where identified by the practitioner.

The following explanation of the Q-Method specialized terminology may prove helpful in understanding Appendix K and the remainder of the dissertation:

Concourse: The complete set of ideas, concepts, and options about the subject of interest held by the individuals of interest.

Q-set: The subset of items in the concourse, which captures with a manageable number of statements, the essential concepts revealed in the concourse.

P-set: The participant set, or a subset of individuals whose social perspectives on the topic are of interest. Like the Q-set, the researcher selects the P-set members with the criteria of wanting to represent the full range of interests and backgrounds of the individuals of interest.

Q-sort: The exercise by the members of the P-set to force-rank the items in the Q-set into the quasi-normal distribution according to terms of instruction.

Factors: The clusters of Q-sorts resulting from the Principle Component Analysis, which represent the social perspectives of the P-set.

To help identify the Q-Method best practice in geography, Appendix K captures the number of statements in the concourse for each study; it identifies the number of elements selected for the Q-set; it quantifies the size of the P-set; and then identifies he number of factors or shared social perspectives determined by the researchers from the factor analysis. Appendix K provides statistics for the size of the Q-set, P-set and the number of Factors identified for the 19 studies from recent years, to provide a comparison for the statistics for this Q-Method study. For each element of researcher choice in developing the Q-Method study, the dissertation closely matches the mode, median, and/or mean for the 19 studies, reflecting a common literature rather than an established goal or target. I calculated the group statistics after the completing the Q-Method analysis.

EMPLOYING Q-METHOD IN THE DELTA

Background in the Literature

Stephenson (1953); Brown (1980); Barry and Proops (1999); Robbins (Robbins and Krueger 2000, Robbins 2005); Webler, Danielson, and Tuler (2009); and Brannstrom, Jepson, and Persons (2011) included reasonably consistent explanations of the activities involved in employing the Q-Method and these scholars provide the guidance for much of what follows. They did not agree on which activities were combined into steps or even the actual number of steps involved, varying from Brown's eight to Brannstrom's four. To encourage expanded use of Q-Method in their academic fields, Brown (1980); Barry and Proops (1999); Robbins (2005); and Webler, Danielson, and Tuler (2009) wrote papers that were primarily works that described the Q-Method. From them I determined that Q-Method for this application entailed ten activities, eight of them defined as steps in Brown (1980). Brown did not emphasize the importance of using interviews to establish the concourse so he did not identify it as a separate activity or step. These interviews played a very critical and time-consuming role in this Q-Method study so I included it as a separate element. Geographers Robbins (2005), Webler, Danielson and Tuler (2009), and Brannstrom (2011) emphasize the importance of a follow-up interview or communication with the P-sorters for verification of the findings as a last Q-Method step, something that Brown (1980) did not yet employ. I believe it was a critical element of Q-Method and, thus, it is the tenth activity.

I prepared Appendix C to tie my ten activities to Brown's (1980) eight step process and the steps identified in the three major methods papers prepared by geographers and related scholars, Barry and Proops (1999); Robbins (2005); and Webler, Danielson, and Tuler (2009). For the most part the four papers describe a consistent but flexible process. Each paper emphasized slightly different aspects of the activities, combining them conceptually. The Q-Method continues to grow as noted above with the addition of the P-sorter follow-up activity as an example. Brown's book (1980) represented the first attempt to provide a detailed explanation for the steps required to employ Q in studies other than psychology; in his case, political science. It included a particularly detailed primer on the statistics and math of correlation, factor analysis, and factor rotation. These are all now fairly well "black-boxed" thanks to the availability of free software packages like PQMethod, use of which is outlined in Webler, Danielson, and Tuler (2009). Kent and Coker (1992) provide a good theoretical background to the principal component analysis performed in the computerized "black-box" of PQMethod. The use of the "black box" may be one reason why some scholars have combined activities as these in later definitions of the Q-Method because these activities are less time consuming now than in 1980 when Brown described them. The computer readouts include several of these, further diminishing the differences these steps or activities.

Q-Method Activity Steps

The ten activities I identified and adapted (as relation to steps of others shown in Appendix B) for my study of the discourse of Delta levee past, present and future are: 1) Define domain of subjectivity; 2) Conduct semi-structured interviews and other research to create the concourse; 3) Select concourse items (Q-set) for sorting representative of the entire concourse; 4) Select P–set, the individuals who will conduct the Q sort and schedule time and place for sorting; 5) Establish conditions of instruction for the sort; 6) Conduct Q sorts, record results and interview sorters for additional input; 7) Run factor analysis and determine appropriate number of factors to use; 8) Rotate factors to simplify and generate factor scores and loadings; 9) Use statistically significant factor statements to interpret, name, and describe the factors; and 10) Prepare summary of factor descriptions and review with high loaders on each factor for input and revision as appropriate.

Activity 1) Define the domain of subjectivity of interest

Robbins (2005) highlights this first step of "defining the domain of subjectivity" as one that needs to be guided by the research question but one free from researcher effort to predestine what the responses would or should be. In my case, I want to understand the primary messages and knowledge that key managers, engineers, and scientists of the Delta socio-ecosystem hold and espouse about the failures of Delta levees. Following Webler, Danielson, and Tuler (2009), I defined the domain as: In the context of failures of Delta levees, this study wants to understand the different social perspectives and knowledge of how levees should be managed and maintained (if at all) in the future to inform the plan for the Delta being developed by the Delta Stewardship Council.

Activity 2) Create the Concourse using dual-purpose semi-structured interviews of key actors

After defining what area of subjectivity needs better comprehension, the Q-Method researcher must create a complete list of statements and thoughts (or pictures of tree species in the case of Robbins 2000) made or held by the individuals of interest. Q-Method practitioners term this creating the Concourse. Scholars have employed one of two methods or a combination of these methods to create the Concourse, either extracting statements from websites, scientific journals (Bischof 2010), newspaper articles, testimony in judicial or in legislative hearings, or findings of previous research (Brannstrom 2009); or through direct interface with the key people living and working in the domain of subjectivity. This second method to develop the concourse represents the "naturalistic" method (Robbins 2005, 212) and can take the form of focus group discussions or semi-structured interviews with representative members of the targeted group. Whereas my research also endeavored to also gather firsthand knowledge of recent levee failures and the results of those failures from the same targeted group of individuals, I elected to use the direct semi-structured interview approach to develop the concourse and combine the two research objectives of the dissertation into the same interview. The following description of the interview method employed also represents a major part of the second part of the research, the development of the detail history of failures of Delta levees.

While not an activity set by the Q-Method, direct contact with human research subjects required approval from the Texas A&M University Institutional Review Board (IRB). The list of instructions and the questions to be asked (provided in Appendix D), must have prior approval of the IRB, an approval received in late June 2009. I next began the task of identifying who to interview and how to approach those individuals. Whereas I did not wish to use the websites and literature from the Delta Vision, the PPIC, and CALFED to generate the concourse, they proved helpful in identifying some of the key actors, such as members of the steering committees for these efforts and other participants. I desired to interview individuals with a working knowledge of Delta levees and levee failures with a diversity of backgrounds to develop a complete concourse, a "purposeful sample" (Longhurst 2003) of individuals for both aspects of the research. Clearly, several basic groups of organizations are involved with the Delta levees, specifically, the local reclamation districts (RDs); Delta residents not on the RD boards; the engineers and other consultants who support the RDs; the various branches of DWR and the federal agencies concerned about levee stability because of a variety of sometimes conflicted mandates to provide water export, flood control, and environmental restoration; the federal and state agencies involved in environmental protection and fish species recovery; and the NGOs and academics supporting their interests. Identifying who should be and would agree to be interviewed became the next challenge.

Fortunately, during my involvement in research on erosion of Delta levees, I had become acquainted with an interesting and interested Delta farmer, reclamation board president, and former Delta Protection Commission member. He had already shared stories of his experience with levee failures, his dealings with the state, county, and federal agencies over levee issues, and many of his views on levees. He became one of my first interviewees but he also identified others I should interview, including those who he did not totally agree with but respected. The second break I received came when I found a poster developed by the consultant URS in 2008 showing, "Levee Failures in the Sacramento-San Joaquin River Delta" (Gaddie, Mierzwa and Marr 2008). I contacted the authors and discovered that the chart had been prepared quickly from data provided by the DWR. When I contacted the individuals at DWR who prepared the information used, they provided their spreadsheet and they became very interested in this project. The spreadsheet became a starting reference point for the database of levee failures and the two individuals helped identify other interview candidates.

Starting from the two diverse sources, I was able to use snowball techniques (Longhurst 2003) to identify and establish contacts with other interviewees. By asking an interviewee near the end of the interview who else I should interview, I was able to schedule and meet 30 key actors in determining the present and future of the Delta levees in July and August 2009. I had some advantage because I could identify myself as a Ph.D. candidate who had been involved for four years in researching Delta levee erosion rates, and I was a professional engineer in Texas (many of the interviewees had engineering backgrounds). I believe the thing that opened the most doors, however, was that I would first identify the individual who had recommended that I request the interview. That sort of "letter of introduction", I believe, helped create the 97% acceptance rate that I experienced. Only one individual that I approached out of 31 could not find the time to meet to do the interview. It also indicates that the snowballing technique helped me reach the "right" people: they all shared a passion about Delta levees and the Delta itself and were willing to make time to share their knowledge, fears, and hopes. In every case I was able collect at least one comment to include in the Concourse, and most provided new data points about the levee failures not available elsewhere.

I initially approached most interviewees by e-mail (Appendix B shows a typical e-mail). If I did not get a response within four or five days, I would follow up with a phone call. I also took advantage of attending a public meeting on Delta issues that several interviewees suggested I attend. It turned out to be the perfect venue because this was the

Levee and Habitat Restoration sub-committee originally established by CALFED. This committee continued to function because it seemed to work for everyone even after the demise of CALFED. I attended the meeting in late July 2009. The sub-committee consisted of federal, state, and reclamation district officials and engineers who had been meeting regularly and publicly for twenty years to informally coordinate levee and environmental issues. This provided the opportunity to approach several new contacts and establish interview schedules. Attendance at the meeting also contributed to researcher credibility with the interviewees, the recommendation to attend came from several of the early interviewees who were members and attended the meeting in July. I conducted the thirty interviews during July and August of 2009.

n many respects, the interviewing process represented the easy part of this work. As a retired engineer and manager, I had the advantage of interviewing individuals whom I was comfortable and experienced dealing with as peers. This spared my efforts of some of the concerns expressed by many researchers of the problems of interviewing “elites.” My interviewee list included those clearly recognizable as “elites” - scientists, engineers, NGO and agency managers, RD directors, and Delta Vision steering committee members. At the same time, some on the list clearly held little positional power. My experience with the combination would tend to confirm the view of Smith (2006) that positional “power” does not necessarily flow to interview space. I did not sense a feeling of inequality of power in any interview. More than one interviewee expressed surprise when I showed up because of my “maturity.” The total number of surprised interviewees likely would have been much higher I had not adequately warned many of the interviewees beforehand. My background and appearance may have contributed to reducing any power imbalances in interview space but I believe that the confidentiality promised, the concept that power is not always transferable, and like Smith the "good nature of the particular research participants I contacted" (Smith 2006) also reduced the any structural problems identified by others with interviewing elites. Indeed some, but certainly not all, respondents, trusted in the confidentiality aspects of the process and the setting of the interview to be free of the constraints of positional power to share information and thoughts that the interviewee probably would not have shared in other contexts. Some interviews lasted several hours with the longest being six hours.

All interviewees agreed to be tape-recorded and all conversations recorded except the one when researcher-error caused the recorder to malfunction. I then coded the interviews, some from a fully transcribed interview and in some cases from transcription of specific comments on the tape. Coding captured two kinds of comments. First, it captured revelations about past levee failures and near misses and entered them into the levee failure datasheet as appropriate as will be discussed below. Second, it recorded strongly held or well elaborated opinions that came out as responses to the open-end questions relative to the meaning of the history of levee failure, the interaction of the levees and the environment, the best organizations to provide governance and governing of the Delta levees, and the catch-all "what else should be known about Delta levees?" Following the literature (Robbins and Krueger, 2000, 638; Eden, Donaldson, and Walker 2005, 416; Venables *et al.* 2009, 1092; Brannstrom 2011). I approached the data in the comments made in the interviews using "Grounded Theory. Glaser & Strauss in 1967, as outlined by Strauss and his student Corbin, first described this qualitative approach (Strauss and Corbin 1990, 8). Corbin (2009) more recently updated description of the method. With Grounded Theory, the researcher resists the temptation to start with a thesis, instead she approaches the available data, studies and codes it, looks across observations for patterns and correlates the data collected, then uses inductive reasoning to develop a theory of what the empirical data, mean. Pini, Previte and Haslam-McKenzie (2007, 430) do not use the term Grounded Theory but describe their process of distilling a concourse out of 93 interviews as "…statement selection is grounded in an inductive design, which in this study emerged from the patterns observed as statements were collected; that is, during interview analysis and identification of dominant themes discussed by interviewees." I started to list the concepts important to the interviewees about Delta levees and continued through the thirty interview transcripts listening to the tapes repeatedly until the ideas began to repeat themselves or I had reached a "saturation point" at about 150 statements. I did round out the concourse with one item from my review of the background literature mentioned earlier; ironically, the document attributed the statement to one of my interviewees.

Whereas the Q-Method literature relies on the concept that the concourse contains a finite universe of views, opinions, and perceptions in the domain of subjectivity on any subject, guidelines for describing the size of an adequate concourse remain variable as shown in Appendix K. Doody *et al.* (2009) reported generating a 750-statement concourse on sustainable development based on their focus group inputs, and a well-funded study by Focht (2002) on watershed issues in the Illinois River Basin in Oklahoma claimed 3000 statements coming from 150 interviews. Brannstrom (2011), however, reached saturation with 42 statements on Brazilian environmental governance.

In developing the concourse, I attempted to capture the selected statements in the interviewees own words, revising wording only to correct grammatical errors introduced under the constraints of normal conversation by having to think and talk at the same time. Many scholars suggest that the potential of Q-Method to remove the subjectivity of the researcher from the research is more limited and in many cases less desirable than once suggested by Q proponents (Robbins and Krueger 2000, Eden, Donaldson, and Walker 2005, Brannstrom 2011). Use of interviewees' own wording or "raw verbiage" (Eden, Donaldson, and Walker 2005) for statements of the concourse can help focus on the researched rather than the researcher.

Activity 3) Select concourse items (Q-set) that cover the entire concourse for sorting

The next step in Q involved reducing the 150 element concourse to a reasonable number of statements, the "Q-set", that can be sorted between extremes of "Most Accurate" to "Most Flawed" by a subset of the key actors, the "P-set." As with the standard for the number of elements required for a good concourse, the literature does not provide meaningful guidance for the size of an adequate Q-set (Robbins 2005). I ended up reducing the 150 items in the concourse through a process that involved typing the statements, including reference to the source and then coding each into areas of concern or "foci". Again relying on Grounded Theory, the development of the categories came from what was in the concourse, not any preconceived hypothesis of what should be there. I tested each foci and then each Q-sort item against my research question, "How does the history of levee failures, as understood by those involved in the Delta, determine perceptions and knowledge of the present conditions of the Delta levees and the role those levees will play in the future Delta."

In the end, six foci emerged: 1) Concern for levee stability, 2) Issues of levee management, 3) Ideas for Delta Governance, 4) Levees and the Peripheral Canal, 5) Levee-environmental interactions, and 6) Levee risk and vulnerability with particular concern for the risk from earthquakes. The foci helped me narrow the Concourse to a 35 statement Q-Set with between four and eight statements covering the range in each focus. I originally targeted to have about five foci and 25 Q-Set items but believed that in several foci additional statements were needed for comprehensiveness (Eden, Donaldson, and Walker 2005, 417) of identifying the critical items of discourse relating to Delta levees. The slightly larger number of Q-set items did not seem to increase the sorting activity to the point of tedium on the part of the P set or unduly increase the time required to complete the sorts. It also seems in line with many of the Q sets in the studies outlined in Appendix K.

The final wording of the Q-set from the selected concourse items sometimes required simplification and shortening to remove or reduce multiple meanings in a statement. I made every effort to preserve distinctive phraseology of the source interviewee where appropriate, and in some cases combined phrasing from similar concourse items to create the Q-set. Again, I seized every effort to remove research bias in development of the Q-set, a requirement somewhat less important because the each sorter can totally accept, reject or anything in between any statement. To assure a sense of balance, I included at least one concept from each of the 30 initial interviewee's comments in the final Q set. The list of Q-sets items and the instructions to sorters appears in Appendix D as the part of the request to the Texas A&M IRB for modification to include the Q-sorting exercise.

Activity 4) Selection of the P–set individuals

Selection of the P-set or key actors who would agree to perform the sorts became the next challenge. As with the interviewee list for the development of the concourse, I sought individuals from local, state, and federal agencies representing the spectrum of skills and interests in Delta levees, including lawyers, engineers, managers, and environmental scientists. I attempted to avoid inputs from public relations or public affairs officers. In the end, 22 individuals prepared sorts as listed in Appendix I. The strict confidentiality requirements of the process severely limit the information provided on each respondent. Those with identification numbers above 130 did not participate in the first phase interviews. Several were individuals whom I wanted to interview during the 2009 concourse development interview but who were not available for one reason or another, others were "targets of opportunity" that I met and who agreed to participate on the spot through the ongoing snowball process. Two of those I originally hoped would participate could not because of conflicts with work schedules or illness during my rather short interview research schedule (two weeks) in the summer of 2010.

Activity 5) Establish conditions of instruction for sort

As shown in Appendix C, only Brown's (1980) methods paper highlighted the step of establishing the conditions of instruction for the Q-sort. I initially relied on a simple "Most Accurate- Least Accurate –Neutral" instruction of forced ranking into a normal distribution as shown in the Table 5.1. My original instructions created problems for the sorters in that they had little problem differentiating the accurate and inaccurate statements; however, they could not differentiate further based solely on accuracy. In retrospect, I developed the Q-sort list based on six foci, each of the foci could have a most accurate and a least accurate statement, making narrowing to two “Top”, and two “Bottom” ranked statement difficult purely based on accuracy. To permit differentiation cross foci, the first respondent and I agreed that a second qualifier would be required to help everyone sort effectively and to achieve the intent of the research. I revised the instructions to require forced ranking of the 35 statements into the same distribution between “Most Accurate and Most Important” to “Least Accurate and Most Dangerous.” Whereas differentiation into the three broad classifications remained a easy step for all sorters, the forcing into the restricted -4, -3, +3, +4 rankings challenged most members of the P-Set and remained difficult. All sorters were able to complete the sort as requested with one exception.

Table 5.1 - Rankings and Distribution for Q sort

	Least	Accurate			Neutral			Most	Accurate
Rank	-4	-3	-2	-1	0	+1	+2	+3	+4
Number	2	3	4	5	7	5	4	3	2

The one exception came where schedule constraints forced one of two individuals to respond by e-mail and did not complete the sort in a face-to-face interview. The literature indicates that entire Q-sort exercise can be completed via e-mail (Raadgever, Mostert, and van de Giesen 2008); and the two individuals who could not complete the face-to-face Q-sort had important fisheries expertise and focus plus first-hand knowledge of Delta levees. Both individuals had serious schedule conflicts and could not meet directly but I thought that to get a comprehensive set of P-sorters, I needed participation of these two individuals. Respondent 127 completed the sort as instructed, but the second, Respondent 136, did not match the perfect normal distribution desired, probably because he received just the original conditions of instruction and so his rankings weighted heavily to the two ends rather than a normal distribution. Unfortunately, efforts to contact the respondent since have not been successful; however, the computer program PQMethod used to run the correlations will process sorts that are not quasi-normally distributed (Webler, Danielson, and Tuler 2009, 19). This individual brings a difficult to find background, experienced in levee restorations with a fisheries interest. I elected to retain the sort, in part because Stephen Brown (1980) argues that the statistical shape has no impact on the results in PQMethod, and in part, because the exercise needed to capture the viewpoint of Respondent 136.

As the sorting went on, it became clear that the "neutral" designation in the middle of the distribution did not help because the researcher cannot truly balance the Q-sort. So the word "neutral" provides no meaning, a ranking of 0 denotes lack of saliency rather than agreement/disagreement, accuracy/inaccuracy. In some cases where sorters questioned giving a 0 ranking to a statement or statements they agreed with or disagreed with, I asked them to mark where in the distribution they placed the divide between agreement and disagreement. This did not happen very frequently and did not play a major role in the analysis but could in certain situations. I revised the conditions of instruction to explain that a ranking of 0 need not be "neutral" and instead represents the middle of the continuum between the two ends and for some may be positive or be negative.

Brown's (1980) emphasis on the Condition of Instruction for Q comes primarily from the potential of using the same concourse with different instructions to gain different insights into social perspectives. Indeed, in this case, a second condition of instruction could have also asked how the individual thinks their boss, their Department Secretary, the Governor, their clients, or in the case of the independent farmer, their bankers would rank the statements, to give a positional perspective. I desired to find the individual's perspectives free as much as possible from positional views. In several cases, the respondents would note or refer to a difference between an official view versus their view and I assured them the research needed their personal perspective, and would remain private.

One concern that has risen in recent literature is the concern over "shamming" or deliberately lying by respondents or sorters to distort the results of a Q-Method study (Hunter In press, 10). One can envision this being a larger threat should Q-Method become more prominent in helping mold public policy as suggested by several scholars (Bischof 2010; Barry and Proops 1999, Ellis, Barry, and Robinson 2007). The concern over possible manipulation of the results of the study is a primary factor in avoiding public relations personnel in the interviews and Q-sorts. Individuals with the primary responsibility to influence, control and manipulate public policy discourse could indeed pose a risk to Q-Method approaches; particularly should public communications experts recognize them as playing an influential role in decisions about public policy. Hunter (In press, 10) suggests that preventing shamming will require "triangulation of purposive sampling, researcher expertise, and theoretical framework." He further suggests that for Q-Method to work properly, collaborative relationships must exist between the researcher and the respondents where they share ownership of the researched issue. With 16 of my 22 sorters having participated in the initial concourse development interviews and the deep commitment, all showed to solving the problems of the Delta levees, I do not believe this effort got "shammed."

Activity 6) Conduct the Q–sorts, record results and interview sorters for additional input

Because I had to refine my conditions of instruction after I started the Q -sort exercises, the discussion of Activity 6 defines much of this step. The actual sorting process involved printing each Q-sort statement on a 3" by 5" paper, which I laminated. I assigned a number to each statement and printed that number upside down on the bottom of the card to allow capture of the sort data easily from the other side of the desk from the sorter. Sorting sessions were at the location picked by the sorter, generally their office, but several were at coffee shops and restaurants, or at their kitchen tables or outdoor patios. With the exception of the two e-mailed responses, after explaining the Q-sorting technique I remained with the sorter during the process, encouraging and recording with permission comments about why they ranked certain statements. Most sorters read the statements aloud and started first making piles of agree-disagree-neutral rated cards. Several participants required gentle encouragement to move to the next step of further differentiating the "Agrees" into the +4, +3, +2 rankings, with most attempting then to work from the outside in. The pattern among all of the sorters proved very similar even though only one purported to have ever completed a similar exercise. My respondents generally agonized over the exercise, spending about a half-hour getting to a completed sort with little variation in the time involved even though I imposed no time restrictions. Upon achieving the required distribution, they all took quick reviews of what they had done but generally it was quick and few made any changes at that point. Most enjoyed the exercise; several seemed surprised by some of the statements.

As suggested by many from Brown (1980, 184) to Brannstrom (2011) the Q-sort activity also represents an opportunity to facilitate another semi-structured interview with contributors to the research. The advantage to this step as Brown put it, "social scientists have an advantage over the more esteemed physicist by virtue of the fact that they can converse with the objects of observations" (1980, 184). In my case, I was able to get updated with the latest developments since the previous interviews, clarify questions I had from those interviews, and obtain new data from individuals previously not interviewed. I did not have to do a lot of follow-up questioning about justification for the sorts as most had followed my suggestion of thinking aloud, particularly where the privacy of the setting permitted. Again, the tape recordings provided a way the researcher could store great data until she could process it. As suggested by Brannstrom (2011), I found that Q-Method provides the qualitative researcher with the *ends* (statistical supported results) and the *means* (an interview environment conducive to asking difficult questions, particularly of elites), to conduct discourse analysis.

Activity 7) Run factor analysis and determine appropriate number of factors to use

The next step involved downloading the DOS version of PQMethod on a PC and entering the 22 sorts into the program. Peter Schmolck developed this freeware program based on a mainframe program created by John Atkinson at Kent State. Schmolck has made it available on his webpage at http://www,rz.unibw-muenchen.de/~p41bsmk/qmethod. Fortunately, easy to follow systematic instructions are available for download from http://www.seri-us.org/pubs/Qprimer.pdf written by Webler, Danielson, and Tuler (2009). Once the researcher enters the data, the program determined in milliseconds the user's choice of a Centroid or Principal Component factor analysis of the 22 sorts of 35 statements. The Q-Method literature suggests that practitioners most commonly use the Principal Component Analysis (PCA), particularly those planning to use another algorithm like Varimax to rotate the factors. (Lopez-i-Gelats, Tabara, and Jordi 2009; Webler, Danielson, and Tuler 2009; Ockwell 2008). Kent and Coker (1992, 186-202) provide a good explanation of Principal Component Analysis, which seeks to identify the highly correlated statement responses and reduce the data points in this case, from 22 to no more than eight and in most cases fewer. This then permits statistical identification of clusters of subjective perspectives of the P-sorters from three, four, five, or even two dimensional space rather than 22 dimensional space.

PQMethod permits factor analysis by the Centroid method as well as PCA, which according to Webler, Danielson, and Tuler (2009), gives the researcher the option of focusing on the either the commonality among sorts by using the Centroid method, or the specificity of sorts as allowed by use of PCA. Centroid and PCA tend to give similar results in environmental studies but Webler, Danielson, and Tuler (2009) warn that it would not always be the case. They also note that most researchers using the Centroid method then rotate the factors manually. I elected to use PCA to run the factor analysis because I did not want to introduce researcher influence as implied by total manual rotation. The literature, with the exception of Danielson (2008), encourages use of PCA. PCA finds the principal axis through the data points in the plane that generates the highest total eigenvalue first, and then generates orthogonal factors with decreasing eigenvalues until it reaches factors equal in number to the number of sorts analyzed.

Eigenvalues measure the amount of variance in the sorts explained by the simplifying factor, and the percentage of the variance explained can be determined by dividing the eigenvalue by the total number of sorts. The PCA generated the eigenvalues and explained variance shown in Table 5.2. The fifth factor exceeded the cutoff that eigenvalues must be greater than 1.00 to be simplifying. By definition, the eigenvalue of an individual sort is 1.00.

Table 5.2 – Results of PCA factor Analysis of Q Sorts

Factor	Eigenvalue	Percentage Explained	Cumulative Percentage
1	**7.39**	**33.60**	**33.60**
2	**4.74**	**21.56**	**55.16**
3	**1.74**	**7.89**	**63.05**
4	**1.32**	**6.00**	**69.05**
5	**1.12**	**5.11**	**74.16**
6	**0.86**	**3.91**	**78.08**
22	**0.02**	**0.10**	**100.00**

Determining the number of factors to use in a Q-method study becomes somewhat of a subjective exercise for the researcher, trying to balance simplicity of fewer factors against completeness implied by employing more factors, while striving for consistency and explanatory power of the range of subjective perspectives resident in the data. Statistically, inclusion of a factor with an eigenvalue lower than 1.00 makes no sense. As shown in Table 5-2, that left options of 1, 2, 3, 4, or 5 factor solutions, with the option of only one factor quickly eliminated because it would only explain a third of the perspectives while implying that only one discourse exists. The next step involved rotating the 2, 3, 4 and 5 factor cases in PQMethod using the Varimax algorithm, a tool that rotates the factors to maximize the total explained variance.

The output of the factor rotation includes a chart showing the calculated factor loadings or Pearson's correlation coefficients of each of the 22 individual Q-sorts with each of the factors of each of the four options (2, 3, 4 and 5 factors). The two-factor case would work but it only explained 55 percent of the discourses and so I discarded it in favor of analysis that is more complete. The three-factor case increased the variance explained to 63%, with two individuals (118 and 120), one of whom had been a confounder or non-loader on the 2-factor solution, loading or being highly correlated with the third factor. Because the Q-Method approach forces a normal distribution of random sorts, the standard error (SE) is equal to the range within about 68% of random sorts would fall and is defined by:

$SE = 1/\sqrt{N}$ where N equal the number of items sorted.

In our case, we had 35 items in the Q-sort so:

$SE=1/\sqrt{35} =0.167$.

Assuming a normal distribution with a mean of 0 (or nearly 0 in this case), correlation factors greater than 1.96 times the standard error, plus or minus, have a 95% probability of being non-random. Conversely, those with correlation coefficients whose absolute value exceeds 1.96 times the SE are correlated with a probability of error of 5% ($p<0.05$). At ±2.58 times the standard error (or ±0.4361 for this case where the number of items to be sorted, N, equals 35), the correlation factors have a 99% probability of being non-random (Brown 1980, 283). Some individuals have high correlation coefficients with more than one factor in which case they are identified as "confounders."

The significance of whether an individual loads on a factor comes in the next step when only the "defining sorts", that is, Q sorts significantly correlated with one and only one factor are then used to calculate the factor scores and then idealized ranking of each statement in each factor. In other words, those sorts that load on a factor help define the factor.

The significance of the number of individuals loading on each factor comes during the development of the idealized or defining sort. Should only one Q-sorter load on a factor, that sort alone must define the factor. Some scholars insist that as long as at least one loader per factor exists, the factor can be determined (Ockwell 2008) while others insist that at least two loaders are required (Venables *et al*. 2009). I believe that for 22 sorts, each factor should have at least two loaders to provide breadth to define each factor. Because Q-Method represents an analysis of ideas and views and not just a statistical exercise, a factor must be describable.. Without at least two individuals whose sorts highly correlate with a factor and whose responses can help define the factor, I could not comfortably describe social perspective using Q-Method. My cutoff of at least two loaders is subjective but ultimately the number of factors that the researcher can describe adequately represents the limit to the number of social perspective a Q-Method study can identify.

In going from a two factor to a three-factor solution, Factor 1's loaders did not change, suggesting stability. The three-factor solution does leave some explanatory capacity on the table because a four-factor solution increased the explained percentage from 63% to 69%. When the four-factor rotation was made, again the loaders on factor 1 remained unchanged as did factor 3 whereas the old factor 2 split into 2 and 4. Not surprisingly, factors 2 and 4 highly correlate with each other and reflect this common origin. In the four factor solution, two individuals failed to automatically load on one and only one factor, indeed 125 had statistically significant loading on factors 2 and 3 (as it had with a 3 factor solution) and 127 loaded on factors 2 and 4.

The fifth factor had an eigenvalue slightly above 1.00, so I investigated the 5-factor solution next. Exclusively sort 136, with a loading of 0.85, loaded the newly created fifth factor on. Sort 136 had been part of factor 2 in the 4-factor solution. Factor 2 changed dramatically, losing 136 to the new factor, losing two members that became confounders (non-loaders), while adding previous non-loaders 125 and 127. Factor 1 lost member 133, which became a non-loader. Therefore, the solution seemed unstable compared to lower number factor solutions and it violated the desire to have at least two leaders per factor. To make matters worse, sort 136 had been the nonconforming (to the normal distribution requirement) and I had not had the chance to do a follow-up interview. All of this combined to suggest that the extra five percent explanatory power in a five factor solution did not justify the problems associated with it and I selected the four factor solution to provide the most insight into the social and knowledge perspectives on Delta levees of the 22 stakeholders and experts participating in the Q-sorts. With an eigenvalue of 15.1912 (out of 22.0), this solution could explain 69% of the variance in the perspectives, a number in line with similar studies (see Appendix A).

Activity 8) Rotate factors to simplify and generate factor scores and loadings

Having selected a four Factor solution, I then used the Varimax rotation option in PQMethod to maximize the total variance between factors. Varimax rotation holds the advantage that researcher does not control the algorithms and reduces opportunity to introduce researcher bias. PQMethod also calculated the factor loadings or Pearson's correlation coefficients of each of the 22 individual Q-sorts with each of the four factors. The researcher can then use PQMethod to determine "objectively" (Robbins 2005, 213) which Q-sorts make significant contributions to defining each factor, or "load on a factor." Completing this step left 20 of the 22 Q-sorts loading on one and only one factor. Q-sorts 125 and 127 loaded heavily on Factor 2 and Factor 4, but not "cleanly" enough to be used to help define either factor.

Researchers can employ a manual rotation to test hypotheses or theories. PQMethod will permit the researcher to rotate manually factors any time after a factor analysis, including after a Varimax rotation or another manual rotation. Looking at this capability and two confounders in the four factor solution, I elected to experiment with the manual rotation function on the solution already run through a Varimax rotation to see if could find a nearby set of axis that would modify the factors so the two non-loaders would load on only one factor. At the same time, I needed to sure that the rotations did not move one of the Q-sorts initial loaded on one and only one factor so much one or more of them became a confounder. My only motive was to see if I could maximize the number of loaders to increase the robustness of the statement rankings and the final analysis.

The literature reviewed was silent on the subject of manual rotation except to say that PQROT, a subroutine in PQMethod, will run the rotation. PQROT allows rotation of two axes at a time by whole degrees. I started to rotate the factors in the program and watching each individual sort changing its relative position to the slowing changing axis. Each run of the rotation program required a re-running of the factor loadings, complete with implementation of the automatic pre-flagging routine in PQMethod to check to see the loadings. As shown in Table 5.3, I performed this in true hit or miss fashion, sometimes having to retreat from a step taken because while trying to get 125 and 127 to load on a factor, 133, 106, or 134 would rotate off their factor. It required 17 small angle

Table 5.3 – Manual Rotation Steps Performed on Varimax Rotation

Step Number	First Factor Rotated	Second Factor Rotated	Angle Change in Degrees
1	3	4	-2
2	2	3	2
3	2	4	2
4	3	4	-2
5	1	2	2
6	1	3	-5
7	2	4	-3
8	2	3	2
9	1	2	2
10	2	3	3
11	2	4	1
12	1	2	2
13	2	3	1
14	2	3	1
15	2	4	1
16	3	4	-1
17	2	4	-2
18	2	4	-4

rotations of 5 of the 6 pairs of axis (Axis 1 was never rotated relative to 4) to achieve the goal of having all 22 sorts load on one, and only one factor as determined by the automatic pre-flagging subroutine in PQMethod. It took so many steps because of the lack of guidance or a real plan resulting in immediate reversal of many steps. To document and show the subtlety of the manual rotation involved, Appendix L includes PQMethod screen shots of the six pairs of principle axes is on a four-factor solution before and after rotation. It should be remembered that the Varimax algorithm works to maximize the eigenvalues, not maximize the number of loaders on a factors or anything thing else. Whereas the manual rotations changed the eigenvalues for each of the factors, the total explained variability remained at a rounded 69%, presumably only less than a half percent below the maximized configuration. PQMethod recalculated the correlation coefficients of each Q-sort with each rotation of paired factors, which in reality involved a slightly different meaning of each factor. The rotations required to achieve this were insignificant enough that all other Q-sorts remained loaded on the same factors, and the individual sorts that scored the highest correlation coefficients for each factor remained so, suggesting that the rotated and Varimax original factors represent only a small deviation of perspective. By including all 22 Q-sorts, PQMethod developed a richer and statistically tighter list of distinguishing statements and key statements for the factors, particularly Factor 2 and Factor 4, which each added a defining loader. The composite reliability of F2 increased from 0.952 to 0.960 while F4 went from 0.941 to 0.952 (F1 and F3 were not affected). Similarly with an additional loader, the Standard Error of factor scores for F2 dropped from 0.218 to 0.200 and for F4 from 0.243 to 0.941 to 0.952 (F1 and F3 were not affected). Similarly, with an additional loader, the rotation caused differences in Q-sort correlation coefficients with each of the factors.

From an analysis standpoint, the one-on-one loading option greatly increased the number of statistically significant distinguishable statements for three of the four Factors. Standard Error of factor scores for F2 dropped from 0.218 to 0.200 and for F4 from 0.243

to 0.218. The standard errors for differences involving F2 and F4 also decreased. The manual rotation increased the number of distinguishing statements of F2 from seven to nine, from seven to eleven for F3, and from six to eight for F4. Only F1 lost a distinguishing statement in the rotations, dropping one to thirteen.

The number of statistically significant consensus statements remained at two, however, one changed. Statement 30 ("*The levee districts tackle the critical erosion and acute problems very effectively but they are not good at minor, everyday maintenance. Unfortunately, this inattention lets minor problems like vegetation on the levees grow into overwhelming problems and now they face major engineering and construction efforts in some many areas to get the levees back into compliance with Corps requirements*") drew a statistically significant lack of support across all four factors, reflecting a lack of support in California for the USACE headquarters initiated enforcement of the bare-levees (no vegetation) policy in the wake of Hurricane Katrina.

The manual rotation did change Factor 2 enough that it no longer statistically shared what had been a consensus item, the view that Statement 15 ("*The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system*") was probably true. Chapter VI will discuss this and the other Q-Method results.

Activity 9) Use statistically significant factor statements to interpret, name, and describe the factors

Once the factor rotation is finalized, the next step is to run the Q Analyze step in PQMethod which then determines the correlation coefficients on each Factor, the percentage of variance explained by each factor and the list of statistically distinguishing statements ($p < 0.05$) for each Factor. PQMethod derives these in turn from the calculated normalized score (z-score) for each statement on each factor and assigns a ranking using identical criteria to that used in the Q-sort each developed from the sorts of those respondents who were identified as loaders on each factor. The program also develops an "ideal Q sort" that represents how an individual loading 100% on that Factor would rank each statement (Ockwell 2008, 274).

I first identified and used the statistically distinguishing statements to describe the subjective perspective of each Factor as these represent the ideas where the perspective significantly deviates from the other Factors. By carefully analyzing the words in these distinguishing statements, I developed narratives describing each Factor. The comments and justifications made by the sorters and recorded during the exercise help support and enrich this effort. I then turned to highest (+4, +3) and lowest (-4, -3) ideal Q-sort rankings and related z-scores for each Factor, to identify the other statements most salient to a particular factor. Frequently, the most salient statements show up as distinguishing statements, however, when two Factors share a high degree of salience on a statement, that particular statement does not differentiate either Factor from ALL other Factors. It does remain, however, essential to defining each of the Factors as demonstrated from the high Q-sort rankings.

Activity 10 – Prepare summary of factor descriptions and review with high loaders on each factor

The final activity in the Q process and one that geographers seem to have played a role in adding (see Appendix B) comes in taking the preliminary results of the naming and describing the discourses back to the participants for additional input, clarification, and assimilation. The literature suggests several forms of this step. Webler, Danielson, and Tuler (2009) suggest mailing or e-mailing a preliminary summary of results to all participants with disguised participant loadings, revealing only the recipient's scores to preserve confidentiality. These scholars along with others (Robbins 2005; Persons 2010; Brannstrom, Jepson, and Persons 2011) mention the advantage of potential of follow-up meetings with some of the strongest loaders on each factor to share the same information and obtain feedback.

I elected to take the preliminary descriptions of the factors and the factor names I assigned to the two or three highest loaders on each factor in a follow-up interview in early November 2010. All of the interviewees quickly identified the factor they were associated with and agreed that the description went a long way to describe their perspective. Several did disagree with the name I had assigned the factor they loaded on. The ten interviews reflected the three primary justifications for taking this follow-up step. First, it gave me additional direct input to this part of the dissertation, and convinced me to change one Factor name and to seriously consider changing another. Second, it opened one more conversation to gather more information from experts, one with a repositioned focus from previous discussions. I found that seeing the total scope of the various perceptions created an increased reflexivity on the part of my interviewees in that they generally seemed a little more open to the perspectives of the others than they had shown in previous meetings. This provides confirmation of Brannstrom's (2011) finding that Q creates *ends* and *means* in qualitative research. It also supports those who suggest that Q can help open and facilitate better policy development in areas of conflicted knowledge bases (Barry and Proops 1999; Eden, Donaldson, and Walker 2005; Ellis, Barry, and Robinson 2007; Ockwell 2008; Lopez-i-Gelats, Tabara, and Jordi 2009; Bischof 2010). Perhaps the strongest indication of this came when Respondent 120 concluded this feedback session by indicating he wanted to get me on the docket of a future meeting of the Delta Stewardship Council to present these findings because he thought that understanding the social perspectives might help the Council develop a better Delta Plan.

CREATING A COMPLETE RECORD OF FAILURES OF DELTA LEVEES

As noted earlier, the second part of this dissertation establishes record of failures of Delta levees with more detail and completeness than previously attempted. The record also adds a compilation near misses, successful flood fights and emergency repairs. The near miss record represents a starting point to gather important information that engineers and managers should communicate widely to maximize learning from prior mistakes. To accomplish this, I applied several methods and approaches to create the database of levee failures and near- misses. Where sufficient data exist, I mapped the failure and near miss sites with an ARC MAP file prepared for the dissertation.

First, I built on the classic works of Thompson (1957, 1962, 1982, 1996, 2006, and 1983 with Dutra) and his student Mitchell (1993, 1994). I employed some of the same approaches that Thompson employed, locating newspaper and magazine reports, court records, oral histories, government agency reports, court documents, reclamation district documents, and the like from libraries and museums in the area, always trying to locate previously untapped sources. While I consulted holdings of the Bancroft Library at Berkeley, the State Library in Sacramento, and the Main County Libraries in Stockton and Sacramento, I also spent time in county library branches in Rio Vista, Antioch, and Walnut Grove, and the historical museums in Walnut Grove, Rio Vista and Lodi. I scanned newspapers around dates of indicated failures from Thompson, the DWR (2009) spreadsheet, and DRMS (URS 2009c) summary of levee failures, going forward and backward from any identified date until reports turned cold. I also conducted electronic searches for other not previously identified times of known levees failures with little success. With the exception of the 1930s when the local and regional newspapers seemed more interested in covering world events like the Russo-Finnish war than Delta levee failures, newspaper coverage proved excellent. The 1930s also predate the period when state started issuing its annual flood reports (initiated in 1962), leaving it the decade with the least complete coverage.

I paid particular attention to gathering maps to help reconstruct the pre- and early development channels and crevasses and locate landmarks and property owners noted in newspaper reports to help pinpoint locations. Living 1800 miles from the Delta did make accessing the local libraries and museums more difficult, particularly considering the California budget constraints in 2009 and 2010 triggered reduced library open hours when I was conducting this research. The excellent collection of California and federal government documents housed at the Texas A&M library and the inter-library access to documents in other libraries helped offset the geographical disadvantage, as did a new website, the California Digital Newspaper Collection at http://cdnc.ucr.edu/cdnc/cgi-bin/cdn. This website served as an excellent resource for incidents before 1922 and it includes a great search engine to help find isolated reports.

As part of the Q-Method, I also employed semi-structured interviews to capture knowledge of the scientists, engineers, and the maintenance personnel or the reclamation districts to record the experiences of those involved in the levee failures and levee management. These 62 interviews with 35 key individuals provided details of failures as well as successful flood fights over the last 50 years. In addition to firsthand accounts of levee failure and near misses, interviewees gave me access to pictures, maps, reports, and in one case, a 1931- vintage surveying log.

The maps and photographic images gathered during interviews and library visits added to the resources I used in pinpointing and confirming failure locations. I used Google Earth to pinpoint changes over the period for which they have historic images, generally 1995 to 2010. Additionally, I made visual comparisons of imagery including the USGS topographic maps at 1:32,800 scale from the 1906-1914 era; the USGS 7-1/2 minute series from circa 1952 and 1978, aerial photography from 1937 for Sacramento and San Joaquin Counties housed at the Shields Library at UC Davis, and Atwater's geological maps (1982). Initially I performed much of the analysis and pinpointing in Google Earth but elected to move everything into ARCMAP, including the failure database as a dBase IV file. I used the UTM-10 Geographic grid system with the 1983 USGS datum in loading the 2008 DWR LIDAR map of the Delta, the Atwater soils maps, and historic maps and photographs as required into the ARCMAP file.

To process the records captured, I elected to store them in a database. I established three main tables in the database, one for the incident reports themselves, one for available information on the islands and tracts, and a table on the levee segments. To provide greater detail to the record, particularly on failure location, I elected to break the island/tract levee description into levee segments based on three factors: 1) by the alignment characteristics of the levee, as discussed in Chapter III; 2) by the differences in ownership and management (Reclamation District); and 3) by the Project, Direct Agreement, and Non Project division of federal-local development responsibility. Thus, one or more levee segments protect each island/tract.

I first elected to break the levees into segments based on the type of alignment the marsh reclaimers constructed the levees as described in Chapter III. In addition to the five alignments as discussed in Chapter III (main river channel, tidal slough, main channel meander bend cut-off, tidal slough meander bend cut-off, and cross-marsh or property line, I elected to divide the origin type of the main river channel into two divisions: those that function as a flood control levees and those that perform as a levee-dam. After review, it was not necessary to divide the other four alignment types this way as all of the others now function as levee-dams in the Delta. This allowed breaking the 1700 kilometers of Delta levees 393 separate segments, each with a shared history as well as common ownership, original builder (USACE or local reclamation district), tractive force loadings, hydraulic loadings, boat and ship wake exposures, and the geomorphic origins of foundations and levee materials. These shared factors could each contribute to levee stability, however, without the ability to relate failure locations to identified segments, researchers cannot begin to explore any relationships that might exist.

I determined the alignment type by comparing levee and channel locations on current maps and LIDAR images with Atwater's maps (1982), and historical maps dating to the 1860s (Tide Lands Reclamation 1868). I also added a seventh type, the back levees, always on tracts (not on islands) built to protect against overland flow from the highland areas. Builders of back levees generally used upland material and these only function as flood-control levees. Finally, I established an “Other” category, which primarily represents railroad embankments that sometimes double as levees.

The second step involved identifying the island or tract and collecting data on each of these. Information gathered and made part of the database includes the best estimate of the first completion of the levee system; the date of abandonment (if appropriate); total length of levees; total area of the tract; the reclamation district number; the county; the water district/irrigation district; and where available, the 1990 total population census data. The water code legal status of the island/tract, (specifically Primary Zone-Delta, Secondary Zone Delta, Suisun Marsh, and Other) is also recorded as are the primary activity(ies), either agriculture, wetland recreation/conservation, legacy communities, industrial/resource extraction, or new urbanization. In some cases, the island/tract economic assignment reflects multiple activities. These data are all included in a datasheet and each levee segment carries an island/tract designator.

The designer/builder of the segment also differentiates the levee segments. These categories include the 1) Project levees built by the USACE as part of the flood control “project”; 2) the Special Agreement levees also built by the USACE either as part of the Stockton or Sacramento Deep Water projects or other areas where the USACE rebuilt a levee; and 3) the Non-Project levees built by the local reclamation districts. I further divided the Non-Project levees based on what they were built and maintained to protect - agriculture, legacy village, wetland recreation (duck hunting) or preservation, New Urban, or “height-restricted.” “Height restricted” refers to the Non-Project levees, which first protect upstream assets by failing at lower water levels than those assets and creating a floodway across the leveed island or tract, primarily Liberty Island, Prospect Island, Little Holland Tract in the formal Yolo By-Pass and McCormack-Williamson Tract, privately negotiated flood way along the Mokelumne. These islands/tracts were farmed but as subordinated activity to flood relief. Finally, I created the class "None" for places in the Delta without levees like Ida Island, a non-leveed sand bar (inhabited) in the Sacramento River near Isleton. It, of course, floods and sometimes shows up in flooded island lists.

All of the above-described data has been included in the levee segment database, along with a best guess of the current minimum design standard for the levee segment. This breakdown includes those designed to 200 year frequency urban flood standards; 100 year frequency urban standard; DWR standard 192-82; the USACE California agricultural levee standard PL-84-99; the interim DWR Hazard Mitigation Plan standard that represents an interim step toward the 192-82 standard; "Sub-HMP", where it is clear that the levee does not meet the minimum HMP standard; and "Unknown." Assignment into these categories is based on the lowest standard met on an island or tract and represents a guess until verified by qualified engineers and surveyors.

I created a georeferenced shapefile in ARCMAP for each levee segment and joined the levee segment database to the record. I employed the LIDAR map (DWR 2006) to establish the proper centerline for the levees.

The incident (failure) database table includes all of the incident reports from the literature search, source document discovery, and interviews. Each incident report for each island/tract gets a separate number and the report include month, day and year of the incident, levee segment impacted, the type of incident defined as Successful flood fight, Emergency Repair, Flood, or Other. I characterized the types of failure as: Levee overtopping–sheet flow; Levee overtopping-collapse; Sunny day Collapse; Excessive seepage or interior rainfall; Human Error; and Other. I characterized failure cause, where known or theorized, into the following classes: 1) High water, 2) Rodent Damage, 3) Excessive Internal Erosion, 4) External Erosion, 5) Excessive seepage or rainfall and 6) Unknown or other. The table also includes the source of the report, the incident number, and where available the estimated cost of repair and dewatering, determination of whether a government agency declared an official disaster and the date levee repaired. Users can access failure photographs when available through the database.

I mapped fully documented failure locations as a georeferenced shapefile and joined in the database record of failure of Delta levees in ARCMAP. Others (Atwood 1982; DWR 1984; URS 2009c) identified many failure locations, most located from eyewitness accounts or by locating the large scour ponds often left behind after a failure. The primary contribution of this dissertation was to add to this list by cross-referencing of photographic images, maps and other source materials and by interviewing additional witnesses. Also loaded into the GIS system were Atwater's soil maps (Atwater 1982), historic crevasse and slough locations, and DWR developed LIDAR elevation map (DWR 2006).

CHAPTER VI

SOCIAL PERSPECTIVES OF THE RECORD OF LEVEE FAILURES

(1874-2010)

INTRODUCTION

As noted in Chapter V, analysis of the sorts by PQMethod yielded four factors or social perspectives on the meaning of the record of levee failure for the present and future of Delta levees. This chapter describes each of the four factors based on the statistically significant rankings of opinions (statements) as determined by the Principal Component Analysis rotated by Varimax followed by a slight manual rotation. The five highest and five lowest ranked statements of each Factor were also used to describe the Factor, regardless of whether they were considered differentiating from the other three factors. The analysis also incorporates the comments of respondents who loaded high on each Factor to describe the Social Perspectives. Finally, I validated the preliminary factor descriptions by personally reviewing the preliminary results during follow-up interviews with the ten individual respondents whose personal perspectives most closely matched a Factor.

Two areas of consensus developed among the four factors and this chapter will discuss these and the areas of greatest differences between the perspectives. These differences in subjective knowledge can hinder the communications if not recognized and addressed in any governance process for the Delta. Raadgever, Mostert, and van de Giesen (2008, 1097) suggest that the first step to achieve consensus among stakeholders in conflicted issues of water management requires defining and understanding the shareholder perspectives.

Appendix J provides the list of the 35 participants in the interviews, remembering that this research was conducted under protocols approved by the Texas A&M University Institutional Review Board (IRB) concerning human subjects in research and, therefore, the individuals are not identified by name or sex and are disguised as much as possible. Six of the thirty-five interviewees are women, however, the use the masculine and feminine pronouns in the text does not necessarily denote the sex of the individual quoted or referenced.

The four social perspectives and the mutually assigned names of the Factors are:
Factor 1 - Delta Sustainers (F1), the social perspective that views the governance in place of the levee system is capable of sustaining the levee system and the agricultural base of the Delta long-term, particularly with continued financial support for levee maintenance and improvement from the non-resident beneficiaries of the current levees through the subventions program. F1 sees the history of levee failures as an indication of a system that has performed adequately and is improving, with primary risks coming from rodents, high water, and erosion. It envisions little risk from earthquakes. The members of the P-sort group who loaded most heavily, that is, whose view most closely matched the Delta Sustainers Perspective as reflected in their sorting of Q-set were primarily Delta farmers/reclamation board members and the engineering and legal consultants who support them.

Factor 2 - Abandon the Levees (F2), the view that seismic forces and rising sea levels will destroy the levees and flood the Delta with seawater, converting it to a more sustainable ecosystem. This perspective holds the continued export of water to be political and economic necessity, thus the state must construct the Peripheral Canal. The top loaders on F2 include members of the Center for Watershed Science at UC-Davis who advocate a similar political position, along with fisheries scientist and managers an engineers working for the one of the major water contractors (recipients of the exported water).

Factor 3 - Levee Pragmatists (F3) view the Delta levees and the socio-ecosystem as not viable in the long term but sustainable for several generations, assuming those generations use more innovative and environmentally responsible approaches. Loaders on this factor are particularly critical of the USACE policy of zero vegetation on the levees and the execution of the subventions program because they inhibit creativity. The perspective worries that time and a lack of commitment to the levees has erode local knowledge long held by the reclamation districts. The top loaders on F3 might describe themselves as independent thinkers and students of the Delta levees, not currently associated with any organization.

Factor 4 - The Multi-Purpose Levee Advocates (F4) social perspective anticipates better science and knowledge will allow the managers and engineers to operate the flood control, water export, and ecosystem aspects of the Delta more effectively. It perceives that the subventions program and habitat restoration projects have been successful. It has concern over the risk of earthquake but not to the exclusion of other dangers. All of the top loaders have enjoyed engineering careers most closely associated with the USACE, USBR, DWR or local flood agencies.

Q-Method has limitations that practitioners accept. First, Q-Method cannot identify the relative popularity or acceptance of a particular viewpoint or concept, nor can Q-Method assess the strength of support in the population of a social perspective. It also cannot determine the “truth” or accuracy of social perspectives.

DELTA SUSTAINERS (FACTOR 1)

The Delta Sustainer factor describes a viewpoint that the Delta levees can protect the farmlands, villages, homes, highways, pipelines, and railroads of the Delta indefinitely. Factor 1 bases this view on the observation that levee failures have declined since 1986, primarily because of the success the of the subvention program to invest in upgrading and improving the levees. It sees that effort as being very efficient and effective, primarily because of the local knowledge employed in the work. The members of the reclamation districts gained this knowledge by responding to the countless threats and occasional failures of levees over their lifetimes. The subventions program takes advantage of this local knowledge by cost sharing with the local district on what has historically been about a 50-50 basis. The reclamation district borrows the money first, completes the work, and then receives reimbursement equal to 75% of approved cost after a $1000/mile minimum annual expenditure. The reclamation districts finance the projects themselves giving them significant incentive to perform efficiently and quickly.

Confidence in practical local knowledge, informed by experience, allows F1 to justify their perspective that the reclamation districts, with technical and financial support from the DWR and USACE, should govern the Delta on an island-by-island basis. This perspective sees the strengthening of the existing levee system as benefitting all of the Delta stakeholder’s interests, including the environment, recreation, and water exports.

The benefits justify the large state investments in levee improvements included in the recent successful bond issues Propositions E1 and 84.

The Delta Sustainer perspective sees continuation of current farming practices as the only way to preserve the entire Delta community. Whereas F1 acknowledges that farming methods caused subsidence in the past, it sees additional subsidence to be a minor issue because most of the volume reduction in the peat has already occurred. This perspective also rejects the argument that the earthquake risk translates into a high probability that multiple simultaneous levee failures will occur, citing the empirical record and suggesting that those raising the fears have no understanding of the properties of the peat materials that make up the foundations of many of the levees.

Descriptive Statistics

Factor 1 explains 29% of the total variance in all perspectives measured and with nine of the twenty-two Q-sorts loading on this factor, it had the lowest standard error (0.164) (See Appendix G). Individual P-sorter correlations ranged from 0.5751 to 0.8930, with six greater than 0.80. Of the respondents loading on F1, seven are Delta residents and all of them actively work to maintain Delta levees. Six of them serve as engineering, legal, or environmental consultants to reclamation districts whereas the other three farm the Delta and serve on reclamation district boards (Appendix I).

The Delta Sustainer factor correlates negatively with each of the other factors, particularly the Abandon the Levees Factor (F2) and the Multi-Purpose Levee Advocates Factor (F4). The -0.3464 correlation score with F2 represents significant disagreement between these two perspectives. The -0.1303 correlation with F4 also suggests more conflict than agreement of views whereas the -0.0337 correlation with F3 indicates little correlation of views between the two.

Distinguishing Statements

In this section I will describe the subjective perspectives of this factor in more detail, relying on the statistically distinguishing statements ($p < 0.05$) identified in the correlation coefficient analysis of the Q-sorts of PQMethod. PQMethod also calculates the normalized score (z-score) for each statement on each factor and assigns a ranking identical criteria to that used in the Q- sorting on each factor for each statement.

As defined by the 13 distinguishing statements ($p< 0.05$) (See Appendix E), the Delta Sustainer factor holds that the existing Delta agricultural community can, and should, be sustained. This requires continuing the improvements of the past 25 years in the Delta levees that F1 sees as having sustained the viability of farming in the Delta. Factor 1 identifies that the recent improvement in levee stability have resulted from proper application of local reclamation district (RD) knowledge and modest infusions of money and skill from the DWR. F1 holds that the legislation that created the "subventions" program considered the DWR investments in the levees as being on behalf of the beneficiaries of the levees from outside of the Delta, primarily the water exporters and their customers. Delta Sustainers perceive little risk of massive damage to the levees from seismic activity, and are suspicious that others raise these concerns only to justify construction of a water conveyance system going around the Delta (Peripheral Canal) that could eventually lead to decreased state support for the Delta levees. The Delta Sustainer social perspective envisions an agricultural Delta sustainable through continued diligence and investment in the levees, with locals playing a large role in governance of the Delta.

For Factor 1, Statement 1 ranked highest at +4, (z-score = +1.50) ("*It is very important to keep the Delta community and economy whole. With far less money than is being estimated, levees in the Delta can be made taller and stronger and set back enough to keep Delta islands afloat indefinitely.")* This statement highlights the importance of the continued viability of the Delta economy, community and lifestyle. It is no surprise that Factor 1 ranked this statement so highly because most of the loaders literally live and work behind the levees; they have total invested their lives and fortunes in the levees. The statement reflects concern for the total community, the farmers and the larger population involved in agriculture support activities - warehousing, seed and chemical sales, trucking, banking, insurance, ands equipment sales and service. Statement 1 notes the confidence in the sustainability of the Delta agricultural islands as shown by F1 loader, Respondent 114, who stated that assuming the RDs get "a sensible source of revenue that we can fix these levees routinely, year-in, year-out, I think we can save the Delta indefinitely – forever!" (Interview 114-2009, 0:31). Respondent 111 emphasized the efficiency of the RDs: "Whatever the solution is, the locals can do it much cheaper" (Interview 111 2010A, 1:38).This rationale suggests that the USACE, DWR, the DRMS study, and others have greatly inflated the cost estimates for the work required to upgrade the levees to acceptable standards. The concept of keeping the Delta "afloat indefinitely" recognizes the artificiality of the Delta islands while asserting that the residents do not plan on a retreat from the Delta in their lifetimes.

Related to support for Statement 1, Factor 1 stands strongly supportive of Statement 11 (rank = +3, z-score = +1.24) *("Since 1986, there has been a substantial reduction in the number of Delta levee failures, primarily because the state subventions* *program allowed the reclamation districts to begin to improve the private levees. During this time, the state has invested about $130 million while the locals have invested $250 million, allowing Delta residents to start to feel comfortable living behind the levees.")* This statement reflects confidence that the subventions program has helped improve the record of levee safety and highlights the central role of reclamation districts in this improvement. Statement 11 also asserts that the state contributes about a third of levee maintenance money contrasted to the implications of the state subventions program support of 75% of the allowable maintenance expenses. The program will not reimburse the first $1000/mile of levee maintenance work each year and certain administrative costs. Reimbursement comes only after the work is completed. In the numbers quoted in Statement 11, DWR likely does not get credit for the legally mandated mitigation offsets in this tabulation of payments, as Delta Sustainers do not necessarily believe that habitat-loss offsets improve levee safety, and it helps confirm the view that the levee districts invested more in the levees than the state or federal agencies. The statement also supports the claim that since 1986 when the subventions program first received significant funding, the frequency of levee failures has declined. Respondent 124 (2010A) wanted to emphasize that "residents" might not be the best term because the subventions program purely dealt with the agricultural levees and residents might be construed to include dwellers behind urban levees in the Delta. He also objected to the term "private levee," noting that only levees built by reclamation districts with elected governing boards were eligible for subventions support. (The correct term is "Non-project" levees.)

Statement 2 directly contradicts the successes referred to in Statement 11 ("*Incremental changes are not going to create a sustainable Delta and even after a few hundred million dollars in improvements, we will still have levees that time and tide are just going to overwhelm.")* Not surprisingly Delta Sustainers reject this statement (rank = -3, z-score = -1.24), convinced that the Delta can be sustainable forever with modest, (less than a few hundred million dollars over all) steady investment over time, not the $40 million dollars a mile for earthquake-proofing suggested by some or the $3 to $13 billion required for an isolated conveyance system required for water exports should the Delta levees be abandoned.

Factor 1 ranked Statement 28 highest (rank =+4, z-score = +1.74) ("*The local reclamation districts maintaining the levees bring incredible institutional knowledge of a constantly evolving system. They have people who can inspect the levees under all kinds of conditions and know what to look for. They have people who know what to do in an emergency and they are ready to defend their homes, livelihoods, and families.*") The reference to "incredible institutional knowledge" suggests the individual and collective local knowledge not available to the experts of the state (DWR, USACE, URS, etc.) considered the scientific and engineering elites. F1 believes this knowledge continues to evolve with new experiences. They also recognize the weakness of the system but they constantly check for signs of those weaknesses becoming manifest, and the farmers and engineers of the RDs execute emergency response activities with skills honed in previous flood-fights and emergency repairs. F1 sees survival as an effective motivator.

Statement 12 highlights the concern that the Delta levee problems originated because farming practices caused island subsidence, and continued farming of the peaty soils will continue this subsidence. The results will be increased hydrostatic pressures on the levees. ("A*s long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levees*"). With a ranking of -1 (z-score = -0.69), F1 rejects the assertion of Statement 12 that farming should stop on the peat soils, with as Respondent 115 noted: "most of the organics that were going to oxidize have oxidized". He then continued "and most of the oxidation that is taking place is taking place in the middle of the island" (Respondent 115, 0:25). Another respondent (124), stated that the "zone of influence" for levee stability for elevation difference between the water elevation and island elevation only extends about 400' from the toe of the levee "and everything beyond that point makes no difference, you could create the biggest hole you want," but as long as the elevation and subsidence is controlled in that first 400', the levee "does not feel any more pressure" (Interview 124-2010, 1:42). Respondent 112 noted the same thing, indicating that the SB-34 legislation that authorized the subvention program and encouraged the DWR to obtain 400' easements on the inside of levees to be able to control subsidence in the "Zone of Influence." The Delta Sustainers alone reject Statement 12. Similarly, the Delta Sustainer factor rejects Statement 8 ("*If we stop federal subsidies to grow subsidence-inducing corn, we have the opportunity to create the world's best carbon sink in the Delta"* Rank = -2, z score = -0.87). This represents the rejection of the view that Delta farmers receive direct subsidies to grow corn and the claim that corn production induces significant subsidence on the peat lands today. According to Respondent 132, "I've grown corn for years and I don't remember getting any subsidies" (Interview 132 - 2010A, 0:57). The rejection also challenges the idea that carbon-sequestering crops represent an "opportunity" for the

Delta community, particularly for those support functions that would be out of business without products to harvest, store, pack, or ship as you would miss with a carbon-sequestering crop. Delta Sustainers see the Delta as an entire community best served by growing real consumable crops for whatever market exists, not being a carbon-sink. Respondent 113 also explained that rice, a water logged crop considered less subsidence causing, or even subsidence reversing, does not do well in the Delta because the cool evening breezes coming through the strait inhibit proper pollination (Interview 113-2010A).

Factor 1 is further distinguished by Statement 9 (rank = -2, z-score = -1.20 ("*Delta levees are precarious and a disaster waiting to happen. They have to work so long and hard and are built of the wrong materials, on the wrong materials. The levee districts are trying hard but all it takes is one overzealous beaver. At the same time, we are now appreciating the earthquake risk and we are just lucky that we have not had a 6.0 or a 6.5 close to the Delta").* Delta Sustainers reject the notion that the levees stand on the verge of collapse and that they will all be flooded out sooner rather than later. They will acknowledge that the levees were built on less than perfect foundation materials and out of a heterogeneous mix of sediments but they also have worked too long and hard to be dismissed as "a disaster waiting to happen." The Delta Sustainers disagree with the reference in Statement 9 to earthquakes representing a critical risk to the Delta levees. They acknowledge that rodent holes present a major risk to the levees and probably cause many failures. Interviewee 124 summarized the F1 perspective when he listed the earthquake risk as a lower priority behind "static stability issues, erosion, rodents, vermin, and those kinds of things" (Interview 124- 2010A).

Factor 1 also rejects Statement 33 (rank = -2, z-score = -0.80) because it also suggests that earthquakes and resulting liquefaction pose an overwhelming risk to the Delta levees ("*A lot has been accomplished on reducing risk of normal every day, vanilla, levee failures but more and more we need to recognize the vulnerability to extreme events such as earthquake and very large floods that are not adequately recognized or acknowledged by some of the Delta stakeholders*"). As established with Statement 9, Delta Sustainers perceive work completed over the last 25 years has reduced the risk of "vanilla" levee failures, assuming anyone can define a "vanilla" levee failure. Factor 1 stands alone in rejecting the overall thrust of Statement 33, because of the implication that earthquake risk represents anything more than a possibility. Delta Sustainers hold strongly to the fact that the levee system has yet to experience earthquake related damage and the others introduced the risk into the discourse as incentive for Delta water export customers to support building the Peripheral Canal. Loader 124, a Delta Sustainer, engineer, and member of the 2000 CALFED seismic study (Torres *et al.* 2000) team of experts, explained that while he acknowledged the expertise of the four seismologists from the team who recently tried to convince him otherwise, he still believed that earthquake risk to Delta levees have been greatly overstated. He explained: "here is my perspective…the rubber band is being stretched very tight and we are likely to have a major seismic event soon here, I'm just saying the reaction will be different (than forecast by the seismologists)… they are basing their view off of three or four borings, I'm basing mine off of watching 1200 miles of levee" (Interview 124 2010, 1:14).

Total rejection (rank = -4, z-score = -2.08) of Statement 6 also defines Factor 1 ("*We have a non-sustainable system. Many levees in the Delta will very likely not be* *around in 30, 50, or 70 years from now. It just doesn't make economic sense to pour more money on top of the ¼ billion dollars the state has already spent to try to maintain some very expensive levee systems against threats of earthquakes, sea-level rise, and ongoing subsidence.")* Indeed, Statement 6 is the antithesis of the Delta Sustainer perspective, with its references to a non-sustainable Delta and levees that will be gone in 30 years. By Factor 1 accounting, it overstates the historic contribution of the DWR to levee maintenance by almost a factor of two ($250 million versus $130 million), whereas it totally ignores local investment in the levees. F1 accepted the $130 million state contribution number in its support of Statement 11. Indeed the Delta Sustainers believe that the state should be increasing its contribution, For example, Respondent 115 complained, "we haven't been truly reimbursed for the damage to our levees caused by the water exports and the boat wakes. People think we have been the beneficiaries of the state when in reality we have been the benefactors" (Interview 115 2010A, 1:02). They point to money approved by the voters in 2006 in Propositions E-1 and 84 bond issues that included millions for Delta levees as indication that public also rejects the argument in Statement 6 which is that earthquake, subsidence, and sea-level rise condemn the Delta levees and that society should cut its losses and stop investing in them. F1 rejection of sea-level rise as a major concern by is based because it will remain slower than subsidence rates and because they believe that the levees can keep growing taller because physical room exist to react and build higher. After winning the E1 and 84 bond issues and convincing the voters of California of the correctness of increasing state investment in Delta levees, F1 finds unacceptable and unfair the reference in Statement 6 to it "doesn't make economic sense… to maintain some very expensive levee systems."

Delta Sustainers worry that DWR, their partners in levee maintenance since the 1973 start of the subvention program, may be turning its back on the Delta levees as an expedient to meet its primary responsibility and driver of the political economy of California, the State Water Project. F1 reveals this fear in their support for Statement 7 (z-score = 0.69, rank = +1 "*The goal of DWR is to let the Delta go back to salt and build a peripheral canal around it").* Levees and island farmland would be virtual useless in a saline Delta but the DWR exports of fresh water south could continue unabated with an isolated water conveyance around it. Combined with concerns expressed in Statement 6 over cost and liability of DWR involvement in levee maintenance, particularly after the Paterno case put so much liability on DWR for Project (USACE) levee failures, Delta Sustainers reveal their fear that DWR will abandon the farmers, levees, and the Delta to get a more manageable water supply situation in their support for Statement 7.

Delta Sustainers support for Statement 16, (rank = +1, z-score = +0.53) ("*DRMS was a DWR conspiracy to justify the Peripheral Canal")* continues to reveal this uneasiness with DWR, if not resentment, and fears that the water needs of 24 million Southern Californians will outweigh the needs of the fewer Delta residents and concern that state interest and financial support for the existing levees stems only from the role the levees currently play in water conveyance. Much of the discussion during Respondent 115's sort revolved around the official (Delta Vision) position that a "dual conveyance" system would be constructed, one that included a dedicated canal or tunnel and a "thru-Delta conveyance," a reinforcement of the non-project Delta levees that currently convey water from the Sacramento River to the export pumps. He expressed concern that the state planners had already settled on a "full sized" (one with design capacity large enough to match the combined capacity of the SWP and CVP system) dedicated conveyance facility. He believes that with such a peripheral canal (or twin tunnels), no need exists for through Delta levees from a water supply standpoint. He believes this would allow the state to renege that part of the project and it would erode support for the subventions program. A less than full sized system would still depend on the existing levees to help convey peak export volumes south. Some Peripheral Canal proponents have proposed this option as a concession to the Delta interests.

Other discourses have used Delta Risk Management Study or DRMS, presented in Chapter IV, to refute the views of the Delta Sustainers on earthquake risk, subsidence, the stability of Delta levees in general, and as a conclusion, the need for an isolated conveyance system. Factor 1 alone showed agreement with Statement 16. Respondent 124 agreed in his response to Statement 16, "I do not think it was a conspiracy… but it was a flawed process intended to support the canal… I think it may backfire on them" (Interview 124-2010A, 1:52).

Delta Sustainers ranked Statement 34 ("*In seismic events, Delta soils become very pliable allowing the levees to roll through without cracking, subsidence, or settlement. The soils are so heterogeneous that they do not behave as poorly as some models project they would")* high (rank =+3, z-score =+0.89), further indication that Factor 1 sees the earthquake risk as vastly overstated. Statement 34 describes a flexible, "living" levee taking the earthquake punch and which cannot be modeled using generalizations of critical soil properties in existing engineering models. Respondent 121, during the sorting activity, related a story from 1990 when she was involved in building a levee toe berm on the north levee of Holland Tract near the site of the 1980 levee failure. As the trucks were rolling in with the levee fill material, the levee was just shaking as in an earthquake. She found herself stumbling against her pickup truck, the loss of balance very similar to an earthquake experience from her youth. She suggested that a MIT professor had a theory that peat levees did better than expected because the peat got stronger as it compressed and that the peat could take considerable flexing without breaking or cracking (Interview 2010A, 0:14). From the Delta Sustainer perspective, the verbal descriptions like that of Interviewee 121 feel more comfortable than computer printouts of model runs because Delta levee building and maintenance has long been more art than science to Factor 1 loaders.

Finally, only Factor 1 agreed (rank = +2, z-score = +0.89) with Statement 27, ("*The best governance structure for the Delta would be to let the levee districts tackle the issues island-by-island with some funding and guidance from DWR*") while all other factors strongly rejected this statement. This score reflects the confidence of Delta Sustainers have in the local knowledge of the reclamation districts and their engineers. It also reveals concern for top down governance structures that would likely favor needs of the millions of water users at the expense of the few Delta farmers. In addition, it recognizes the love – hate, hope–fear relationship the Delta Sustainers feel for the DWR. F1 holds out hope for continued funding from the levee subventions program, for support of the levees section of DWR in flood-flights, for help in repairing future levee failures, and perhaps more help de-watering after a break, if it is in the larger interest of the state, like keeping Highways 4, 12, or 160 open. This balances against the fear that DWR will abandoned the levees because of the pain of the Paterno lawsuit and the potential future liabilities the court rule dealt the state.

Other Key Statements

Whereas the statements identified by PQMethod as statistically distinguishing define the unique social perspectives of Factor 1 relative to the other three factors, the idealized statement rankings also help characterize the social perspectives. Statistically distinguishing statements at the $p > 0.05$ level as used in this analysis help differentiate among all perspectives, that is, the statement ranking identifies a sort as being part of one and only one Factor with 95% certainty. Statements very salient to more than one Factor, however, are not statistically distinguishing to either Factor; they do not help isolate the Factor from all others. However, statements with the greatest saliency (ranks -4, -3, +3, and +4) do help define the entire social perspective and so these will be describe under the "Other Key Statement" subsection for each Factor. I have noted these with a designation "N.S." to identify that while important to defining the Factor, it shares this view with at least on other Factor.

For the Delta Sustainers, most salient of these statements is Statement 18 (rank = -4, z-score =-1.817 –N.S.) ("*From a water supply perspective, the only reliable, sustainable, earthquake proof way to get water around the Delta is the Peripheral Canal.*") Delta Sustainers ranked this so low because it, like Statements 9 and 33, suggests that the threat of earthquake damage to the levee should be the major concern while arguing that the Peripheral Canal represents an economical, lower risk alternative. Respondent 124 (124-2010) suggested that the isolated conveyance proposals do not go around the Delta they go through "the same seismic risk zone that they reported on, it [the peripheral canal] has nothing to do with it [reducing earthquake risk]"(Interview 124-2010A, 1:49). He then admitted that the most efficient way to move water around was a canal or pipeline but dismissed the canal because of the seepage predicted on an unlined canal and the cost that he estimated at $75 billion for the tunnels. He then suggested that what appears to be the Factor 1 perspective that the investments in existing levees makes more sense than a new isolated conveyance system. He also suggested that the increased cost of the isolated conveyance facilities tacked on the cost of water to end users would push water retailers to desalination of brackish ground water and re-use of treated wastewater. Respondent 111 backed up these comments, noting, "We have been moving water through the Delta for 60 years now without a hiccup" (Interview 111-2010, 2:17).

Not surprisingly, given the ranking of Statement 34, Factor 1 also ranked Statement 35 at -3, (z-score = -1.52 –N.S.) ("*Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years*"). In rejecting Statement 35, F1 repeats the message that multiple failures of Delta levees triggered by a major regional earthquake failures does not represent a main risk to water supply of California. Respondent 124 again noted, "I deal directly with the scientists [raising the concern] and they have a tremendous background with the seismology and seismic activity. Unfortunately, it is with the consequences that they do not have experience… they claim they have experience but they run them [a particular levee section] through a few models and run a stability analysis but five feet away from that section I can get another section or run a different model that disproves their findings" (Interview 124-2010A, 2:04).

Delta Sustainers give the levee subventions program high grades in ranking Statement 26 (rank = +3, z-score = +1.29 – N.S.) ("*The DWR subventions program was a model of efficiency; the DWR staff was lean, and the local levee districts, because they had their money out there, managed projects very effectively").* This statement reflects the same positive feelings for the DWR involvement in the subventions program established in Statement 11 but in the past tense. The state budget freeze experienced in 2009 saw promised reimbursements held up for almost a year, financially strapping the reclamation districts who largely borrowed the money and got stuck with large debt service and strained credit ratings (Interviews 115-2010, 124-2010). The statement also reflects the concern that DWR had added significantly to the number of staff members in the levee program without increasing the amount of funding for the subventions and work on special levee projects. Respondent 114 explained: "they have $14 million overhead whether they deliver $3 million or $30 million." Clearly, Factor 1 supports the intentional use of past tense in talking about the leanness of DWR staffing.

In the same vein, Factor 1 rejected Statement 25 (rank = -3, z-score = -1.30 – N.S.) ("*The current system of local levee districts performing much of the routine maintenance is dysfunctional, disjointed, and inconsistent. They have a deep distrust of DWR and it is disturbing how poorly they work together").* Delta Sustainers have great confidence in the ability of the levees districts to perform routine maintenance and more as demonstrated by their strong rejection of Statement 25. Respondent 124 (Interview 2010A, 1:59) summarized the rejection by F1 in his remark about DWR, "We work together very well with them, if you sat in a meeting with us and you heard the two of us talk you could come away thinking we hate each other but…we are passionate people in our business and when we have a disagreement we let it be known and we are comfortable together doing that. But we highly trust DWR."

Statement 15 (*"The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system,")* (rank = +3, z-score =+0.98 – N.S.) provides the final key piece of the Factor 1 social perspective, noting the complicated permitting process that the Peripheral Canal, or other isolated conveyance system, would be required to navigate. It also highlights the Delta Sustainers view that the Delta residents hold senior water rights and property rights that must be acquired before major changes can be made in the Delta levees (Interview 115 2010A). The struggles have already begun with recent threats of violence (Interview 135-2010) and legal actions against surveyors working on a route for a Peripheral Canal. The Delta Sustainers foresee a long struggle over the twin-tunnel or peripheral canal in the courts on environmental as well as water and property rights issues.

Iteration Phase

Three of the six top loaders on Factor 1 were interviewed as part of Step 10 of the Q method, the iteration phase, in November 2010 (see Exhibit H for the material presented to each of them). I requested each of them provide feedback, first to confirm which factor best described their personal perspective and then to comment on the name assigned to their factor. The six top loaders on Factor 1 all had correlation factors above 0.8185 on the factors so I selected the most correlated farmer, the highest scoring consulting engineer, and a second engineer with whom I also wanted to do follow-up questioning on some of the historic failures. Fortunately, with such high factors, all three quickly identified that Factor 1 represented their personal perspective most closely. The name I originally assigned F1, “Levee Preservationist” did not fare as well.

Starting with Respondent 111, “Levee Preservationist” drew criticism. First, he believed that the factor focused not on the levees but the Delta itself, that his perspective revolved around the holistic Delta, the levees, the channels, the farms, the habitat, the infrastructure, and the communities. Respondent 111 also struggled with the word Preservationist, first suggesting that his perspective really should possess the title “Pragmatists”, the Factor 3 sounded more like “Critics “and “Defeatists” rather than “Pragmatists”. He went on to muse, “Around here ‘preservationist’ has a rather negative connotation” (Interview 111-2010B). After some thought he suggested “Sustainers” as reflecting, the more positive approach of the perspective.

Respondent 124 also expressed concern for the use of the word “Preservationist” because of the confusion generated over what would be preserved, the pristine pre-settlement Delta or the Delta as reclaimed by the settlers in response to the 1850 Arkansas Act. He believed he could accept the idea of preserving the reclaimed Delta but was nervous about the connotations of the word. Given the opposition, I elected to change the name to Delta Sustainers.

Respondent 111 also highlighted his frustration over the focus on the catastrophic events that would take place in the Delta in the event of a huge earthquake, suggesting that the relative vulnerability of Delta levees to the same event is much lower than of other infrastructure such as the Bay Bridge, the water pipelines serving the East Bay, and even the other elements of the SWP and CVP water delivery systems. He also suggested that the levee subventions program had provided financial and emotional support to the reclamation districts. Respondent 111 claimed that in the subventions program, California recognized the importance of the Delta levees and role of reclamation districts in sustaining the system. He felt that this program had increased the self-confidence and self-worth of the reclamation districts and made them better, more committed levee "sustainers." He also acknowledged as a real concern, the fear expressed by Factor 3 that the RDs were at risk of losing the institutional knowledge of individual farmers. He indicated that the trustees were increasingly dependent on the engineering consultants, who in turn were a rather small, relatively "experienced" group that is also aging.

Respondent 115 went so far as to go through all of the summary statements, providing additional support for all of the Factor 1 statements and providing arguments against the summary perspectives of the other three factors, with a couple of exceptions. He too reluctantly agreed with the Factor 3 perspective that the RD's local knowledge is inconsistent and eroding, stating "There are some islands that have people that are less into it than others, there are some islands whose power-trust, if you will, holds knowledge tightly and won't transfer it on to the next generation. We have trustees that are eighty years old and don't have the energy to do it anymore but they don't want to transfer it to anyone else" (Interview 115-2010B). This represents one example noticed during the Q-Method follow-up step, of individuals reflecting on and recognizing the social perspectives of others as meaningful. Raadgever, Mostert, and van de Giesen (2008, 1105) tout the ability to "promote reflection by the stakeholders and increase awareness of similarities and differences in each other's perspectives" as a prime advantage of the Q-method to help resolve conflicting technical knowledge and/or values and interest in water resource management conflicts.

Respondent 115 further agreed with Factor 4 and questioned the degree of risk of earthquakes to Delta levees, stating that certain individuals were quoting parts of the DRMS study out of context and using it for political purposes. He also made an interesting comment on the Factor summary sheet notation of a lack of enthusiasm by Multi-Purpose Levee Advocates for the isolated conveyance system, stating that while he opposed an isolated conveyance system, he could not publicly do so because of his role in an organization, he was contractually committed to not publicly oppose the Peripheral Canal. In return, the contract signed in 1981, apparently requires DWR to operate any isolated conveyance system in a manner that will not impact the quantity and quality of water available to the members of North Delta Water Authority . The North Delta Water Authority includes the leveed islands and tracts in the northern part of the Delta all of which currently drawing water directly from the Sacramento and Mokelumne Rivers and related channels.

The follow-up interviews of the Factor 1 loaders confirmed the findings on the general perspectives but suggested the need to rename the perspective to Delta Sustainers from Levee Preservationist, given their intent to sustain the whole Delta not just the levees and concern over which vintage Delta would be preserved.

ABANDON THE LEVEES (FACTOR 2)

For the Abandon the Levees factor, Delta levees are structures that cannot be sustained much longer, particularly in the face of sea-level rise, the threat of mass levee liquefaction and collapse under imminent seismic forces, and continued subsidence of the land behind them, driven by unnecessary farming activities in the Delta. F2 believes that it is highly probable that seismic-driven multiple levee failures will disrupt water deliveries to 25 million Californians for many years. The Abandon the Levees factor believes that no one can afford re-building the existing levees to earthquake-proof standards because of excessive costs and perceives that California should move as quickly as possible to let time and tide overwhelm the levees and let a "New Delta" emerge, as an open, mostly salt water bay. To continue vital water exports, DWR must construct immediately the long delayed Peripheral Canal or other isolated water conveyance around or under the Delta so continued vital water deliveries via the CVP and SWP can continue. With additional research on the ecosystem, DWR can operate the isolated conveyance system in a manner to maximize volumes and quality of water exports at the same time as it maximizes salinity variability in the bay to help restore estuarine species, particularly the smelt and striped bass. The Abandon the Levees factor believes California should discontinue making major investments in the doomed existing Delta levees and carefully plan an immediate withdrawal from most land-based human activities in the Delta.

Moreover, the Abandon the Levees factor does not support dredging activities that might harm the environment while only delaying slightly the inevitable abandonment of the levees. F2 believes that some of the environmental restoration projects, particularly those in Liberty Tract and Prospect Island may keep the native estuarine fish species alive until the levees are abandoned and a brackish environment established across the Delta. F2, unlike the three other factors, takes the view that it may not take 30 years for an isolated conveyance system to be fought over, permitted, and built, thus, eliminating the need to maintain the Delta levees for export water conveyance sooner rather than later.

The Abandon the Levees factor believes that the natural forces dooming the levees likely will force faster action.

Descriptive Statistics

The Abandon the Levees Factor shows the second largest explanatory power with 17% of the total variance explained with a standard error of factor scores of 0.200 (Appendix G). Six of the 22 respondents loaded on this factor, second in numbers only to F1. The individual correlations ranged from 0.5546 to 0.8339. As identified in Appendix I, the six loaders on F2 represent several interests, including a water supply engineer/manager, two government biologists concerned with recovery of threatened fish species and runs in the Delta, two of the six DWR engineer/managers who participated in the Q-sort, and one academic consultant to NGOs working on policy issues in the Delta. None of the loaders lives in the legal Delta, but all are long time northern California residents.

Factor 2 correlates strongly with Factor 4 with a score of 0.6137 and suggests considerable overlap of perspectives between the two factors. As noted above, F2 correlates very negatively with F1 at -0.3464 and indicates a wide divergence of views and knowledge between these factors.

Distinguishing Statements

PQMethod identifies nine statements that statistically distinguish the Abandon the Levees factor ($p < 0.05$); led by Statement 6 ("*We have a non-sustainable system. Many levees in the Delta will very likely not be around in 30, 50, or 70 years from now. It just doesn't make economic sense to pour more money on top of the ¼ billion dollars the state has already spent to try to maintain some very expensive levee systems against threats of* *earthquakes, sea-level rise, and ongoing subsidence*"). Factor 2 ranks this statement at +3 and with a normalized score of +1.41 and establishes the F2 perception that the levees of the Delta will be destroyed by earthquakes, sea-level rise, and/or increasing subsidence on the island side because of farming. Respondent 125 expressed his pessimism about the ability to save many of the existing levees in the short term, stating "we have almost lost them already and the storms just keep getting worse, with sea-level rise, no money in the state to repair the levees, you know the way to bet is that Patwin Bay is going to be there someday, if not in my lifetime, then in the lifetime of the next generation" (Interview 125-2009, 0:04). For Respondent 125, "Patwin Bay" is the pet name for the salt-water bay that would replace the Delta, a reference to the Patwin Indians who once occupied the Delta. Respondents 125 and 129 expected a nearly complete collapse of most the levees because of earthquake, sea-level rise, and/or subsidence within the 30-70 year timeframe while Respondent 117 expected an unidentified number of "unsustainable" levees to fail and remain un-reclaimed. Statement 6 came directly from Respondent 117 who confirmed (Interview 117-2009) that state had invested the $250 million in total subventions and special projects since the programs began in1974, a number almost double that noted in Statement 11 that F1 accepted. The difference appears that F1 only counts the subventions money that runs through the reclamation districts and does not credit the special projects money managed directly by DWR, which has mostly gone to Sherman and Twitchell, largely owned by the state, or for remediation projects.

Factor 2 supports this claim with strong ranking (rank = +4, z-score = +1.63) of Statement 13 ("*It is not affordable or justified at an estimated cost of $40,000,000/mile* *to build new earthquake resistant Delta levees when you look at the miles of levees that would require upgrading*".) This represents the second highest z-score of all statements on all factors in the exercise. The Abandon the Levees factor strongly asserts that earthquake risk runs high on the Delta levees, however, they are not worth the $40 million per mile some have estimated to make them secure against earthquake-induced liquefaction. This leaves the total cost of securing the water supply and the Delta communities around $44 billion, far more than the estimated $3 billion to $13 billion to build an isolated conveyance system. Additionally, Respondent 129 believes that the isolated conveyance system will provide the tool to manage the New Delta for exports and the environment, while farming in the Delta and the containing levees limit the options to do so.

Factor 2 agrees with the perception of a highly probable massive, multi-island earthquake caused levee failures as revealed in Statement 35 (rank = +3, z-score = +1.10) ("*Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years").* Engineering Ph.D. holder, Respondent 129, explained the F2 view in technical terms, stating that when he talks to other experts, "they basically all say that these levees are junk, and in an earthquake they are junk, and this is California. Aside from the engineers who make a living keeping these things up, the general consensus is that most of these levees are just temporary" (Interview 129-2009, 0:08). Respondent 129 later referred to the DRMS study and Suddeth, Mount and Lund (2008) for explanation of F2 concern over multi-island levee failures in an earthquake and the problems of multiple levee repairs and flushing the salt out after multiple failures. Statement 35 also indicated that 25 million Californians depend on the Delta for all or some of their water and a number confirmed in the assertion by Respondent 117 that the SWP-supplied MWD alone has 22 million residential customers.

F2 is the only Factor that supports the assertion in Statement 18 ("*from a water supply perspective, the only reliable, sustainable, earthquake proof way to get water around the Delta is the Peripheral Canal*"), with a ranking of +1 and a z-score of 0.79. This support confirms that F2 holds that the cross-state water supply can be sustainable only if the state finishes the original SWP and builds an isolated conveyance system across the Delta because the Delta will soon be a salt water bay. The isolated conveyance system would increase reliability because it would free the SWP and CVP from the current restrictions of the biological opinions. Respondent 117 noted that the only risk to water supply greater than earthquake is ecological collapse (Interview 117-2010A). Respondent 129, the highest loader on F2, argues that the Peripheral Canal would give the managers of the "new Delta" the tools to manipulate the Delta for the fish rather than water supply concerns. Respondent 125 explains that it would allow water export managers to vary the salinity through the year without losing quality water for export at the SWP and CVP pumps. It would also end flow reversals in some channels that confuse already endangered salmon trying to find their spawning gravels up the San Joaquin using chemical signals in the stream when no San Joaquin River water gets as far downstream as Stockton. He tempers his enthusiasm because on the Sacramento River, "where the winter run and spring run that rarely show up at the export facilities will now have to transit the world's largest water project with bigger fish screens than have ever been built… and there are issues that we just don't understand… So I'm a reluctant fan of the Peripheral Canal" (Interview 125-2009, 0:35). Allowing salinity in the Delta to fluctuate would more closely simulate natural conditions of seasonal salinity variability, viewed as a help to certain endangered species while making life more difficult for invasive species in the Delta. It is not clear whether F2 includes Delta farmers in the list of invasive species. Finally, the arguments of Statement 13 rule out the possibility, for Factor 2, that engineers can render the existing levees earthquake-proof in any economically viable way. These perceptions alone are sufficient to lead Factor 2 to support the absolute need for the Peripheral Canal.

Mild support for Statement 5 ("*DWR has a clear legislature-mandated responsibility to maintain the status quo in the Delta, but DWR is really working to preserve the current conditions in the Delta until it is clear what to do to have a healthy Delta ecosystem")* distinguishes Factor 2 with a ranking of +1 and a z-score of +0.42. By contrast, Factors 1 and 3 had negative rankings and z-scores, and Factor 4 had a high ranking of +3 (z-score = +1.37.) This statement holds much more meaning than is initially apparent. The first phrase refers to the wording in the water code that requires DWR and other agencies to work to preserve the "unique" agricultural and cultural aspects of the Delta, granting special status to the islands and waterways of the Delta (Robie 1975, 21). The CALFED charter, Delta Vision and the Delta Stewardship Council have all affirmed this status for the Delta. Respondent 129 dismissed the concerns over the salt water intrusion that the Delta will experience following the inevitable loss of the Delta levees: "Now that would harm the Delta farmers but a lot of them will be gone, the seismic will put them underwater and *that problem will solve* *itself*" (Interview 129-2009, 0:16). "That problem" refers to Delta farmers losing levee side access to fresh water for irrigation. He further elaborates the F2 perspective that the "pretty low value agriculture" on the Delta islands should not be preserved and, therefore, the Abandon the Levees perspective becomes slightly positive toward Statement 5, reflecting that the second part of the statement suggests that DWR recognizes that ultimately the status quo cannot be preserved without destroying the ecosystem and the water supply system. Factor 2 supports the search by DWR for solutions to restore the Delta to a sustainable ecosystem, to gain, in the words of Respondent 129, a "more mechanistic understanding of the eco-system" so that people learn to manage the "New Delta" (Interview 129-2009). Inherent weakness of the levees doom efforts to retain the Delta communities and agricultural lifestyle and salt-water recreation represents the best economic future for the Delta.

Factor 2's support of the efforts of DWR to gain greater understanding of the Delta ecosystem shows in the statistically significant rejection (rank = -2, z-score = -1.04) of Statement 22 ("*Delta habitat restoration projects have been a big joke and a waste of taxpayer's money. Planting trees and shrubs on the levees in conflict with new Corps guidelines, and within five years it has become just a big weed pile").* Many of these projects, like the Twitchell Island wetlands project, represent experiments in ecological restoration. Whereas the results may appear to be weed piles to critical observers, Factor 2 appreciates the effort and also applauds any increase in the habitat for endangered species that may be achieved as noted by Respondent 125, "Habitat restoration is a good thing because we know the values they bring" (Interview 125-2009, 0:39). Factor 2, however, sees that the final solution of abandoning levees will wipe out some of current restoration projects. Respondent 117 highlighted the Decker Island wetland restoration project as an exception. The Decker Island restoration involved removing spoil the USACE dumped on the point bar Horseshoe Bend they cutoff as they straightened the river at Sherman Island in 1913. The restoration involved removing the spoil to return the surface elevation to water levee and allow it to function as a marsh. It, therefore, does not depend on doomed levees to survive which pleased Respondent 117.

F2 takes a distinguishingly neutral (rank =0, z-score = 0.36) view of Statement 15 ("*The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights and water rights lawsuits to be settled and then actually build the isolated conveyance system").* The other factors accept the view that under normal circumstances the permitting and construction of the isolated conveyance system, including resolving litigation, will be a long and drawn out process. Respondent 125 summed up the Abandon the Levees factor perception underlying its lack of salience for this topic "when we lose them (the levees), there will be a lot of political pressure to build as big a ditch as possible as quickly as possible" (Interview 125-2009, 0:05). When Respondent 129 talks about the earthquakes that will make the status quo fail to the "New Delta," it is in terms of days and weeks, a maybe a year, not decades or centuries, reflective of the perception Factor 2 holds that that collapse of the existing system could be imminent, which would trigger a rapid change in the political attitudes entirely in favor of an expedited development of the isolated conveyance. This perception fuels Factor 2's rejection (rank = -2, z-score = -1.04) of Statement 23 ("*Restrictions on dredging and use of dredged materials, particularly in the north Delta need to be eliminated, because they have no real scientific justification*").

Factor 2 sees any investment in or taking any risk to rebuild the non-sustainable, doomed existing levees as unacceptable.

The statistically significant ranking (rank = -3, z-score = -1.36) of Statement 1 summarizes the strong opposition of Abandon the Levees factor perspective to that of the Delta Sustainers: ("*It is very important to keep the Delta community and economy whole. With far less money than is being estimated, levees in the Delta can be made taller and stronger and set back enough to keep Delta islands afloat indefinitely*"). Respondent 129 applauded the work by Logan (1989, 1990) that raised the issue of how few Delta islands could be economically resuscitated after levee failure and Suddeth, Mount and Lund's recent work (2010) that concludes that it makes no economic sense to even improve the existing levees, no matter how strong or weak they were (Interview 129-2009). To the Abandon the Levees factor, no amount of money and effort can protect some of the existing levees, even near and intermediate term. This will convert many of the existing agricultural islands into open water fringed with marsh, greatly decreasing the agricultural production of the Delta and suggesting reduced economic viability for agricultural service functions. F2 believes that the legacy communities, like Isleton and Locke, can be preserved as securely diked enclaves but their economic viability will depend less on agriculture and more on tourism.

Other Key Statements

Several statements ranked -4, -3, +3, or +4 did not make the statistically distinguishing list generated by PQMethod, but are critical in fully defining Factor 2 as a social perspective. Four of these statements carry similar scores and ranking with F4, the factor highly correlated with the Abandon the Levees factor, and one with Factor 3, which explains why they are salient but do not differentiate F2 from all other Factors.

Statement 19 ("*Nothing could be worse for fish than what we currently have in Delta today: rock-lined levees that are serving as water supply channels that are held at as constant flow condition as possible. It is exactly what an estuary should not be")* ranks a +3 for F2 and F3, scoring normalized scores of +1.460 and +1.410 (N.S.), respectively. This suggests total agreement; however, comments made during sorting suggest that the two factors differ significantly in emphasis. Respondent 125 noted that "that statement is right, we have done as bad as we can for them (the estuarine fish) and the loss of the levees and the use of them as a water supply conduit could only be good for them (the smelt)… they are used to a fluctuating salinity environment, that's what gives them their ecological edge, so the loss of the levees... would provide more water to dilute pollutants, it would in many ways solve the problems those fish face" (Interview 125-2009, 0:11). Respondent 129 noted that the fish in trouble are the ones that move in and out of high salinity zones and that by controlling the salinity in much of the Delta to maximize water deliveries with the current configuration, we have limited the habitat of the smelt, striped bass, and longfin. (Interview 129-2009, 0:14). The Abandon the Levees factor strongly suggests that the Delta is part of the San Francisco Bay estuary, implying a gradient of salinity. Further, this salinity gradient naturally fluctuates seasonally because of the Mediterranean climate of the most of the watershed. This perspective emphasizes the native fish, particularly the smelt species that prosper in an estuary with a fluctuating salinity, whereas the invasive species (black bass, pike, etc.) threatening the natives benefit from constant fresh water flows in open channels. The Abandon the

Levees factors responded to Statement 19 focused primarily on the threatened native fish and the constant fresh water flow maintained with the current export pumping schemes in place in the Delta.

The reference in Statement 19 to the Delta as an estuary made the respondents indicate their perspective on whether the Delta functions as a riverine delta or as a salty estuary. This has become an important point of contention in the discourse surrounding the future of the Delta, with support of Statement 19 indicating Factor 2's perspective that the Delta was an estuary with salinity fluctuating temporally and spatially, not a bayhead delta feeding an estuary with fresh water. F2 always highlights estuarine fish and the need to manage the Delta as an estuary. Statement 19 originated with Interviewee 125, an F2 loader (Interview 125-2009).

Following on the habitat theme, F2 and the Multiple Purpose Levees Advocates (F4) rejected Statement 20 ("*Every ounce of habitat out in the Delta, right now, is either behind the levees or between the levees. Once the levees are gone, the habitat is all gone*") with rankings of -3 and -2, respectively. This shared rejection of this statement by Factor 2 and Factor 4 stems from refusal to accept the implication that the existing levee-based habitat represents the only possible habitat. Respondent 125 voices the Abandon the Levees factor perspective that once the levees go away, that natural forces will establish a new set of habitats, those of a saline estuarine bay, more desirable and sustainable. This will leave the Delta an ecosystem not unlike Suisun Marsh, the largest remaining brackish marsh in the country that sits immediately west and is directly connected to the Delta (Interview 125-2009).

The Abandon the Levees perspective and F4 also score Statement 12 ("*As long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levee")* very high with rankings of +4 for both of them and z-scores of +1.476 for F2 and +1.550 for F4 (N.S.). In the case of Factor 2, this scoring reflects a rejection of continued agriculture behind the non-sustainable levees and additional evidence of the eventual demise of the Delta levee and agriculture system. Respondent 117 talked about his involvement in a planned program to grow rice on a Delta island to reduce subsidence but he noted rice slowed subsidence versus growing corn, but does not stop or reverse it. Factor 2 does not show much concern for levee stability and security except to suggest that pressures will only get worse over time as long as agriculture continues in the peat soil areas, while for Factor 4, the increased subsidence represents a major levee stability issue caused by agriculture in the peat Delta. Factor 1 was the only perspective that rejected Statement 12 with a z-score of -.069 and a rank of -1 (N.S.).

The Abandon the Levees factor strongly rejects (rank = -4 and z-score = -1.88 – N.S.) Statement 16 ("*DRMS was a DWR conspiracy to justify the Peripheral Canal")*. Respondent 106 explained that the 2004 Jones Tract failure triggered the DRMS effort it suddenly forced DWR into management of a levee repair on an island which some believed should be abandoned. The DRMS consultants were ask to look at everything for every island to determine how the levees fit into flood control, agriculture and conveyance. They were to look at the earthquake risk, high water risk, and make an island by island comparison of which islands would be resuscitated in event of failure, and what developments should be encouraged or discouraged. He believed the period was too short to achieve these goals and the politicians applied too much pressure to come up with answers (Interview 106-2009). Respondent 129 thought the URS consultants did excellent work but the URS management found itself in over their heads in selling the findings and did a poor job of presenting the results (Interview 129-2009). Respondent 129 believes that no one conspired, however, the DRMS work simply leads to the logical conclusion that the Peripheral Canal is required to be able to operate the New Delta for water supply and estuarine fish (Interview 129-2009).

Similarly, Factor 2's rejection (rank = -4, z-score =-1.82 – N.S.) of Statement 32 ("*over the last 35 years, there has never been any earthquake damage to a levee in the Delta and the whole earthquake risk thing is junk science. It is a reality that the earthquake threat has been wildly overstated and is rather specious")* shows that loaders on F2 stand convinced that the Delta is overdue for the inevitable earthquake that will liquefy multiple levees. Again, the discourse over the future of Delta levees resonates with claims and counter-claims about the likelihood of multiple island failures because of earthquake-induced liquefaction. Rejection of Statement 32 firmly establishes where Factor 2 stands on this issue.

Iteration Phase

In early November 2010, I conducted follow-up interviews with the two most strongly correlated respondents on the Abandon the Levees factor, respondents 129 (loading on Factor 2 = 0.8339) and 119 (loading = 0.7111). They were shown a table showing the original factor summary sheet dated 9 November 2010 (Appendix H) and asked to identify which factor they would have loaded highest on, what they thought of the name assigned the factor, "Abandon the Levees", and whether summary comments were correct from their individual perspective for the viewpoint they were assigned. They easily identified that their perspective aligned with the summary sheet description of Factor 2; however, Respondent 117 believed the name assigned miss-stated his perspective in that he did not believe that all Delta islands should be abandoned, just the ones that were non-sustainable. He produced a map of his view of which islands were sustainable and what the final configuration of the Delta would look like after abandonment of all the non-sustainable islands. The map had no title and was clearly not for publication, and showed perhaps 40%-45% of the Delta agricultural lands remaining in “Wildlife-friendly Agriculture.” Most of the “peat” islands in the lowest part of the ‘pool” were shown as abandoned to wetlands. Respondent 117 suggested revising the summary of social perspectives to reflect that the state should not waste any more money on the non-sustainable levees. He also expressed the view that the people knowledgeable of the levees recognized the variability across the Delta of levee designs, elevations, materials of construction, and foundations and did not condemn all of the current agricultural islands to abandonment. He expressed concern that those politicians, scientists, and general citizenry did not pick up that distinction and the general discourse is moving incorrectly to a discussion of abandoning all Delta levees. He recommended changes to the title for F2 “Abandon the Non-sustainable Levees” and minor wording changes in the summary and introductory paragraphs of this section of the dissertation, which he reviewed.

The general agreement with the overview of Factor 2 and the similar but slightly different pushback on some points by the two strongest loaders added to confidence in the analysis of this factor. In the end, however, I determined to stay with the Abandon the Levees because even if all loaders agreed on what made a levee sustainable, every island could end up on someone's list of levees "To be abandoned."

LEVEE PRAGMATISTS (FACTOR 3)

Factor 3, the Levee Pragmatist social perspective, perceives major flaws in the approaches of all the prime actors in Delta levee maintenance and management except their own different, but very pragmatic approach. This factor views all of the resource utilization demands on the Delta as being unsustainable in the long term, while opting for pragmatic approaches that can get the get the most out of the Delta for the longest time with the least input of resources. This social perspective sees inherent non-sustainability of most human-impacted socio-ecosystems everywhere, and they believe that farms protected by levees are no more or no less sustainable than agriculture in the arid Central Valley or a city the size of Los Angeles relying on sources of water more than 400 miles away. They do not see sustainability as truly possible; this perspective believes that society should do the best it can for as long as it can.

Factor 3 is critical of the policies and efforts of the Corps of Engineers, the DWR, and the local levee districts because it believes that many of their policies weaken the levees by not recognizing the ability of proper vegetation growth to strengthen them. Levee Pragmatists have not been impressed with the levee work completed under the subventions program and are concerned that the RDs, DWR, and USACE often employ methods that cannot achieve the desired results. F3 worries that the local reclamations district stand in danger of losing the levee expertise and dedication they historically enjoyed. Levee Pragmatists see enough variety in the levee system that it remains neutral about the risk of the levees failing or being melted by earthquakes, worrying instead about levees weakened by de-vegetation and failure to apply the best methods to find and eliminate structural weak points. Levee Pragmatists remain very concerned about the contaminants potentially remaining in the sediments continually deposited in the channels of the Sacramento River so they oppose dredging these materials to build up the levee system.

Descriptive Statistics

Factor 3 explains about 8% of the total variance with two individuals loading on this factor. It correlates with none of the other factors, either positively or negatively. The loaders on this factor do not correlate strongly with the other factors. It might be tempting to ignore this perspective as an outlier except that the two loaders on F3 each hold Ph.Ds. in scientific fields and each has spent significant time and energy studying Delta levees. They are as knowledgeable as any of the other experts are and they bring unique expertise and experiences to the discussion. The loaders have correlation factors of 0.7092 and 0.6814. They work independently and as far as I know do not know each other. One lives along a levee in the Delta, the other does not.

Distinguishing Statements

The PQMethod identified eleven statistically significant distinguishing statements at $p<0.05$. The high ranking (rank = +4, z-score = +1.51) Statement 25 *("The current system of local levee districts performing much of the routine maintenance is dysfunctional, disjointed, and inconsistent. They have a deep distrust of DWR and it is disturbing how poorly they work together")* shows the concern over the current levee maintenance program and the organization of that work. The statement comes verbatim from Respondent 118 (Interview 118-2009), an F3 loader, who further expressed that whereas the engineers provide guidance to the boards, and the final decisions come down to the personal preferences of the 86 local reclamation district (RDs) boards. Respondent 118 recognizes that "they [district people] are often strapped for money, and my feeling is that they should care more than they do and they have a lot of resentment of the rules and regulations and they have a deep distrust of DWR… the dysfunction runs up to DWR" (Interview 118-2009 0:15). Respondent 118 went on to add that the budget problems of California that plagued the government during the summer of 2009, when DWR could not pay the reclamation districts the promised money that the district had already borrowed and spent, added to the this distrust.

F3 doubts that the individual RD boards can develop consistent and coordinated approaches to levee maintenance. Respondent 120 has spent considerable time boating through the Delta channels and comments about seeing completely different maintenance methods being employed on levees on the two sides of the same channel. He summed it up saying, "Yes, every district does its own thing!" (Interview 120-2010A, 0:16). The Levee Pragmatists have experienced the greatly varying resources available to the local districts and worry that while some landowners hold properties in several districts and some serve on more than one board, no overall coordinating group exists, formally or informally, to share best practices or resources. This may be a legacy of the days when the best defense against levee failure involved a weaker nearby levee that would fail first and relieve the flood height.

The Levee Pragmatist concern over the role of the reclamation districts in levee maintenance shows in the response to Statement 24 ("*Reclamation districts that own the levees are not prepared for levee failure and many of them are poor at communications* *with their own constituents*”). Agreeing with this statement (rank =+2, z-score=+0.89), the Levee Pragmatists distinguish their views by their criticism of the reclamation districts (Interviews 118-2009, 2010A, 2010B and Interviews 120-2009, 2010A, 2010B).

Criticism of the involvement of the reclamation districts by the Levee Pragmatist factor continues in the challenge to what the other factors consider to be a definite strength of the RDs as expressed in Statement 28 (“*The local reclamation districts maintaining the levees bring incredible institutional knowledge of a constantly evolving system. They have people who can inspect the levees under all kinds of conditions and know what to look for. They have people who know what to do in an emergency and they are ready to defend their homes, livelihoods, and families*”). With a ranking of -3 for this statement (z-score= -1.79) implies that F3 lacks reverence for the local knowledge accumulated by the reclamation districts. The comments made during the sorting exercise, however, suggest more of a concern over the ability to maintain and reproduce the local knowledge. When I questioned Respondent 120 (Interview 120-2010A) who loaded on Factor 3 about why he rated the Statement 28 negatively during the Q-sort, he remarked that the older generation of farmers were really involved and dedicated to the levees but that they were starting to die off. Respondent 120 believes that the younger generations do not seem to care as much and it would not be long before time depleted the local knowledge. Respondent 118, the other loader on F3, expressed concern that several local reclamation districts did not seem to care about the condition of their levees. The historical record and the conventional wisdom in the Delta would suggest that the members of levee districts have mobilized quickly in response to any threat and won many flood fights. If Statement 28 is inaccurate, it represents a serious concern for the future of Delta levees under reclamation district leadership, a situation acknowledged and noted above by two Delta Sustainers during the iterative phase.

Continuing this lack of confidence in the commitment and expertise of the reclamation districts, Levee Pragmatists revealed a very negative reaction (rank = -4, z-score -2.06) to Statement 27, wanting no part of increased reclamation districts involvement in the governance of the Delta ("*The best governance structure for the Delta would be to let the levee districts tackle the issues island-by-island with some funding and guidance from DWR"*). This represents another clear rejection of the expertise and commitment of local districts, as Respondent 120 bluntly explained quoting Forest Gump, "'Stupid is as stupid does,' I know enough of them to know that would not work" (Interview 120 -2010A, 0:22). He later added "I know these people and they have something to offer and they should be a part of the equation, but to just turn it over to them, you see what we have" (Interview 2010A, 0:29).

Further, the Levee Pragmatists factor alone questions the cost effectiveness of the subvention program that started with passage of the Way Bill in 1973. The Levee Pragmatists scored Statement 25 negatively (rank = -2, z-score =-0.86) ("*The DWR subventions program was a model of efficiency; the DWR staff was lean, and the local levee districts, because they had their money out there, managed projects very effectively*"). Factor 3 distinguishes itself by seeing the weakness in the subventions program. Respondent 118 became disenchanted with execution of the program in 2009 after the infusion of the Propositions E-1 and 84 bond money. DWR established a higher reimbursement percentage but planned to distribute the $50 million in 2009 to the districts based on the merits of their project proposals. They did not even publish the interim guidelines for the selection process until January 2009 and allowed only a short lead-time for submittal of proposals (a March 2009 deadline). DWR did not announce the winners until June and the construction windows close for the year in October. As of July 2009, however, the bond money remained frozen by the budget crisis of 2009. Respondent 118 (Interview 118-2010A) explained that all of this bond money had been approved by the voters to straighten out Delta levees. The voters had been convinced the Delta levees were in "dire straits. And they voted to build them better… and really what has happened out there is they developed a 'Band-Aid' approach with huge projects fixing only a small portion of the weak levee sections with most of the funds going into 'over-the-top' habitat elements" (Respondent 118-2010A). Respondent 118 believes that the minimum levee standard PL-84 should be met everywhere before the money goes to the habitat enhancements. (Interview 118-2009, 0:42). Factor 3 also laments over use of less cost effective methods for erosion control such as use of riprap.

In addition to being critical of the local reclamation districts and DWR, the Levee Pragmatists also see problems with the involvement of the other major entity attempting to maintain Delta levees, the USACE. At a statistically significant level ($p < 0.05$), F3 distinguishes itself with its support (rank = +3, z-score =+1.44) of Statement 29 ("*Federal official maintenance practices are destabilizing the levees by denuding them completely. We are spending huge amounts of money destroying vegetation and huge amounts of money creating habitat that is not sustainable*"). More than just another criticism of an entity working Delta levee issues, objection to the vegetation ban on levees ordered by the USACE Washington headquarters in 2007 shapes much of subjective perspective of the Levee Pragmatists. Factor 3 emphasizes that properly selected vegetation on the levees provides stabilization of the levees while providing habitat for aquatic and terrestrial species. Whereas other factors and the RDs and DWR have all pushed back on the nationwide ruling of the USACE as being inappropriate for California and too costly to implement immediately, Factor 3 sees the policy as dangerous to levee stability. Respondent 120 points to the bare levee that failed at Jones Tract in 2004 and the unmaintained, abandoned but vegetated and still standing levees at Franks Tract and Mildred Island as evidence (Interview 120-2010A) that vegetation adds more to levee stability than it detracts. Respondent 120 asserts that the local levee boards that receive the highest scores from the USACE on levee maintenance are the wealthiest ones who can in his terms, just “nuke” (heavy spraying of herbicides) the levees to comply with the new USACE rules. In doing so, they lose the strength of a properly vegetated levee (Interview 120–2010A).

Other distinguishing statements for the Levee Pragmatist factor include Statement 23 (rank = -4, z-score = -1.94) (“*Restrictions on dredging and use of dredged materials, particularly in the north Delta, need to be eliminated, because they have no real scientific justification*”). As respondent 120, one of the loaders on Factor 3 stated while conducting the sort, “there are too many unknown things out there (in the sediments) that are bad, going back to the days of hydraulic mining, to disturb them” (Interview 120-2010A). He later concluded, “You never know what is in there, I actually believe that some dredging should be done. But no restrictions?” (Interview 120-2010A, 0:29). Respondent 118 expressed concern over the mercury potentially in the channel sediment and suggested but “you talk to anybody and they have their own truths about this. As far as DWR and Fish & Game, they create their own ‘truths’ as well” (Interview 118-2009, 0:23).

Consistent with the "pragmatism" indicated in the name assigned Factor 3 is the neutral ranking (z-score= 0.00, rank = 0) for Statement 2 ("*Incremental changes are not going to create a sustainable Delta and even after a few hundred million dollars in improvements, we will still have levees that time and tide are just going to overwhelm*"). This ranking statistically distinguishes the viewpoint of F3 from F2 and F4 that support this statement with a rank of +2 (z-scores = +0.81 and 0.84, respectively) and the Delta Preservationist factor that strongly rejects it (rank =-3, z-score = -1.24). Levee Pragmatists do not find little interest in plans for Peripheral Canals or other grand projects to save the Delta levees or habitat, nor does it concern itself with philosophical debates about the nature of sustainable outcomes for the Delta. This perspective concentrates more on the methods and technologies that reclamation districts can employ to improve levee stability one foot at a time, and not the grand schemes or even what the ultimate outcome of the battle in the Delta between human effort and the natural processes will be. When questioned during the Q-Sort, Respondent 120 suggested that while humans likely could not sustain the levee system forever, the Delta residents have enough motivation and energy to overcome their less-than-perfect efforts to sustain the system for at least a few more lifetimes, at least in face of the normal threats. Respondent 120 sees the Delta levees as just one many non-sustaining human impacts at work in the Delta. Just as the water exporters will work to keep the water flowing south, the farmers of the Delta islands will maintain the levees to continue their livelihoods until it just becomes impossible. He did not see that happening in the near future (Interview 120-2010A).

The lack of salience of F3 with the doomsday forecast reflects also in the statistically distinguishing scores and ranking of Statement 9 (rank = 0, z-score = -0.24) ("Delta *levees are precarious and a disaster waiting to happen. They have to work so long and hard and are built of the wrong materials, on the wrong materials. The levee districts are trying hard but all it takes is one overzealous beaver. At the same time, we are now appreciating the earthquake risk and we are just lucky that we have not had a 6.0 or a 6.5 close to the Delta")*. Respondent 120 placed it in the neutral category and indicated parts were true such the developers of the Delta levees built them out of the wrong materials and on the wrong foundations; but she also believed that the earthquake risk is overstated. F1 looks at the levees in the Delta and sees many different kinds, some robust and well maintained, some poorly built and improperly maintained. They see the rodent problems as real but manageable with different approaches and they do not agree that all the RDs work hard or effectively at maintaining the levees. At the same time, while recognizing the possibility of seismic destruction of the levees, Factor 3 remains somewhat unconvinced of the inevitability of massive levee destruction by earthquake. This bears out in the statistically significant lukewarm rejection (rank = -1, z-score = -0.28) of Statement 16 ("*DRMS was a DWR conspiracy to justify the Peripheral Canal*"). Whereas the Levee Pragmatists believe in the reality of the risk of earthquake damage and that the science of the DRMS report appeared to be a legitimate effort, Respondent 118 noted that some of "the researchers mean well, but it has been odd to me how the academics have fueled the DWR agenda about the earthquake risk" (Interview 118-2010A, 0:24). F3 sees much of the emphasis on earthquake risk as political rhetoric aimed at paving the way for acceptance of an isolated conveyance system. To Factor 3, it not so much a conspiracy as it is a politically motivated emphasis (Interview 120-2009) and the claim of a conspiracy as just "hearsay" (Interview 120-2010A, 0:41).

Similarly, the Levee Pragmatists give the concern that "*As long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levees*," Statement 12, only statistically significant weak support with a ranking of +1 and a z-score of +0.52. Again, the Levee Pragmatists confirm that whereas earthquake, additional subsidence, and sea-level rise represent real threats to the levee system, they pale in comparison to the daily issues of bare levees maintained by people not taking advantage of the latest technologies. Meanwhile, the rock-lined levees have destroyed the riverine environment, making the levees weaker and environmentally and aesthetically barren, coming often at a higher installed cost than more pleasing, vegetated approaches that strengthen the levees.

Other Key Statements

The Levee Pragmatist factor has five highly ranked (-4,-3, +3, and +4) statements which did not make the statistically distinguishing list because the scores were not significantly different than one or more other factors. F3 shared some highly ranked statement with each of the other factors, reflecting the low correlation of F3 with any other factor. Levee Pragmatists shared agreement with the Delta Sustainers and the Multi-Purpose Levees (rank = +4, z-score = 1.51) on Statement 15 ("*The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system").* This reflects the pragmatic view that barring an emergency, the completion of a huge canal or tunnel system around the Delta will take many years DWR receives approval to proceed. The strong local opposition, a plethora of environmental regulations, and a massively oversubscribed water rights system suggest that property right and environment lawsuits, injunctions, and other legal delays will render realistic a 30-year time frame for the process. The continuing change of political leaders and their views will like not speed things.

Factor 3 and Factor 1 also had nearly identical scores and rankings (rank for both = +3, z-scores = +1.48 and +1.45 respectively – N.S.) for Statement 10 ("*Although the levees are not well-engineered structures, riddled with penetrations and random objects, and inherently unstable because of their peat foundations, they survived record high water due to very high tides in 1998 and the 2006 high water and wind events without a failure. Somehow they are stronger than they seem to be").* This statement actually originates with one of the Factor 3 loaders (Interview 118-2009) and represents a pragmatic acceptance of the strengths and limitations of the Delta levees. Respondent 118 has studied many of the reports from non-destructive levee inspection tool investigations, hoping to gain greater understanding the strengths and weaknesses of these inspection systems. Respondent 120 comments "It is amazing what hasn't broken out here. All these lands are all below sea-level and if you believe Jeff Mount, they all should have been toast a long time ago" (Interview 2010A, 0:18). He reflected later on the opinion of a geomorphologist who once suggested to him that the constant hydrostatic head on the Delta levee may be working them to a higher strength while exposing any problems in the levee quickly for immediate repair.

Relative to this, Statement 14 (*"Improving the reliability of and employing non-destructive levee inspection tools represent a great opportunity to improve levee safety*") ranked highest by F3 and F4 at +2, but in both cases the sixth highest ranked statement (z-scores of F3 = 1.201 and of F4 = 1.00 – N.S.). This shows the concern of F3 (as well as F4) for the unidentified suspected penetrations and anomalies in the levees, As suggested above, this statement came from Respondent 118 who loaded on F3 (Interview 118-2009). Some of these non-destructive inspection methods have been used with some success since the mid-1980s on Tyler Island (Interview 115-2009) and a lot of inspection work was planned under a joint DWR-FEMA program but was cancelled in the confusion of the 2009 California budget meltdown (Interview 118-2009).

The Levee Pragmatists social perspective joined the Delta Sustainers in giving Statement 18 a very low ranking (F3 rank = -3, z-score -1.20; F1: rank = -4, z-score = -1.82 – N.S.) ("*From a water supply perspective, the only reliable, sustainable, earthquake proof way to get water around the Delta is the Peripheral Canal*"), and Statement 35 (F3: rank = -3, z-score -1.17; F1: rank = -3, z-score = -1.52 – N.S.) ("*Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years*"). Respondent 120's comment on Statement 35 was "I do not discount that it might happen, but I'm more concerned about losing levee vegetation as a more proximal worry" (Interview 118-2009, 0:24). The rejection of Statements 18 and 35 shows that the Pragmatists do not accept the discourse about the great risk of earthquake to the Delta levees and the rhetoric about the resulting need to build the isolated conveyance system.

Finally, the key statements also show agreement on ranking Statement 19 (rank = +3, z-score= +1.41 – N.S.) with the Abandon the Levee factor (rank = +3, z-score =

+1.46 – N.S.) that (“*Nothing could be worse for fish than what we currently have in Delta today: rock-lined levees that are serving as water supply channels that are held at as constant flow condition as possible. It is exactly what an estuary should not be*”). The agreement of F3 with Statement 19 emphasizes its disappointment in overuse of riprap and concrete rubble to resist erosion on the levees, creating a poor habitat for native fish and terrestrial species alike, while questioning the need to export a quarter or more of the Delta inflows. As noted above, F2 support of Statement 19 emphasized the lack of fluctuation in the flow rates resulting in reduced seasonal variability of salinity in the Delta and confusing signals for returning salmonoids trying to find their spawning grounds.

Iteration Phase

I reviewed the preliminary findings with both individuals who loaded on Factor 3 in mid-November 2010. Neither suggested a better idea for the factor name and they seemed comfortable with the “Levee Pragmatist” moniker. Also during the follow-up interview with F-4 loaders, Respondent 116 looked at the original of the table in Appendix H and commented that Factor 3 seemed to be a very negative perspective, which he had not heard and was surprised existed. Then at the follow-up interview with Respondent 120, after reading the write-up several times, he agreed that it described much of his perspective and then said, “I wish I were not so negative” (Interview 120-2010B).

Appendix H incorporates the suggested changes F3 loaders to the original defining descriptions that they reviewed. Specifically, they thought it important to state that the Delta levees were sustainable near term with “intelligent inputs” (120) rather than just "minimum inputs" or with "appropriate, targeted, and effective resources" (118) rather than just "minimum inputs" as I had originally expressed it. Respondent 118 also suggested that the idea of a maintaining the Delta the way it is long-term is a possibility, not a probability.

MULTI-PURPOSE LEVEE ADVOCATES (FACTOR 4)

The Multi- Purpose Levees Advocates social perspective earns the title by believing that with additional knowledge, investment, and commitment, California can achieve the Delta Vision and Delta Stewardship Council goals of maximizing water deliveries, restoring and maintaining the Delta ecosystem for the various native and now endangered fish species. It perceives that the state can do this while preserving the Delta as a unique place and protecting it from flooding long associated with the Sacramento and San Joaquin watersheds.

F4 has confidence in the science of the DRMS study, particularly in its highlighting of the risk of earthquakes inducing levee failures but it is not as confident in the ways the study results have been used and interpreted. F4 sees the DRMS study as highlighting the potential of earthquake damage but they remain concentrated on improving the stability of Delta levees structurally and finding ways to reverse subsidence. On the environmental side, they strive to first figure out what the endangered species need in the way of habitat and then figure out ways to produce that in the environment. They are not convinced that the isolated conveyance is an absolute necessity but will make it work if it exists. The lack of real knowledge about the levee failures and the current condition and the processes at work in the ecosystem frustrates F4. Multi- Purpose Levees Advocates are opposed to the denuded levees policy of the

USACE. In many ways, F4 supports the philosophy of behind the CALFED dream: if everyone works together, we can get more out of the system.

Descriptive Statistics

Factor 4 explained 15% of the total variance in all perspectives measured, and at a standard error of 0.218 (See Appendix G). Five of the 22 respondents loaded on this factor, the third highest number of any factor with individual correlations ranging from 0.5684 to 0.8024. Four of the five loaders on Factor 4 were identified as "State" (includes County) employees or contractors and all were listed as involved in "Water" (includes water management - flood control and water supply, as either engineers or managers). All four spent considerable portions of their careers with DWR, giving F4 a four to three majority over F2 among the DWR related participants. The fifth F4 loader's background is as a federal water engineer/manager. None of the Multi-Purpose Levee Advocate loaders live in the Delta and all office in Sacramento. Factor 4 shows strong correlation with the Abandon the Levees factor (0.6137), suggesting considerable sharing of perspectives but F4 loaders remain committed to the levees in the Delta. Factor 4 shows strong deviation of perspectives with from Factor 1, with a correlation between factor scores of -0.1303.

Distinguishing Statements

Eight statements statistically distinguish the Multi-Purpose Levee Advocate factor from the factors. Factor 4 takes the strongest positions on two statements relating to the future of Delta without the levees and the approaches of DWR to levee integrity. First, the Multi-Purpose Levee factor agrees strongly (rank = +4, z- score = +1.63) with Statement 3 ("*The Delta islands are now well below sea level and if we lose the levees,* *we are going to have a saltwater bay. It will be a bay rimmed by urban levees, except perhaps up the Yolo By-Pass where new tule marsh may become established.*") The F4 acceptance of this statement appears to relate the truth that the loss of the agricultural levees would increase the size of the tidal prism to the point that all or much of the legal Delta would become a saltwater bay. All perspectives rated this statement positively, but F4 was unique in the high ranking it gave it. Unfortunately, the comments recorded during the sorts do not elaborate on this strongly held perspective, it just seemed an accepted fact not requiring elaboration.

The Multi-Purpose Levee Advocates, with so many DWR officials loading heavily on the factor, perceive that the DWR works hard to prevent the loss of the levees and the resulting undesirable outcome as shown in the strong rejection (rank = -4, z-score = -2.16) of Statement 7 ("*The goal of DWR is to let the Delta go back to salt and build a peripheral canal around it*"). The very strong rejection suggests that Factor 4 holds the perspective that DWR remains committed to maintaining the Delta as a unique and viable agricultural place as specifically identified as state government policy in the Water Code, and is not totally committed to an isolated conveyance. The very strong rejection of Statement 7 by F4 suggests that it does not accept the "back to salt" and the Delta-as-an-estuary concepts prominent in the F2 discourse.

The rejection of Statement 7 is affirmed by F4 support (rank = +3, z score = 1.33) for Statement 5 ("*DWR has a clear legislature-mandated responsibility to maintain the status quo in the Delta, but DWR is really working to preserve the current conditions in the Delta until it is clear what to do to have a healthy Delta ecosystem*"). This statement originated in the 2009 interview with Respondent 127, who loaded on F4. He went on to say "the jury is not yet in on what the best course of action is and it really depends on what you want to manage this already heavily impacted ecosystem to do" (Interview 127-2009, 0:24). Statement 5 also represents an insider's view of DWR knowledge of the Delta reflecting a healthy amount of uncertainty. It also reveals how DWR managers and engineers approach the multiple and sometimes conflicted responsibilities of the organization. The California Water Code clearly requires preservation of the Delta as much as possible as a unique place and the Multi-Purpose Levee Advocate factor perceives that DWR pursues that requirement while trying to work in support of the Delta Stewardship Council "co-equal" goals of enhancing the water supply and the protection, restoration, and enhancement of the ecosystem. As Respondent 127 acknowledges, however, with the environmental element, "everything is experimental, the uncertainties far outflank what we know...The problem is that the Delta is far more complex ecologically than we know…we are always behind…" (Interview 127-2009, 0:14). Statement 5 implies frustration with the lack of scientific information and the fact that they may be using approaches that may prove very incorrect.

The uncertainty of Multi-Purpose Levee Advocates over the level of knowledge about the Delta extends to the probability of and risk posed by earthquake-triggered cascading multi-levee failures. Factor 4 scores a statistically distinguishing neutral ranking (Rank = 0, z-score = 0.39) on Statement 35 ("*Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years*.) Whereas F1 and F3 strongly reject (F1: rank -3, z-score =-1.52; F3: rank -3, z-score = -1.17) this view that earthquakes induced failures of Delta levees represents the main risk to the SWP and CVP water supply, Factor 4 distinguishes itself as being concerned over earthquake risk but not ready to declare it the main risk, a middle ground position. Respondent 116 notes that "this statement [35] is not provable, we don't really know the true underlying frequency of earthquakes and nor when the next one is coming. I would say that an earthquake is one of the big risks, the other is hydrologic, and another is terrorism…it [earthquake] is a big risk but I cannot accept that it is the main risk" (Interview 116-2010A, 0:54). Respondent 131 suggested that whereas earthquake represented a risk, drought presented the largest risk because the resource has been so terribly overcommitted (Interview 131-2010A). F4 backs away from classifying the odds of a multiple levee failure scenario as "likely" and recognizes the other risks to the water supply system such as earthquake damage to the long distribution system of pumps, canals, and pipelines.

The strong support of the Multi-Purpose Levee Advocates for the efforts of the DWR in the Delta continues with the distinguishing rejection (rank = -3, z-score = -1.70) of Statement 22 ("*Delta habitat restoration projects have been a big joke and a waste of taxpayer's money. Planting trees and shrubs on the levees in conflict with new Corps guidelines, and within five years it has become just a big weed pile*"). Since 1992, DWR and DF &G have directed the habitat restoration projects required as environmental offsets and enhancements required in the levee subventions program (Interview 127-2009). Factor 4 perceives the direct benefits to the environment and what is learned about habitat restoration in the Delta well worth the money and time invested. The mention of the planting of trees and shrubs, in conflict with USACE guidelines, refers to the 2006 emergency levee repair program in which DWR spent millions installing riprap on eroded levees. Part of the project included planting shrubs, trees, and dead logs near the water line to improve the riverine habitat. The state provided the money and the USACE and at least one reclamation district managed the construction (Interview 111-2010A). As noted in Chapter IV, 2007 saw USACE headquarters issue the enforcement of the zero-vegetation policy for levees nationwide, making most of the plantings of the previous year subject to removal. Respondent 131 explained his rejection of Statement 22 as "Yes we probably have planted some stuff will have to take out to meet the new Corps guidelines, but part of the idea of restoration projects is learning, and you learn from the mistakes as well as from the things that go right" (Interview 131-2010A, 1:42). Respondent 127 (Interview 127-2009) explained that the riparian projects have been particularly successful and expects that the Corps will rescind the "Zero Vegetation" policy. It also sees the plants growing on the Decker Island restoration site and the Twitchell Island marsh project not as weeds but vegetation that restore Delta habitat.

Multi-Purpose Levee Advocates loaders find little salience with the strong criticisms of the reclamation districts in the concourse. Statement 25 ("*The current system of local levee districts performing much of the routine maintenance is dysfunctional, disjointed, and inconsistent. They have a deep distrust of DWR and it is disturbing how poorly they work together*") received a neutral score (rank = 0, z-score = 0.02) suggesting either a perception that average best describes the effort of the reclamation districts or possibly that the performance of the different RDs varying from good to poor and averages out to neutral. Respondent 131, the highest loader on F4 stated during the ranking session. "They are not all that way (dysfunctional, disjointed, and inconsistent) but the system is somewhat dysfunctional with all the districts being independent" (Interview 131-2010A 1:49). Respondent 116 allowed "it is a series of fiefdoms but there is more cooperation than you might think and there is a fair amount of consistency in how they do their work." Further, she suggested that the reclamation districts are "wise and they know they can't count on DWR in the long term because programs and people are constantly changing" (Interview 116-2010A).

In a related item, The Multi-Purpose Levee Advocates take a distinguishing neutral view (rank = 0, z-score =+0.08) of Statement 24 ("*Reclamation districts that own the levees are not prepared for levee failure and many of them are poor at communications with their own constituents*"). Again, with 86 districts with very different resource bases and personalities, F4 loaders find it difficult to characterize the situation, or they may believe that RDs make average emergency preparations. Again Respondent 131 explained, "you have some very good ones (Reclamation Districts) and some that are just a few farmers. Most can't afford to do what they need to do and most can't afford to prepare for a levee failure" (Interview 131-2010A, 1:25).

The final statistically distinguishing comment for Factor 4 comes in the lack of support (rank = -2, z-score = -0.70) for the concern outlined in Statement 4 ("*The voices of those who have a local knowledge of the role of levees in Delta are probably not as strong as voices of the water exporters and the environmentalist advocates focused solely on endangered fish species*"). Respondent 103, an F4 loader, perhaps summed it up best, "I think everyone is pretty vocal… I think the underrepresented voices are the other 53 counties, the ones who are not getting the water, who are not interested in the environment... Sutter County… sometimes when they get grumpy they comment to the Department, 'all you care about is the Delta'" (Interview 103-2010A).

Other Key Statements

Given the strong correlation between the Abandon the Levees and the Multi-Purpose Levee Advocates, four of the ten statements ranked very strongly (defined as +4, +3, -3, -4) but did not earn the statistically significant distinguishing category because the views of the statements were shared by the two factors. The Multi-Purpose Levee Advocates also share similar high rankings on one statement with both the Delta Sustainers and the Levee Pragmatists.

One major view shared between Factor 4 and Factor 2 relates to Statement 16 ("*DRMS was a DWR conspiracy to justify the Peripheral Canal*"). Both perspectives reject this statement, accepting the DRMS as a valid scientific study and supportive of the role DWR role in guiding the effort. Factor 4 recorded the most negative z-score for this statement of any factor on any statement (rank = -4, z-score = -2.16 – N.S.). Three of the five loaders as Multi-Purpose Levee Advocates ranked this statement at -4, one at -3 and the other at -2. Respondent 134 stated that as much as people "sometimes don't like to hear the truth, there is a science behind it [the DRMS report]" (Interview 134- 2010, 0:23). All the other F4 loaders refused to respond to the claim that DWR tried to steer the findings of the DRMS to recommend building the Peripheral Canal. Factor 2, again with many DWR employees, also strongly rejected efforts to taint the DRMS work with suggestions of political manipulation (rank = -4, z-score = -1.88 – N.S.).

Factor 4 also strongly rejects (rank=-3, z-score =-1.54 – N.S.) Statement 32 ("*Over the last 35 years, there has never been any earthquake damage to a levee in the Delta and the whole earthquake risk thing is junk science. It is a reality that the earthquake threat has been wildly overstated and is rather specious*"). This comment takes clear aim at the DRMS earthquake risk section and studies sponsored by PPIC (Suddeth, Mount and Lund 2008; Mount and Twiss 2004; Mount and Twiss 2005) and others raising concern over multiple levees failures caused by an earthquake. Statement 32 references the lack of a history of earthquake induced levee failure, citing most exactly the lack of damage experienced during the Loma Preita 1989 earthquake. Respondent 116 noted that she knows of creditable reports of Delta levees visibly moving up and down during the Loma Preita quake, and she questioned if anyone could say categorically that they were not damaged (Interview 116-2010A). Citing the 2010 Haiti earthquake, Respondent 134 in rating this comment very negatively noted that "just because it hasn't happened doesn't mean it won't happen… and 35 years is geologically nothing " (Interview 134-2010, 0:26). Whereas the risk of earthquake damage to Delta levees did not show up as dominant perspective with the Multi-Purpose Levee Advocates, they respect the scientists who have been raising the concerns as Respondent 116 states, "I think very good scientific work has been done and we have applied the very knowledge that is available" (Interview 116-2010A, 0:24). Again, this perspective is shared with Factor 2 (rank = -4, z-score =-1.82 – N.S.).

Factor 4 (rank= +3, z-score = +1.22) and Factor 2 (rank = +1, z-score = +0.80 – N.S.) both support Statement 33 ("*A lot has been accomplished on reducing risk of normal every day, vanilla, levee failures but more and more we need to recognize the vulnerability to extreme events such as earthquake and very large floods that are not adequately recognized or acknowledged by some of the Delta stakeholders*"). Again, the issue of the susceptibility of Delta levees to failure by liquefaction forms a giant divide among interviewed levee experts, a divide created by widely varying perceptions of probabilities. Clearly, the claims and counter claims stem from both sides' frustration of having much at stake but having little or no "science" to convince the public or themselves.

Another area of agreement between Factors 4 and 2 comes in the concerns over additional subsidence caused by continued commercial farming in the Delta as demonstrated by the strong acceptance of Statement 12 (rank = +4 for both Factor 2 and Factor 4; Factor 4 z-score= +1.55, Factor 2 z-score = +1.48 – N.S.) ("*As long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levees*"). Much of the discussion with the Multi-Purpose Levee Advocates revolved around finding ways to halt subsidence and to reverse it. Some Multi-Purpose Levee Advocates talk about the experimental test plots where DWR grows rice on Bradford Island and a private effort on Bract Tract to grow a cooler weather variety of rice, thereby retaining agriculture and slowing subsidence. Respondent 116 suggested in his support of this statement a novel idea that Delta subsidence could be reversed through a subsidized effort to grow water hyacinth, the invasive species that otherwise chokes the waterways of the Delta, in flooded section inside of the islands (Interview 116, 2010-B). This farming would provide a carbon sink and the cut and submerged "crop" would be an *in situ* biomass generator.

Where Factor 4 diverges its views from the Abandon the Levees factor and finds some agreement with Factors 1 and Factor 3 comes in Statement 15 ("*The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system").* Factor 3 strongly agreed (rank = +3, z-score =+1.11 – N.S.) with the concept that regardless of one's views of the sustainability of the Delta levees long term, they must be maintained for a generation before a suitable replacement system can be designed, permitted, fought over in the courts, and built. Interviewee 116 only commented "Certainly at least 30 years, perhaps more" (Interview 116-2010A, 0:46). Only the Abandon the Levees factor keeps this perspective from becoming a consensus item.

Finally, the Multi-Purpose Levee Advocates rejected (rank =-3, z-score = -1.19 – N.S.) Statement 27 ("*The best governance structure for the Delta would be to let the levee districts tackle the issues island-by-island with some funding and guidance from DWR*"). Whereas Factor 3 rejected this statement with even more vigor because of the disappointment with the reclamation districts, DWR, and the lack of Delta-wide thinking about the levees, Factor 4's objections from Factor 4 come primarily with the concept of island-by-island governance and secondarily, heavy reliance on the reclamation districts.

Iteration Phase

I reviewed the preliminary findings with the top three loaders on the Multi-Purpose Levee Advocates factor (Respondent 131 (loading 0.8024), Respondent 116 (loading 0.7343), and Respondent 103 (loading 0.6428). All three had little difficulty redacting that they loaded most strongly on Factor 4. Two of them were particularly fond of the title "Multi-Purpose Levee Advocates." No one had changes to the summary comments or the draft of the introduction. Respondent 103 commented that the statement "Believes that DWR tries to manage the Delta and the levees in compliance with the requirement to maintain status quo in the Delta while exploring a better path for the environment and water supply" sounded like a restatement of the Delta Stewardship Council charter. The state legislature charged the DSC (DSC 2010a) to prepare a plan by 2012 to manage the Delta with the two co-equal goals of maximizing water supply and restoration of the environment. This led Respondent 103 to additionally comment that the newly created Delta Stewardship Council, just nearing its first year of existence (November 2010), while largely staffed by former DWR employees, regularly placed huge stresses on the DWR and presumably many Factor 4 loaders. The DSC members were making requests for information and data to DWR staffers with very tight deadlines, that by the nature of the political process, the DWR employee sensed great pressure to respond to the request. He suggested that DWR employees tried hard to avoid these requests because of the un-budgeted effort involved and also because the information request often took the form of investigating the results, methods, and execution of old and current DWR programs. While Respondent 103 allowed that the Delta Stewardship Council staff was acting to execute its mandate to challenge how the Delta has been managed, he saw a rise in stress within the DWR from having to answer questions and sometime admit to mistakes made to this new and suddenly powerful organization, one whose power was been defined and refined each day (Interview 103-2010B). Given the strong support some Factor 4 loaders feel for the programs and effort of the DWR, such second guessing by the Delta Stewardship Council could prove stressful for Multi-Purpose Levee Advocates within the Department.

Respondent 103 also noted that one thing he saw was that if he went into a meeting to solve a problem, he thought it would be easier to come to a solution with the people sharing the same social perspective. Whereas this might seem intuitive, it also points out how groupthink might represent a challenge for members of any one of these factors interacting consistently and exclusively with people with similar social perspectives. It makes it easy to come to a solutions, however, those solutions may lack innovation or ready acceptance by others factors.

Respondent 116 did not have any suggestions to improve the naming or description of Factor 4, but when reading the Levee Pragmatist description he questioned, “How can there be people out there who are so negative about everything?” (Interview 116-2010B).

AGREEMENT IN THE DISCOURSE

Two of the 35 sorted statements created a statistical consensus. Statement 21 (“*We need more innovation like the $2.5 million CALFED funded project on Tyler Island to restore subtidal berms and levee vegetation. About two miles of shaded shallow riverine habitat were gained long term while reducing potential flood damage to the levee*”) scored neutral rankings from all four factors (Factor 1: rank = 0, z-score =+0.33; Factor 2: rank = 0, z-score +0.05; Factor 3: rank = -1, z-score = -0.38; Factor 4: rank =+1, z-score = +0.64). The fact that Statement 21 lacked salience in all the factors surprised me in that statement had come from one of the strong loaders on the Delta Sustainers factor and had been very positively reviewed during the sorting exercise by Factor 3 loader 118 (Interview 118-2010 A). Also during the sorting process one of the loaders on The Multi-Purpose Levee Advocates supported the concept of the statement but believed that I had the location incorrect, he had been involved with a similar successful project on Staten Island (Interview 116-2010A). I went back to review the individual sort results and found that indeed the Factor 1 loaders ranked this statement from a -1 to a +3, the two loaders on factor went in opposite ways with -3 and +2 rankings. Overall as individuals, a full 8 of the 22 ranked this statement at 0, or 36.3% as compared to the

20% average percentage of 0 rankings for a statement. This ranking by all the perspectives suggest that encouragement of innovation lacks salience for those working levee issues, particularly with regard to attempting to use organic materials instead of rip-rap to prevent levee erosion. I began to think that the concept of encouraging innovation was the part of Statement 21 lowering its saliency, particularly after my follow-up meeting with one of the top loaders on the Multi-Purpose Levee Advocates. After reviewing the preliminary name and description of Factor 4, Respondent 116 started discussing his concept to reverse subsidence, specifically growing and drowning water hyacinths inside the islands. Then he dismissed the prospects of trying out his idea with the words “I have lots of ideas that can help the Delta but no one wants to listen” (Interview 116-2010B). My observation is that Respondent 116 is one of the most experienced and respected senior managers working Delta levee issues for the state and his big picture ideas form the heart of some of the major Delta projects now under construction or in the final planning stages. Looking carefully at Statement 21, I realize now that it is the smallest scale idea in the concourse and Q-set. Similarly, Respondent 116’s idea of growing water hyacinths as an experiment is a relatively small. Meanwhile, CALFED, the Delta Vision, and now the Delta Stewardship Council efforts have re-scaled Delta levee issues to the statewide scale. It seems probable that the scores for Statement 21 reflect not so much consensus except perhaps that local scale issues just are not as important as the larger scale issues. Perhaps the problem comes back to the researcher forcing a local issue in the Q-set. Q-Method identified a consensus that local issues have little salience, which does not represent the kind of consensus conflicted social perspectives can build on.

All factors also reached consensus on Statement 30 ("*The levee districts tackle the critical erosion and acute problems very effectively but they are not good at minor, everyday maintenance. Unfortunately, this inattention lets minor problems like vegetation on the levees grow into overwhelming problems and now they face major engineering and construction efforts in some many areas to get the levees back into compliance with Corps requirements*"). This statement originally came from a representative of the USACE (Interview 126-2009). The ranking of this statement, (Factor 1: rank = -2, z-score =-0.92; Factor 2: rank = -1, z-score -0.66; Factor 3: rank = 0, z-score = -0.18; Factor 4: rank =-1, z-score = -0.25) suggests that the USACE (perhaps more accurately the USACE Headquarters) stands alone with their policy of requiring denuded levees. The rejection of Statement 30 by Factor 3 seems weak in light of Levee Pragmatists view that vegetation helps strengthen not weakens levees; however, this statement is also critical of the everyday maintenance practices of the reclamation districts as are the Levee Pragmatists.

This consensus item captured in Q-Method seems be to showing in the public discourse and legal actions. DWR has filed a challenge to the USACE enforcement (Cowen and McCamman 2008), backing the reclamation districts, and questioning the suitability of the requirements for California levees. A set of interim agreements have been developed between the reclamation districts and the USACE that set a go-slow approach but it is only good until 2012. As the discussions continue, the consensus at the Delta-wide scale rejects the national scale answer of the USACE to the role of vegetation on levees.

SUMMARY

Q-method has provided a mechanism to quantify social perspectives of experts on Delta issues. Four social perspectives emerged:

F1 - the Delta Sustainers factor holds that the existing levee system is sustainable long term, primarily because of the improvements made under the subventions program of state sharing investment in locally executed levee maintenance and improvement projects and the dedication and local knowledge of the Delta residents, the reclamation boards and the engineers and consultants they employ. They are far more concerned with rodent damage, levee heights, and erosion than earthquake damage that they see as potentially overstated to support the building of a Peripheral Canal they oppose.

F-2 - the Abandon the Levees factor believes that sea level rise, continued subsidence behind the levees and the high probability of multiple levee-destroying earthquakes doom the existing system. The levees support and control an undesirable ecosystem where the estuarine native species struggle to survive so replacement with an open water environment will probably be more desirable. With an isolated conveyance system, DWR can manage an open water Delta to maximize water export quality, quantity, and reliability while creating a simulated natural estuarine environment.

F3 - the Levee Pragmatist factor envisions the Delta levee and the Delta socio-ecosystem as just one of many human impacted system places that are not viable long term (excess of 100 years) but they are sustainable for several generations with more innovative and environmentally responsible approaches. They are particularly critical of the USACE policy of zero vegetation on the levees and the execution of the subventions program because they inhibit trying new approaches. F3 worries that local knowledge of levees is declining in quantity and quality.

F4 - The Multi-Purpose Levee Advocates believe that the managers, engineers, and scientist operating the flood control, water export, and ecosystem aspects of the Delta are effectively keeping the system, including the levees, functioning while they also try to close the information gaps, to "learn what levers we can pull" (Interview 103-2009). They believe that money spent on the subventions program and habitat restoration projects associated with Delta levees have been a good investment.

The four factors explain approximately 69% of the total variance in social perspectives about the failures of Delta levees as of the date of the sorting by the P-set of levee experts. It would be encouraging if some ideas got enthusiastic support or rejection from all Factors but this did not happen. Two "Consensus Statements" exist but these were statements of a shared lack of salience. The first related to innovation coming in the form of a perhaps in a too specifically defined vegetated erosion prevention project. The second consensus item came on a statement concerning the new USACE enforcement of the zero levee vegetation that drew low to neutral scores from all factors. The common ground identified would not appear to be the starting point of for consensus building among factors.

The four factors hold significantly different perspectives as evidenced by years of conflicted discourse in the Delta. Understanding of the social perspective of the managers and engineers in the system could be the first step in reconciling the differences. The Delta Stewardship Council needs to do this to achieve consensus on a

Delta Plan or to overcome resistance to an imposed plan, even if the non-consensus plan represents a majority plan.

CHAPTER VII

THE HISTORY OF FAILURES AND NEAR MISSES OF THE DELTA LEVEES

(1868-2010)

INTRODUCTION

To understand a potential source of divergent social perspectives, the second research question this dissertation asked was: What is the history of the failures of Delta levees? This chapter introduces the Access 2010 empirical database and ARCMAP GIS mapping of the data point developed to answer the question. It then presents the findings from this research. In addition, this chapter reviews the catalogs and maps of the near-miss incidents experienced by Delta levees where information is available. This dissertation defines "near misses" as levee failures narrowly avoided through successful flood fighting or completion of emergency repairs. Flood fights involve the stacking or sandbags or other methods of raising the levee height or otherwise strengthening weak points on a levee during flooding events, usually involving contractors with large earthmoving equipment and large numbers of volunteer hand laborers. Emergency repairs involve cases where crews find and fix on a non-stop; no resources spared basis a major flaw or problem that poses an imminent threat to the levee. The near miss record, particularly of emergency repairs, remains far less complete and does not go back in time far because engineers, managers, and public have only recently recognized the value of documenting and discussing such incidents. The lack of public interest in what does not fail and, thus, does not gain media attention renders it difficult to re-create this record from newspapers and journals.

The chapter will then discuss the sources and compare the findings for the period 1868 to 1956 with Thompson's reporting (1958, 1962, 1996, and 2006). It will then compare the levee failure history as defined in the DRMS report (URS 2009c) which also appeared verbatim as a staff white paper prepared for the Delta Stewardship Council (DSC 2010b). Comparison with DRMS will include the difference in base number of failures recorded. Definitional restrictions on what is recorded as a "levee failure" will be used to make the trends and history more insightful for those wanting to understand the past, present, and future of Delta levees. The chapter will review the implications of the differences in the definitions used to establish trends.

Several findings relevant to the contested social perspectives explored in the previous chapter will be introduced including (1) records from the year 1906 of the effects of an 8.3 (Richter) magnitude San Andreas Fault earthquake on the Delta levees as they were at that time; (2) discussion of the implications of the past abandonments of Delta levees; and (3) the differences in statistical performance of various types of levee sections.

This dissertation represents the first attempt to locate the failures and near misses to levee sections rather than islands as discussed in Chapter V. Therefore, statistical comparisons of the rates of historic failures by levee construction method and levee original builder (Project-Direct Agreement, Non-Project), purpose (agricultural, urban, wetland control and height-restricted), and hydrostatic loading (levee-dam or flood control levee) will be calculated and presented.

THE DATABASE OF DELTA LEVEE FAILURES AND NEAR MISSES

The dissertation developed a database in Access 2007, containing 997 incidence reports of levee failures and near misses that documented 265 failures of levees dating back to 1868 that have occurred in the Legal Delta. Appendix M provides a full list of the identified failures of Delta levees. I have identified the exact levee segment (out of 404 identified segments) on which 155 failures have taken place. Of these, the dissertation identifies the precise location of 102, which Figures 7.1, 7.2 and 7.3 show. This precision extends to the location of all 46 failures since the 1972 Brannan-Andrus failure except one failure on Van Sickle Island and one on Prospect Island. In total, the record includes one hundred twelve (112) failures recorded in the past one hundred years (1911-2010) and 188 since 1900.

The 188 represents 26 more than the number of "flooded islands" the DRMS (URS 2009c) reported for the same period. Figure 7.4 shows numerically how this difference developed. Part of the difference stems from definitions. Appendix M and Figure 7.4 for the dissertation include only records from the Legal Delta and excludes failures of levees in the Suisun Marsh and elsewhere, which the DRMS list sometimes includes and sometimes does not. The dissertation database does not include records of failures outside of Legal Delta. Appendix N provides a list of "Other Reports not Failures of Delta Levees" which includes some of reports of levee failures outside of the Legal Delta, reports of floods on areas not leveed (Ida Island for example), and floods that were not caused by failure of a levee. Some of these were included in the DRMS list. Appendix O lists the "Questionable" reports, some of which also made the DRMS list. These are primarily isolated reports of a failure that cannot be substantiated with another

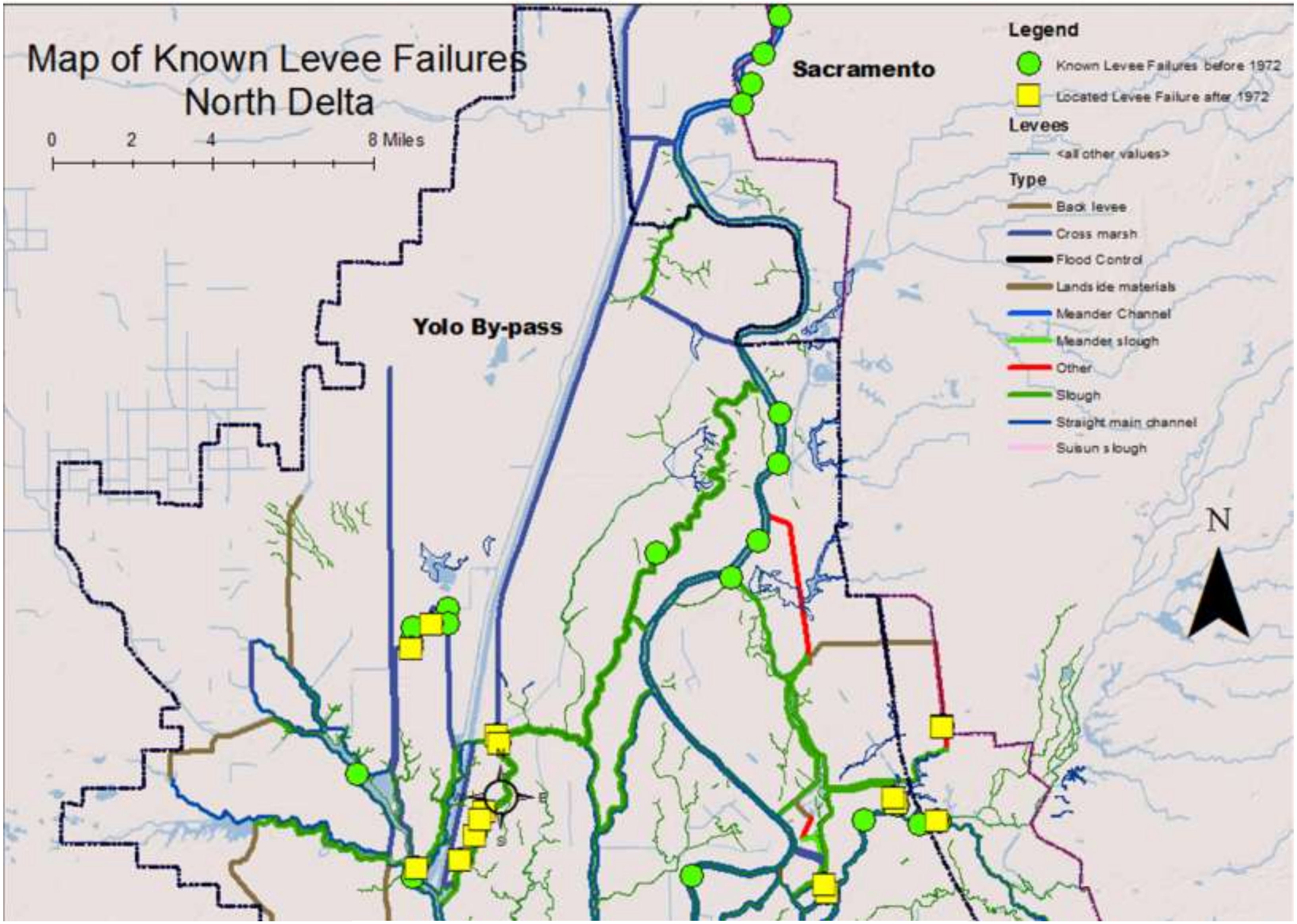


Figure 7.1 - Map of Known Levee Failures – North Delta

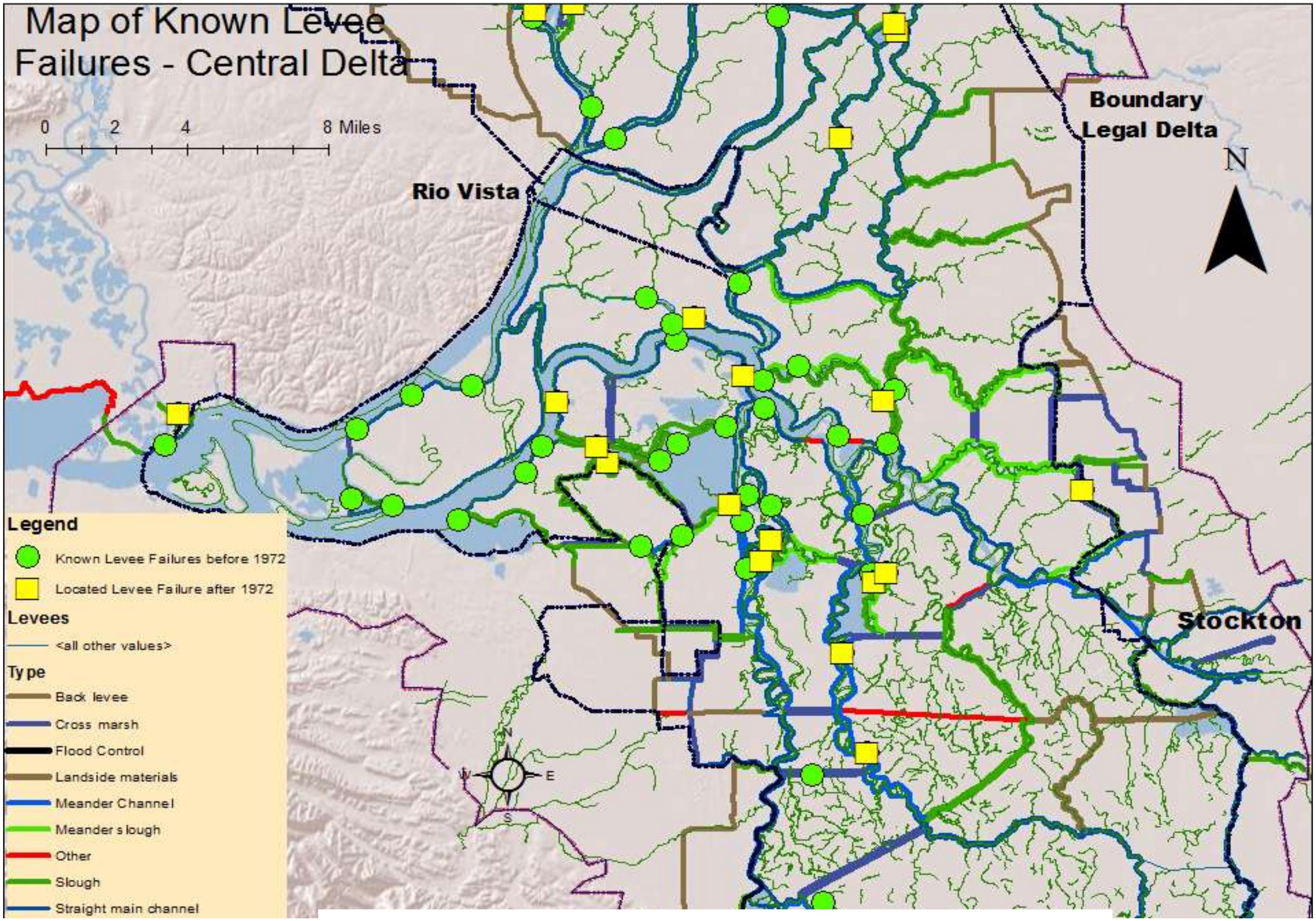


Figure 7.2 – Map of Known Levee Failures – Central Delta

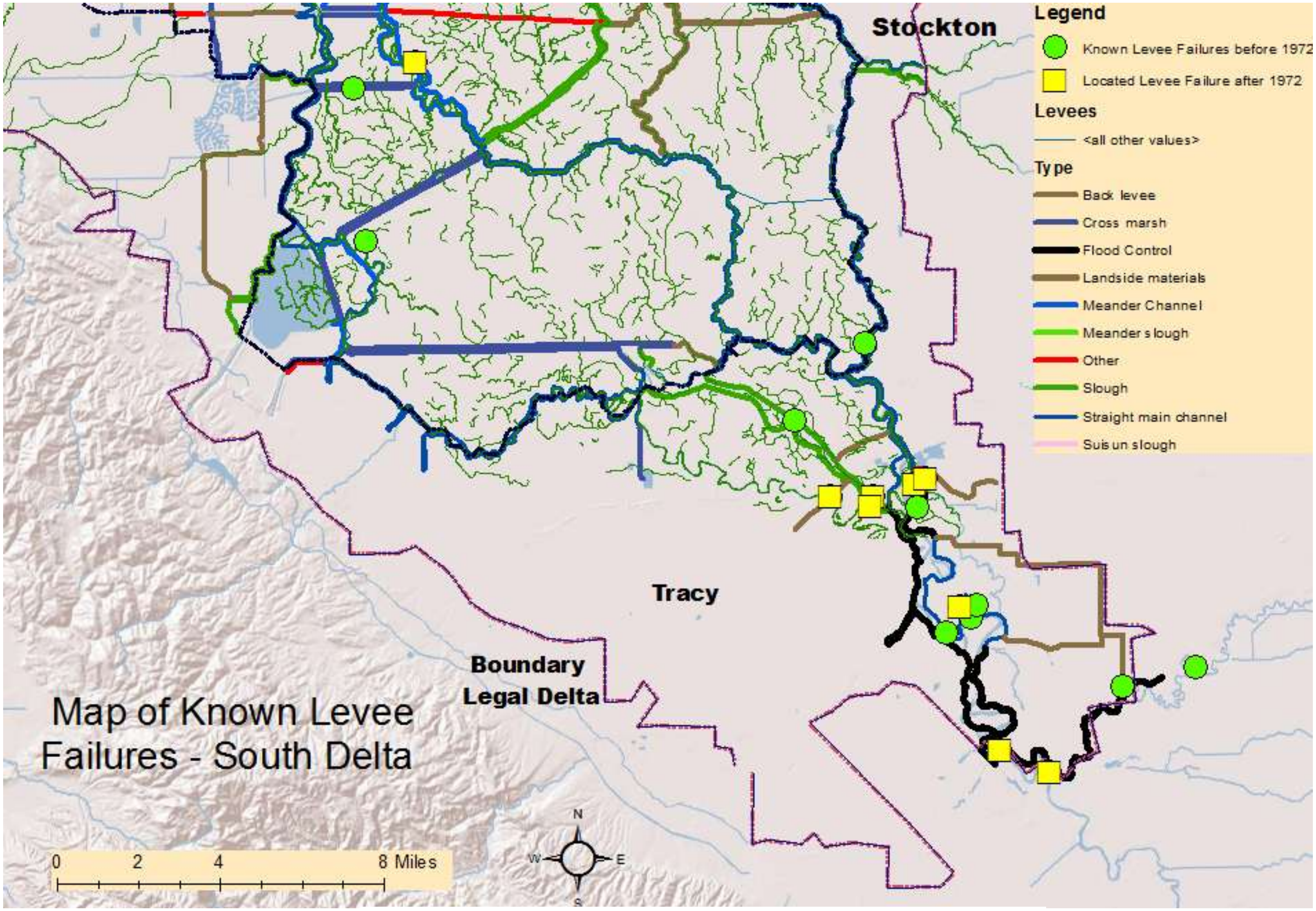
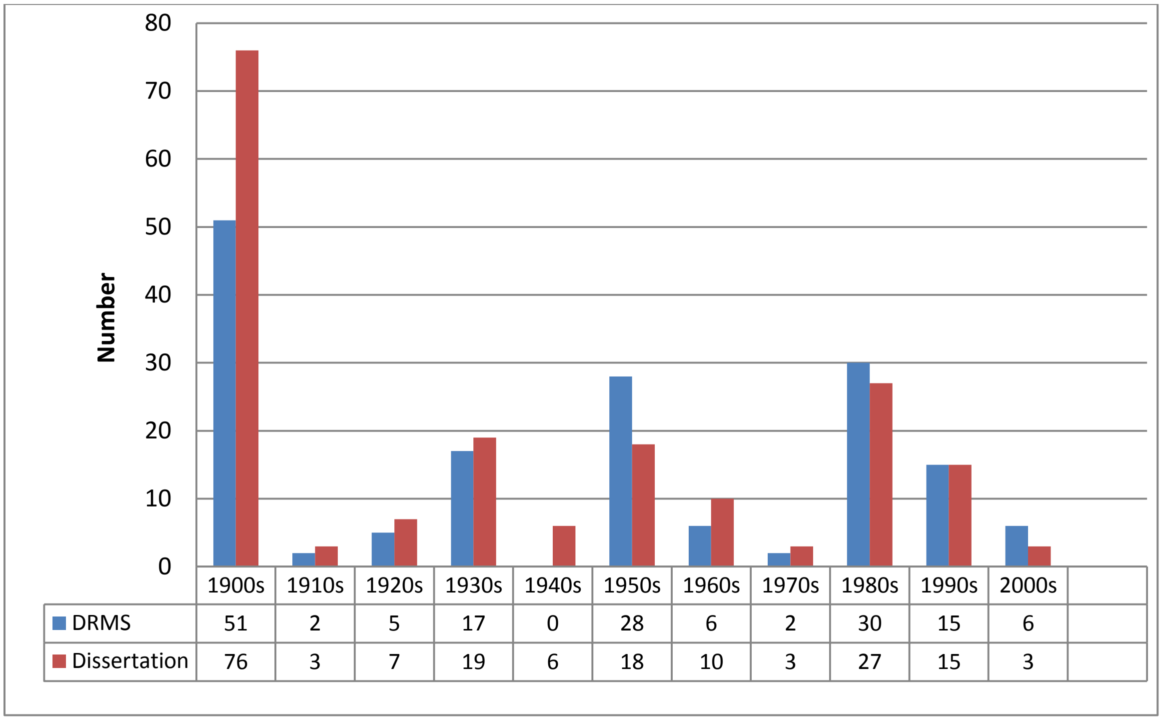


Figure 7.3 – Map of Known Levee Failures – South Delta



	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	
DRMS	51	2	5	17	0	28	6	2	30	15	6	
Dissertation	76	3	7	19	6	18	10	3	27	15	3	

Figure 7.4 - Comparison of Numbers by Decade of DRMS “Flooded Islands” and Dissertation List of Delta Levee Failures

report and lack adequate detail and/or confirming and independent reporting. Some are simply reports that reference only the calendar year and not the correct “water year.” The database records the failure in the proper water year in the database. Some of these may prove to be documented failures through future investigation; however, this research uncovered data that challenge the validity of the many of these failure reports listed in other sources.

The database also documents 24 cases of emergency repairs, all since 1981 that prevented imminent levee failures and 53 records of successful flood-fights, 23 since 1950, 13 since 1973, and 5 since 1986. Engineers consider near-miss analysis an important learning tool and can learn more from sharing detailed knowledge of these near misses failures can be learned from actual failures. This is perhaps most true with earthen levees where the floodwaters wash way and destroy everything, rendering reconstruction of "failures" impossible in most cases. Near-miss analysis often is the best way to add to engineering knowledge. Appendix P includes the list of emergency repairs in the database.

SOURCES

The 35 experts interviewed in the summer and fall of 2009 and 2010 added significant contributions to database and mapping, particularly relative to events of the past 40 years. Thompson's work over the last 50 years represents about one-quarter of the total entries into the database.

The number of incident reports in the database by source breaks down as follows:

237 – Thompson (1958, 1996, 2006 and 1983 with Dutra)

159– DWR reports (DWR undated; 1964; 1973, 1983; 1984, 1985, 1988, 1997, 2008, 2009; Cole, Finch, and Newmark1986; Rabbon and McCullaugh 1986; Robie 1974; 1975; 1985)

139 – Newspaper reports (*San Francisco Chronicle; San Francisco Call;* Slack 2003*, Sacramento Bee; Sacramento Daily Union; River News Herald; Pittsburg Post Ledger, Los Angeles Times, Los Angeles Herald; Delta Herald; Antioch Ledger; Alta California*)

68 – Eyewitness reports collected during 2009-2010 interviews

161 - DRMS report (DRMS 2009c)

28 – Other Agency reports (CALFED 1998, S4; Siegfried 2000; Neudeck 2008)

44 – Google Earth and other maps and aerial images

96 – Other (URS 2009c; Cosio 2009; Dillon 1982; GlobalSecurity.org 2005; Houston, Duncan, and USACE 1978)

1 –Legal (Higgins-Monckton 1938)

Taken all together, recording data from these sources helped expand the list of failures of Delta levees, initiate compilation of lists of emergency repairs and successful flood fight, and provide detail to make analysis more powerful.

COMPARISON TO THOMPSON'S HISTORY

Thompson's dissertation (1957), as augmented by later work (1962, 1996, 2006), provides the base for understanding the geography of the Delta and the early Delta levee failures. Figure 7.5 summarizes the number of failures he identified by five-year period and compares that to the Dissertation levee failure record complied for the period 1868 to 1956 when his record keeping stops. Figure 7.6 provides a cumulative total of failures recorded for Thompson, the Dissertation, and DRMS for the period 1900-1956, the period the three records overlap. These charts should provide some indication of just how complete Thompson's record was for his period of interest, particularly from 1868 through1911. After 1911, I did find a few new records that he never mentioned, however, his did not focus on levee failures. I was able to add to Thompson's work relative to the 1906 earthquake. Thompson never mentions the earthquake and only describes high tides as causing flooding on seven islands in July 1906 in the Delta, unlike his detailed description of 1904 and 1907 floods and levee failures. Given the current interest in earthquake risk in the Delta, I checked to see if evidence existed in the record that would

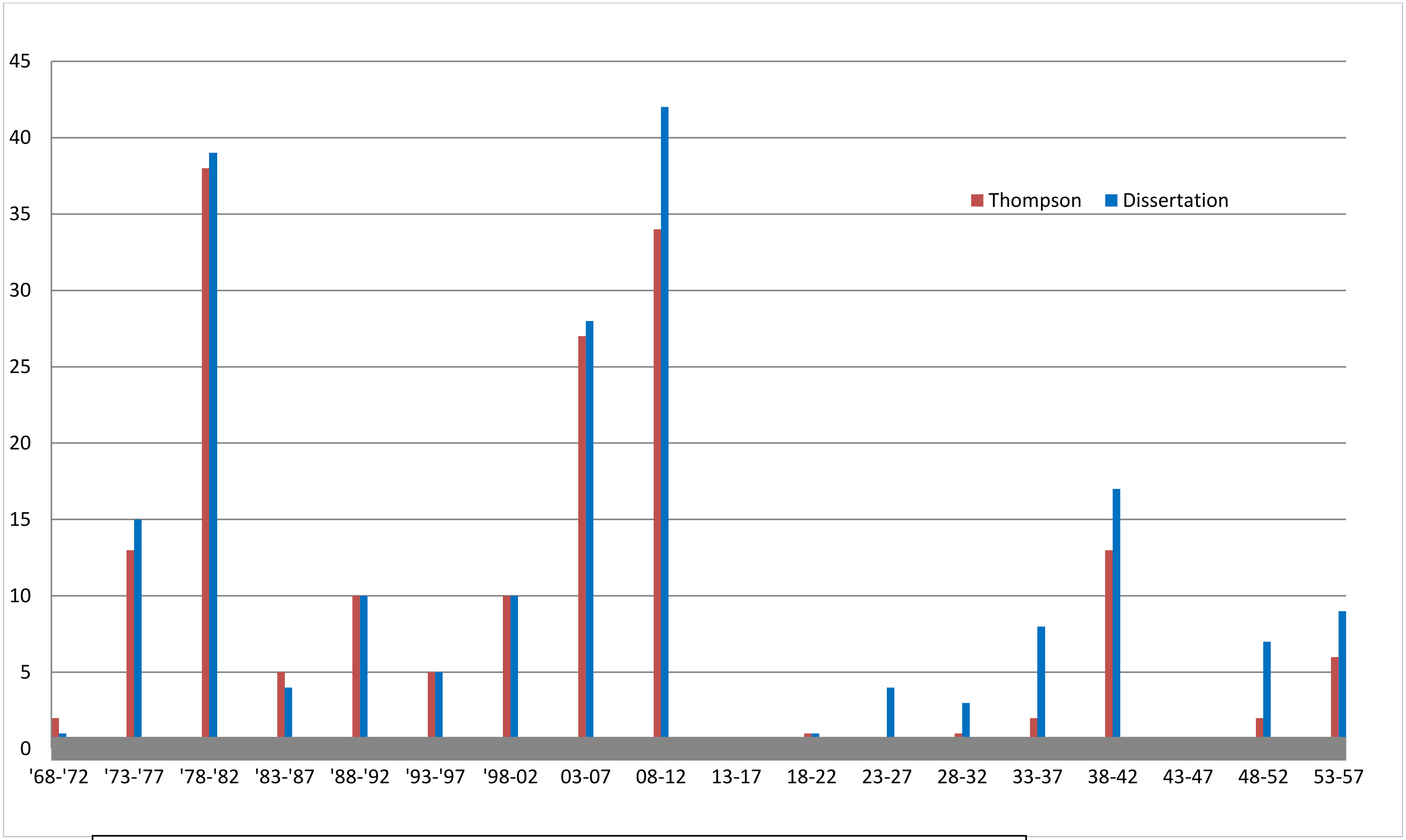


Figure 7.5- Comparison Thompson *vs.* Dissertation - Failures Recorded 1868-1957

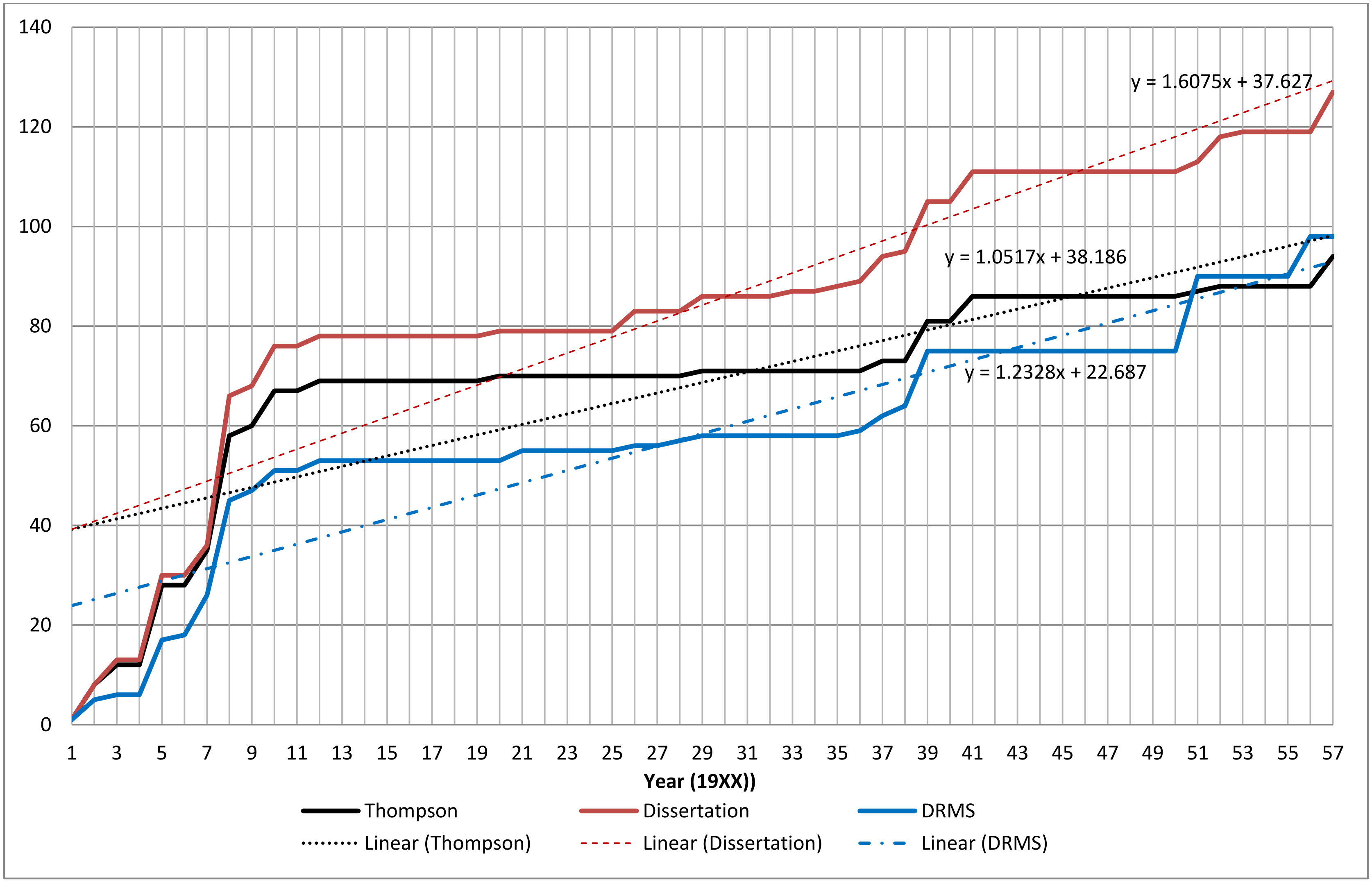


Figure 7.6 – Cumulative Number of Levee Failures Reports -1900-1957 (Period of Overlap) - Thompson, DRMS, and Dissertation Database

link the April earthquake to the 1906 levee failures. I found reports of six islands that were flooded by a late season high water event on the San Joaquin that first knocked a hole in the Union Island levee, and then the levee on what is now Roberts Island failed and the flood ending up inundating Venice, Twitchell and Sherman as the high levels moved downstream. I looked back to the time of the earthquake and found no levee failures. I did find that the earthquake dropped the foundation of the railroad bridge on the Middle River one meter and twisted it, while the pier supporting the bridge over the main San Joaquin River sank 8 cm. (Youd and House 1978). Meanwhile, the railroad tracks that cross the Delta on the levee built in 1899 (*San Francisco Call* 1899) appeared to have suffered no damage. One might think that Thompson's newspaper sources could have been limited because of a slow recovery of the San Francisco papers still reeling from the April disaster, but some of my data entries did come from the *San Francisco Call* in July and August of 1906.

In summary, Thompson's work forms the base of the levee failure history in the Delta and this record serves to extend it. I did spot check Thompson's records, and found that particularly before 1911, they appear very well researched and complete, and so this database does rely very heavily on Thompson's work. Whereas 2006 represents the most recent date on work on the Delta produced by Thompson, I could not find any case where he described any flooding or levee failure that occurred after the date of his dissertation (1957).

DISSERTATION IMPROVEMENT OVER THE DRMS LIST OF DELTA LEVEE FAILURES

As shown in Figure 7.4, the Dissertation database list of "failures of Delta levees" differs significantly the DRMS (URS 2009c) listing of "flooded islands." The objective of the two studies was essentially the same: to understand the historical geography of the failures of Delta levees to understand the stability of the levee system and the trends as identified empirically. The DRMS report developed an accounting of the failures that suggested a dim future for the Delta levees as summarized in the DRMS Executive Summary (URS 2009a). This dissertation actually increased the number of levee failures since 1900, however, the detail and the analysis that the new list facilitated led to a significantly different perspective on the meaning of the history.

The DRMS recording of "flooded islands" by year since 1900 (URS 2009c, Table 7-9) represented a checkpoint for the work. Three major problems stood out however. First, the DRMS list provides little detail about the failures, often leaving it unclear whether the flood took place in the listed calendar year or the water year (October 1 – September 30), generally omitting any other information. The list includes no references to permit check the information, the second major issue. It makes it impossible to learn more from the record or check the accuracy of the reports. The third problem stems from a definition of what should be reported. DRMS confused the Delta failures with the Suisun Marsh levee failures.

Treating the levees in the Suisun Marsh the same as the levees in the Delta represents the first definitional problem with the DRMS report, as the history, purpose, funding, governance, and location of Suisun Marsh make its levees very different from the Delta agricultural levees. Until the 1990s, few paid any attention to flooding in the Suisun Marsh and counted or documented levee failures (Interview 132-2010). Even the landowners, primarily absentee duck-hunting club members, paid far less attention to Suisun marsh levees than Delta farmers do their levees. The levees in the Suisun Marsh largely control flooding, not necessarily prevent it, and the cost of failure tends to be far less, at least until DWR determine that certain levee failures in the Marsh could increase salinity in the Delta pool. Counting Suisun Marsh floods as Delta levee failures but only starting in 1993 when about 22 miles of the 230-mile system became eligible for subventions money, skews trends in the records over the past 50 or 100 years (Interviews 109-2009 and 132-2010). The dissertation database includes failures from two islands in the Suisun Marsh that were included in the Legal Delta, Spinner and Van Sickle.

The DRMS list also suffers with ambiguity because it lists "Flooded Islands" which may or may be related to a failure of a levee. When Houston, Duncan, and the USACE (1978) collected a list of levee failures to work their empirical model of Delta levee failures, they recognized that it was critical to consider only failure data on the type of levees of importance to the study. In their case, they were interested in modeling the response of the levees to protect the main 34 agricultural islands. They specifically excluded the levees designed to fail so as to provide floodway entry; floods that were not related to failures of levees such as the over washing of sandbars without levees in the Sacramento River; floods on swamp remnants that had been reclaimed by overly optimistic developers who lacked the resources because of the small size and large levee length to be viable as reclaimed farmland. The DRMS list includes examples of all of these in its attempt to help assess the failure rate for the levees in the subventions program.

Again, the issue of inadequate detail in the DRMS list (URS 2009c) creates the real concern in that it included seven Suisun Marsh levee failures and thirteen incidents on levees vulnerable to flooding because of height restrictions place on them because of their location in or near a floodway. It also included ten floods of marginally reclaimed marsh remnants smaller than 100 hectares and three cases of non-leveed sandbars in the Sacramento River as suffering “levee failures”.

The DRMS report is not alone in recording incidents that have little in common with the 50 or so Delta subvention program eligible agricultural islands (termed AG in Figure 7.8 and 7.9) in the Delta. This only confuses the record of how stable those islands are and the success of failure of the Subvention Program. Appendix M also includes failures of the “Height Restricted Levees,” levees “protecting” small (less than 100-hectare) recreational islands, and includes some levee failures of levees not eligible for the Subventions Program. It even includes failures from two islands in the Suisun Marsh as noted earlier. Figure 7.7 reveals that the cumulative list of the DRMS flooded islands and the Dissertation Database list of failures of Delta levees show similar slopes, in the slope suggesting an overall failure rate of around 1.3 failures per year since 1900. Figure 7.6 also shows the failures of only the Agricultural levees included in the Subventions program, which have a much flat slope and a different slope and reveals a different perspective. Figure 7.8 and 7.9 show similar curves for analysis since 1950, and since the 1973 start of the early subventions program.

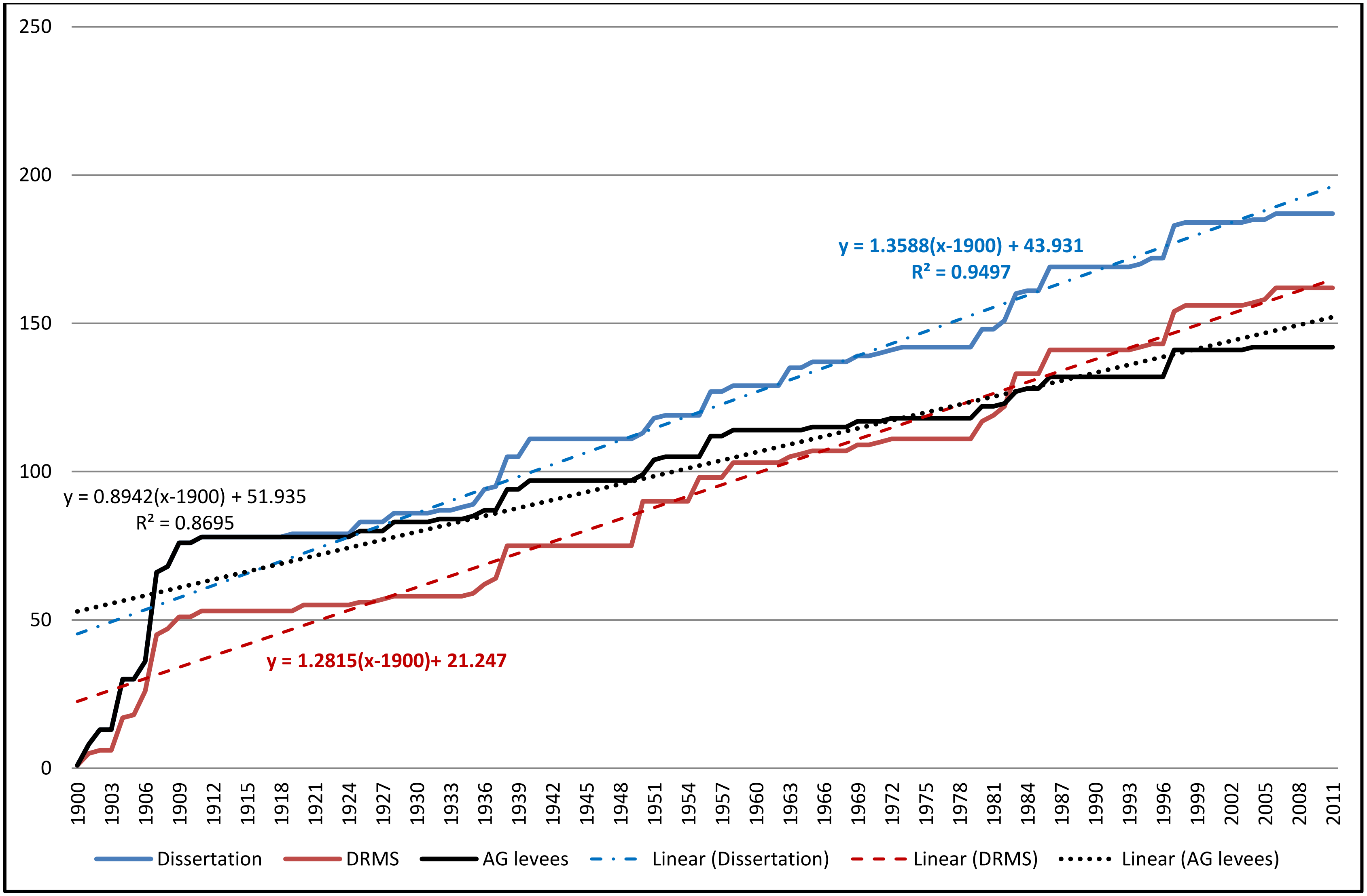


Figure 7.7 – Comparison of Cumulative Flooded Islands (DRMS), Delta Levee Failures and Delta AG Levee Failures Since 1900

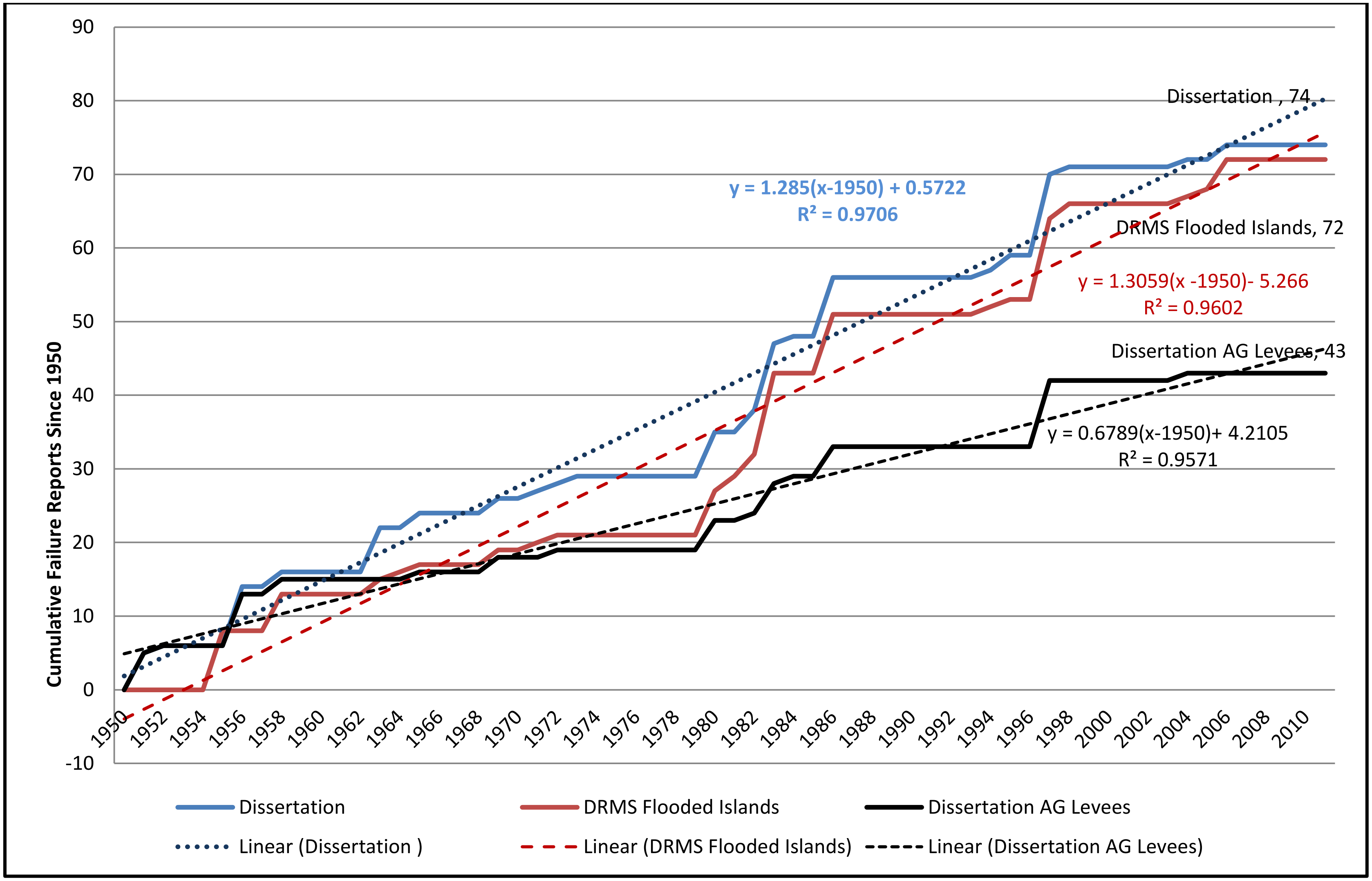


Figure 7.8 – Comparison of Cumulative Flooded islands (DRMS), Delta Levee Failures, and Delta AG Levee Failures since 1950

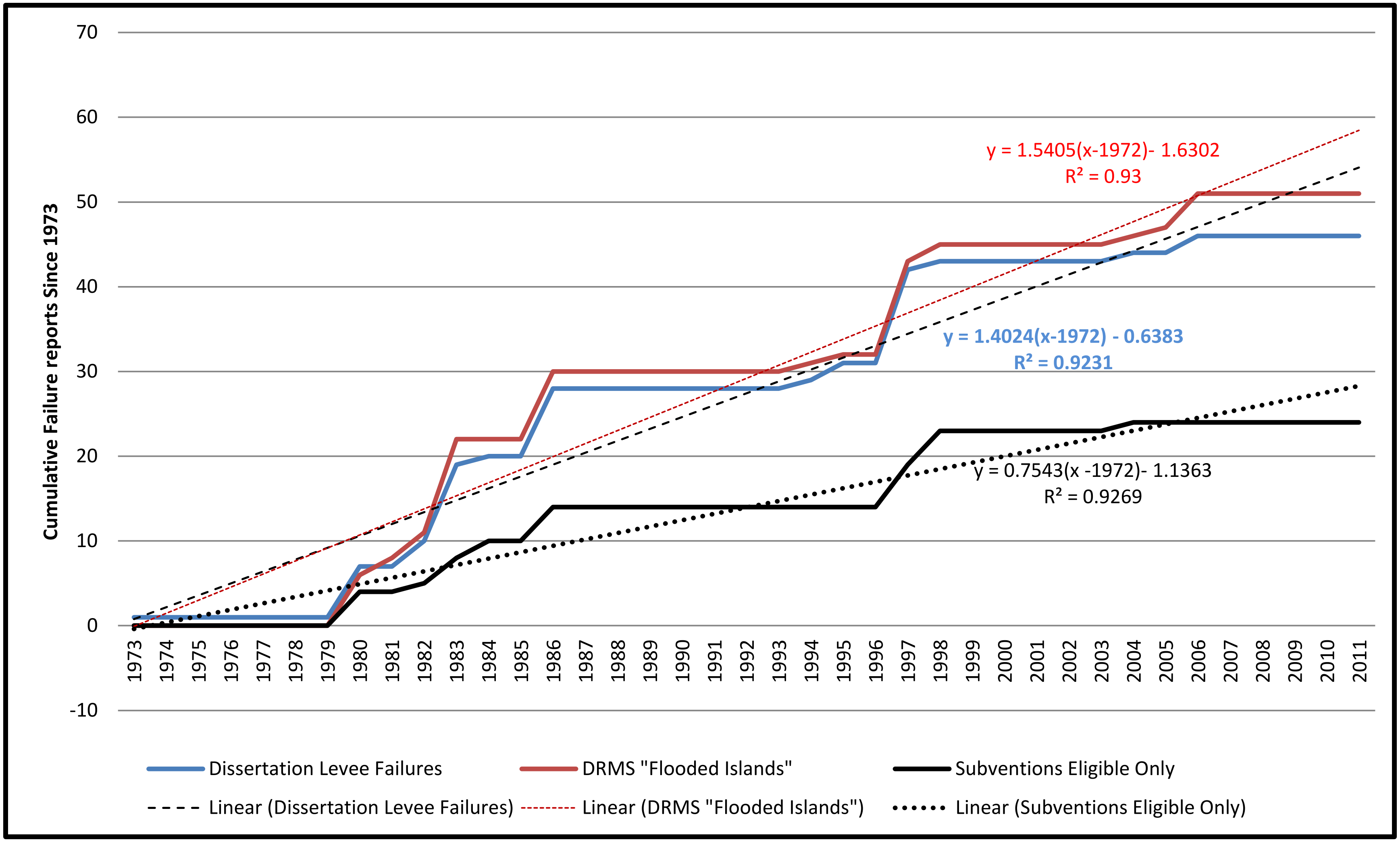


Figure 7.9 – Comparison of Cumulative Flooded Islands (DRMS), Delta Levee Failures, and Delta AG Levee Failures since 1973

The argument to treat the failures of the "Restricted Height," small and wetland island levees, and the non-subvention eligible levees differently requires explanation and justification. The restricted height levees are located in two areas and the levee failure list for Prospect and Liberty Islands reflect their significance. The USACE incorporated Prospect and Liberty into the Yolo Bypass Flood Protection system for Sacramento. Their levees routinely "fail" to save Sacramento from floodwater. As noted earlier, the Yolo Basin historically and prehistorically served as the flow path for most of the floodwaters of the Sacramento River and so it remained marsh until the construction (1917-1940) of the USACE Sacramento River Flood Control project. This project included levees restraining the floods and deliberately smaller levees protecting fields in the floodway from minor flooding and permitting farming of those fields between significant floods. The project also included two sets of weir gates to control flow from the Sacramento into the By-Pass, one at Sacramento and the second upstream at Fremont. The USACE constructed the By-Pass facilities between 1918 and 1938 and designed them to handle 17,052 cubic meters per second, or almost four times the flood capacity of the main channel of the Sacramento south of Sacramento. Engineers designed Prospect Island and Liberty Island to function as exit points for flood flows as they return to the main river channel between Rio Vista and Isleton through Cache Slough. The first planned overtopping of the limited height levees (3.505 meters -11.5 feet above sea level) came in 1938, as the USACE first opened the weirs to protect Sacramento. Appropriately, over toppings of these levees escaped mention in the DRMS reports before 1963, even though the islands flooded every time flood hit the Sacramento River since 1938. To make matters worse for Prospect Island, the construction of the

Sacramento Ship Channel in the 1950s and 60s severed it from the rest of floodway and removed about half of the area of the island. Prospect was left with too little area to justify building stronger and taller levees at that point. The Port of Sacramento purchased most of property and developed a plan to incorporate it in a proposed North Delta Wildlife Refuge. When Congress refused to fund the Refuge in 1999, the Port turned Prospect over to the U.S. Bureau of Reclamation. In January of 2010, USBR transferred the island to DWR, the latest government agency to manage the levees of this island through seven floods since 1980. It currently sits in a purgatory-like state waiting for approval for conversion into habitat. Meanwhile, it helped swell the record of Delta levee failures (flooded islands officially) and particularly contributed to the indication of a decline since it was not farmed until 1938. Liberty Island finally was abandoned in 1995 or so.

After the 2007 failure of the Prospect levees, the USBR left them unrepaired and the island remained inundated. Anglers boated into the flooded island but often were grounded and trapped when the tide went out. The USBR then closed the gaps in the levee to protect boaters, trapping many endangered fish in the slowly drying island lake, creating a media event as local groups organized a giant fish rescue operation (Weiser 2007b). Meanwhile, with the Ship Channel levees forcing more water against the levees on Liberty, floods breached them so many times that the state purchased the island for habitat. Liberty remains flooded on the southern end and waits for likely inclusion in the habitat developed in the BDCP.

The levees of the McCormack-Williamson Tract along the Mokelumne River serve a similar purpose. Not a formalized floodway, the McCormack-Williamson Tract

(MWT) nonetheless plays a similar role for the Mokelumne River as it enters the Delta. As MWT was one of the last Delta tracts reclaimed, the neighbors forced the developer of MWT to limit the height of the upstream levees to elevation 6.264 meters to protect the town of Thornton. Floodwaters on the Cosumnes and Mokelumne Rivers collect upstream of MWT, blocked partially by the restricted height east MWT levee. Before they can rise to a level to damage upstream property, they overtop the deliberately lower levee section and dump into MWT. MWT becomes a 6.4-kilometer long flood channel with an elevation drop of 0.7-meters as the floods surge from west to east across it on one of the steepest gradients in the Delta (Interview 114-2010A).

Whereas the developers of MWT planned and expected normal flooding of the tract, the steep gradient serves to accelerate flood velocities across the tract and then the floodwaters slam into the MWT west levee. The waters surge over that levee and then run straight as a wall of water across narrow Dead Horse Channel to the east levee of Dead Horse Island. Thus, the restricted height levee and the hydraulics of MWT as a flow channel create the so-called “toilet bowl effect” which helps overtop the east levee on Dead Horse every time the low levee of MWT has been breached except in 1964 (Interview 114-2010). In 1986, the flood surge roaring down MWT dislodged boats anchored at the marina where the Dead Horse Cut meets the Mokelumne. The flood carried the boats that formed a raft en masse down the Mokelumne where they lodged against the bridge on the Walnut Grove –Thornton Road, creating a temporary dam. The floodwater piled up behind and then broke through the logjam (boat jam) at the bridge, releasing another flush of water, which probably overtopped the Tyler Island levees on 17

February 1986 (Interview 114- 2010A). Figure 7.10 maps the location of these restricted height levees and shows the resulting failures.

Island size, particularly relative to length of levee required, can also limit levee viability. The list of “flooded island” (DRMS) and “Failures of Delta Levees” includes the numerous floods of 40 hectare Fay Island, 40 hectare Rhode Island, 80 hectare Little Mandeville Island, and 140 hectare Little Franks Tract. The first three started as point bar meander bend cutoffs from the construction of the Old River levees on Bacon Island and Holland Tract. These small island reclamation projects developed very late in the levee building era and contained very little farmable area, particularly on a per mile of levee basis. Lack of area and resources to support large levees made it difficult to maintain levees, particularly for relatively low value agricultural use. The levees tended to deteriorate, leading to frequent overtopping and failure. Little Franks Tract represents part of the old Franks Tract that was saved from flooding by a cross levee when that island flooded for good in 1938. It too was not economical viable as farmland and the levees deteriorated. Contra Costa County Parks took over the site and tried to maintain Little Franks Tract as a natural wetland education center. Eventually levee failure led to permanent flooding, as the necessary repairs were (Mitchell 1993) never funded. So of the four, only Fay is currently completely leveed and dry and is apparently being used as a private recreational area (Interview 124-2010A). Figure 7.11 shows these islands and the resulting levee failures.

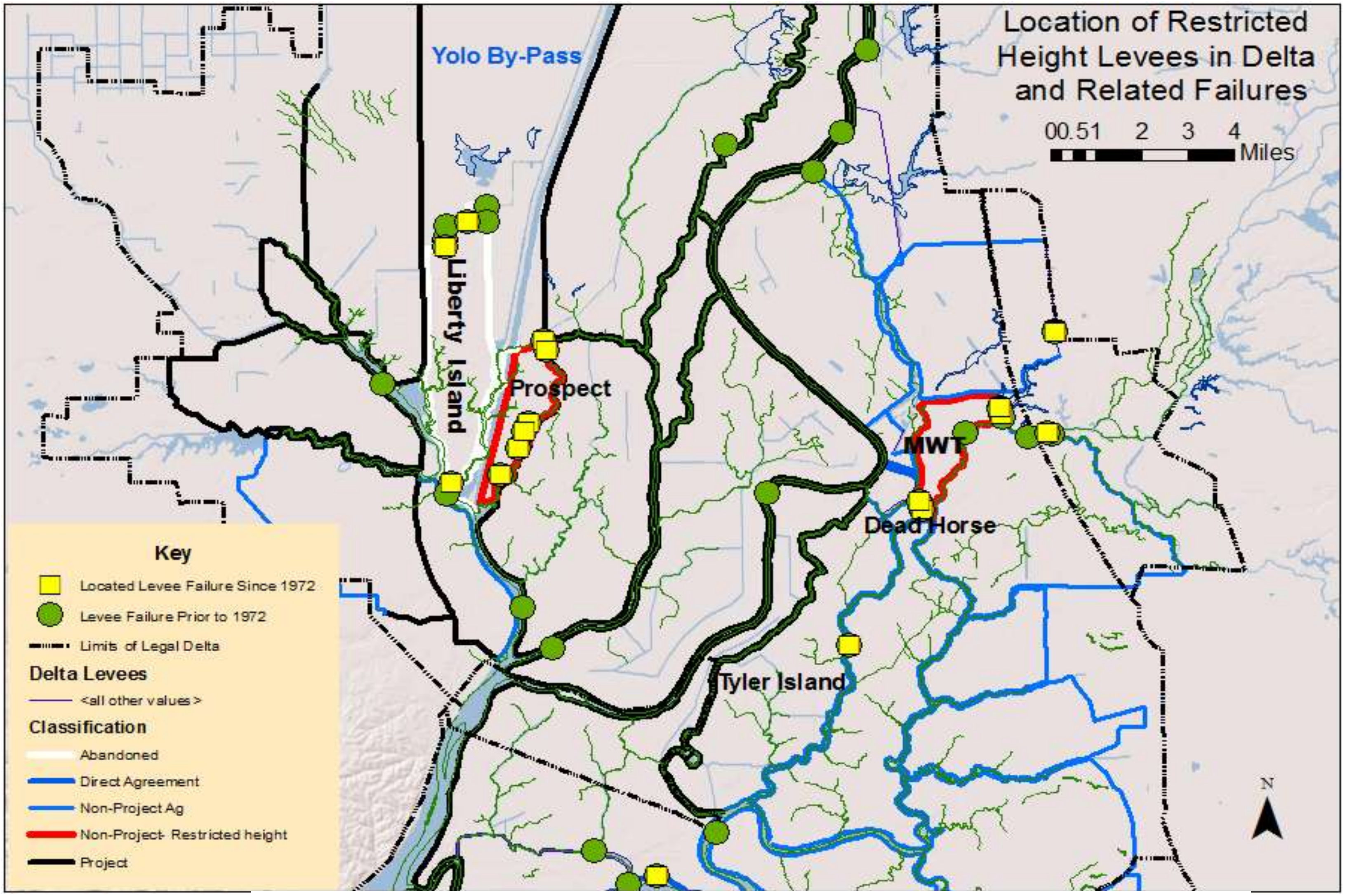


Figure 7.10 – Location of Restricted Height Levees in Delta and Related Levee Failures

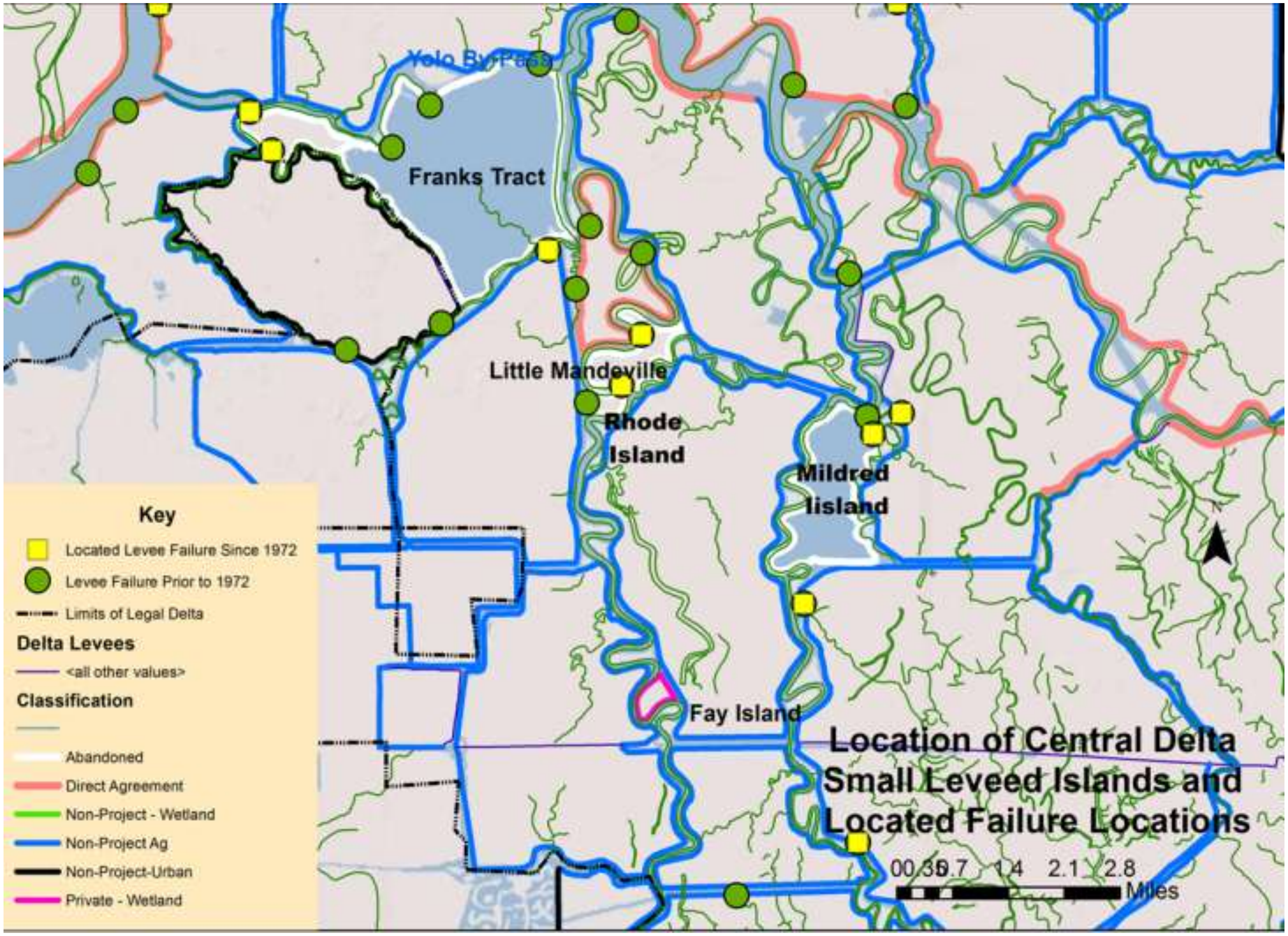


Figure 7.11 – Location of Central Delta Small Leveed Islands and Located Failure Locations

The third type of levee failure that should not affect the assessment of success of Delta Levee Subventions Program are those not eligible to participate in the program. Most islands and tracts are eligible in the Legal Delta except those in the Secondary Zone that are protected by Project Levees, in other words, the few true Flood Protection levees (not dams) in the Delta up the San Joaquin River as shown on map Figure 7.12. In the past 25 years, these levees have high rates of failure as will be discussed later; however the failure rate cannot be attributed to the Subventions Program to which they are not eligible.

The DRMS list contains what appear to be outright errors, but poor referencing makes it difficult to confirm or deny. One of the more significant apparent errors comes from the listing of some 15 islands as flooding in 1950, other records, including Thompson's, indicate that no more than two islands flooded in water year 1950 and six more in December of 1950 (or water year 1951 by DWR definition and practice). To compound the error, one of two levees that failed in June 1950 was not recognized (Bradford Island) while the other June 1950 failure was listed as a sunny-day failure and was used in the six event list of sunny-day failures used to predict frequency of future sunny-day failures (URS 2009b). Newspaper reports (*Pittsburg Post Ledger* 1950) indicate that Webb Tract failed because of unusually high tides, winds, and atmospheric pressure conditions that caused adjacent Bradford to also flood the same day. This would indicate that the Bradford and Webb Tract 1950 failures were high-water, not "sunny-

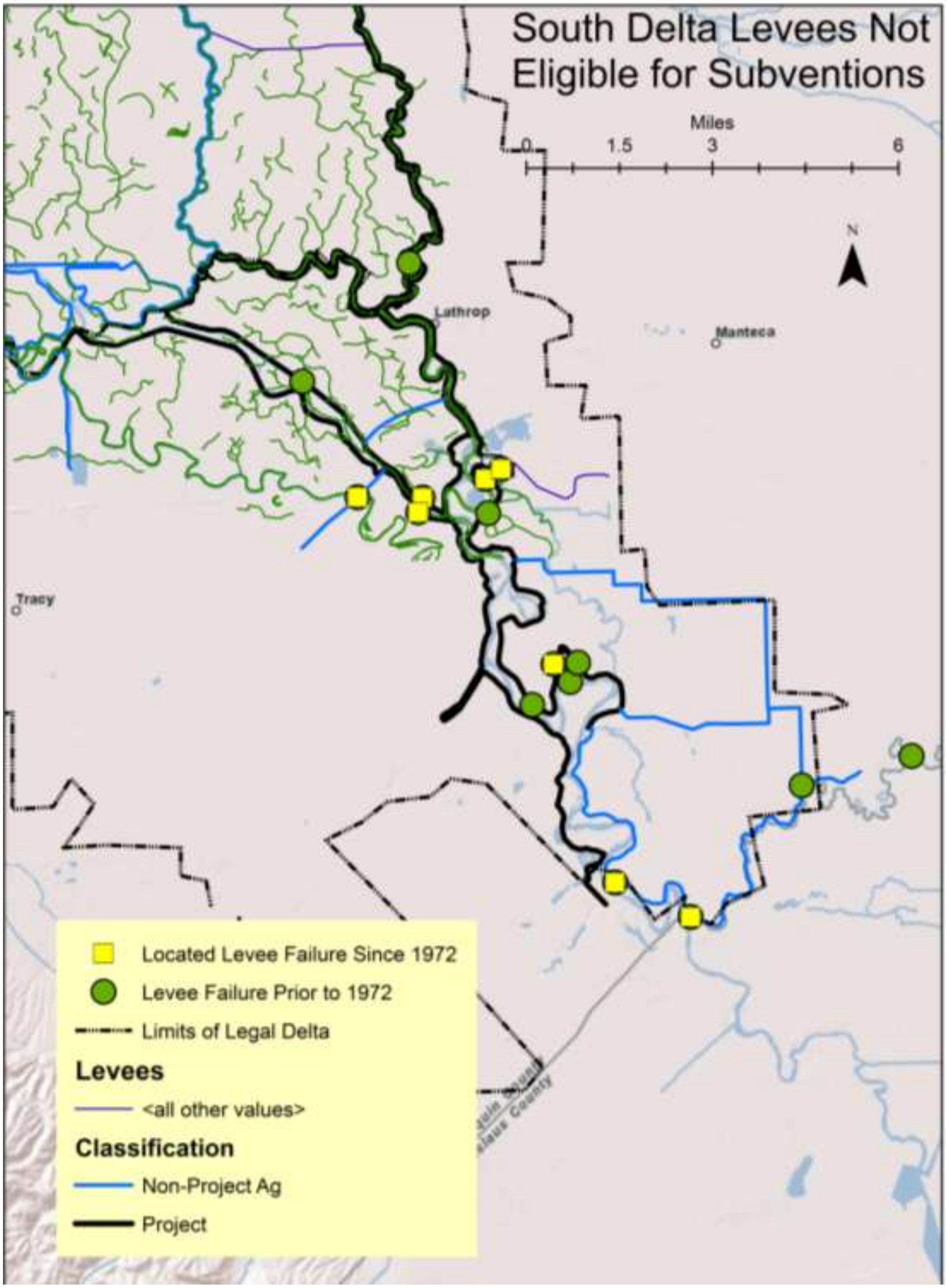


Figure 7.12 – South Delta (Secondary Zone) Levees Not Eligible for Subventions

day" events. In listing Webb Tract 1950 as a "Sunny-Day" failure, the DRMs report invalidates its empirical analysis of the rate of forecasted "Sunny-day" failures, which relied on it as one of six total data points they had available for the analysis.

The major problem with DRMS "Flooded Island" lists comes because of not following the recommendations of Houston, Duncan, and the USACE (1978) to consider only failure data on the type of levees of importance to the study. This led DRMS to include many levee failures unrelated to the subventions-assisted levees on the 50 or so main agricultural islands. Figures 7.13 and 7.14 show the results of separating out failures that took place directly on levees designed to fail, the "height restricted" levees. Secondly, it separates the incidents on the smaller (less than 200 hectares) islands levees from the total list along with those in the Suisun Marsh and not designed to protect the agricultural, residential, and other economic activities of the main Delta agricultural islands. Figures 7.15 and 7.16 then show the locations of the failures of Delta levees occurring since 1972, breaking down the levees into the categories listed.

The detailed data on the failures of Delta levees indicates that the performance of the levees on the Delta Analysis based on the DRMS history of "flooded Islands agricultural levees has been far better than indicate in the DRMS Executive Summary, a performance that appears to be improving under the subventions program. Any analysis based on the conclusions of the DRMS study relative to the history of levee failures, including but not limited to the DRMS "sunny day" levee failure analysis, should be review and potentially reevaluated.

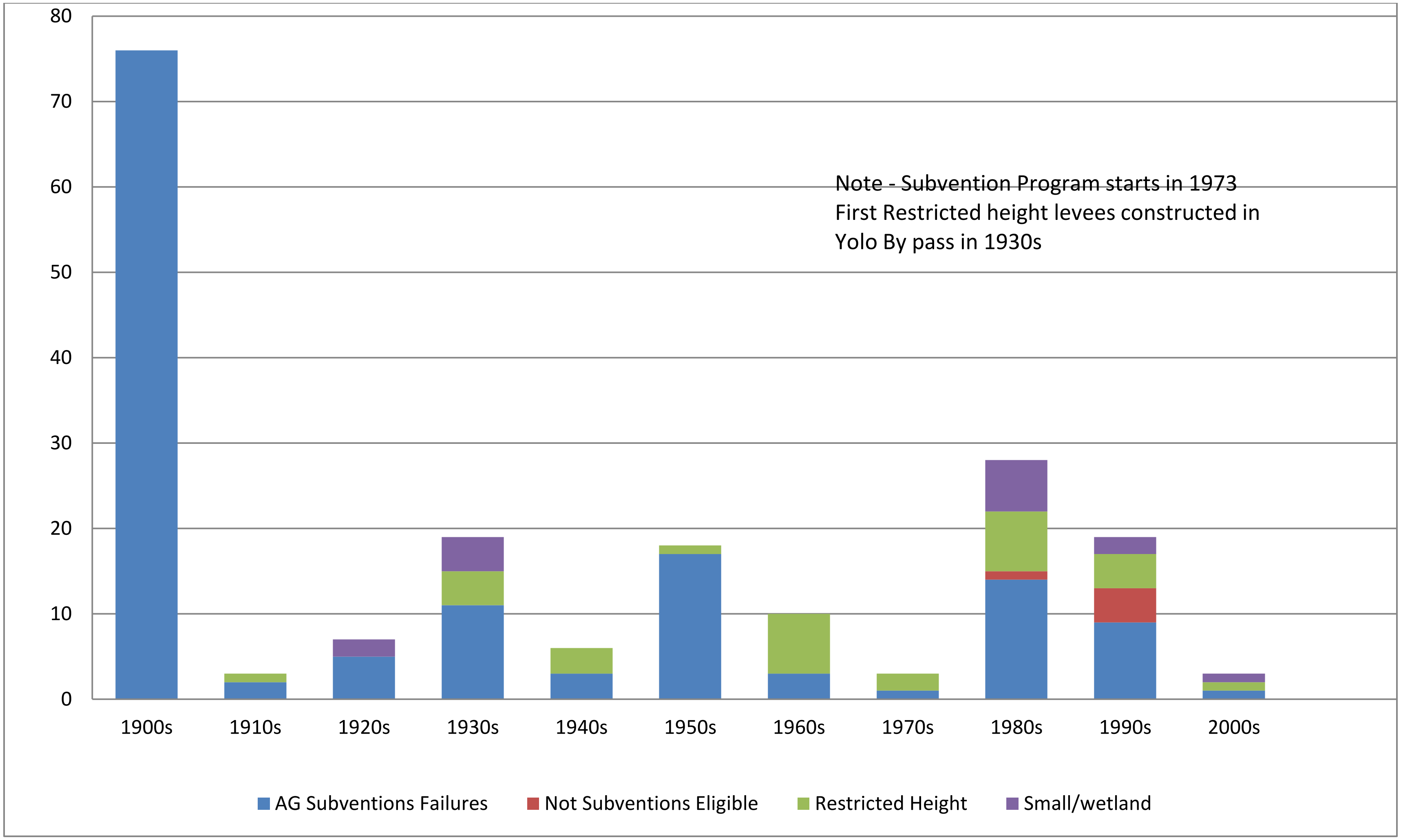
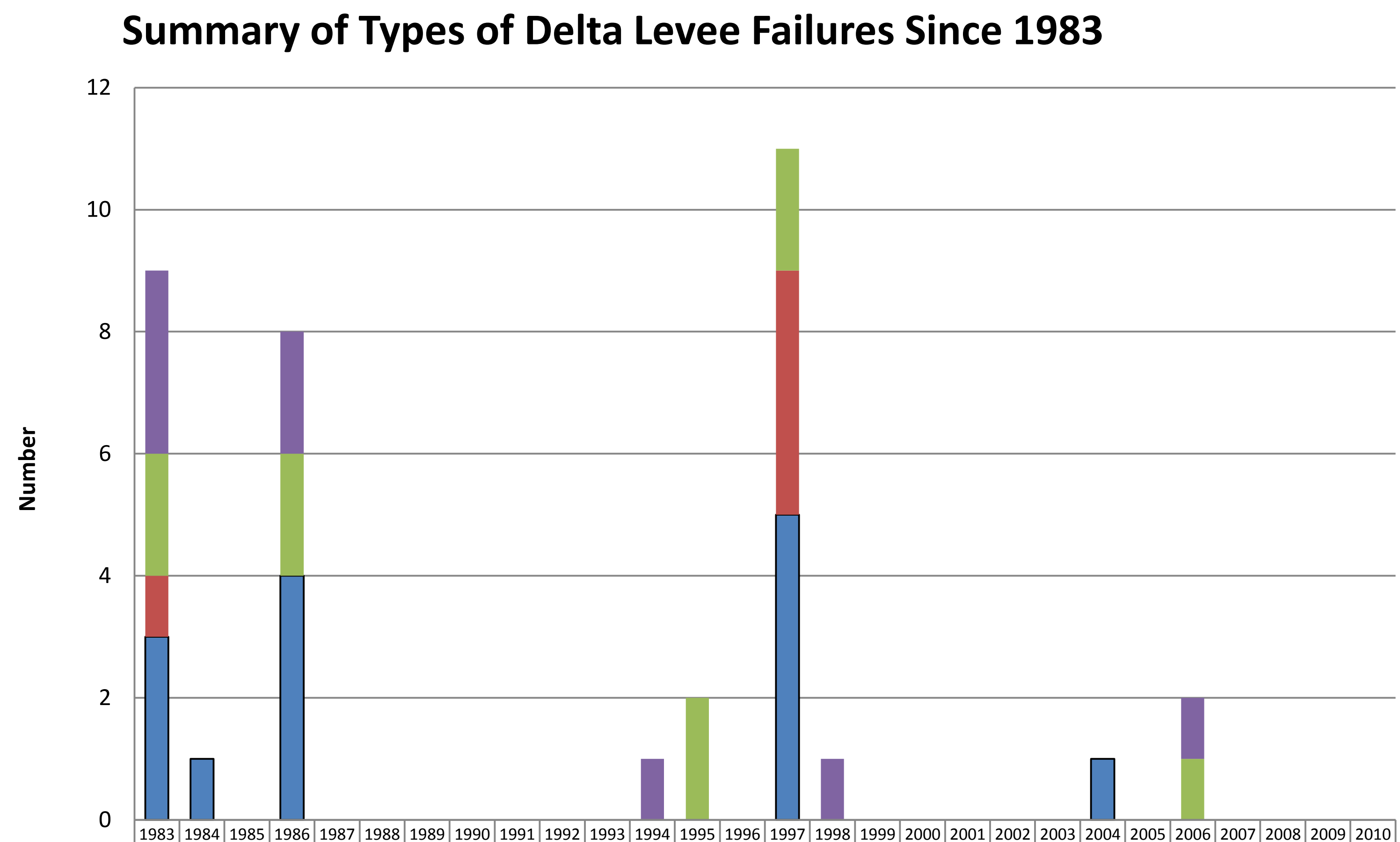


Figure 7.13 – Breakdown of Characteristics of Delta Levee Failures Reports by Decade since 1900



	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Small/wetland	3			2								1				1								1				
Restricted Height	2			2									2		2									1				
Not Subventions Eligible	1														4													
Delta AG Subventions Levee Failures	3	1	0	4	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0

Figure 7.14 – Summary of Types of Delta Levee Failures Since 1983

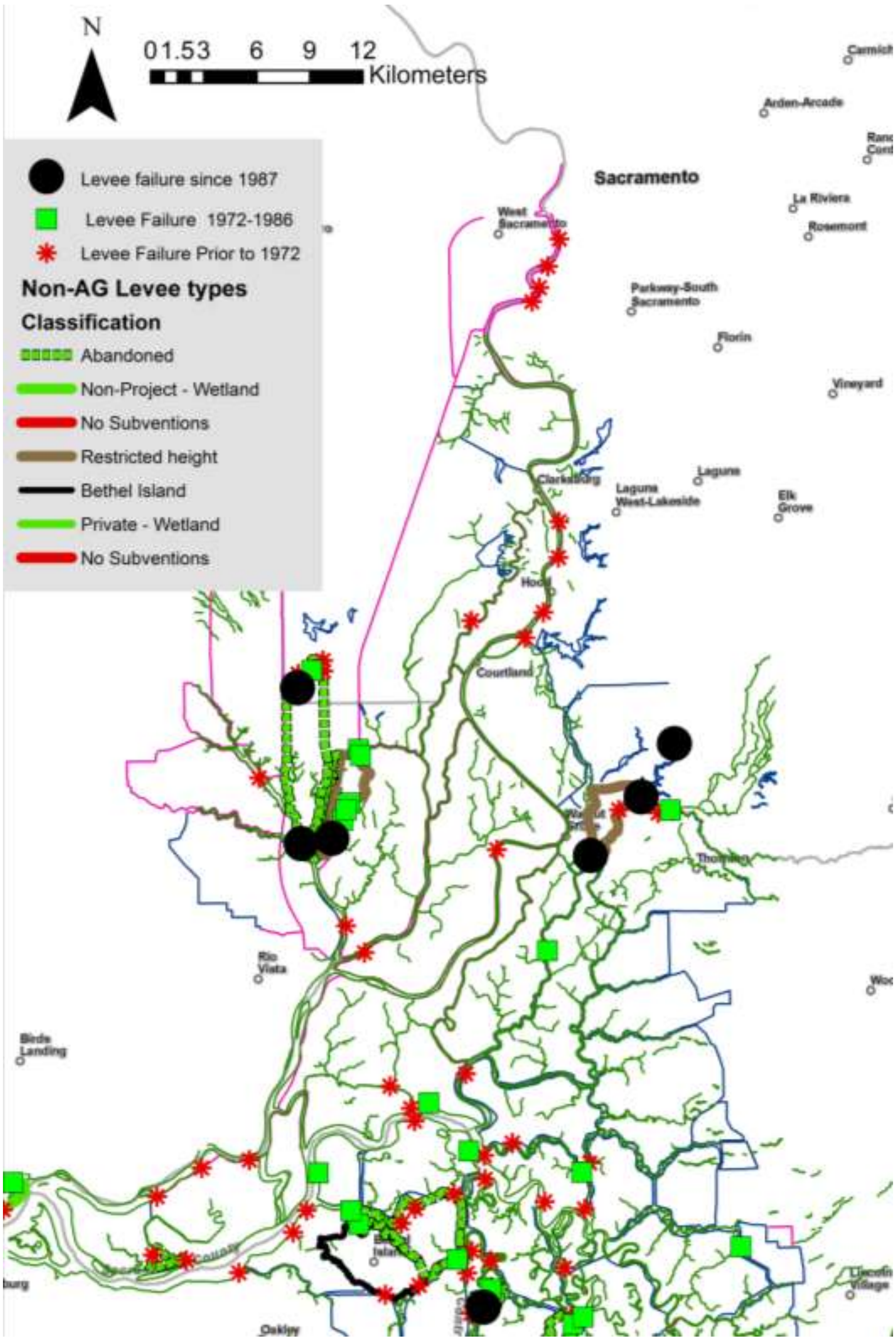


Figure 7.15- Location of the Non-Ag Type Levees in the Northern Delta and the Located Levee Failures

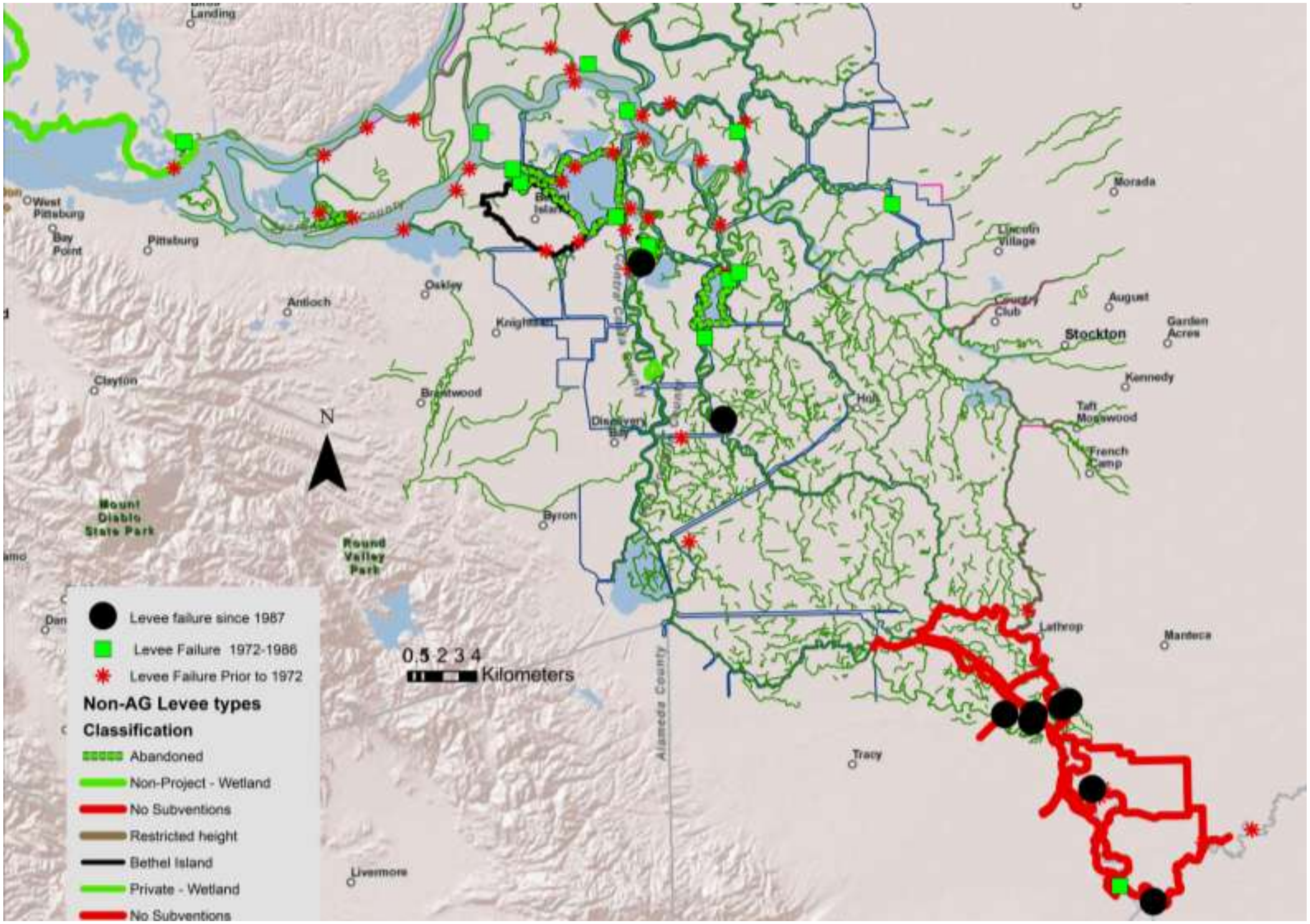


Figure 7.16 – Location of the Non-Ag Type Levees in the Southern Delta and the Located Levee Failures

based on the conclusions of the DRMS study relative to the history of levee failures, including but not limited to the DRMS "sunny day" levee failure analysis, should be review and potentially reevaluated

OTHER FINDINGS FROM RECONSTRUCTING THE HISTORY OF FAILURES OF DELTA LEVEES

The Q-Method study presented in Chapter VI identified several other contested issues between the social perspectives to which the historical record speaks, specifically, the reaction of Delta levees to the effects of an 8.3 (Richter) magnitude San Andreas Fault earthquake, the causes of past levee abandonment, and a comparison of the performance of USACE Project levees and levees built purely by farmers through the local reclamation districts.

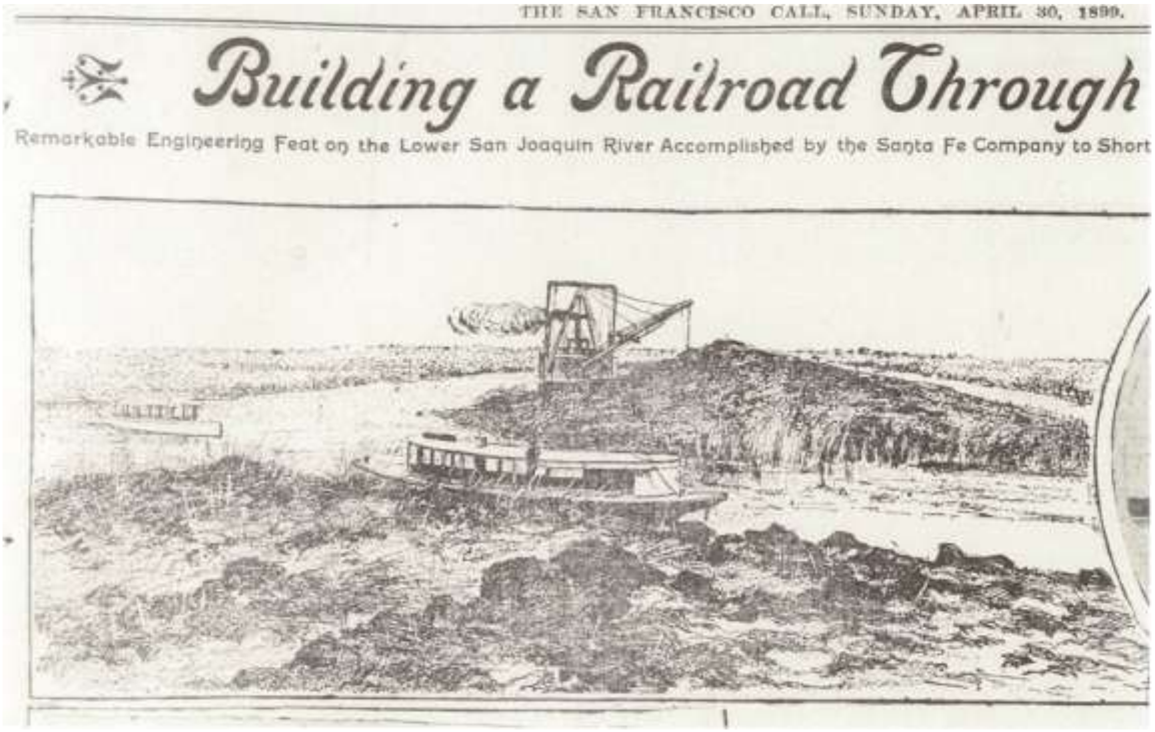
Record of the Effects of the 1906 Earthquake on the Delta

As noted in Chapter IV, Torres *et al*. (2000, 5) defined the conventional wisdom about the role of the historical record in understanding the earthquake risk, stating that "no report could be found to indicate that significant damage had ever been induced by earthquake shaking…the 1906 San Francisco earthquake occurred 81 kilometers to the west, on the San Andreas Fault and produced only minor levels of shaking in the Delta; as the levees were not very tall yet in 1906, these shaking levels posed little threat…lack of historic damage to date should not lead, necessarily, to the conclusion that the levee system is not vulnerable to moderate to strong earthquake shaking. The current levee system simply has never been significantly tested." Thompson (1957) took little note of the earthquake, indicating that in 1906, several months after the April earthquake, six islands flooded because of unusually high tides. As noted in Chapter VII, I initially concentrated on these late June and early July 1906 levee failures as possible evidence of earthquake damage that did not manifest for a couple of months. This hypothesis does not appear to be proven, I found instead evidence of a large, late season snowmelt flood that started moving down the San Joaquin River in late June. The *San Francisco Chronicle* on 26 June 1906 reported a levee failure at Kuckuk Landing on Union Island on the Old River, indicating that a 15-meter gash soon widened to 60 meters. The river remained high and apparently after Union Island filled with water, river levels began rising again, reaching 3.81 meters at Clifton Court (now the forebay for the State Water Project pumps), thereby breaking the old record high levee on that gauge by 7.62 cm (3 inches). The same article indicated that water levels upstream on the San Joaquin at Paradise Cut were finally starting to fall. The next day, the levees at the Drexler Tract, (attached to Middle Roberts) on the Middle River gave way, followed down river by failures of levees on Venice, Twitchell, and Sherman Islands the following day (July 10, 1906). Reports of receding waters finally hit the paper over a week after the Sherman levee failed. Before that, however, reports were appearing in the newspapers that residents had requested the sheriff to investigate possible sabotage to the Union and Drexler levees. Locals felt that two levees that failed were among the most substantial in the Delta so the failures appeared suspicious. The records discovered so far do not indicate that the sheriff ever caught anyone or even really investigated this charge, but it is reasonable to conclude that the 1906 levee failures relate to a late San Joaquin River high water event and high tides in the Delta pool, and possibly saboteurs, but not an earthquake.

I then looked at reports of other structural damage or shaking recorded in the Delta in April 1906. A collection of oral histories of Grizzly Island residents (Suisun Marsh) in the Rio Vista Historical Museum that recorded the remembrances of one resident of the 1906 earthquake shaking her home on Grizzly Island and tilting it. She claimed they could see the flames (smoke?) from San Francisco from Grizzly so her father, apparently knowing that his levees had not been damaged, loaded up provisions on their boat to go help the citizens of San Francisco (Frost 1963).

A better-documented and more official report, however, came from Geological Survey Professional Paper 993 (Youd and Hoose 1978). It records that on April 18, 1906, the "big" Santa Fe Railroad Bridge across the Middle River between Richmond Junction and Stockton sank a little less than a meter (3 feet) and was shoved out of line. Sixteen (16) kilometers away, the bridge on the San Joaquin River main channel settled several inches. The tracks connecting the apparently liquefaction damaged bridges cross the Delta on an east-west alignment on a "levee-like" embankment. The alignment and elevations of these tracks are likely at or near those originally constructed. This suggests that this railroad embankment could serve as a test levee after the fact, one at that has been exposed to real earthquake conditions. A *San Francisco Call* article dated 30 April 1899 (see Figure 7.17) described the construction of this same levee-railroad embankment and the two bridges. Figure 7.18 represents a current picture of the bridge, still in use, which sank one meter. According to the newspaper article, the railroad engineers supported the bridge built on concrete piers with a timber pile foundation. This type of failure could indicate that the subsurface layer on which the piles rested liquefied and lost bearing capacity during the San Francisco earthquake. Even on the east edge of the Delta it appears that some liquefaction took place. Yet the "levee" running through a known area of liquefaction appeared to have suffered no damage. Figure 7.19 shows a Google Earth image of the Middle River and the Santa Fe railroad embankment levee and the pile-supported bridge that reportedly suffered significant damage from the 1906 earthquake.

Torres *et al.* (2000) dismiss the significance of no damage in the Delta from the 1906 earthquake because the Delta levees of 1906 were small and unsubstantial. The record is not clear how large most of the levees were that day but an article in the *San Francisco Call* dated July 21, 1907 indicated that the Victoria Island levees, reportedly completed in 1905 (Thompson 1957) were over 30 meters wide at the base, 3 to 6 meters wide on top and from 1.22 to 1.83 meters above the high water mark. This levee today has similar dimensions. This levee also ran very close to the railroad embankment discussed above. No record exists of failures on Victoria Island until the great flood of 1907. The record suggests that Union Island levees and perhaps others were also at or near current dimensions in 1906. None of this proves that the science of any of the social perspectives of Delta experts is better than the others; however, it does suggest that potentially enlightening empirical data does exist. The fragmentary reports of the bridge foundation failures and the lack of damage to the tracks require detailed investigation. If the Delta soils did liquefy in 1906 but the railroad embankment and other levees did not fail, or if they did fail, investigation of the soil conditions in those levees and foundations might reveal more about the reaction of at least some of the Delta levees to earthquake and liquefaction. More scientific information could lead to different social perspectives


THE SAN FRANCISCO CALL, SUNDAY, APRIL 30, 1899.

Building a Railroad Through

Remarkable Engineering Feat on the Lower San Joaquin River Accomplished by the Santa Fe Company to Short

Figure 7.17 – Picture from the *San Francisco Call* 30 April 1899 Showing a Clamshell Dredge Building the Railroad Embankment Levee that is Still Used to Cross the Delta Today.

Figure 7.18 – Picture of the Drawbridge over the Middle River that Reportedly Sank 91 cm on 18 April 1906.

Figure 7.19 – Google Earth Image of Sante Fe (BNSF) Levee Embankment and Bridge at Middle River.

of Delta experts, which in turn could lend to a different "best available science." Normative science depends on the social perspectives of its practitioners to fill in the gaps when hard questions need time critical answers. Scientific findings change the social perspectives of scientists which in turn then modifies what is produced as science

The Record of Levee Abandonment in the Delta

The information collected for the database the on failures of Delta levees provides a record of levee abandonments that contradicts the viewpoint of Factor 2 that the leveed islands of the Delta cannot survive for long. The list of leveed islands/tracts that owners have abandoned include the Big Break near Oakley (1928), Franks Tract (1938), Rhode Island (1971), Mildred (1983), Little Franks Tract (1983), Little Mandeville (1994), Liberty (1995), and Prospect (2007). Additionally, Sherman Island was abandoned from 1880 to 1894, Twitchell from 1882 to 1894, and Bouldin from 1908 to 1918 (Thompson 1957). As discussed earlier, Rhode and Little Mandeville Islands were cutoff point bars each smaller than 80 hectares, farmland too small support maintenance of levee-dams. The abandonment of eastern Franks Tract in 1938 left the west side still protected by a cross interior levee. This remnant also proved to be too small to make leveed agriculture profitable. When the levee failed, the cost of restoration and future maintenance overwhelmed the owners and they elected not to rebuild. Contra Costa County reclaimed it once for recreation but then found it too small to maintain the levees for public use. Quimby, Fay, and Dead Horse represent islands that are also small for agriculture but the owners rebuilt the levees for personal recreational uses or because of other non-agricultural economic reasons.

Gathering information on the “Big Break,” now a county park near Oakley proved to be difficult. Farmers reclaimed the area in the late 1800s by building levees against the waters of Dutch Slough and the San Joaquin River, growing asparagus there until either 1927 or 1928. It appears that part of the levee crumbled into the San Joaquin following heavy rains in one of those years and caused a "big break, ” flooding 640 hectares of asparagus. Before the owner could recover financially and rebuild, the Port of Stockton apparently condemned the property and incorporated it somehow into the Stockton Deep Water Channel project (Slack, 2003).

Franks Tract, also now a State Park, represents a more interesting case. John Franks, a rancher from Monterey County, got involved with partners in land reclamation in the Delta starting about 1898. The partnership rented clamshell dredgers to reclaim Bradford Island and then purchased two dredgers to reclaim Bethel Island and Franks Tract between 1902 and 1906 (Thompson, 1957; Thompson and Dutra 1983, 255). The Franks family ended up owning about five clamshell dredges, under the direction of son Fred Franks. Their dredging company worked through the reclamation boom in the Delta that lasted until about 1918 and then under Fred the company diversified into industrial and harbor dredging and other construction work. By 1936 when the levee on Franks Tract failed, John Franks had apparently died as had most of his original partners in the Franks Tract venture. Tenants had leased most of the farmland on the island. The flooded out renters sued the owners because they failed to maintain the levees. None of the Franks was listed as defendants at trial but the University of California – Berkeley and the Bank of America as trustees were listed; apparently, the ownership position had been left to the University as a gift, the bank's involvement was less clear. The owners repaired the levee in time for the 1937 growing season and a lower court found for the plaintiffs. In March of 1938, however, the judgment against the defendants was overturned by the State Supreme Court who ruled that because the Franks Tract developers had agreed to build and maintain the levees as a voluntary activity, they were free to stop maintaining the levees anytime they wanted to regardless of other agreements like a lease (Higgins vs. Monckton 1938). About the same time the floodwaters of 1938 damaged the levee, and this time the owners, apparently decided it was time to stop the association and avoid further litigation and repair cost. Fred Franks that same year terminated dredging operations in the Central Valley and moved with his last dredge, a suction dredge purchased in 1929, to San Diego where he operated a construction firm until the 1970s (Thompson and Dutra, 1983, 255). The owners did not the restore the levee and it currently is a state park known for its invasive game fishery (Mitchell 1993).

The abandonment of Mildred Island also involved an unusual ownership twist. Mildred was a small (364-hectare) reclamation, one of the very last major reclamations in the Delta, with the first crops produced in 1922 (Thompson 1957). It first flooded in the high water of 1969 that also took down the Sherman Island levee. Its owners rebuilt the levee and restored the fields but fourteen years later the property sat in escrow during the negotiated sale to new owners when another levee section failed. The purchasers fought the unsuccessful flood fight but the uncertain ownership status made it impossible for anyone to commit the estimated $250,000 local share of the repairs (FEMA had approved funding of the restoration of the island from the federal side). Nevertheless, Mildred, like the other permanent island abandonments, involved extenuating circumstances and cannot be taken as a sign of a trend toward mass island abandonment. When Tyler Island flooded in 1986, the reclamation district tackled the repair and pump out. Although they Whereas they received FEMA flood insurance money, it took RD 562 about 22 years to repay the bank loan taken out to fund the repairs (Interview 113-2010).

In summary, over the years, owners abandoned lands after levee failures on several smaller islands that have a high levee length and thus high cost to farmable or usable area ratio. Only a handful of islands smaller than 400 hectares have survived intact, notably Fay, Quimby, and Dead Horse, all more valued by their owners as a home than as farmland. Franks Tract represents the largest levee land that has been allowed to return to the waters, however it was still relatively small compared to other Delta tracts. The Great Depression, generational change, the impact of two levee failures in two years, and an unusual court ruling likely contributed to the decision to not rebuild the levees in 1938. Whereas some owners have abandoned their tracts, levee history lends credence to the Factor 3 social perspective that the Delta residents exhibit sufficient energy to maintain their homes, lifestyles and levees for another at least another 100 years.

The Record of Performance of Delta Levees by Classification of Builder

As noted in Chapter V, records in the database are tied to as much as possible to the one of the 404 levee segments I identified that share some uniformity of properties. I located 165 of the 265 total failures to a particular levee segment, not just the associated island. Of these, I pinpointed 106 failures to more exact locations within a particular levee segment, including most failures suffered since 1950. The database also includes segment identification on 45 near-miss incidents. This breakdown facilitates analysis not possible when failures identification takes place on an island/tract basis, such as provided in the DRMS study and as used by Duncan and Houston (1978, 1983) in their empirical models of Delta levee failures.

Spurred by the assumption of Houston, Duncan, and the USACE (1978) that the “Project” levees were so strong that the probability they would fail approached zero, I wanted to determine if this assumption was justified. With the segments in part decided by which type of organization built them or built them to the current standard, it becomes possible to determine failure rates for each type as shown on Table 7.1.

The term “Project” levee, as used in the Delta, implies the pinnacle of engineering standards for levees because the USACE designed and re-built these from 1917 to about

1953 as part of the Sacramento and the San Joaquin River flood control projects. I measured 330 miles of "Project" levees in the Delta and found that since 1950, when the

Table 7.1– Summary of Comparison of Historic Rates of Failures of Various Classifications of Delta Levees

Levee Standard	Miles in Delta	Failures Since 1951	Historic Failure Rate Per Mile	Historic Failure Rate Per Year Per Mile
Project	330	9	0.0273	0.0005
Direct Agreement	66	6	0.0909	0.0016
Non Project Ag	511	16	0.0314	0.0006
Non Project Restricted	40.6	23	0.5665	0.0140
Other	39.8	3	0.0754	0.0013
Non Project Wetland	30	8	0.2667	0.0045

projects were completed, that nine failures have taken place on Project levees (1951 failures on the San Joaquin River levees in the Secondary Zone are not included in this count because the USACE had not yet start construction on these levees) (Interview 124-2010). As shown in Table 7.1, the USACE designed levees share almost identical statistical performance with the Non-project Agricultural levees, assuming separate calculation of the failures of Non-Project restricted height levees. The performance of the Direct Agreement levees, also the product of the USACE, primarily along the two ship channels, has failure rates almost three times higher than these two. The Non-Project levees suffer the stigma "not being engineered" and the product of local farmers and developers, whereas "Project" and "Direct Agreement" levees wear the mantle of the USACE and assumed state-of-the-art approaches.

In reality, soil engineering really did not get its start in the US until after the arrival of the father of soils engineering Terizaghi from Europe in the 1930s. By then most of the Project, Direct Agreement (Stockton Ship Channel) and all of the Non-Project levees in the Delta had been complete. None of the engineering standards applied in the Delta today include any detailed specification for soil properties or soil compaction. Cost considerations make it unlikely that engineers will be able to apply specifications for stringent properties for soil materials used in the construction of levees in the Delta region in the future, including the levees that would become the Peripheral Canal. Soils required for “engineered fill” does not exist near the surface of the Delta, including the last half of Peripheral Canal route.

Engineers from the Sacramento Delta applied the best engineering practices of the day to the construction of the levees and they were in communications and shared knowledge with levee engineers in the Mississippi Valley at least as early as 1912 (Haviland, Dozier and Tibbetts 1912). The development of the tracked-tired construction equipment (also forerunner of the military tank), the “caterpillar” tractor (Hugill 1999), took place in Stockton and Delta levee builders perfected the clamshell dredge building Delta levees, Project and Non-Project. The engineering of levees experienced a Darwinian phase, in that only the fittest levee sections survived the next flood. The agriculturalists simply employed new techniques and geometries as they rebuilt the failed sections. They repeated this process until only the strongest levee sections survived, or the builders gave up. As late as 1997, floods were knocking down the weakest sections of the 1950s vintage USACE built Project levees along the San Joaquin in the south-east corner of the Delta. The USACE have since re-built the levees to new standards informed by the failures suffered in 1997.

As suggested earlier, the “Restricted Height” levees and the levees protecting small or wetland habitat or recreational island (Van Sickle, Little Mandeville, etc.) experience very high failure rates. The “Other” category includes primarily railroad embankments that under certain conditions (Lower Jones Tract, Glanville Tract) double as flood control levees with mixed success. The Houston, Duncan, and the USACE (1978) and Logan (1989, 1990) developed their models of levee failures on the empirically determined relationship of the thickness of peat under the island or tract and the rate of failure of the levees on that particular island, all the analysis performed at the “island/tract scale.” By identifying and establishing fine scale levee segments for data collection, similar analysis could be performed at a more detailed level, for example the failure rate of a levee segment versus the thickness of peat under that segment. In defining the particular segments, I considered the original builder and purpose defined above and I considered the characteristics of the levee alignment. Levee alignment could reflect the sediment characteristics of the material used in the particular segment, which could be a factor in determining failure rates. Table 7.2 presents relationships between alignment-type and implied original geomorphology to the rate of levee failures. The rate calculated reflects the number of failures over the life of the levee and only reflects the 102 failures that were pinpointed to an exact location. This includes almost all of the failures since 1950 but lesser numbers from the early years (1860-1950). It, therefore, cannot be considered a failure rate because it does not include all failures and the relative length of service of the levees is not taken into account. So it represents an indicator, not

Table 7.2 – Summary of Levee Failure Database Breakdown of Miles, Historic Levee Failures and Historic Levee Failure Frequency by Type of Levee Alignment

Type of Alignment	Miles	Located Failures in record	Located Failures/mile
Straight main channel	494.3	43	0.086992
Slough	250.0	17	0.068000
Meander Channel	48.2	4	0.0829878
Meander Slough	38.3	3	0.078329
Cross Marsh	152.2	18	0.1118265
Other	37.6	5	0.132979
Landside	81.4	1	0.012285
Flood control	23.1	11	0.47619

a rate. It also breaks out the straight main channel levees in the Secondary Zone which function as true levees, not “levee-dams”. I have listed these as “Flood control” levees and surprisingly, at least in the Legal Delta, this group has experienced more failures per mile than any of the “levee-dam” categories, suggesting that the near constant hydrostatic loading on the ‘levee-dams” becomes a positive, rather than a negative factor. Greater diligence on the part of those protected represents the most logical explanation for this difference.

Another category that does not function as “levee-dams” comes in the “Other” classification, hold the second highest frequency number. This category includes the railroad embankments that double as secondary flood control levees. In four of the five cases, either trestle sections or culverts broke the containment of the embankment that either people did not realize existed, or they forgot that they needed to be closed in the event of a flood emergency. The “Landside” levees, those generally built of drier upland soils to protect tracts from overland flow flooding from the upland areas, not surprisingly, have the best history.

Among the "levee dam" groups, the calculated failures per mile are similar for the channel and slough types whereas the "cross-marsh" category calculated slightly higher. Closer investigation, however, reveals a different story. All of the "restricted height" levees in the Delta were constructed as "cross marsh" levees. If we take out the 14 failures on the 13 miles of restricted height levees (Liberty, MWT, and Dead Horse), the remaining 139.2 miles of "cross marsh" levees have suffered only four failures (one since 1907), for a rate of 0.0287 per mile. It can be argued, therefore, that the "cross marsh" type of alignment has performed with much lower frequency of failures. This is not necessarily intuitive as the back marsh from which they were constructed likely had the highest content of organic material (peat), any of the "levee dam" alignments. Perhaps the lower rate of failures can be explained by the concept that the back marsh levees were built by clamshell dredges that in the back marsh could deliver relatively dry and undisturbed sediment to an undisturbed foundation (also with a highly organic content). In addition, many of the cross-marsh levees sit on thinner peat layers and the clamshells may have gotten into underlying layers of clays, silts, and sands to top off the levees in these back-marsh areas. In these areas, the mix of soil types (peat, sand, and clay) and the relatively dry conditions during excavation potentially created a stronger levee.

SUMMARY OF FINDINGS

The database of Delta levee failures introduced in the chapter closes significantly the gap in the shared knowledge of failures of Delta levee. Whereas Thompson (1957, 1962, 1996, 2006) provided a strong base of knowledge of levee failure through 1957, the efforts to maintain record keeping has faltered. Proponents of the state initiated DRMS hoped to close the information gaps but the limitation placed on the consultant to compile only existing reports left the record open. This is unfortunate given the importance the DWR and other state agencies assigned to the findings of the report. The DRMS defined a poorly performing and perhaps doomed Delta agricultural levee system with levees failing at an excessive and increasing rate. The dissertation database, however, shows that the Delta levees have performed adequately against their individual design requirements. Moreover, the subvention program has helped the reclamations districts reduce the risk of failure.

The database provides a more detailed synthesis of the overall performance and problems of the levees. Potentially this record can help pinpoint specific areas of concern by looking at performance against a large list of variables of levee differences and history and by sharing information about near-miss incidents. In this regard, the dissertation database helps fill the void of sharing information on the causes of Delta flooding created when the DWR was forced to slow down issuance of the planned annual Series 69 - Reports on High Water in California.

The historical geographic research involved in this dissertation also uncovered evidence that the 1906 Earthquake may provide empirical evidence of how the Delta levees will perform in future earthquake events, an area where certainly more work is required. The database and GIS mapping of records will allow scholars to continue to close the gap, correcting errors in the record and expanding the information available to help form better understand of where the levees have been and how they stand today.

CHAPTER VIII

DISCUSSION

INTRODUCTION

This dissertation measured and defined the social perspectives regarding the history of failures of Delta levees. It also created a detailed history of the levee failures. This chapter will discuss the advantage of using discourse analysis, and particularly the quantitative/qualitative approach of the Q-method to understand the social perspectives of experts who manage complex human altered environments. The chapter will also discuss the relationship between an incomplete or contested knowledge of the history of levee failures and the diversity of social perspectives found. The chapter will close with a brief comparison of observations of the scholars discussed in Chapter II with the social perspective of the four factors.

SOCIAL PERSPECTIVES OF DELTA LEVEE EXPERTS

The Abandon the Levees Factor (F2) reflects the political perspective of the PPIC-CWS at UC-Davis identified in Chapter II. The Abandon the Levees factor represents what appears to have the widest variety of loaders from an organizational affiliation standpoint, with one university professor, a federal environmental scientist, a state environmental manager, an engineer from DWR, and an engineer with a water contractor. The perspective sees the Delta levees as unsustainable at any cost because of the poor condition they are in, sea-level rise, continued subsidence, and the high probability of massive failures in a likely earthquake. This translates into political support for the Peripheral Canal and the elimination of state financial support for the levees.

On the other end of the spectrum, in what Focht (2002) would term the bi-polar opposite perspective, are the Delta Sustainers (F1). This perspective sees the Delta levees as sustainable with moderate investments. They see local knowledge as the critical element by extension, a governance scheme that fully appreciates that local knowledge is vital to success. The Delta Sustainers (F1 loaders) are almost exclusively the reclamation district board members and the engineers and consultants who support them. Seven of the nine strongest loaders on Factor 1 live in areas protected by a Delta levee. As a group, they have been directly involved in most, if not all, of the flood fights since the 1972 Brannon-Andrus levee failure, and in one case as early as 1956. Six of them volunteered how they participated in their first flood fight with their fathers. Politically, they align with the Restore the Delta group because they sense reduction in interest by the public in the levees and water quality will deteriorate in the Delta once DWR builds the Peripheral Canal.

Factor 4, the Multi-Purpose levee advocates, is the other somewhat predictable Factor; four of the five loaders on F4 hold engineering degrees and the fifth holds of couple of degrees in environmental science. All have worked much of their professional careers with DWR, USBR, and/or the USACE. They are all dedicated to the work of those organizations. None of them, however, lives in the Delta. This social perspective comes from the individuals who have been striving to provide reliability in water exports, to re-establish a viable ecosystem, and help to provide flood protection for those living behind the Delta levees. They are lukewarm in their support for a peripheral canal, and take a middle ground position between F1 and F2 on the stability of Delta levees and risk of multiple liquefaction related levee failures.

F3, the Levee Pragmatists, represent a viewpoint that surprised the eight strongest loaders from the other factors that I met for follow-up interviews. One can speculate that the eight were surprised because the agencies, reclamation boards, and scholar focusing with each other in discourses on Delta levee have ignored or just not heard less vocal and less powerful local interests. Uncovering this social perspective demonstrates a benefit of discourse analysis in general and Q-Method in particular. With only two loaders and a low interest in the politicized Peripheral Canal debate, society and the key actors could easily miss this perspective. Yet as with all valid perspectives, the public should not ignore this contrarian viewpoint with its healthy amount of criticism for many. The loaders of F3 are two of the most diligent and knowledgeable students of the Delta levees interviewed for this dissertation, topping a list of interviewees whose knowledge and commitment are exceptional. Both of the loaders hold Ph.Ds. in sciences and live behind levees, one in Delta itself. Both extensively travel and work on Delta levees so their concerns others should not dismiss their perspectives. The best solutions for Delta levees would likely come from parts of all the social perspectives, making the need to recognize them and deal honestly with the differences so important in levee governance.

One of the advantages of Q-Method is to help identify areas of agreement among perspectives. USACE Headquarters provides one such area of consensus of social perspectives in that all agree that the USACE should rescind its bare levees policy. The perspectives share also a high confidence in technology and science and all appear to agree that engineering created the problems and engineering can solve them. The Delta Sustainers believe that more rip-rap and more height and wider toe berms can make the levees work for generations, just as they have in the Dutch polders and the English Fens.

The Abandon the Levees factor sees a well-engineered isolated conveyance system easily allowing the water exporters to draw the best water for Californians and Central Valley agriculture and manage the salt-water bay that will replace the Delta as the best possible habitat for smelt and striped bass. The Levee Pragmatists see the need for more subtle technologies and techniques to improve the levees as flood protection structures and as habitat. Finally, the Multi-Purpose Levee Advocates perspective, most closely associated with the engineers and managers who run the Delta today, insist that the best technology, the best levees, the best habitat restoration projects, and the best Folsom Dam spillway configurations give the greatest flexibility to manage the Delta. They are not uniformly enamored with the Peripheral Canal but, if built, they will use it.

AREAS OF DISAGREEMENT BETWEEN PERSPECTIVES

Three concepts stand out as dividing Delta levee experts into views that would seem to be irreconcilable, absent efforts to break down, or at least soften, the differences in basic understandings. The first differences stem from views of stability and security of the existing levees to withstand the current level of destructive forces and increased future loads imposed by climate change and continued subsidence. Delta Sustainers perceive a history that indicates that Delta levees have never been stronger and the number of levee failures is reasonable and declining. In addition, with appropriate investment by all the stakeholders, they will continue to get stronger. The other perspectives, quoting the levee failure history outlined in DRMS (URS 2009a; 2009c), are less confident in the stability of the existing levee system, finding an unacceptable history of performance of the levees that continues to deteriorate in spite of increased state investment. The Abandon the Levees factor that considers Delta levees doomed by nature and not worth saving, represents a perspective contradictory to that of the Delta Sustainers. The Abandon the Levees factor sees the process of levee abandonment well under way with the abandonment of the Big Break Area, Franks Tract, Mildred, Liberty, and Prospect with the rest to follow. The other two perspectives fall in between but they are generally concerned about stability of the existing levees. Multi-Purpose Levee Advocates mainly worry about the levees because of continuing subsidence and all the challenges from rising sea levels to rodents to possible earthquakes. Levee Pragmatists fret because they see reclamation districts employing inadequate maintenance practices on Delta levees. Many who worry about the stability of the Delta levees picture the Chinese labor crews building the levees with wheelbarrow and shovel out of blocks of peat a century ago or more without the benefit of engineering skills or knowledge

Second, the level of risk to the levees and the Delta from earthquakes, and specifically multi-island, simultaneous failures caused by liquefaction represents a significant area of difference that appears impossible to resolve between F1 and F2. The Abandon the Levees perspective, supported by the DRMS Executive Summary (URS 2009a), sees the catastrophic earthquake as a near certainty, an overdue event that should be the primary focus of future planning for the Delta. This risk drives the need for quick action on an earthquake-proof isolated conveyance system and reluctance to commit any funds for maintaining or improving the existing, but doomed, Delta levees, even for habitat. On the opposite side, the Delta Sustainers look at the entire levee history and find no earthquake-related failures. They have fought and stopped too many boils, filled in too many beaver and squirrel dens, rocked over too many erosion scallops, sandbagged too many settled levee sections during floods, and even rebuilt half of the Bradford Island levee in August 2009, torn out by a "softly colliding" runaway Greek freighter (Interview 103-2010A) to have much time to worry about hypothetical earthquake damage they have not experienced. The Delta Sustainers hold that whereas earthquake forces could shake the Delta, the levees themselves are more resilient to earthquakes than other structures and features. This view received additional support in August of 2011when NSF funded researchers from UCLA simulated a near 7.0 magnitude Hayward Fault earthquake and failed to damage the test levee they build on Sherman Island (Weiser 2011). Between these views, the Multi-Purpose Levee Advocates and the Levee Pragmatists respect the scientists sounding the alarm, but long for more convincing proof one way or another, hopefully not in the form of a levee-wrenching earthquake. The heart of the science in the DRMS study relies on the 2000 CAL-FED study (Torres, *et al.* 2000), which relied on "expert elicitation" to help quantify the risk. Several of the nine participants on the expert panel of the CALFED-sponsored Torres study continue to question publicly qthe results of the elicitation they participated in.

A third bi-polar concern is the F3 view that the local knowledge of the reclamation districts and their ability to manage Delta levees has deteriorated and is now vastly overrated. They also feel that the DWR and the local districts work poorly together on the wrong things. The negative beliefs of F3 toward the strength and importance of local knowledge holds them in significant conflict with F1.

Finally, the Q-Method analysis focused on the role of the Delta levees in future water conveyance, especially relative to the desirability of a Peripheral Canal to take over that responsibility. Whereas in the political discourses, two of the three identified strongly supported the necessity of the Peripheral Canal, only the Abandon the Levees social perspective perceives the absolute necessity of a Canal. F3 and F4 remain unconvinced of the need while the Delta Sustainers strongly oppose the construction. This research only focused on the meaning of Delta levees. The social perspectives of environmental restoration issues, water rights, all of which influence the Peripheral Canal debate were not addressed. Only F2 perceives that the Peripheral Canal is justified by the history and anticipated future of the Delta levee failures.

THE HISTORY OF THE FAILURES OF DELTA LEVEES AND THE FOUR SOCIAL PERSPECTIVES

A primary focus of this dissertation was to understand why Delta levee experts expressed such conflicting views of the stability and sustainability of Delta levees. Q-Method identified different views of the performance of Delta levees as a major factor in determining perspectives. The DRMS report appeared to resolve this problem, as the consultant used the existing documentation to create a list of historic levee failures back to 1900. However, as noted in Chapter VII, this DRMS listing (URS 2009c) which then got copied directly by the Delta Stewardship Council staff (DSC 2010b) for the DSC's use in policy-making, lacks detail, precision, and references. Its conclusion that the annual Delta-wide frequency of island flooding increased from 0.80 during 1950 to 1980 to 1.39 between 1980 and 2006, (URS 2008c, 25) suggests that the increased maintenance and subvention program money were not paying off is inaccurate at best.

Questions about this analysis led to the development of the levee failure history database in this dissertation. As noted on Figure 7.11, in the past 25 years since the levee subvention program finally received significant funding (see DRMS Figure 4-4c URS 2008e, 26), only three failures of agricultural levees in the subventions program occurred and only 12 since 1980 for a frequency of 0.4 failure per year between 1980 and 2010. When considering the period 1981-2010, the rate drops to 0.233. The rate for the last 25 years is 0.08 failures per year. Houston, Duncan, and the USACE (1978) might suggest this still overstates the rates because they include the flooding of Dead Horse Island in 1980, 1986 and 1997, an island they did not include in their analysis because it is so directly affected by the hydraulic surge created by the height-restricted levee on neighboring McCormack-Williamson Tract.

One of the statements in the Q-sort related to whether DRMS was merely a conspiracy to justify the Peripheral Canal. Whereas the conspiracy theory drew little support among any of the Factors, the DRMS consultants and staff were under considerable political and time pressure. Just a year before, the Little Hoover Commission (Alpert 2005) issued its report that would help kill the CALFED effort. It was critical of the lack of metrics to determine the progress made on the goal of improving the integrity of the levees. The Little Hoover report suggests that while the numbers that were available indicated that the integrity of the levees seemed to be improving, it dismissed those trends with the conclusion that the metric "does not account for levee foundations that compress under new loads, causing the levees to sink" (Alpert 2005, 33). Kallis, Kiparsky and Norgaard (2009, 634) determined that Governor Schwarzenegger concluded that CALFED "…had largely failed to achieve its goals, particularly those of reversing declining species populations and improving levee stability." With no standard measured record of the failures, plus pronouncements from the governor and the chairman of the Little Hoover Commission that things were getting worse out on levees, and no real funding for research or science, the consultant and DWR folks who were asked informally to provide data did the best they could. This environment made it hard, however, for consultants trying to keep some 90 islands and tracts straight to remember the warning of Houston, Duncan, and USACE about "supposed failures that were not failures" (1978, 7). Perhaps the extreme case in the DRMS history of levee failures was the listing of a 2006 levee failure on Honker Bay Club Island. This particular levee district is not in the Delta but rather in the Suisun Marsh where the owners have built and maintained the levees to control flooding to promote the care, feeding, and luring of migratory waterfowl for conservation and hunting. The owners of Honker Bay Club only became eligible for state support to maintain levees in 1999 (Dreher et al. 2008) and then only for the one levee section fronting Honker Bay itself. No one was keeping track of a history of levee failures, with only the absentee sportsmen owners possibly noticing a Suisun Marsh levee failure prior to recent concerns raised over the possible effects of Marsh levee failure on Delta salinity levels. Given the differences in purposes, levees in the Suisun Marsh do not even approach the standards of Delta HMP levees. Perhaps the worst case of confusing "flooding" and with "levee failure" shows in the recording of the flood at Honker Bay (Suisun Marsh) in 2006 in the DRMS record. The island was covered with water in early October 2006 (water year 2007) after DWR, USBR, and other sponsors deliberately cut 18.6 meters of the levee to create 28.3 hectares of new tidal wetlands known as the Blacklock Restoration project. The perceptions of the levees made it possible for DRMS preparers to see in this planned restoration project as a levee-failure related flood.

The DRMS study (URS 2008c, URS 2009a) and Executive Summary portray a subventions program that has failed to save the levees from continuing deterioration, whereas the work presented in Chapter VII suggests certain improvement. The subventions program has enjoyed success making a levee system grow stronger in spite of poor pedigrees, sea-level rise, continuing subsidence, and a variety of rodent and ocean-going vessel groundings on the levee..

LOCAL KNOWLEDGE

I expanded the database of levee failures to document also emergency repairs and successful flood fights. With one possible exception, Tyler Island, this record is incomplete. Since 1980, one reclamation district experienced one over-topping levee failure flood but had to make six emergency repairs and fight at least one successful flood fight. Assume the ratio of near-misses to floods at Tyler is anywhere near reflective of the Delta as a whole, it suggests that Delta levees performance results more from the constant human input than the inherent strength of the levee system. The levees as structures do not function as impervious, impregnable structures that generate a great deal of confidence. They leak constantly but island farmers have learned how to control the leakage. The levees also settle differentially but sandbags raise the elevation of low spots in a flood fight to avoid significant overtopping. Rodents burrow into the levees along a 1760-kilometer front. Every reclamation district engineer and director interviewed stressed that the critical factor for survival of Delta levees is constant patrolling of every inch of the levee system. The Delta levees form a system with human inputs, one well suited to an agricultural setting where residents are equipped with Earth moving and smoothing machinery and skills and are constantly monitoring soil moisture conditions..

Tyler Island experience suggests the importance of the local knowledge and diligence of the reclamation districts and the flood fighting and repair assistance from

DWR and the California Conservation Corps in preventing additional failures. This elevates the concern in the difference in perception between Factor 1 and Factor 3 over the effectiveness and depth of local knowledge about the levees. Key to this concern is admissions by Factor 1 loaders 111 and 115 that the distribution of local knowledge lacks uniformity and consistency across levee districts and may soon face a generation gap as the current leaders fail to pass on the knowledge fully to the next generation. A prime reason for differences in social perspectives is difference in experiences. Factor 3 loaders with implicit agreement by factor loader, suggest that local knowledge and involvement is not uniform across the Delta and these levee systems are as dependent on the people as they are on the rock and soil of the levees themselves.

One might suggest that the USACE or DWR could take a larger role, with the perception that the "Project" levees are perfect. As noted in Chapter VII, the Project and Direct Agreement levees have performed no better than the Non-project levees over the 60 years since the USACE completed their work on the Georgiana Slough and the San Joaquin River south of Stockton levees. The local reclamation districts have maintained, patrolled, and repaired the Project and Non-Project levee alike, so it should not be surprising that they would have similar rates of failure. The Project levees also have the advantage or disadvantage that many miles of that system are "Upland" or Secondary Zone flood control levees not exposed to water lapping against the side of levee except during high water. This should give Project levees an advantage over the Non-Project levees, which are mostly levee-dams under constant hydrostatical loading and stress. Perhaps it is that constant testing that triggers patrols that are more diligent and exposes seepage points of weakness before the middle of high water events.

CONTRIBUTION TO THE LITERATURE

As noted in Chapter II, a number of scholars have studied the development of wetland reclamation, flood control, and large water transfer projects in the American West. Their writings have influenced the discourses about these activities in general and about Delta levees specifically and this dissertation reveals how the Delta levee experts interviewed view these scholars' opinions today.

Prince (1999) explored the changing discourses on the value of the wetlands, suggesting that in the Midwest, changing definitions of Nature by society were forcing farmers of reclaimed wetlands to reinvent their farms as "mixed species communities" (Prince 1997, 346) where humans were one of the acceptable species. Whereas the subsidence precludes returning the Delta island to anything like the pre-development tidal freshwater marsh, the Abandon the Levees social discourse push for an open salt water bay as the most desirable habitat option. The Delta Sustainers (Delta farmers) social perspective talks about the value of the terrestrial and marsh ecosystems protected by the levees while resisting any need to modify farming methods. F4, represented in the P-Set largely by engineers and managers from DWR and the USACE strongly supports statement 5 that the agencies "preserve current conditions in the Delta while it is clear what to do to have a healthy Delta ecosystem." This dissertation confirms that the social redefining of nature places the same pressures on the farmers of the Delta as experienced in the Midwest to work to continue the perception that their activities in the Delta remain legitimate..

O'Neill (1998, 2006) argues that the USACE, the states and local agencies and elites over time developed a seamless governing of the flood control system. A challenge she saw was that the system might be too rigid to execute effectively the environmental protection and restorations that society expects in these systems. Factors 1 and 4 see the DWR, local reclamation district and the local USACE office as working effectively together, albeit with some tension around how to execute elements of habitat restoration. The apparent inflexibility of USACE Headquarters on the bare levees policy and the friction it has created with the DWR and RDs supports O'Neill's concern that the smooth working relationships could break down in the face of ecosystem restoration.

The dissertation extends Kelley's (1989) work describing the levee failure along the Sacramento by detailing those in the Delta, which he largely ignored. In a negative way, the social perspectives identified confirm his argument that the "Whig-Republican" view dominates. None of the Factors questioned the concept of the state and federal governments building and managing major infrastructure projects to help support economic activities. Politically, support for the Peripheral Canal does not appear to be associated directly with a political party. We do see, however, support from Factor 3, particularly for Kelley's concept that the USACE, reclamation districts, and DWR can be "a people slow to learn."

As noted in Chapter II, four scholars, Worster (1985), Reisner (1986), Hundley (2001), and Pisani (2002), have looked at the great hydraulic engineering projects in the American West including the systems supplied by the Sacramento-San Joaquin River systems and developed very different perspectives on them. The social perspectives of Delta levee experts reflect these differing views.

Worster's search for the evil hydraulic empire in the CVP and SWP does not gain full support in the social perspectives of Delta levee experts but concerns may be reflected in the rejection by F1 and F3 and the lack of salience by F2 and F4 for a single agency to manage the Delta (Statement 3). No perspective sees DWR and the USBR as despots, the view from Reisner's (1989) argument that political leaders cannot be trusted when it comes to water politics. F1 with acceptance of Statement 16 that "DRMS was a DWR conspiracy to justify the Peripheral channel" reveals some support for Reisner's concerns. Perhaps the greatest contribution of Reisner and Worster was to raise awareness of at least the appearance of transgressions and warn of the potential of future corruption of California water politics by powerful and wealthy water interests.

Hundley (2002) focused more fully on the Delta and its role. His work was either the most insightful or the most convincing, because he suggested a Task Force be established to tackle Delta issues and that, of course, happened with Delta Vision and the Delta Stewardship Council. Hundley suggests that the sins of water resource abuse in the American West can be blamed on the continued willingness of the American Public to support major water export projects, perhaps reflected in the fact that only Factor 3 even questions the idea of water exports from the Delta. Factor 3 perspective appears to be the one factor most aligned with Huntley's view that the important issue is to educate the public to "abandon those attitudes and institutions that were born of an earlier era when abundance encouraged abuse" (Huntley 2001, 564).

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The social perspectives of key actors on the governance and role of Delta levees has been hidden by the prolonged and fierce debate and discourse alliances developed over the desire of southern California and Central Valley water users to gain direct access to Sacramento-San Joaquin through a Peripheral Canal or other Isolated Conveyance System. Those arguing for such a Canal use the apparent or assumed weakness and instability of Delta levees as a major part of the argument advanced in support of the Canal.

Understanding the social perspectives of experts and decision makers in areas where resource utilization and sustainability debates have become contentious is important for at least two reasons. First, the science and knowledge of those expected to provide the “best available science” for policy makers can be, and often are, subsumed, integrated, or implicit in major political debates. This hides scientific uncertainty in the effort to make simple, sellable arguments. Second, normative science typically deals with unknowns or unknowables. Therefore, as Bischof (2009) suggests, when science provides input into policymaking, we should have understanding of the social perspectives that support the recommendations.

In the case of the Delta levees, an accidental water supply hub since 1951, public discourses have been structured around the idea of fatal defects in the levee system, rather than idea that a strong levee is better able to fill the water hub role than at any time in history. Each political perspective has developed a set of "facts" that have become what Bischof (2009) would term a "polarizing certainty" that drives the discord in the political debate and makes formation of coalitions between the parties difficult to form. The Q-Method determination of social perspectives of Delta levees found two social perspectives strongly connected to the political arguments and two that diverge. For Factor 3, problems with the governance and governing of the levees themselves are major concerns. For Factor 4, engineering and science can extract increasing demands from the Delta and its levees. The need for a Peripheral Canal only became a major element of in Factor 2; however, in the political arena this means little as Q-Method cannot determine the political support each perspective holds.

Q-Method revealed bi-polar perspectives with differences based on conflicted views of the past performance (not having failures) and the probability of massive damage to Delta levees in an earthquake. The Abandon the Levees and Delta Sustainers factors held perspectives so conflicted that collaboration or even compromise appears unlikely. Raadgever, Mostert, and van de Giesen's (2008) assertion that understanding and sharing social perspectives can help resolve conflicts will likely go untested with Delta levees given the bi-polar nature of the perspectives. Reducing the uncertainty level for all perspectives will be required to begin the close the gaps between perspectives. This dissertation compiled and analyzed the history of failures of Delta levees. I found a levee system that performed much better than the DRMS analysis implies. The historical review also uncovered evidence that indeed Delta levees in near-current configurations experienced liquefaction caused by the San Francisco Earthquake of 1906. However, no evidence exists of damage to any of the Delta levees from those forces. These 1906 reports require further investigation and confirmation. If appropriate, follow-up could include detailed soils and geotechnical analysis. It would seem prudent to do so before Californians commit to a Canal, costing an estimated $13 billion and justified largely because of the potential of earthquake damage and a faulty or exaggerated history of levee failures.

The stability of Delta levees represents just one of many issues related to justifying the Peripheral Canal, but it might be the only one that if proven or widely believed, would demand the building of the Peripheral Canal. More broadly, other influences on the Peripheral Canal include consideration of the best and legal use of the Delta and the water resources of the state and the desired socio-ecosystem that can be sustained in the Delta. On the habitat side, goals for smelt recovery conflict with those of the Sacramento River Chinook runs and sturgeon. Q-Method study of Delta environmental issues could help bring clarity to what the experts think can and should be done (Focht 2002).

Q-Method, as demonstrated by Focht (2002), Raadgever, Mostert, and van de Giesen (2008) and Bischof (2010) is an effective way to understand what scientific issues underlie the political discourses and disputes. Q-Method represents an effective approach to perform discourse analysis to gain this understanding without the practiced skills involved in other forms of discourse analysis. Particularly for scientific, technical and policy areas, its quantitative elements serve to reassure the scientific, technical, and management communities whose discourses are of interest. It also permits scholars with an understanding of the science or technology but inexperienced with discourse analysis methodologies to have confidence in the results. Unfortunately, Q-Method cannot measure how widely held a social perspective is; nor can generalization be made based on the factors identified.

RECOMMENDATIONS

The two major findings of this dissertation, the presence and nature of four social perspectives on the past, present and future of Delta levees and a detailed compilation of the history of failures and emergency repairs, should be shared with all experts and decision-makers on Delta levees. Scholars (Ellis, Barry, and Robinson 2007; Swedeen 2007; Raadgever, Mostert, and van de Giesen 2008; Lopez-i-Gelats, Tabaran and Jordi 2009) have suggested that knowledge and recognition of the perspectives of others can lead to better collaboration and selected outcomes. Each of the perspectives has validity and should be valued by policy makers and should be considered in the solutions and decisions reached.

The record of levee failures challenges previous studies, most importantly, DRMS. Studies, decisions, and even social perspectives based on earlier studies should be reconsidered based on the details provided in the database of levee failures. Earlier studies presented little more than a simple count of flood events in the Delta, but did not identify the individual circumstances of failure that provide the ability to explain the past and provide the necessary information to improve future outcomes.

The discovery of this dissertation that the 1906 earthquake caused significant damage in the Delta but apparently not to the levees deserves further investigation. Empirical evidence of effects of a major earthquake on the Delta levees may exist that has largely been ignored with the frustration of not being able to simulate such an event.

The disparity of views on this risk divides the social perspectives on the Delta levees more that the Peripheral Canal.

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APPENDIX A

Expanded List of Selected Q-Method Studies in Geography and related Fields 1999-2011

Year	Reference	Subject	Concourse	Q-set	P-Set	Factors
1999	*(Barry and Proops)*	*"Attitudes towards the environment by members of several Local Employment and Trading Systems (LETS) Groups. "(England) p 339*	*Finite diversity of concourse. Created by structured interviews.*	*36 Found to be manage-able, developed through discourse matrix*	*25*	4 ideal sorts
2000	(Robbins)	Explores the differences between state and local environmental knowledge in Rajasthan, India, both within and outside the state forest bureaucracy	17 pictures of vegetation	17 pictures of vegetation	62 stratified by caste	4 Factors explain 67% of variance in species preference
2000	(Robbins and Krueger)	Development of a participatory planning process for the Northern Forest Lands region of the US	400 reliance on "Grounded Theory" to develop representative concourse stressed	45 (target range 4 to 5 dozen)	37 people Purpose-fully sampled to represent variety of (Scale -5 to +5)	5
2001	(Fairweather and Swaffield)	The ways tourists experienced Kaikoura N.Z. as a vacation spot	220 pictures	30 pictures	66 randomly selected but with local/international split	5 61% of variance explained
2005	(Eden, Donaldson, and Walker)	Examining the production and use of environmental science by NGOs. (More of a discussion of Q Method and details of case application not specifically noted)	200-500 Naturalistic using "raw verbiage" "Grounded Theory" used to take to "Saturation Point"	40? 36-60 target Comprehensiveness rather than representativeness (p. 417) Four foci	13? Not identified	2?
2006	(Robbins)	Looks at how First World (North Yellowstone region) local hunter elk knowledge converge with that of state officials, environmentalists, landowners and others to see how discourse coalitions (following Hajer, 1997) actually work and the interaction of knowledge, policy, and power in this environment.	20 from informal interviews and literature search	20	30 including original interviews	2
2007	(Swedeen)	Used Q to gain insight into a classically conflict-ridden ecosystem management concern, forest management in the Northwest of the United States.	200 items from interviews and documents (EIS, etc.) Stopped when started repeating	64 statement derived using 4 X 4 political matrix	30	3 Used Centroid factor analysis followed by both Varimax rotation and

Year	Reference	Subject	Concourse	Q-set	P-Set	Factors
						manual rotation
2007	(Pini et al.)	Stakeholder perspectives on rural government management of natural resources in Australia per the Local Agenda 21 of the UN	Concourse developed from 93 interviews with local officials in 15 different local sub- divisions across 4 Australian states	56 Target 30-60, ended up with 56 from a 7 by 8 matrix	21 face to face, 7 telephone, 28 total is consist-en with literature	5 22 sorts loaded with statistical significance with the five factors
2007	(Hall)	Scottish farmer attitudes toward genetic modified crops	700 from mailed survey with 13 open ended questions	48 selected using matrix	15	3
2007	(Ellis, Barry and Robinson)	Identify the discourses of support and objection to wind farms offshore Northern Ireland .	458 – Dryzek & Berejikian 4X4 matrix used	50	71 agreed, only 46 finished it correctly	4 supporters, 4 objectors
2008	(Raadgever , Mostert, and van de Giesen)	Identify stakeholder perspectives on future flood management in the lower Rhine basin in Germany and Holland.	Literature search and 23 semi-structured interviews. Unidentified number collected on 4 issues	46	47 200 were asked to participate 47 did using online tool, set up using free web-based software (available at http://q.sortserve.com) (p. 1099)	3
2008	(Ockwell)	Investigating Q as a method to open up and make more reflexive fire management policies in the Dry Cape York region of Australia	304 drawn mostly from literature and prior research with particular attention paid to studies of aboriginal anthropological studies because of language problems	36 Developed using 4X4 matrix	32 stake-holders representing cross section of key interest groups	4
2008	(Hawthorne, Krygier and Kwan)	Use of Q –method and GIS to study NIMBY effects relative to rails to trails convergence in Delaware, Ohio.	19 pictures of trail sites	19 pictures of trail sites	18 Members of community with 2 conditions of instruction at two scales	2 for each scale
2008	(Danielson)	Does Grid Group Cultural Theory (GGCT) help understand views of wildfire risk in N.J. and N.S.W. Australia?	Based on 11 field interviews + various published papers	56	25-N. J. 28- N.S.W. Australia	5- N.J. 4 –NSW For both discourses
2009	(Venables et al.)	Understand the perspectives on nuclear power plant operating risk of long term neighbors to two plants in the UK.	400 - Generated from 32 biographical narrative interviews	62 based on ten themes, mostly from concourse with addition of a couple added by researcher	84, 41 from each site who were initially identified using professional recruitment	4 At least two Q-sorts “load” uniquely on each factor (p 1094)

Year	Reference	Subject	Concourse	Q-set	P-Set	Factors
2009	(Tuler and Webler)	Learn about perspectives and goals of oil spill emergency response in four US regions	Created from literature and two oil spill case studies	42	49 12 each from 3 regions, 13 from Washing-ton state.	4
2009	(Lopez-i-Gelats, Tabara, and Jordi)	Local perspectives of what is rural in an area of the Spanish Pyrenees	21 interviews generated 200 statements	36 (manageable)	Same 21 completed sort	4- Used PCA and Varimax rotation to get 75% explained variance
2009	(Hennessy)	Exploration of key stakeholder perspectives on the barriers to graywater reuse in Vancouver, B.C.	250 written from literature	47 to cover 10 categories	25	3
2009	(Doody et al.)	Developing bottoms up and tops down sustainability measures using Q	750 items from 11 focus group meetings	40 developed in the 4 by 4 matrix	37 from public	6 Used PCQwin software (http://www.pcqsoft.com/) Varimax rotation
2010	*(Person)*	*Understand the social perspectives of the elites in Nolan County relative to the wind energy business arriving in the region.*	*300 Mainly from semi-structured interviews with Key actors*	*27 - 16 categories reduced to 5*	*21 purposively chosen key actors.*	5 - 77% of variance explained no factor with less than two loaders
2011	(Brannstrom)	Describe and analyze discourses concerning environmental governance in the expanding soy belt in Bahia state, Brazil.	42 -Develop with Naturalistic approach supplemented with written material Use Grounded theory to create categories	26 statements developed from four foci	21, 12 government farming &environ-mental; 4 NGOs; 5 farmers	4 extracted using PQ-Method
2010	(Bischof)	Finding consensus among competing scientific discourses about what to do about the worldwide coral	158 Scientific “Facts” from the literature that are contextualized in human arenas, making them	43 generated around	240 reef specialists contacted-31 e-mailed sorts	4

Year	Reference	Subject	Concourse	Q-set	P-Set	Factors
		reef environmental crisis	subjective enough to be part of a concourse.	three major topics and included issues of scale, governance, and forecasts	by target date. (Stated goal was not more than one P-sorter for each 2 Q-sorts	
		AVERAGE		41.04	33.26	4.22
		LARGEST	750	64	66	8
		SMALLEST	19	17	15	2
		MEDIAN		42	30	4
		MODE		36	21	4
		THIS DISSERTATION	150	35	22	4

APPENDIX B

This is a copy of an e-mail message I sent to introduce myself to a potential interviewee who agreed and became Respondent 116. Other e-mails varied slightly over time as conditions changed schedule and the snowball technique provided the name of candidates for interviews and the name of the individual who suggested the name changed.

-----Original Message-----

From: Hopf, Frank, Jr. [mailto:fhpf@neo.tamu.edu]

Sent: Wednesday, June 24, 2009 6:59 AM

To: (Respondent 116)

Subject: Interview request

Dear Mr. __________

My name is Frank Hopf and I was given your name by (Respondent 115) who suggested that I request an interview with you. I am a Ph. D. candidate in Geography at Texas A&M University working on my dissertation on the historical geography and implications of the levee failure in the Sacramento-San Joaquin Delta. I am also a professional engineer (civil) in

Texas and for the last four years I have been part of a research team measuring erosion on Delta levees.

I have proposed two major parts to my dissertation. Both parts require input from interviews of the key players like you from the levee district to federal levels in Delta levee management, maintenance, and failure response. The first effort is to a compile a detailed database of the location, causes, and factors in the Delta levee failures since 1869. Your comments on the accuracy of the detail compiled on the incidents you had direct involvement on will be requested.

The second part requires confidential 45 minute interviews of the key players to learn the major concepts and messages that those involved have taken away from the levee failures and flood fights they have experienced. This will be a key piece of a study using a methodology recently being used by geographers to add to the understanding of complex issues in environmental and resource governance.

I will be in Sacramento-Stockton area from July 13 to 24, 2009 to conduct these interviews and request the opportunity to interview you at a time and location convenient to you for my dissertation. If this impossible, or you have additional questions before agreeing, please contact me via e-mail or call my cell phone at 832-687-2147. I will also return in August for a similar round of interviews if the July time period does not work for your schedule. Thank you and I look forward to talking with you.

Frank Hopf

APPENDIX C

Dissertation Q Method Steps Compared to those defined in Selected Methods Papers

. Source Dissertation	(Brown 1980)	(Barry and Proops 1999)	(Robbins 2005)	(Webler, Danielson, and Tuler 2009)
1 Define domain of subjectivity.	1)Identify a relevant problem and select statements from books, newspapers, etc. and then complete with interviews to define concourse about subject	1) Identify the areas of 'discourse' of interest and the population of important in the discourse	1) Determine the domain of subjectivity, carefully considering the breadth of scope of the area of interest.	1) Determine objectives and identify topic and subset of population. Need to identify context, what social perspectives as being studied and the purpose.
2) Conduct semi-structured interviews and other research to create concourse	See step 1 (above)	2) Conduct interviews with a sample of the relevant population. From these identify the statements that define the concourse, generally using interviewees own words.	2) Obtain or develop a concourse statements about the domain, using "naturalistic" methods or statements drawn from interviews or from secondary sources.	2) Conduct Interviews and prepare concourse. Interviews should be with persons with a deep knowledge of the subject and site. Use "grounded theory "to establish 100-300 Q statements
3) Select concourse items (Q-set)that cover the entire concourse for sorting	2) Produce 40 to 50 statements and for prepare for Q-sorting.	3) Select Q-statements to be sorted. Found 36 to be manageable. Used 4 by 4 concourse matrix of Dryzek and Berejikian (1993)	3) Select the Q-set, 10 to 1000 statements, pictures, sounds, smells, etc. representative of the concourse.	3) Select an edit Q-statements to create 20-60 statements for the Q-sample. Good Q statements are salient and may have excess meaning
4) Select P–set, individuals to conduct the sort and establish time and place for sorting.	3) Select 40-60 P-set members (or far fewer) who are theoretically saturated per Glaser and Strauss, (1967, 61-62). Really need 4 or 5 per factor	4) 25 participants do Q-sort with condition of instruction to rank the statements on the scale 'Agree to 'Disagree with most strongly'	4) Depending on objective. Key actors or randomly selected individuals sort the Q-set under the condition of instruction such as	4) Recruit 12 to 36 P- Sorters, using snowball sampling. They should be knowledge with range of perspectives (1:3 or 1:2 P Sorter to Q statements

. Source Dissertation	(Brown 1980)	(Barry and Proops 1999)	(Robbins 2005)	(Webler, Danielson, and Tuler 2009)
			‘‘most agree/most Disagree’’ Actual shape of normal distribution curve not important.	ratios recommended
5)Establish conditions of instruction for sort	4) Set conditions of instructions which may be simple or complex and multiple	See step 4 (above)	See step 4 (above)	Not specifically discussed
6) Conduct Q – sorts, record result and interview sorters for additional input		See step 4 (above)	See step 4 (above) and 5) Conduct “open-ended” interview with sorters to get obtain reasons and logic for the sorting of items	5) Conduct Q-Sorts with cards and sort board, voice record (with permission) the session. Record results and ask follow up questions.
7) Run factor analysis and determine appropriate number of factors to use	5)Use computer program to run correlations and factor analysis	5) Run statistical analysis to allow the extraction of a few ‘typical’ Q sorts.	6) Compute correlation coefficients for each pair of sort and run factor analysis using the centroid or simple summation method. Select the number of factors to use, generally all those with eigenvalues greater than 1.00	6) Run Factor Analysis, Decide on final set of factors, determine meaning of factors and compare and contrast social perspectives. Use freeware PQMethod (includes instructions for running DOS program on PC.)
8) Rotate factors to simplify and generate factor scores and loadings.	6) Rotate factors unless the computer’s rotation accidently works out acceptably, pursue revise loadings to test theory; AND 7) Identify pure factor loaders as those loading on only one factor	See step 5 above?	7) Use an “objective” (such as Varimax) or theory-testing manual method to simplify factors by axis rotation. Interpret the factors from these results.	See Step 6 (above)

. Source Dissertation	(Brown 1980)	(Barry and Proops 1999)	(Robbins 2005)	(Webler, Danielson, and Tuler 2009)
	with loadings greater than 2.58(1/√N) where N is the number of Q-sorts. Determine factor scores for each factor from these loaders. Use computer program and factor scores differing by 2 or more are distinguishing.			
9) Use statistically significant factor statements to interpret, name, and describe the factors	8) Using factors scores and loading, describe and interpret each. Either accept or reject original theory (if there was one) or create hypothesis de novo	6) Interpret the typical Q sorts, giving a series of “ideal” discourses	See step 7 (above)	See Step 6 (above)
10) Prepare summary of factor descriptions and review with high loaders on each factor for input and revision as appropriate.	Not mentioned	Not mentioned	8) Return to the participants in the Q-sort with results for validation and additional insight. Particularly important if one of the objectives is to promote communications or help establish policy.	7) Share results with Q participants by mail in a consensus making process.

APPENDIX D

INFORMATION SHEET
Levee failures in the Sacramento-San Joaquin Delta: Characteristics and Characterizations

Introduction
The purpose of this form is to provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research.
You have been asked to participate in a research study about the history and meaning of levee failures in the Sacramento-San Joaquin River Delta. The purpose of the study is two-fold. First purpose is to document the history of levee failures in the Delta. The second purpose is to determine the views held by key actors regarding the meaning of this history of levee failures and what changes in levee maintenance and planning should be initiate in response to this experience. You were selected to be a possible participant because you are a key actor in past Delta levee failure response(s) and/or are involved in governance of levee maintenance and/or emergency response planning. This study is being conducted to support Frank Hopf's dissertation (PhD. – Geography) at Texas A&M University.

What will I be asked to do?
If you agree to participate in this second phase of the study, you will be asked to force rank from "most accurate" (+4) to "most flawed" (-4) with zero a neutral ranking, 35 statements about what the history of Delta levee failures could mean to the present and future of the levees and the therefore the Delta itself. The force rankings will be into a quasi-normal distribution developed for this study. The statements were largely generated from the study's first phase of 30 interviews conducted during the summer of 2009. The original interviewees were members of the same pool of candidates as for this phase. Participation in both phases is acceptable for this research. After the sorting is complete, you will be asked to briefly explain some of the rankings assigned.. Your contribution to this phase of the study will take approximately 45 minutes to an hour. Your participation may be audio recorded.

What are the risks involved in this study?
The risks associated with this study are minimal, and are not greater than risks ordinarily encountered in daily life.

What are the possible benefits of this study?
You will receive no direct benefit from participating in this study; however, potential benefits to society include greater understanding of views held by other stakeholders in the role of levees in the future of the Sacramento- San Joaquin River Delta.

Do I have to participate?
No. Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University being affected.

Who will know about my participation in this research study?
This study is confidential. Your name will be coded and the records of this study will be kept private. No identifiers linking you to the study will be included in any sort of report that might be published. Research records will be stored securely and only Frank Hopf and his advisors, Professors Douglas Sherman and Christian Brannstrom will have access to the records.

If you choose to participate in this study, you may choose to be audio recorded. Any audio recordings will be stored securely and only Frank Hopf, Professor Sherman, and Professor

Brannstrom will have access to the recordings. Any recordings will be kept for five years and then erased.

Whom do I contact with questions about the research?
If you have questions regarding this study, you may contact Frank Hopf, telephone +1 979 690-2420 or 832-687-2147 (fhpf@.tamu.edu).

Whom do I contact about my rights as a research participant?
This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at (979) 458-4067 or irb@tamu.edu.

Participation
Please be sure you have read the above information, asked questions and received answers to your satisfaction. If you would like to be in the study, we will begin when you are ready.

Q-sort statements to be sorted

1) It is very important to keep the Delta community and economy whole. With far less money than is being estimated, levees in the Delta can be made taller and stronger and set back enough to keep Delta islands afloat indefinitely.

2) Incremental changes are not going to create a sustainable Delta and even after a few hundred million dollars in improvements, we will still have levees that time and tide are just going to overwhelm.

3) The Delta islands are now well below sea level and if we lose the levees, we are going to have a saltwater bay. It will be a bay rimmed by urban levees, except perhaps up the Yolo By-Pass where new tule marsh may become established.

4) The voices of those who have a local knowledge of the role of levees in Delta are probably not as strong as voices of the water exporters and the environmentalist advocates focused solely on endangered fish species.

5) DWR has a clear legislature-mandated responsibility to maintain the status quo in the Delta, but DWR is really working to preserve the current conditions in the Delta until it is clear what to do to have a healthy Delta ecosystem.

6) We have a non-sustainable system. Many levees in the Delta will very likely not be around in 30, 50, or 70 years from now. It just doesn't make economic sense to pour more money on top of the ¼ billion dollars the state has already spent to try to maintain some very expensive levee systems against threats of earthquakes, sea-level rise, and ongoing subsidence.

7) The goal of DWR is to let the Delta go back to salt and build a peripheral canal around it.

8) If we stop federal subsidies to grow subsidence-inducing corn, we have the opportunity to create the world's best carbon sink in the Delta.

9) Delta levees are precarious and a disaster waiting to happen. They have to work so long and hard and are built of the wrong materials, on the wrong materials. The levee districts are trying hard but all it takes is one overzealous beaver. At the same time, we are now appreciating the earthquake risk and we are just lucky that we have not had a 6.0 or a 6.5 close to the Delta.

10) Although the levees are not well-engineered structures, riddled with penetrations and random objects, and inherently unstable because of their peat foundations, they survived record high water due to very high tides in 1998 and the 2006 high water and wind events without a failure. Somehow they are stronger than they seem to be.

11) Since 1986, there has been a substantial reduction in the number of Delta levee failures, primarily because the state subventions program allowed the reclamation districts to begin to improve the private levees. During this time, the state has invested about $130 million while the locals have invested $250 million, allowing Delta residents to start to feel comfortable living behind the levees.

12) As long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levees.

13) It is not affordable or justified at an estimated cost of $40,000,000/mile to build new earthquake resistant Delta levees when you look at the miles of levees that would require upgrading.

14) Improving the reliability of and employing non-destructive levee inspection tools represent a great opportunity to improve levee safety.

15) The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system.
16) DRMS was a DWR conspiracy to justify the Peripheral Canal.

17) We have created this massively altered system and it isn't working very well but everyone thinks we need just one more structural fix. The Peripheral Canal is not the solution; we need a broad water policy based on alternatives developed recognizing realistic values of the state's water.

18) From a water supply perspective, the only reliable, sustainable, earthquake proof way to get water around the Delta is the Peripheral Canal.

19) Nothing could be worse for fish than what we currently have in Delta today: rock-lined levees that are serving as water supply channels that are held at as constant flow condition as possible. It is exactly what an estuary should not be.

20) Every ounce of habitat out in the Delta, right now, is either behind the levees or between the levees. Once the levees are gone, the habitat is all gone.
21) We need more innovation like the $2.5 million of CALFED funded project on Tyler Island to restore sub tidal berms and levee vegetation. About two miles of shaded shallow riverine habitat were gained long term while reducing potential flood damage to the levees.

22) Delta habitat restoration projects have been a big joke and a waste of taxpayer's money. Planting trees and shrubs on the levees in conflict with new Corps guidelines, and within five years it has become just a big weed pile.

23) Restrictions on dredging and use of dredged materials, particularly in the north Delta, need to be eliminated, because they have no real scientific justification.

24) Reclamation districts that own the levees are not prepared for levee failure and many of them are poor at communications with their own constituents.

25) The current system of local levee districts performing much of the routine maintenance is dysfunctional, disjointed, and inconsistent. They have a deep distrust of DWR and it is disturbing how poorly they work together.

26) The DWR subventions program was a model of efficiency; the DWR staff was lean, and the local levee districts, because they had their money out there, managed projects very effectively.

27) The best governance structure for the Delta would be to let the levee districts tackle the issues island-by-island with some funding and guidance from DWR.

28) The local reclamation districts maintaining the levees bring incredible institutional knowledge of a constantly evolving system. They have people who can inspect the levees under all kinds of conditions and know what to look for. They have people who know what to do in an emergency and they are ready to defend their homes, livelihoods, and families.

29) Federal official maintenance practices are destabilizing the levees by denuding them completely. We are spending huge amounts of money destroying vegetation and huge amounts of money creating habitat that is not sustainable.

30) The levee districts tackle the critical erosion and acute problems very effectively but they are not good at minor, everyday maintenance. Unfortunately, this inattention lets minor problems like vegetation on the levees grow into overwhelming problems and now

they face major engineering and construction efforts in some many areas to get the levees back into compliance with Corps requirements.

31) A single agency should be established to manage the Delta, working with counties on land use planning, superseding DWR and the Corps to execute its carefully, but expeditiously developed plan, funded on a tax on water crossing the Delta.

32) Over the last 35 years, there has never been any earthquake damage to a levee in the Delta and the whole earthquake risk thing is junk science. It is a reality that the earthquake threat has been wildly overstated and is rather specious.

33) A lot has been accomplished on reducing risk of normal every day, vanilla, levee failures but more and more we need to recognize the vulnerability to extreme events such as earthquake and very large floods that are not adequately recognized or acknowledged by some of the Delta stakeholders.

34) In seismic events, Delta soils become very pliable allowing the levees to roll through without cracking, subsidence, or settlement. The soils are so heterogeneous that they do not behave as poorly as some models project they would.

35) Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years.

Interview Matrix for Q-Sort

Most Flawed Neutral Most Accurate

-4	-3	-2	-1	0	+1	+2	+3	+4

APPENDIX E

Z-scores and rank of each statement by factor. Bold indicates significance at P < .05; bold underline identifies significance at P < .01 (for information only.)

No.	Statement	Factors 1 z-score	1 rank	2 z-score	2 rank	3 z-score	3 rank	4 z-score	4 rank
1	It is very important to keep the Delta community and economy whole. With far less money than is being estimated, levees in the Delta can be made taller and stronger and set back enough to keep Delta islands afloat indefinitely.	**1.50**	**4**	**-1.36**	**-3**	-0.31	-1	-0.50	-2
2	Incremental changes are not going to create a sustainable Delta and even after a few hundred million dollars in improvements, we will still have levees that time and tide are just going to overwhelm..	**-1.24**	**-3**	0.81	2	**0.00**	**0**	0.84	2
3	The Delta islands are now well below sea level and if we lose the levees, we are going to have a saltwater bay. It will be a bay rimmed by urban levees, except perhaps up the Yolo By-Pass where new tule marsh may become established	0.18	0	0.66	1	0.48	1	**1.63**	**4**
4	The voices of those who have a local knowledge of the role of levees in Delta are probably not as strong as voices of the water exporters and the environmentalist advocates focused solely on endangered fish species.	0.86	2	0.43	1	0.62	2	**-0.70**	**-2**
5	DWR has a clear legislature-mandated responsibility to maintain the status quo in the Delta, but DWR is really working to preserve the current conditions in the Delta until it is clear what to do to have a healthy Delta ecosystem	-0.27	-1	**0.42**	**1**	-0.89	-2	**1.37**	**3**
6	We have a non-sustainable system. Many levees in the Delta will very likely not be around in 30, 50, or 70 years from now. It just doesn't make economic sense to pour more money on top of the ¼ billion dollars the state has already spent to try to maintain some very expensive levee systems against threats of earthquakes, sea-level rise, and ongoing subsidence.	**-2.08**	**-4**	**1.41**	**3**	-0.83	-2	-0.41	-1
7	The goal of DWR is to let the Delta go back to salt and build a peripheral canal around it	**0.69**	**1**	-1.27	-3	-0.58	-1	**-2.16**	**-4**

No.	Statement	Factors 1 z-score	1 rank	2 z-score	2 rank	3 z-score	3 rank	4 z-score	4 rank
8	If we stop federal subsidies to grow subsidence-inducing corn, we have the opportunity to create the world's best carbon sink in the Delta.	**-0.87**	**-2**	-0.01	0	0.00	0	0.54	1
9	Delta levees are precarious and a disaster waiting to happen. They have to work so long and hard and are built of the wrong materials, on the wrong materials. The levee districts are trying hard but all it takes is one overzealous beaver. At the same time, we are now appreciating the earthquake risk and we are just lucky that we have not had a 6.0 or a 6.5 close to the Delta.	**-1.20**	**-2**	0.84	2	**-0.24**	**0**	0.71	1
10	Although the levees are not well-engineered structures, riddled with penetrations and random objects, and inherently unstable because of their peat foundations, they survived record high water due to very high tides in 1998 and the 2006 high water and wind events without a failure. Somehow they are stronger than they seem to be.	0.88	2	0.02	0	1.48	3	0.13	0
11	Since 1986, there has been a substantial reduction in the number of Delta levee failures, primarily because the state subventions program allowed the reclamation districts to begin to improve the private levees. During this time, the state has invested about $130 million while the locals have invested $250 million, allowing Delta residents to start to feel comfortable living behind the levees.	**1.24**	**3**	0.36	0	0.00	0	-0.15	0
12	As long as farming continues on peat soils in the Delta, subsidence will continue with a concomitant increase in pressure on the levees.	**-0.69**	**-1**	1.48	4	**0.52**	**1**	1.55	4
13	It is not affordable or justified at an estimated cost of $40,000,000/mile to build new earthquake resistant Delta levees when you look at the miles of levees that would require upgrading. .	0.12	0	**1.63**	**4**	0.55	1	-0.09	0
14	Improving the reliability of and employing non-destructive levee inspection tools represent a great opportunity to improve levee safety.	-0.01	0	-0.25	-1	1.20	2	1.00	2
15	The water users are going to need the Delta levees for another 30 years because it will take that long for the environmental, property rights, and water rights lawsuits to be settled and then actually build the isolated conveyance system	0.98	3	**0.36**	**0**	1.51	4	1.11	3
16	DRMS was a DWR conspiracy to justify the Peripheral Canal	**0.53**	**1**	-1.88	-4	**-0.28**	**-1**	-2.16	-4

No.	Statement	Factors 1		2		3		4	
		z-score	rank	z-score	rank	z-score	rank	z-score	rank
17	We have created this massively altered system and it isn't working very well but everyone thinks we need just one more structural fix. The Peripheral Canal is not the solution; we need a broad water policy based on alternatives developed recognizing realistic values of the state's water.	0.65	1	0.08	0	1.13	2	0.45	1
18	From a water supply perspective, the only reliable, sustainable, earthquake proof way to get water around the Delta is the Peripheral Canal.	-1.82	-4	**0.79**	**1**	-1.20	-3	-0.73	-2
19	Nothing could be worse for fish than what we currently have in Delta today: rock-lined levees that are serving as water supply channels that are held at as constant flow condition as possible. It is exactly what an estuary should not be.	-0.39	-1	1.46	3	1.41	3	-0.45	-1
20	Every ounce of habitat out in the Delta, right now, is either behind the levees or between the levees. Once the levees are gone, the habitat is all gone.	0.47	0	-1.55	-3	0.31	0	-1.10	-2
21	We need more innovation like the $2.5 million of CALFED funded project on Tyler Island to restore sub tidal berms and levee vegetation. About two miles of shaded shallow riverine habitat were gained long term while reducing potential flood damage to the levees.	0.33	0	0.05	0	-0.38	-1	0.64	1
22	Delta habitat restoration projects have been a big joke and a waste of taxpayer's money. Planting trees and shrubs on the levees in conflict with new Corps guidelines, and within five years it has become just a big weed pile..	-0.13	0	**-1.04**	**-2**	0.34	1	**-1.70**	**-3**
23	Restrictions on dredging and use of dredged materials, particularly in the north Delta, need to be eliminated, because they have no real scientific justification.	0.93	2	**-1.04**	**-2**	**-2.03**	**-4**	0.44	1
24	Reclamation districts that own the levees are not prepared for levee failure and many of them are poor at communications with their own constituents	-0.79	-1	-0.75	-1	**0.89**	**2**	**0.08**	**0**
25	The current system of local levee districts performing much of the routine maintenance is dysfunctional, disjointed, and inconsistent. They have a deep distrust of DWR and it is disturbing how poorly they work together.	-1.30	-3	-1.12	-2	**1.51**	**4**	**0.02**	**0**
26	The DWR subventions program was a model of efficiency; the DWR staff was lean, and the local levee districts, because they had their money out there, managed projects very effectively.	1.29	3	0.81	2	**-0.86**	**-2**	0.84	2
27	The best governance structure for the Delta would be to let the levee districts tackle the issues island-by-island with some funding and guidance from DWR.	**0.71**	**1**	-0.95	-2	**-2.06**	**-4**	-1.19	-3

No.	Statement	Factors 1		2		3		4	
		z-score	rank	z-score	rank	z-score	rank	z-score	rank
28	The local reclamation districts maintaining the levees bring incredible institutional knowledge of a constantly evolving system. They have people who can inspect the levees under all kinds of conditions and know what to look for. They have people who know what to do in an emergency and they are ready to defend their homes, livelihoods, and families.	**1.74**	**4**	0.90	2	**-1.79**	**-3**	0.95	2
29	Federal official maintenance practices are destabilizing the levees by denuding them completely. We are spending huge amounts of money destroying vegetation and huge amounts of money creating habitat that is not sustainable.	0.08	0	-0.41	-1	**1.44**	**3**	-0.28	-1
30	The levee districts tackle the critical erosion and acute problems very effectively but they are not good at minor, everyday maintenance. Unfortunately, this inattention lets minor problems like vegetation on the levees grow into overwhelming problems and now they face major engineering and construction efforts in some many areas to get the levees back into compliance with Corps requirements.	-0.92	-2	-0.66	-1	-0.18	0	-0.25	-1
31	A single agency should be established to manage the Delta, working with counties on land use planning, superseding DWR and the Corps to execute its carefully, but expeditiously developed plan, funded on a tax on water crossing the Delta	-0.79	-1	0.27	0	-0.83	-2	-0.12	0
32	Over the last 35 years, there has never been any earthquake damage to a levee in the Delta and the whole earthquake risk thing is junk science. It is a reality that the earthquake threat has been wildly overstated and is rather specious.	0.73	1	-1.82	-4	0.31	0	-1.54	-3
33	A lot has been accomplished on reducing risk of normal every day, vanilla, levee failures but more and more we need to recognize the vulnerability to extreme events such as earthquake and very large floods that are not adequately recognized or acknowledged by some of the Delta stakeholders.	**-0.80**	**-2**	0.80	1	0.24	0	1.22	3
34	In seismic events, Delta soils become very pliable allowing the levees to roll through without cracking, subsidence, or settlement. The soils are so heterogeneous that they do not behave as poorly as some models project they would.	**0.89**	**2**	-0.58	-1	-0.34	-1	-0.37	-1

No.	Statement	Factors							
		1		2		3		4	
		z-score	rank	z-score	rank	z-score	rank	z-score	rank
35	Earthquakes represent the main risk to the water supply for 23 million Californians because of the likelihood of multiple levee failures during a significant earthquake, potentially causing severe disruptions to water supply drawn from the Delta for years.	-1.52	-3	**1.10**	**3**	-1.17	-3	**0.39**	**0**

APPENDIX F

Correlations between factor scores with 98 percent confidence interval

(Brown 1980: 286) Formula: SE=1-r^2 /SQRT(N)

	1	2	3	4
1	1.0000	-0.3464±0.1487	-0.0337±0.1688	-0.1303±0.1662
2	-0.3464±0.1487	1.0000	0.0015±0.1834	0.6137±0.1054
3	-0.0337±0.1688	0.0015±0.1834	1.0000	0.0958±0.1675
4	-0.1303±0.1662	0.6137±0.1054	0.0958±0.1675	1.0000

APPENDIX G

General statistics of factors extracted and rotated.

Factor Characteristics	1	2	3	4
No. of Defining Variables (Loaders)	9	6	2	5
Eigenvalue	7.3923	4.7439	1.7351	1.3199
Composite Reliability	0.973	0.960	0.889	0.952
Standard Error of Factor Scores	0.164	0.200	0.333	0.218
% Variance Explained	29	17	8	15
No. of distinguishing statements	13	9	11	8

APPENDIX H

Summary of social perspectives on levee failure history for the Sacramento-San Joaquin River Delta. Revised after review with highly correlated sorters.

Social Perspective	Defining Ideas
Delta Sustainers (F1)	-The Delta agricultural community levees are sustainable long term with adequate but relatively small investment. -Local knowledge and state support through the subventions program have created considerably safer and stronger levees than 25 years ago. -Concern over continuing subsidence of the islands and earthquake risk to the levees is overblown, probably for political reasons .
Abandon the Levees (F2)	-The current fresh-water Delta is non-sustainable and we should not waste more money improving doomed levee systems. -The probability is very high that multiple levee failures will be induced by seismic activity, converting the Delta to a sustainable salt-water estuary. -If water exports are to continue, the isolated conveyance system around the Delta will be required.
Levee Pragmatists (F3)	-The Delta levees may not be sustainable over the long term (100 years plus) but they can be maintained for some time with minimum resources. -The RDs, state and federal agencies all make huge errors in their work and they do not work well together in trying to manage the Delta levees. -The RDs' local knowledge is inconsistent across the Delta and tends to be eroding with time. - USACE policies on vegetation on levees decreases levee stability and damage the environment. -The effectiveness of the subventions program is overrated, in part because new methods are not encouraged.
Multi-Purpose Levees (F4)	-Recognizes that if the levees fail that the Delta will become a saltwater bay, but disagrees that DWR is promoting that development. -Believes that DWR tries to manage the Delta and the levees in compliance with the requirement to maintain status quo in the Delta while exploring a better path for the environment and water supply. - Concerned about the earthquake risk but not totally convinced it represents the main threat to Delta levees. - Open to idea of an isolated conveyance system but not enthusiastic supporters. - Believes that the environmental restoration projects have been a good investment.

APPENDIX I

ID	Respondent	Factor 1	Factor 2	Factor 3	Factor 4
135	State, Env., Manager, NR	0.1985	**0.5546**	-0.1038	0.2216
103	State, Water, Eng./Manager, NR	-0.0476	0.1985	0.2643	**0.6428**
105	State, Water, Eng., NR	-0.1085	**0.6223**	-0.3996	0.3972
111	Consult. RD, Res	**0.8377**	-0.0980	-0.0941	-0.2128
112	Consult. RD, Res	**0.8153**	-0.2552	0.0939	-0.0787
114	Farmer, RD official, Res	**0.6898**	-0.2809	-0.0055	-0.1883
115	Farmer, RD official, Res	**0.8930**	-0.1593	-0.0379	0.0867
116	State, Water, Manager, NR	0.1287	0.0824	-0.1211	**0.7343**
117	Water Contractor, Eng., NR	-0.4199	**0.7111**	-0.0130	0.3438
118	Consult Independent, Res.	-0.2477	-0.2556	**0.7092**	-0.0134
119	State, Water, Manager, NR	0.1987	**0.6628**	-0.1279	0.5064
120	Consult, Independent, NR	0.0966	0.2662	**0.6814**	0.2167
124	Consult. RD, Res.	**0.8185**	-0.1301	0.0749	0.1352
125	Fed., Env. Scientist, NR	-0.3890	**0.6305**	0.3260	0.3650
127	State, Env. Manager, NR	-0.0865	0.4777	0.2636	**0.5684**
129	NGO, Env., NR	-0.2956	**0.8339**	-0.0053	0.1412
131	Fed., Water, Eng., NR	-0.1903	0.2046	-0.0037	**0.8024**
132	Consult. RD, Res.	**0.8321**	-0.0358	0.3036	-0.1534
133	Consult. RD, Manager, NR	**0.5751**	0.4321	0.2011	0.3531
134	State, Water, Manager, NR	0.0738	0.4519	-0.3241	**0.6218**
135	Farmer, RD official, Res.	**0.8413**	0.0479	-0.0415	-0.2462
121	Consult. RD, NR	**0.7788**	-0.1728	-0.0906	0.2526

NOTES: 1) Consult. RD = provides engineering, management, and/or legal support primarily to levee districts
2) Consult. Independent = provides construction, environmental, or engineering support at all levels
3) State includes state and county agencies
4) "Water" includes flood control and water supply
5) NR = Not a Delta resident, Res. = Legal Delta resident
6) Env. = environmental resources

APPENDIX J

APPENDIX J				
Respondent Number	Background	2009 Interview Month -2009	2010 Q-Sort Month -2010A	2010 Q-Sort Verification -2010B
101	Consult, Industry,Eng., NR	July	N/A	N/A
102	Manager, RD, Advocacy, NR	July	N/A	N/A
103	Eng./Manager, State, Flood control, NR	July	July	November
104	Consult., General, Flood control, NR	July	N/A	N/A
105	Engineer, State, Flood control, NR	July	July	N/A
106	ENGO, Manager, NR	July	N/A	N/A
107	Consult. Ind. Eng/ Manager, NR	July	N/A	N/A
108	Consult. Ind. Engineer, NR	July	N/A	N/A
109	Consult-RD, Eng. NR	July	N/A	N/A
110	Consult.- Gov, Engineer/Manager, Flood Control	July	N/A	N/A
111	Consult. RD, Engineer ,Res	July	July	November
112	Consult. RD, Law, Res	July	July	N/A
113	Gov., Advocacy, NR	July	N/A	N/A
114	Farmer, RD official, Res	July	July	N/A
115	Farmer, RD official, Res	July	July	November
116	State, Water, Manager, NR	July	July	November
117	Water Contractor, Eng., NR	July	July	November
118	Consult-Independent, Eng., Levee, NR.	July	July	November
119	State, Water, Manager, NR	July	July	N/A
120	Consult, Independent, Res.	July	July	November
121	Consult. RD, Eng., NR	August	July	November
122	State, Water, Eng. NR	August	N/A	N/A
123	Political official, Law, Resident	August	July	N/A
124	Consult. RD, Eng, Res.	August	July	N/A
125	Fed., Env. Scientist, NR	August	July	N/A
126	Fed., Engineer, Flood Control, NR	August	N/A	N/A
127	State, Env. Manager, NR	August	E-Mail	N/A
128	State, Engineer Manager, NR	August	N/A	N/A
129	NGO, Engineer, NR	August	July	November
130	Local activist, Res.	August	N/A	N/A
131	Fed., Eng., Flood control, NR	N/A	July	November
132	Consult. RD,Law, Res.	N/A	July	N/A
133	Consult. RD, Manager/Biology, NR	N/A	July	N/A
134	State, Water, Manager, NR	N/A	July	N/A
135	Farmer, RD official, Res	N/A	July	N/A
136	State, Environmental/Manager NR.	N/A	E-Mail	N/A

Consult RD = provides engineering, management, and/or legal support primarily to levee districts; Consult-Ind. (Indepedent) - consults for all, Consult Gov.=consulting for state or federal; Political official= elected or appointed; State includes state and county agencies, NR = Not resident of Legal Delta, Res . = Resident of Legal Delta, Fed. = federal employee

APPENDIX K

Summary of selected Q-Method Studies in Geography and related Fields 1999-2011

Paper	Subject	Concourse	Q-set	P-Set	Factors	Finding and Notes
(Barry and Proops 1999)	How individuals think about the environment so that socially and politically acceptable policies can be generated. *(England)*	Created by structured interviews.	36	25	4	Q-Method is a statistically rigorous approach to the subjective perceptions of human–nature relationships, making it useful for environmental policy making.
(Robbins 2000)	Differences between state and local environmental knowledge *(India)*	N/A	17	62	4	Found that the state versus local epistemological division was less meaningful than the daily conflict over resources in the local political economy.
(Robbins and Krueger 2000)	A participatory planning process for the Northern Forest Lands region of the US	400 "Grounded Theory" important	45	37	5	Q-Method is qualitative and quantitative, and can lead to "discursive democratization" but cannot nor necessarily should it totally remove the subjectivity of the researcher.
(Focht 2002)	Watershed management in Oklahoma where scientific uncertainty exist about the probable impacts of policy options and persistent value disagreement over ends and goals. Divided into: A) Impact concerns B) Impact Management Preferences	3000 (from 150 Interviews)	47 58	99 99	5 4	Q-Method found to be powerful in assessing conflict allowing opportunities for resolution between parties "Q methodology gets beneath positional posture by providing insight into the underlying premises and values" (1337)
(Eden, Donaldson, and Walker 2005)	Production and use of environmental science by NGOs.	200-500	40	13? Not stated	2? Not stated	Q-Method helps render viewpoints more explicit which helps make it useful in policy development. Judgment required infuses Q with researcher subjectivity.

Paper	Subject	Concourse	Q-set	P-Set	Factors	Finding and Notes
(Robbins 2006)	Investigation of interaction of state, civil society, and local knowledge and power in the formation and working of discourse coalitions.	20	20	30	2	Montana wildlife management policies have developed from discursive alliance of landowners, outfitters, and environmentalists, to the exclusion and disadvantage of the local hunters.
(Swedeen 2006)	Conflict-ridden ecosystem management concerns in the forest management in the NW United States.	200	64	30	3 (See Note 1)	Q-Method can help gain understanding of the values held by various stakeholders' discourses about ecosystem management. Talks about several ways to employ Q in consensus building efforts.
(Pini, Previte and Haslam-McKenzie 2007)	Rural government management of natural resources in Australia per the Local Agenda 21 of the UN	Developed from 93 interviews	56	28	5	Several perspectives exist which do not support the concept of local government agencies taking a larger role in environmental management, contrary to Agenda item 21 of the UN.
(Hall 2008)	Scottish farmer attitudes toward genetic modified crops	700	48	15	3	Scottish farmers looking at genetic modified crops have concerns but hold a middle ground position between the pro and anti GM interests.
(Ellis, Barry and Robinson 2007a)	Discourses of support and objection to wind farms offshore Northern Ireland.	458	50	46	8 Note 2	Q-Method can add to understanding of how public acceptance is constructed (of wind power), gained by bridging positivist and post-positivist approaches.
(Raadgever, Mostert and van de Giesen 2008)	Stakeholder perspectives on future flood management in the lower Rhine basin. (Germany &NL)	N/A - 23 semi-structured interviews.	46	47 (See Note 3)	3	Q-Method can help develop an overview of stakeholder perspectives, which can increase awareness of other perspectives, potentially facilitating interactions and reflection, which may help develop consensus.
(Ockwell 2008)	Fire management policies in the Dry Cape York region of Australia	304 – (see note 4)	36	32	4	Q-Method allowed the fire policy in Queensland to be opened; it gave voice to some marginalized, but valuable, perspectives. Q can take snapshots of discourses only, cannot measure trends.

Paper	Subject	Concourse	Q-set	P-Set	Factors	Finding and Notes
(Venables et al. 2009)	Perspectives of neighbors of operating risk of two UK nuclear power plant.	400	62	84 (Note 5)	4	Q-Method helped confirm that “. nuclear power in the United Kingdom continues to elicit strong opposition as well as support.” (p. 1102)
(Lopez-i-Gelats, Tabara and Jordi 2009)	Local perspectives of what is rural in an area of the Spanish Pyrenees	200	36	21	4	Q-Method enables emerging and neglected perspectives to be identified. It also can encourage more meaningful and open policy and discourse dialogue identifying areas of difference/consensus.
(Hennessy 2009)	Key stakeholder perspectives on the barriers to graywater reuse in Vancouver, B.C.	250 (from literature)	47	25	3	Exposed opportunity to study graywater users in other area or understand the perspectives of a wider population
(Doody et al. 2009)	Bottoms up and tops down sustainability measures using Q	750 from 11 focus group meetings	40	37 from public	6 (See note 6)	“Q-Method helped generate robust sustainability indicators that reflected the technical needs of the government agencies and that reflected the concerns, interest, and views of the general public.
(Person 2010)	Social perspectives of the elites in Nolan County, Texas relative to the wind energy business arriving in the region.	300	27	21	5	Q-Method generated understanding of perceptions of the elites, decision makers, and key stakeholders, information that can help wind power companies understand how their projects are perceived.
(Brannstrom 2011)	Environmental governance in the expanding soy belt in Bahia state, Brazil.	42	26	21	4	Q-Method is an ends and a means in research, providing social perspectives as it develops an interview setting conducive to asking confrontational questions.
(Bischof 2010)	Find consensus among competing scientific discourses about what to do about the worldwide coral reef environmental crisis.	158	43	31 (See Note 7)	4	Q-Method provides an organized way to understand basic beliefs embedded in scientific knowledge (of coral reefs), allowing them to be reorganized in different ways to better guide policy and research.

Paper		Subject	Concourse	Q-set	P-Set	Factors	Finding and Notes
		STATISTICS FOR 19 STUDIES					
		Average (Mean)		41.04	33.26	4.22	
		Maximum	3000	64	66	8	
		Minimum	19	17	15	2	
		Median		42	30	4	
		Mode		36	21	4	
		THIS DISSERTATION	150	35	22	4	

Summary notes: 1) Swedeen used centroid factor analysis followed by both Varimax rotation and manual rotation

2) Ellis *et al*. initially found just two factors, supporters and non-supporters of wind energy, but when they divided the responses into those two groups, four factors or perspectives emerged from each of those viewpoints.

3) Raadgever *et al*, In establishing their P-set, 200 were invited to participate, 47 did so using online tool, set up using free web-based software (available at http://q.sortserve.com)

4) Concourse included items from aboriginal anthropological studies because of language problems

5) Venebles *et al*. in the P-set, 41 from each site who were initially identified using professional recruitment service

6) Doody *et al.* used PCQwin software (http://www.pcqsoft.com/) and Varimax rotation

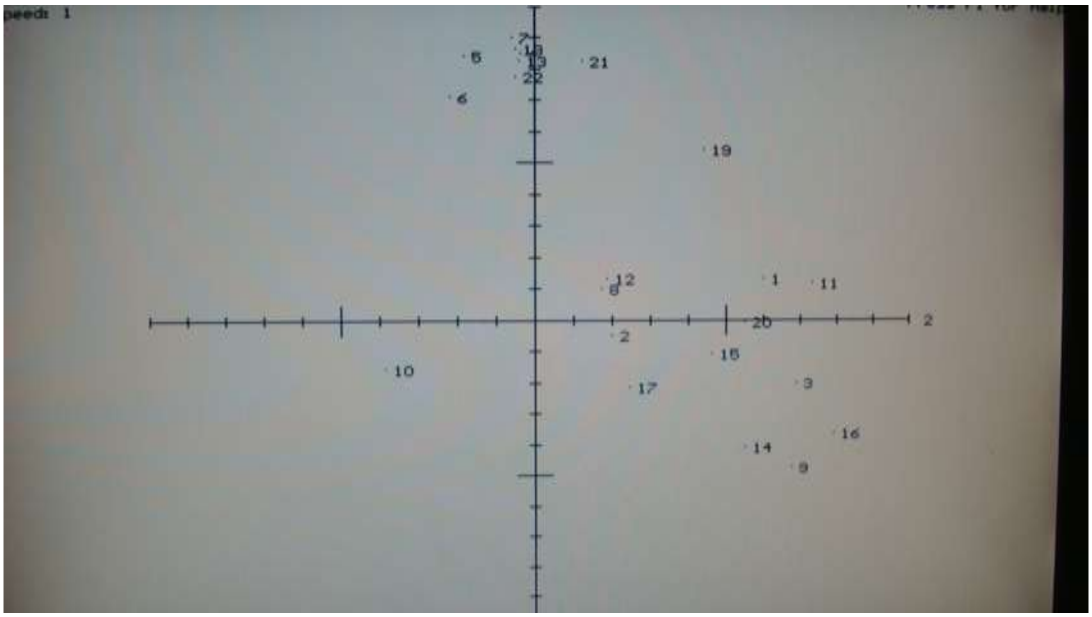
7) In Bischof, for the P-set, 240 reef specialists were contacted by e-mail, 31 sorts returned by target date

APPENDIX L

Screen shots of P-Method before and after manual rotation steps.

Figure L.1- Plot of Factors 1 and 2 Before and After Manual Rotation

L.1A FACTOR 1-2 After Varimax Rotation



L.1B FACTOR 1-2 After subsequent manual rotations

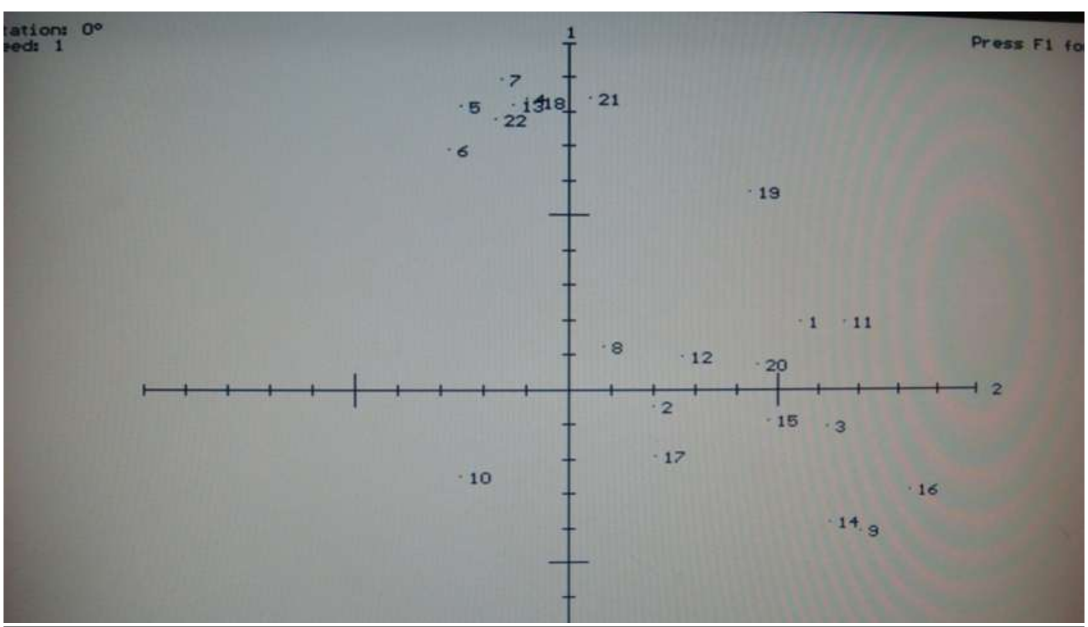
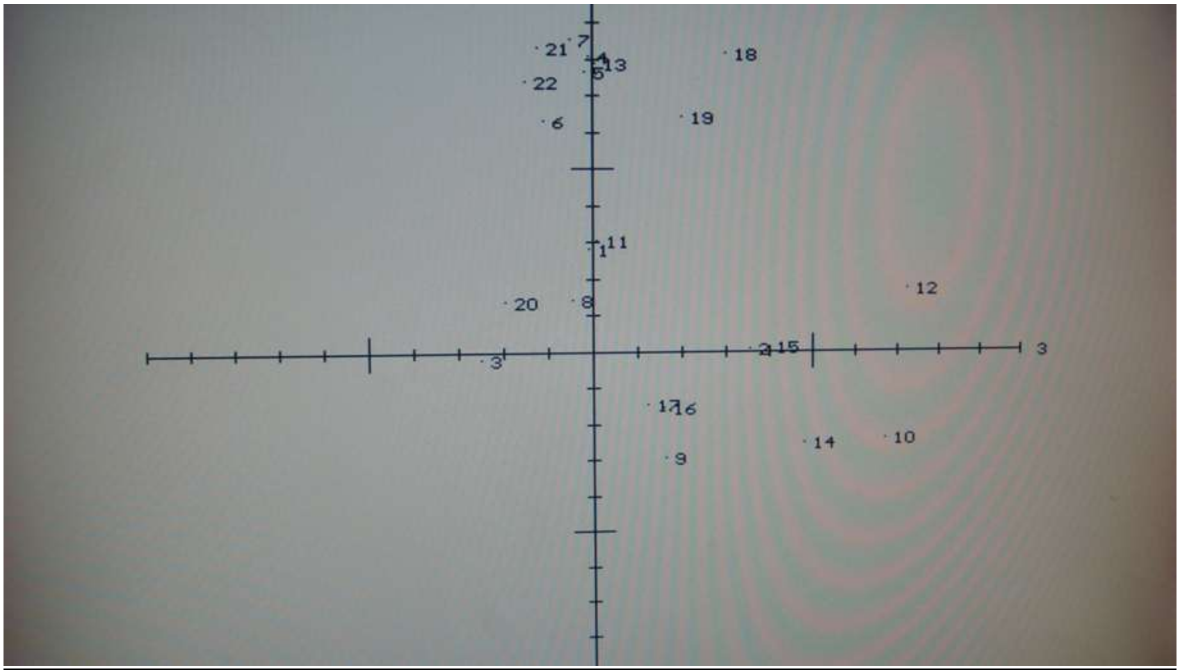


Figure L.2 - Plot of Factors 1 and 3 Before and After Manual Rotation

L.2A FACTOR 1-3 After Verimax Rotation



L.2B FACTOR 1-3 After manual rotation

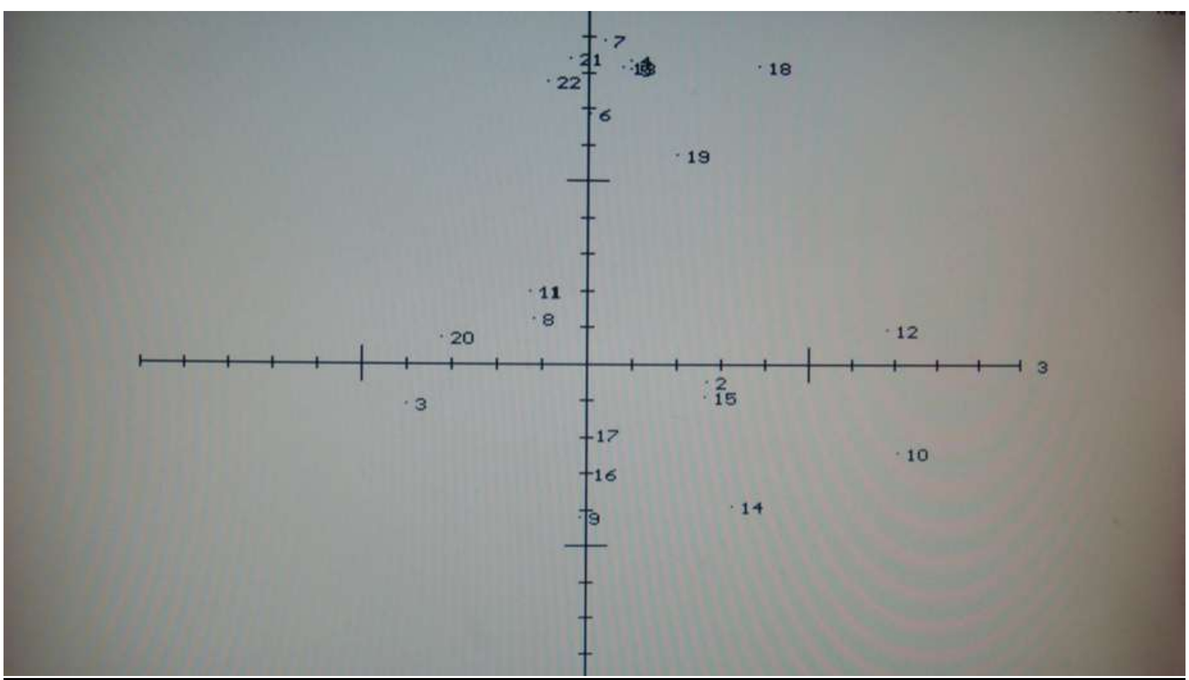
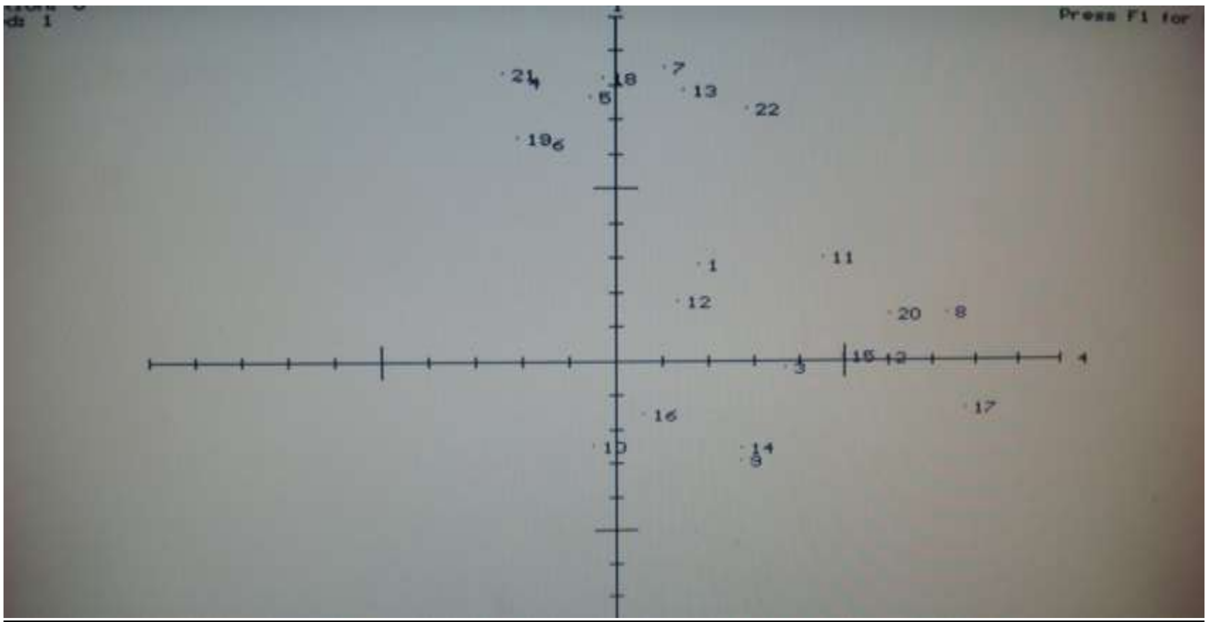
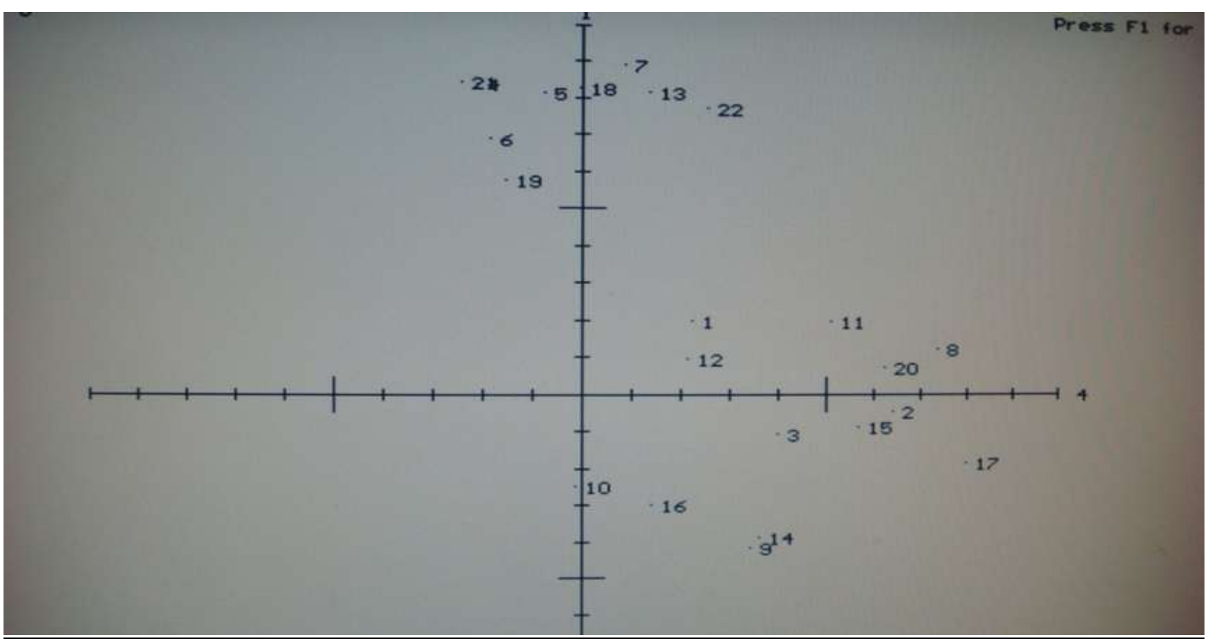


Figure L.3- Plot of Factor 1 and 4 Before and After Manual Rotation

L.3A FACTOR 1-4 After Varimax Rotation



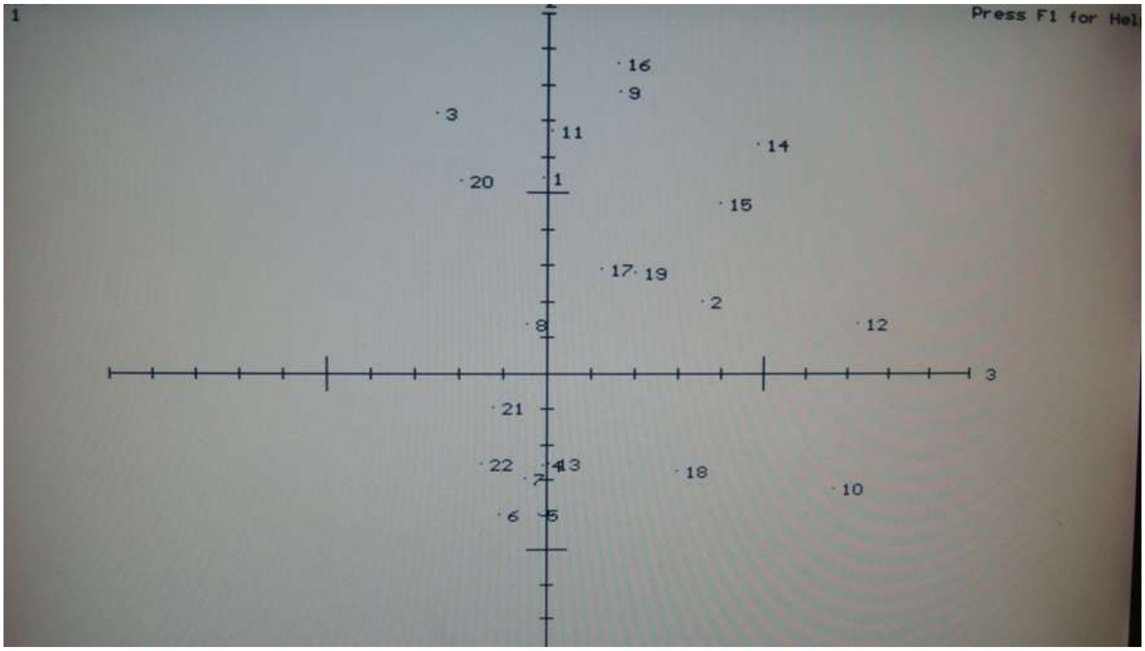
L.3B Factors 1-4 after Manual rotation



Note: factors 1 and 4 were not directly rotated against one another, however they rotated relative to each other as part of their respective rotations with Factors 2 and 3.

Figure L.4- Plot of Factor 2 and 3 Before and After Manual Rotation

L.4A FACTOR 1-2 After Varimax Rotation



L.4B FACTORS 2-3 after rotation

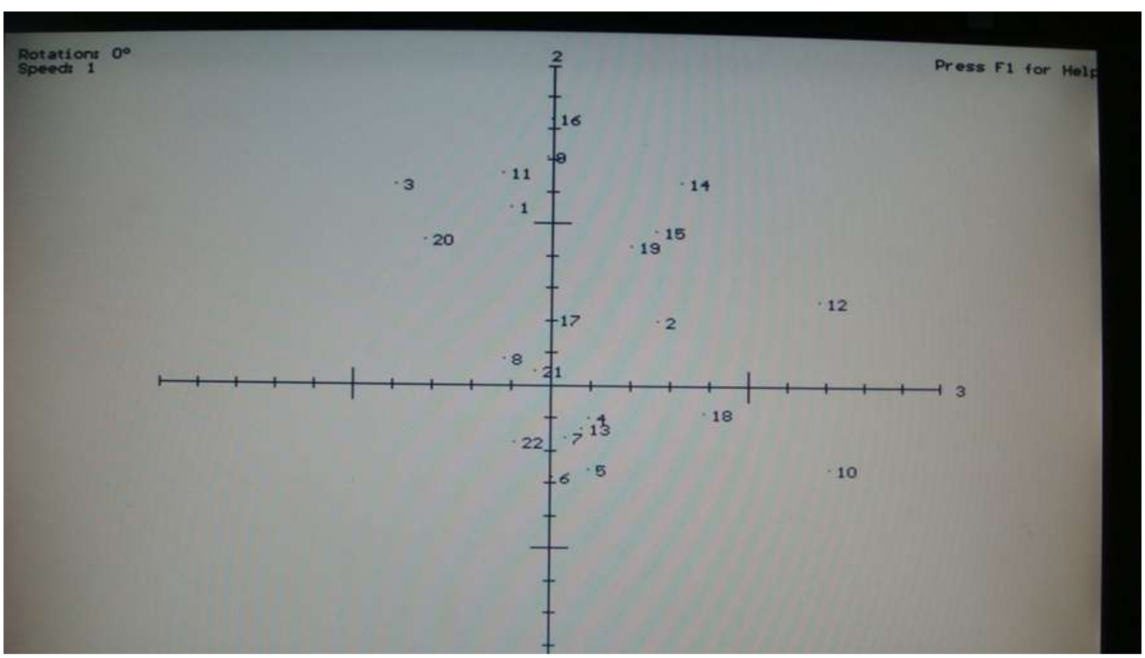
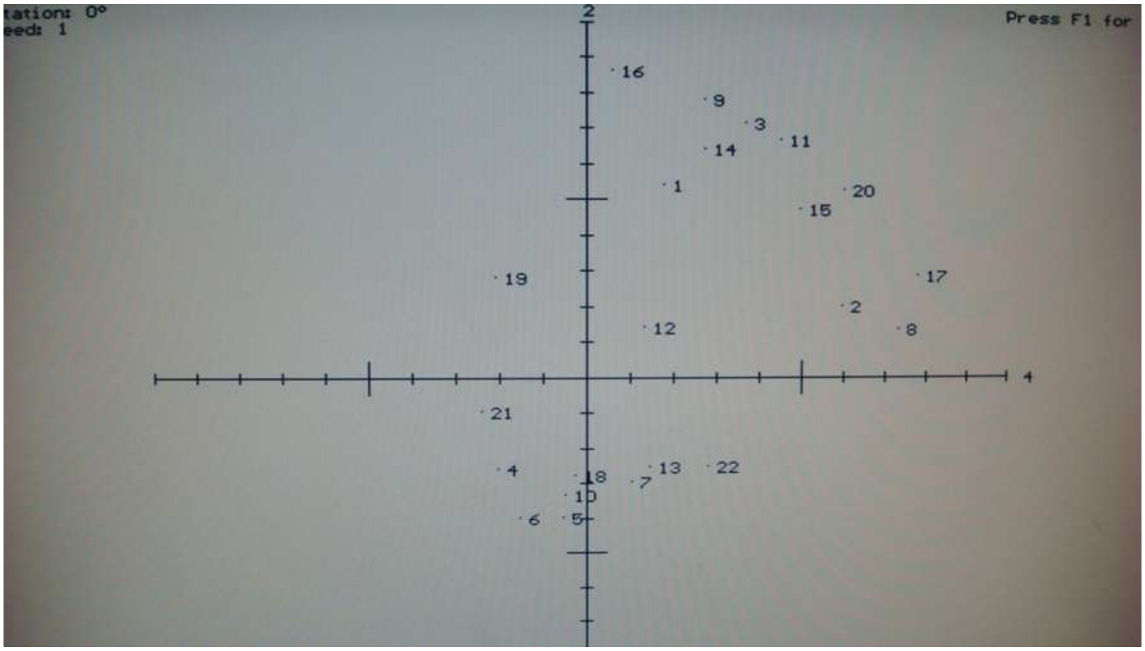


Figure L.5- Plot of Factor 2 and 4 Before and After Manual Rotation

L.5A FACTOR 2-4 After Varimax Rotation



L.5B FACTOR 2-4 After Manual Rotations

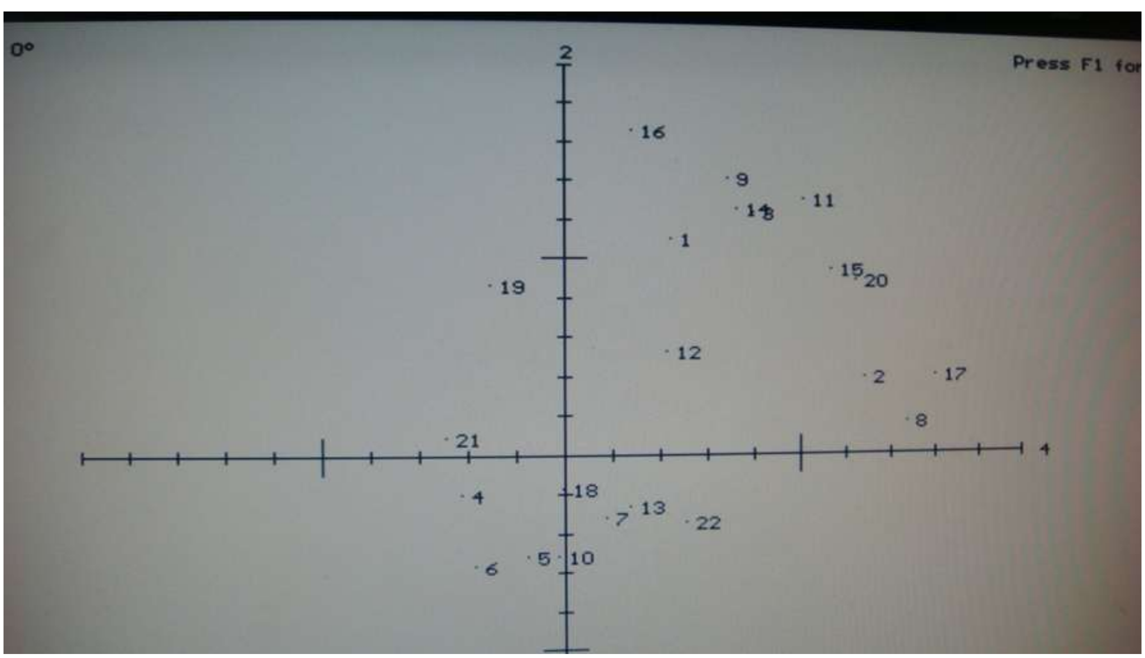
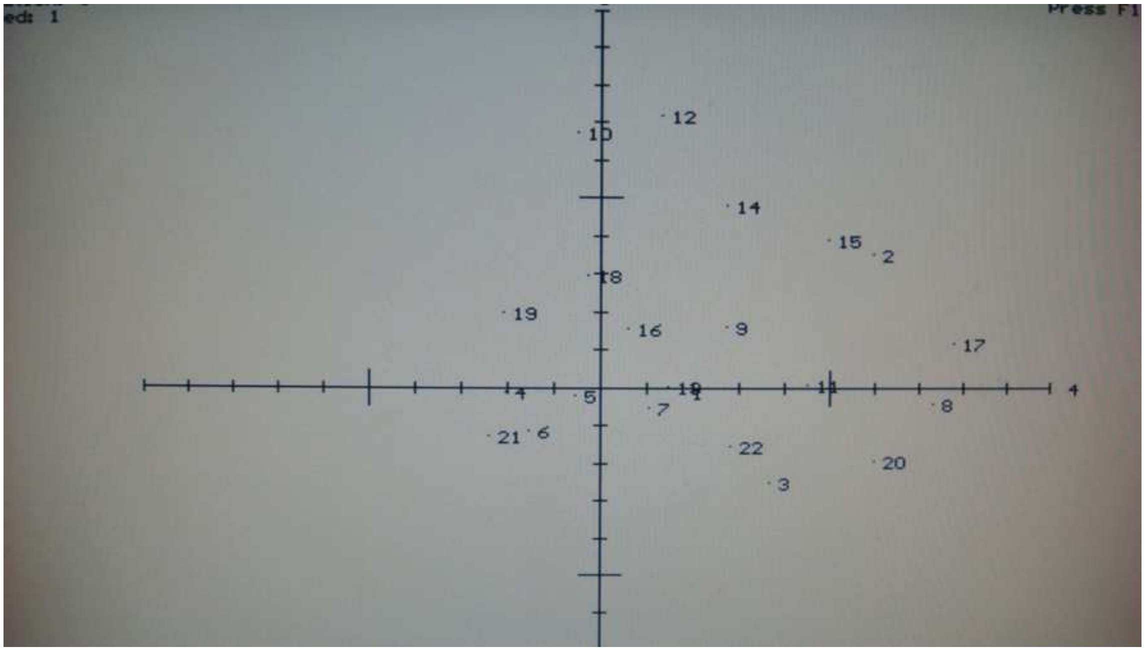
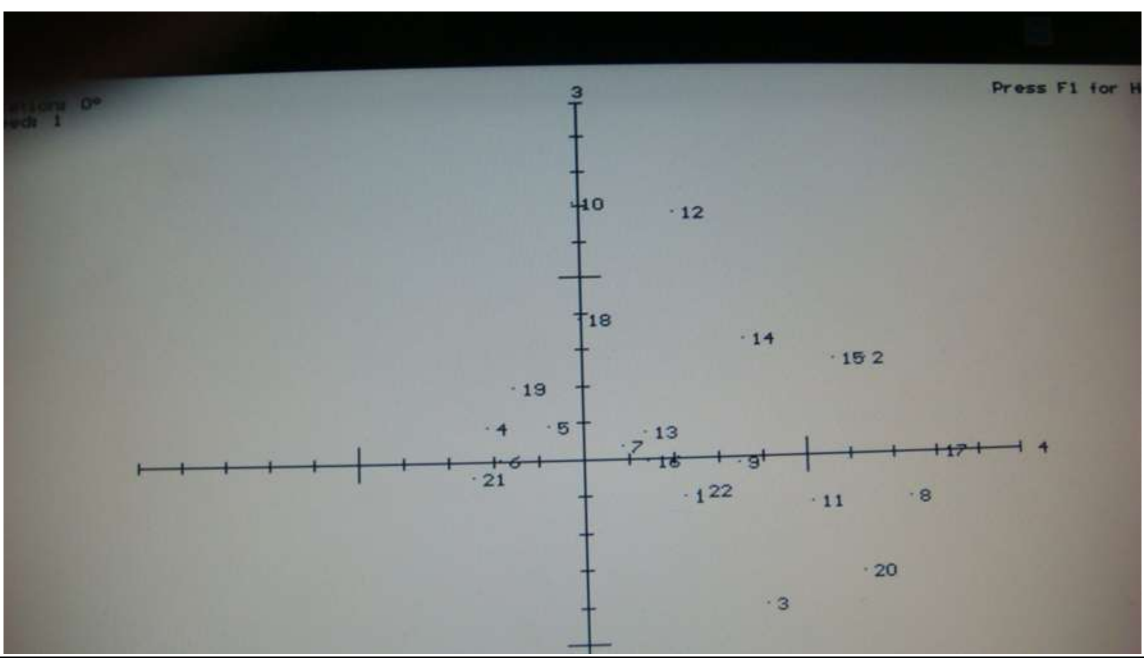


Figure L.6- Plot of Factor 3 and 4 Before and After Manual Rotation

L.6A FACTOR 3-4 After Varimax Rotation



L.6B FACTOR 3-4 After Manual Rotation



APPENDIX M

APPENDIX M - DELTA LEVEE FAILURES 1868-2010						
1868	R.D. 17			Peat levee	N/A	5800
1872	Brannan-Andrus		BRA-SAC	Peat levee	N/A	15003
	Grand			Peat levee	N/A	16000
	Sherman	1/8/1872	SHE-SAC	Peat levee	N/A	10420
	Twitchell			Peat levee	N/A	3633
	Twitchell			Peat levee	N/A	3633
1873	Jersey			Peat levee	N/A	3471
1874	Bethel			Peat levee	N/A	3520
	Bouldin			Peat levee	N/A	6047
	Twitchell		TWI-SAN	Peat levee	N/A	3633
1875	Byron Tract		BYR-OLD	Peat levee	N/A	
	R.D. 17		D17-SAN	Peat levee	N/A	5800
	Rough and Ready			Peat levee	N/A	1216
	Sherman			Peat levee	N/A	10420
	Twitchell	1/15/1875		Peat levee	N/A	3633
1876	Sherman	2/1876		Peat levee	N/A	10420
	Union			Peat levee	N/A	24951
1878	Brannan-Andrus	2/21/1878	BRA-SAC	Peat levee	N/A	15003
	Byron Tract	2/24/1878		Peat levee	N/A	6933
	East Sacramento	2/5/1878	SAC-SAC	Peat levee	N/A	
	Freeport area	2/3/1878	SAC-SAC	Peat levee	N/A	
	Grand	2/21/1878	GRA-STE	Peat levee	N/A	16000
	Jersey	2/24/1878		Peat levee	N/A	3471
	Lisbon	-		Peat levee	N/A	
	Merritt Island	2/22/1878	MER-ELK	Peat levee	N/A	
	Netherlands (Clarksburg)	2/22/1878		Peat levee	N/A	
	Pierson District	2/22/1878		Peat levee	N/A	8990

APPENDIX M - Continued						
W. Year	**Island or tract**	**Date**	**Levee Segment**	**Classification**	**Subvention status**	**Area** Acres
	Ryer	2/25/1878		Peat levee	N/A	11600
	Sherman	2/19/1878	SHE-SAC	Peat levee	N/A	10420
	Staten Island	2/21/1878		Peat levee	N/A	
	Twitchell			Peat levee	N/A	3633
	Tyler	2/24/1878	TYL-MKN	Peat levee	N/A	8583
	Union	2/21/1878	UNI-MID	Peat levee	N/A	24951
	Union	5/15/1878		Peat levee	N/A	24951
	Venice	2/24/1878		Peat levee	N/A	3220
1879	Brannan-Andrus		BRA-SAC	Peat levee	N/A	15003
	Grand		GRA-SAC	Peat levee	N/A	16000
	Sherman		SHE-SAC	Peat levee	N/A	10420
	Sutter		SUT-SAC	Peat levee	N/A	
1880	Roberts, Lower	6/22/1880		Agricultural	N/A	10600
	Roberts, Middle			Agricultural	N/A	13687
	Roberts, Upper			Agricultural	N/A	8260
1881	900	1/31/1881	900-SAC	Agricultural	N/A	
	Bouldin			Agricultural	N/A	6047
	Brannan-Andrus	1/29/1881		Agricultural	N/A	15003
	Brannan-Andrus	2/2/1881	BRA-SAC	Agricultural	N/A	15003
	Grand	2/4/1881		Agricultural	N/A	16000
	Lisbon	1/31/1881		Agricultural	N/A	
	Merritt		MER-ELK	Agricultural	N/A	4900
	Pierson District	2/2/1881	PEA-SAC	Agricultural	N/A	8990
	Roberts	2/5/1881		Agricultural	N/A	
	Sherman	2/3/1881	SHE-SAC	Agricultural	N/A	10420
	Staten	2/1/1881		Agricultural	N/A	9088
	Sutter	2/3/1881	SUT-SUT	Agricultural	N/A	

APPENDIX M - Continued						
W. Year	Island or tract	Date	Levee Segment	Classification	Subvention status	Area Acres
	Sutterville-Freeport	1/31/1881	SAC-SAC	Agricultural	N/A	
	Union	2/6/1881		Agricultural	N/A	24951
1886	R.D 17	1/26/1886	D17-SAN	Agricultural	N/A	
	Roberts, Lower	1/31/1886	ROL-SOU	Agricultural	N/A	10600
	Roberts, Middle	1/26/1886	ROM-SAN	Agricultural	N/A	13687
	Staten Island	2/12/1886		Agricultural	N/A	
1890	900	12/22/1889	900-SAC	Agricultural	N/A	
	Brannan-Andrus	3/12/1890	BRA-SAC	Agricultural	N/A	15003
	Drexler Tract	5/29/1890	DRE-MID	Agricultural	N/A	
	Lisbon	1/26/1890	LIS-BAB	Agricultural	N/A	
	New Hope Tract	3/5/1890	NEW-MOK	Agricultural	N/A	9743
	Paradise Junction		PAR-SAN	Agricultural	N/A	9300
	Ryer	12/16/1889		Agricultural	N/A	11600
	Sutter	12/26/1889	SUT-SUT	Agricultural	N/A	
	Tyler	3/8/1890		Agricultural	N/A	8583
	Union	5/23/1890	UNI-GRA	Agricultural	N/A	24951
1892	Rough and Ready			Agricultural	N/A	1216
1893	Roberts, Lower			Agricultural	N/A	10600
	Roberts, Middle			Agricultural	N/A	13687
	Roberts, Upper			Agricultural	N/A	8260
	Ryer	1/2/1893		Agricultural	N/A	11600

APPENDIX M - Continued						
W, Year	**Island or tract**	**Date**	**Levee Segment**	**Classification**	**Subvention status**	**Area** Acres
1899	New Hope Tract	3/27/1899	NEW-MOK	Agricultural	N/A	9743
	Terminous Tract	3/27/1899	TER-SMO	Agricultural	N/A	10470
1900	Jersey			Agricultural	N/A	3471
1901	Clifton Court	2/24/1901		Agricultural	N/A	3100
	Fabian Tract	2/24/1901	FAB-OLD	Agricultural	N/A	6530
	Fabian Tract	5/20/1901	FAB-OLD	Agricultural	N/A	6530
1901	Pescadero	5/20/1901	PES-PAR	Agricultural	N/A	3000
	R.D. 17	2/21/1901	D17-SAN	Agricultural	N/A	5800
	Stewart Tract		STE-PAR	Agricultural	N/A	3900
	Victoria	2/24/1901	VIC-OLD	Agricultural	N/A	7250
1902	Brack Tract	3/2/1902		Agricultural	N/A	4873
	Brannan-Andrus	3/2/1902	BRA-SAC	Agricultural	N/A	15003
	Egbert Tract	3/1/1902		Agricultural	N/A	
	Ryer	3/2/1902		Agricultural	N/A	11600
	Sargent-Barnhart Tract	3/2/1902		Agricultural	N/A	1214
1904	900 (Washington 'West Sac")	2/26/1904		Agricultural	N/A	
	Bishop Tract	3/3/1904		Agricultural	N/A	2169
	Bouldin	3/3/1904	BOU-SMO	Agricultural	N/A	6047
	Brack Tract	3/1/1904	BRK-SYC	Agricultural	N/A	4873
	Brannan-Andrus	3/2/1904		Agricultural	N/A	15003
	Cohen Tract	3/3/1904		Agricultural	N/A	

APPENDIX M - Continued						
W, Year	Island or tract	Date	Levee Segment	Classification	Subvention status	Area Acres
	Edwards Break	2/28/1904	SAC-SAC	Agricultural	N/A	
	Egbert Tract			Agricultural	N/A	
	Jersey	3/2/1904		Agricultural	N/A	3471
	New Hope Tract	2/29/1904	NEW-MOK	Agricultural	N/A	9743
	Ryer	3/2/1904	RYE-CAC	Agricultural	N/A	11600
	Sargent-Barnhart Tract	3/2/1904		Agricultural	N/A	1214
	Sherman	3/2/1904	SHE-SAC	Agricultural	N/A	10420
	Staten	2/29/1904		Agricultural	N/A	9088
	Terminous Tract	3/2/1904		Agricultural	N/A	10470
	Tyler	2/29/1904	TYL-MKN	Agricultural	N/A	8583
	Venice	3/3/1904		Agricultural	N/A	3220
1906	Drexler Tract	7/9/1906	DRE-MID	Agricultural	N/A	
	Sherman	7/9/1906		Agricultural	N/A	10420
	Twitchell	7/8/1906		Agricultural	N/A	3633
	Union	6/25/1906		Agricultural	N/A	24951
	Upper Jones Tract	7/11/1906		Agricultural	N/A	6259
	Venice	7/9/1906		Agricultural	N/A	3220
1907	Bethel	3/26/1907	BET-SOU	Agricultural	N/A	3520
	Bouldin	3/26/1907	BOU-POT	Agricultural	N/A	6047
	Brannan-Andrus	3/23/1907	BRA-SAC	Agricultural	N/A	15003
	Bryon Tract	3/26/1907		Agricultural	N/A	
	Clifton Court	3/26/1907		Agricultural	N/A	3100
	Coney			Agricultural	N/A	935
	Franks Tract		FRA-FAL	Agricultural	N/A	3300
	Jersey	3/26/1907		Agricultural	N/A	3471
	Lisbon District	3/24/1907	LIS-SAC	Agricultural	N/A	
	Lower Jones Tract	3/1907		Agricultural	N/A	5894

APPENDIX M - Continued						
W, Year	**Island or tract**	**Date**	**Levee Segment**	**Classification**	**Subvention status**	**Area**
1907	New Hope Tract		NEW-MOK	Agricultural	N/A	9743
	Palm Tract	3//1907	PAL-OLD	Agricultural	N/A	2436
	Pierson (Private) Gammon Ranch			Agricultural	N/A	8990
	Pierson(Private) Terry Estate	3/24/1907		Agricultural	N/A	8990
	Pierson (Private) Hollister Ranch	3/24/1907		Agricultural	N/A	8990
	Pierson (Private) Johnson Ranch	3/24/1907		Agricultural	N/A	8990
	Randall	3/26/1907	RAN-SAC	Agricultural	N/A	420
	RD 813	3/24/1907		Agricultural	N/A	
	Rindge Tract		RIN-SAN	Agricultural	N/A	
	Ryer	2/24/1907	RYE-CAC	Agricultural	N/A	11600
	Sargent-Barnhart Tract			Agricultural	N/A	1214
	Smith Tract	3/26/1907		Agricultural	N/A	
	Staten			Agricultural	N/A	9088
	Terminous Tract			Agricultural	N/A	10470
	Twitchell			Agricultural	N/A	3633
	Tyler	2/24/1907		Agricultural	N/A	8583
	Union	3/26/1907		Agricultural	N/A	24951
	Veale Tract	3/26/1907		Agricultural	N/A	1298
	Venice	3/26/1907		Agricultural	N/A	3220
	Victoria	3/1/1907	VIC-NOR	Agricultural	N/A	7250
1908	Bouldin	1/15/1908		Agricultural	N/A	6047
	Jersey	1/1/1908	JER-SAN	Agricultural	N/A	3471

APPENDIX M - Continued						
W, Year	Island or tract	Date	Levee Segment	Classification	Subvention status	Area Acres
1909	Bethel	1/24/1909	BET-SOU	Agricultural	N/A	3520
	Brannan-Andrus			Agricultural	N/A	15003
	Clifton Court	1/21/1909	CLI-BAC	Agricultural	N/A	3100
	Jersey		JER-SAN	Agricultural	N/A	3471
	Lower Sherman			Agricultural	N/A	
	Sherman	1/21/1909	SHE-SAC	Agricultural	N/A	10420
	Twitchell	1/21/1909	TWI-SAN	Agricultural	N/A	3633
	Venice	1/21/1909	VEN-SAN	Agricultural	N/A	3220
1911	Bethel			Agricultural	N/A	3520
	R.D. 17	2/1/1911	D17-SAN	Agricultural	N/A	5800
1919	Prospect			Agricultural	N/A	1100
1925	Bouldin			Agricultural	N/A	6047
	Donlon			Agricultural	N/A	3000
	Lower Sherman			Agricultural	N/A	
	Pico/Naglee			Agricultural	N/A	3000
1928	Big Break		BIG-SAC	Abandoned	N/A	2200
	New Hope Tract			Agricultural	N/A	9743
	River Junction	3/26/1928	RIV-STA	Agricultural	N/A	3000
1932	Venice		VEN-SHC	Direct Agreement	N/A	3220
1934	Donlon	1/2/1934		Agricultural	N/A	3000
1935	River Junction	5/31/1935	RIV-SAN	Agricultural	N/A	3000
1936	Franks Tract	2/23/1936	FRA-FAL	Agricultural	N/A	3300
	Liberty	2/15/1936	LIB-PRO	Non-Project-Restricted height	N/A	3449
	Little Holland	2/15/1936	LHO-ALL	Non-Project-Restricted height	N/A	
	Medford	2/2/13/1936	MED-MID	Agricultural	N/A	1219
	Quimby	2/15/1936	QUI-OLD	Agricultural	N/A	769

APPENDIX M - Continued						
W, Year	**Island or tract**	**Date**	**Levee Segment**	**Classification**	**Subvention status**	**Area Acres**
1937	Donlon		DON-WES	Abandoned	N/A	3000
1938	Franks Tract	2/11/1938	FRA-FAL	Abandoned	N/A	3300
	Liberty	2/12/1938	LIB-DRE	Non-Project-Restricted height	N/A	3449
	Mandeville	2/13/1938	MAN-SAN	Direct Agreement	N/A	5238
	Pescadero	2/12/1938		Agricultural	N/A	3000
	Prospect	2/19/1938		Non-Project-Restricted height	N/A	1100
	Quimby		QUI-OLD	Agricultural	N/A	769
	Rhode Island	2/13/1938	RHO-OLD	Agricultural	N/A	100
	River Junction	2/14/1938		Agricultural	N/A	3000
	Stewart Tract			Agricultural	N/A	3900
	Venice		VEN-SAN	Direct Agreement	N/A	3220
1940	Egbert Tract	3/1/1940	EGB-LIN	Agricultural	N/A	
	Hastings Tract	3/1/1940		Agricultural	N/A	
	Liberty		LIB-DRE	Non-Project-Restricted height	N/A	3449
	Little Holland	1/12/1940		Non-Project-Restricted height	N/A	
	Prospect	3/2/1940		Non-Project-Restricted height	N/A	1100
	Rio Vista	3/3/1940		Urban	N/A	
1950	Bradford	6/2/1950	BRD-SAN	Direct Agreement	N/A	2143
	Webb Tract	6/2/1950	WEB-SAN	Direct Agreement	N/A	5490
1951	McMullin Ranch	11/25/1950	MCM-SAN	Agricultural	N/A	6792
	Mossdale			Agricultural	N/A	1325
	Pescadero	12/5/1950		Agricultural	N/A	3000
	R.D. 17	12/7/1950	D17-SAN	Agricultural	N/A	5800
	Venice	12/3/1950	VEN-SHC	Direct Agreement	N/A	3220

APPENDIX M - Continued						
W, Year	Island or tract	Date	Levee Segment	Classification	Subvention status	Area Acres
1952	McMullin Ranch	6/15/1952	MCM-SAN	Agricultural	N/A	6792
1956	Bradford	12/24/1955	BRD-SAN	Direct Agreement	N/A	2143
	Dead Horse	12/26/1955	DEA-DEA	Non-Project Ag	N/A	211
	Empire Tract	12/26/1955	EMP-LPO	Non-Project Ag	N/A	3723
	Hastings Tract	12/26/1955	HAS-CAC	Project	N/A	
	McCormack-Williamson Tract	12/25/1955	MWT-EAS	Non-Project-Restricted height	N/A	1639
	McMullin Ranch	12/25/1955	MCM-SAN	Project	N/A	6792
	Quimby		QUI-HOL	Non-Project Ag	N/A	769
	River Junction	12/25/1955	RIV-SAN	Project	N/A	3000
1958	Dead Horse	12/25/1957	DEA-DEA	Non-Project Ag	N/A	211
	McCormack-Williamson Tract	4/4/1958	MWT-EAS	Non-Project-Restricted height	N/A	1639
1963	Liberty	10/16/1962	LIB-DRE	Non-Project-Restricted height	N/A	3449
1963	Liberty	2/2/1963	LIB-DRE	Non-Project-Restricted height	N/A	3449
	Little Holland	10/15/1962		Non-Project-Restricted height	N/A	
	Little Holland	2/1/1963	LHO-ALL	Non-Project-Restricted height	N/A	
	Prospect	10/15/1962	PRO-MIL	Non-Project-Restricted height	N/A	1100
	Prospect	2/1/1963	PRO-MIL	Non-Project-Restricted height	N/A	1100
1965	Egbert Tract	12/24/1964	EGB-LIN	Project	N/A	
	McCormack-Williamson Tract	12/1/1964	MWT-EAS	Non-Project-Restricted height	N/A	1639

APPENDIX M - Continued						
W, Year	**Island or tract**	**Date**	**Levee Seg.**	**Classification**	**Subvention status**	**Area Acres**
1969	Mildred	2/16/1969	MIL-MID	Non-Project Ag	N/A	998
	Sherman	1/20/1969	SHE-SAN	Direct Agreement	N/A	10420
1971	Rhode Island		RHO-CUT	Non-Project - Wetland	N/A	100
1972	Brannan-Andrus	6/21/1972	BRA-SAN	Direct Agreement	N/A	15003
1973	Liberty	1/17/1973	LIB-DRE	Non-Project-Restricted height	N/A	3449
1980	Holland Tract	1/18/1980	HOL-SMS	Non-Project Ag	N/A	4225
	Liberty	1/16/1980	LIB-DRE	Non-Project-Restricted height	Subventions-Limited height	3449
	Lower Jones Tract	9/26/1980	JOL-MID	Non-Project Ag	Subventions-Ag	5894
	Prospect	2/12/1980	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
	Upper Jones Tract	10/23/1980	JOU-UPR	Other	Subventions-Ag	6259
	Webb Tract	1/18/1980	WEB-SAN	Direct Agreement	Subventions-Ag	5490
1982	Little Franks Tract	12/24/1981	LFR-FAL	Non-Project Ag	Subventions Wetland	350
	McDonald	8/23/1982			Subventions-Ag	6145
	Prospect	12/23/1981	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
1983	Fay	1/29/1983	FAY-OLD	Private - Wetland	Subventions Wetland	100
	Little Franks Tract	1/27/1983	LFR-PIP	Non-Project Ag	Subventions Wetland	350
	Mildred	1/27/1983	MIL-LAT	Abandoned	Subventions-Ag	998
	Prospect	1/30/1983	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
	Prospect	3/1/1983	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
	River Junction	3/6/1983	RIV-SAN	Non-Project Ag	Non-Subventions	3000

APPENDIX M - Continued						
W, Year	**Island or tract**	**Date**	**Levee Segment**	**Classification**	**Subvention status**	**Area Acres**
	Shima Tract	1/27/1983	SHM-WES	Non-Project Ag	Subventions-New Urbanization	2394
	Van Sickle	1/16/1983	VAN-MON	Non-Project - Wetland	Subventions-Suisun	2500
	Venice	11/30/1982	VEN-POT	Non-Project Ag	Subventions-Ag	3220
1984	Bradford	12/3/1983	BRD-SAN	Direct Agreement	Agriculture, Subventions-Ag	2143
1986	Dead Horse	2/19/1986	DEA-DEA	Non-Project Ag	Subventions-Ag	211
	Glanville Tract	2/19/1986	GLA-RRE	Other - Railroad	Subventions-Ag	7092
	Little Mandeville		MAL-OLD	Non-Project - Ag	Subventions-Ag	200
	McCormack-Williamson Tract	2/18/1986	MWT-EAS	Non-Project-Restricted height	Subventions-Limited height	1639
	New Hope Tract	2/18/1986	NEW-MOK	Non-Project Ag	Subventions-Ag	9743
	Prospect	2/19/1986	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
	Spinner	1/27/1983	SPI-MON	Non-Project - Wetland	Subventions-Suisun	51
	Tyler	2/19/1986	TYL-MKN	Non-Project Ag	Subventions-Ag	8583
1994	Little Mandeville	8/2/1994	MAL-OLD	Abandoned	Subventions-Ag	200
1995	Liberty		LIB-CAC	Non-Project-Restricted height	Subventions-Limited height	3449
	Prospect		PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
1997	Dead Horse	1/3/1997	DEA-DEA	Non-Project Ag	Subventions-Ag	211
	Glanville Tract	1/3/1997	GLA-RRE	Other	Subventions-Ag	7092
	McCormack-Williamson Tract	1/3/1997	MWT-EAS	Non-Project-Restricted height	Subventions-Limited height	1639

APPENDIX M - Continued						
W, Year	Island or tract	Date	Levee Segment	Classification	Subvention status	Area Acres
	McMullin Ranch	1/7/1997	MCM-SAN	Project	Non-Subventions	6792
	Mossdale	1/10/1997	MOS-PAR	Non-Project Ag	Non-Subventions	1325
	Paradise Junction	1101997	PAR-PAR	Project	Non-Subventions	9300
	Pescadero	1/5/1997	PES-TOM	Non-Project Ag	Non-Subventions	3000
	Prospect	1/5/1997	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100
	River Junction	1/5/1997	RIV-SAN	Non-Project Ag	Non-Subventions	3000
	Walthall Tract	1/7/1997	WAH-SAN	Project	Non-Subventions	1025
	Wetherbee Lake	1/7/1997	WEL-LAN	Non-Project-Urban	Non-Subventions	155
1998	Van Sickle	2/1/1998	VAN-MON	Non-Project - Wetland	Subventions-Suisun	2500
2004	Upper Jones Tract	6/3/2004	JOU-MID	Non-Project Ag	Subventions-Ag	6259
2006	Prospect	1/1/2006	PRO-MIL	Non-Project-Restricted height	Subventions-Limited height	1100

APPENDIX N

				APPENDIX N - Other Reports not Failures of Delta Levees	
Year	**Island or tract**	**Date of Incident**	**Subvention status**	**Notes**	**Reference**
1868	Yolo Basin and Maine Prairie		N/A	High water flooded Maine Prairie in Yolo Basin in mid-winter of 1868	Thompson 1957 p. 450
1876	Big Break		N/A	High water in Marsh Creek floods reclamations south of Jersey Island from the unleveed up side	Thompson 1957 p. 451
1878	Bacon	2/24/1878	N/A	$10MM in Estimated total damages in Delta, all islands flooded north of San Joaquin except Bouldin and Randall	Thompson 1957 p. 455
1880	mainland tracts along Mokelumne		N/A	Seepage ruined crops along mainland tracts along Mokelumne, April 1880.	Thompson 1957, p 455
1881	Tyler	2/4/1881	N/A	Thompson 1958 says it held but wet from seepage, Thompson 1996 says it was submerged. It had just finish the tallest levees in the Delta. High water on Mokelumne and Sacramento Basin combine to over top levee,7 '	Thompson 1957, p 488.
1881	Rough and Ready		N/A	Levees is not break but seepage covered island	Thompson 1996
1890	Roberts, Lower	1/27/1890	N/A	Only pre- March 1890 flooding before destruction of Paradise Cut dam. Seepage likely cause.	Thompson 1996
1902	Staten	3/2/1902	N/A	Awash but apparently due to seepage only, no levee breaks	Thompson 1996
1902	Ida	2/27/1902	N/A	Thompson 1996, Island not leveed	Thompson 1996
1902	Wood	2/27/1902	N/A	Island not leveed	Thompson 1996
1904	Sherman	2/29/1904	N/A	Dredger Sierra sucked in, hit submerged pile working on Sherman Island while working the flood fight	*Sac Bee* 2/29/1904

APPENDIX N Continued					
Year	**Island or tract**	**Date of Incident**	**Subvention status**	**Notes**	**Reference**
1904	Staten	2/29/1904	N/A	Staten Island levee will not hold out the day.	*Sac Bee* 2/29/1904
1904	Brannan-Andrus	2/29/1904	N/A	Levee on lower end feared weakest in entire lower river system, still hold with highest water this aftenoon	*Sac Bee* 2/29/1904
1907	Pierson District	2/21/1907	N/A	March 1907 floodwater were 532,000 cu feet per minute on the Sac between 3/18 and 3/21. SJ ran at 227,000 cu ft per minute. Numerous breaks into Yolo basin from breaks north of Sacramento. Breaks into Pierson District after 2/21/1907.	Thompson 1957 p462
1907	Donlon		N/A	Lower Sherman - never restored - could not have failed	CAL-FED 1998, S-4
1907	Vincine Island (Venice?)	3/26/1907	N/A	Island flooded and acreage as of 3/26/1907: Vincine Island 3500	*Sacramento Union* 3/26/1907
1909	Collinsville	1/22/1909	N/A	Suddenly flooded, emergency evacuation by fishing boats	*San Francisco Chronicle* 1/23/1909
1936	Dead Horse	2/15/1936	N/A	During recent Heavy rains in Delta district, this Dead Horse flooded	*River News* 47:2 3/15/36
1950	Ida		N/A	ICAL-FED does not show this, only DRMS and White Paper, Ida is an unleveed sandbar in the Sacramento River,	URS 2009,Table 7-9b; DSC 2010, 3-11
1951	Stewart Tract		N/A	Recorded as "1950" flood of 3,900 ACRES, likely did flood but water escaped under railroad trestle from Mossdale	Cecil Report 1960
1951	River Junction	11/25/1950	N/A	Stanislaus River flows reached 68,000 cfs. Extensive rains on Thanksgiving Day caused last general flood of area. Flood peaked at 68,000 cfs. Flood waters broke out south of intersection of Mohler and Moncure Roads and extended north of Mohler and Moncure	KSN map 2011

APPENDIX N Continued					
Year	**Island or tract**	**Date of Incident**	**Subvention status**	**Notes**	**Reference**
1956	Grizzly	12/26/1955	N/A	Levees on south end began to fail but dredger dispatched. State fish and game cancelled duck hunting to prevent accidental shooting of levee workers	*River News* 12/29/1955 66:45 p1
1956	Collinsville	12/27/1955	N/A	"The Collinsville area, scene of annual flooding was well under water."	*River News* 12/29/1955 66:45 p 1+-+
1956	Ida		N/A	Sandbar (inhabited) in Sacramento River, no levee, reported as 1955 flood (DEC)	URS 2009,Table 7-9b; DSC 2010, 3-11
1958	Brack Tract		N/A	No data provided map indicates only lower quarter flooded	DWR "Delta Levee" 1973
1958	Terminous Tract		N/A	No data provided	DWR "Delta Levee" 1973
1958	Shin Kee Tract		N/A	No data provided	DWR "Delta Levee" 1973
1958	Canal Ranch Tract	4/6/1958	N/A	Canal Tract experience standing landside runoff trapped by the Blossom Road levee but levees held. About 288 A affected	KSN Inc, noted
1958	Roberts, Middle		N/A	Listed as 500 acre flood	Cecil list 1960
1958	Roberts, Upper		N/A	Listed as 500 acre flood	Cecil list 1960
1983	Grizzly		N/A	Listed as Grizzly West, on DRMs and WP only	URS 2009,Table 7-9b; DSC 2010, 3-11
1986	Ryer	2/19/1986	Subventions-Ag	Miner Slough spilling water on Ryer Island	*River News Herald* 2/19/1986 96:14

APPENDIX N Continued					
Year	**Island or tract**	**Date of Incident**	**Subvention status**	**Notes**	**Reference**
1986	Rio Vista	2/19/1986	Legacy community	Edgewater Drive and its expensive home flooded. High gauge at 9.7' Thornton, Lodi, and Gault inundated 2/26/86 $1.8 million damage estimate by Mayor	*River News-Herald* 2/19/1986, 2/26/1986
1986	Shin Kee Tract	2/19/1986	Subventions-Ag	Dante Nomelini indicated there was no levee break Gage B95586	DWR list 2009
1986	Decker		Not leveed	CAL-FED 1998 reported flooding on Decker, a spoil pile and island created by the Sac River Straightening in 1917 t	CAL-FED 1998, S-5
1997	Stewart Tract	1/10/1997	Non-Subventions	Gil Casio indicated Stewart Tract did not fail, Adjacent tract did fail, overflowed from Paradise Junction failure	DWR list 2009
1997	Stewart Tract	1/10/1997	Non-Subventions	Levee damage in cut to release water taken in after Mossdale District levee failure on Paradise Cut	FEAT 1999
1998	Grizzly		Subventions-Suisun	February 1998 Gage E32750	DWR list 2009
1998	Simmons-Wheeler	2/1/1998	Subventions-Suisun	El Nino storms of February 1998 brought high tides and winds that caused significant levee breaches, overtopping, and erosion on Montezuma Slough and northern shore of Honker, Suisun and Grizzly Bays, Flood waters completely inundated public and private lands	GlobalSecurity.org, 2005
1998	Joice	2/1/1998	Suisun Marsh	El Nino storms of February 1998 brought high tides and winds that caused significant levee breaches, overtopping, and erosion on Montezuma Slough and northern shore of Honker, Suisun and Grizzly	GlobalSecurity.org, 2005
1998	Hammond	2/1/1998	Suisun Marsh	El Nino storms of February 1998 brought high tides and winds that caused significant levee breaches, overtopping, and erosion on Montezuma Slough and northern shore of Honker, Suisun and Grizzly Bays	GlobalSecurity.org, 2005

APPENDIX N Continued					
Year	**Island or tract**	**Date of Incident**	**Subvention status**	**Notes**	**Reference**
1998	Grizzly	2/1/1998	Subventions-Suisun	El Nino storms of February 1998 brought high tides and winds that caused significant levee breaches, overtopping, and erosion on Montezuma Slough and northern shore of Honker, Suisun and Grizzly Bays, Flood waters completely inundated public and private lands	GlobalSecurity.org, 2005
1998	Lower Joice	2/1/1998	Suisun Marsh	El Nino storms of February 1998 brought high tides and winds that caused significant levee breaches, overtopping, and erosion on Montezuma Slough and northern shore of Honker, Suisun and Grizzly Bays, Flood waters completely inundated public and private lands	GlobalSecurity.org, 2005
1999	Sunrise Duck Club	7/1/1999	Suisun Marsh	High tide and possible beaver activities	DRMS Risk Report Section 9, 2009
2004	Upper Jones Tract	6/3/2004	Subventions-Ag	News report in Sac Bee in January 2009 that the levee failure repair was still leaking,, due to the closure method of placing big rocks in the hole and dump finer material on top to fill in voids. Estimated cost of additional repairs $350,00	Weiser 2009
2005	Simmons-Wheeler	7/20/2005	Subventions-Suisun	Water level 7.51', top of levee 7.3',High tide, breach occurred between two water control structures; beaver activities suspected	DRMS Risk Report Section 9, 2009
2005	Liberty		Subventions-Limited height	Chunk of In 1995, a more than routine flood occurred, as a big chunk of levee at the island's southern tip crumbled into Cache Slough. Repaired, it failed for good in 1997.	Hart 2010
2006	Honker Bay		Subventions-Suisun	After CAL-FED list, on DRMS and WP	URS 2009,Table 7-9b; DSC 2010, 3-11
2006	Simmons Wheeler			After CAL-FED list, on DRMS and WP	URS 2009,Table 7-9b; DSC 2010, 3-11

APPENDIX O – QUESTIONABLE RECORDS IN DATABASE				
Water year	**Island or tract**	**Date of Incident**	**Notes**	**Reference**
1878	Bacon	2/21/1878	Not positive Bacon flooded	Thompson 1878 p.4
1881	New Hope Tract	2/4/1881	Submerged? Broken levee or seepage?	Thompson 1996
1886	New Hope Tract	1/26/1886	Additional tract on Mokelumne may also have flooded	Thompson 1957 p. 457
1890	Fabian Tract	3/11/1890	Failure data not clear. Problem starts when submerged dam at Paradise Cut built by Corps in 1888 has its weir destroyed. This dam was built to encourage flow down the new channel, the loss of the weir sends higher flows down the Middle and Old forks. High water floods the southern division of Union Island	Thompson 1996
1900	New Hope Tract		No detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1904	Walnut Grove	2/29/1904	Break at floodgate on cross levee between Millers Ferry and Jackson Slough on the C. Clark Ranch near camp 3 Dredger on way, Water from Edwards Break	*Sac Bee* 2/29/1904
1905	New Hope Tract		Not on 1998 CAL-FED list, no other record	URS 2009,Table 7-9b; DSC 2010, 3-11
1907	Bradford	3/27/1907	Grand, Sutter, Merritt, Sherman, Bradford and RD 744 intact everything else under water between Sacramento and Antioch	*Sacramento Union* 3/27/1907 p 1
1907	Brooks Tract	3/26/1907	Island flooded and acreage as of 3/26/1907 Brooks Tract 3500	*Sacramento Union* 3/26/1907

APPENDIX O – Continued				
Water year	**Island or tract**	**Date of Incident**	**Notes**	**Reference**
1908	Bethel		No detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1909	Bouldin		CAL-FED 1998 showed failed but never recovered from 1908 flood until 1918	CAL-FED 1998, S-4
1920	Paradise Junction		No detail _ DRMS and White paper only	URS 2009,Table 7-9b; DSC 2010, 3-11
1920	Roberts, Middle		No detail _ DRMS and White paper only	URS 2009,Table 7-9b; DSC 2010, 3-11
1926	Bethel		Listed as 3,400 A flood	"Cecil" 1960 report for Delta Water Project, List of Historical Inundations
1927	Big Break		On list of levee failures, no detail, remains flooded	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1928	Hastings Tract		Listed as 6,900 A flood	"Cecil" 1960 report for Delta Water Project, List of Historical Inundations
1928	New Hope Tract		New corner listed as 2,000 acre flood	"Cecil" 1960 report for Delta Water Project, List of Historical Inundations
1936	Jersey	2/15/1936	Heavy rains, islands flooded	*River News* 47:2 3/15/36
1936	Mildred	2/15/1936	Island flooded - heavy rains	*River News* 47:2 3/15/36

APPENDIX O – Continued				
Water year	**Island or tract**	**Date of Incident**	**Notes**	**Reference**
1936	Prospect	2/15/1936	No doubt of the large amount of damage done due to flooding	*River News* 47:2 3/15/36
1937	Donlon		Noted as remaining flooded, no other detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1937	Sherman		No detail - DRMs and White Paper only	URS 2009,Table 7-9b; DSC 2010, 3-11
1938	Bacon		On list of levee failures, no detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1938	Hastings Tract	2/14/1938	50 families evacuating for second time this winter	*Sacramento Union* 2/14/1938
1938	Medford			Robie, 1975
1938	Roberts, Middle			Robie, 1975
1938	Roberts, Upper		No Detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1938	Shin Kee Tract		No detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1938	Stewart Tract		No details	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1939	Pescadero		No Detail	Robie, 1975
1939	Quimby	12/1/1938	No Detail	Robie, 1975

APPENDIX O – Continued				
Water year	**Island or tract**	**Date of Incident**	**Notes**	**Reference**
1950	Dead Horse		No Detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Empire Tract		DRMS and White paper show this, CAL-FED 1998 does not	URS 2009,Table 7-9b; DSC 2010, 3-11
1950	McCormack-Williamson Tract		No details	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1950	New Hope Tract		CAL-Fed 1998 does not show only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Paradise Junction		CAL-Fed 1998 does not show only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Pescadero		No details	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Quimby		CAL-Fed 1998 does not show, only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1950	R.D. 17		No detail	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Roberts, Upper		CAL-Fed 1998 does not show, only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1950	Stewart Tract		No details (Probably 12/5/1950 Mossdale water escaping under railroad tracks reported in 1951 record	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11

APPENDIX O – Continued				
Water year	**Island or tract**	**Date of Incident**	**Notes**	**Reference**
1956	Bouldin	12/26/1955	Reported flooded on 12/29/1955 by higher water than 1907	*River News* 12/29/1955 66:45 p. 4
1956	Grand		Only DRMS &White Paper reported this	URS 2009,Table 7-9b; DSC 2010, 3-11
1956	New Hope Tract		CAL-Fed 1998 does not show, only DRMs & White paper, reported as 1955 flood (DEC)	URS 2009,Table 7-9b; DSC 2010, 3-11
1958	River Junction		CAL-Fed 1998 does not show, only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1958	Terminous Tract		Listed as 5,000 acre flood	Cecil list 1960
1964	McCormack-Williamson Tract		No Detail, probably same as 12/1/1964	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1965	Little Holland		Listed as 2,800 acre flood in 1964	Cecil List updated date post 1972
1965	Mildred		CAL-Fed 1998 does not show, only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1965	New Hope Tract		No data provided	DWR "Delta Levee" 1973
1965	Shin Kee Tract		CAL-Fed 1998 does not show only DRMs & White paper	URS 2009,Table 7-9b; DSC 2010, 3-11
1965	Shin Kee Tract			Robie, 1975
1980	Dead Horse	2/1/1980	Gage B94150	DWR list 2009
1980	Little Mandeville		No details	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11

APPENDIX O – Continued

Water year	Island or tract	Date of Incident	Notes	Reference
1980	Van Sickle		On CAL-FED list, not on DRMS or WP	CAL-FED 1998, S-4
1981	Little Franks Tract		No detail - Must be 12/23. 1981 listed in water year 1982	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1982	Little Mandeville		Listed on CAL-FED 1998, not in DRMS or WP	CAL-FED 1998, S-4
1982	Venice		No detail - Probably the November 27, 1982 failure listed in 1983 water year	CAL-FED 1998, S-4; URS 2009,Table 7-9b; DSC 2010, 3-11
1983	Edgerly		Not on CAL-FED 1998 list, on DRMS and WP	URS 2009,Table 7-9b; DSC 2010, 3-11
1983	Little Franks Tract		Flooded twice in 1983, Remains flooded, second flood only on CAL-FED 1998	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1983	Shima Tract		Second flood in 1983	CAL-FED 1998, S-4: URS 2009,Table 7-9b; DSC 2010, 3-11
1984	Little Franks Tract		No data Available. Believed to be a mistake	DWR (not dated- Schwarzenegger Governor)
2006	Fay		No indication of problems comparing 12/30/2005 and 8/29/2006 Google images. Levee repair work does show up on April 2008 image centered at noted coordinates	Google Earth

APPENDIX P

APPENDIX P - RECORDED EMERGENCY REPAIRS							
Inc #	**YEAR**	**Island or tract**	**Date**	**Levee Seg.**	**Classification**	**Subvention ?**	**Notes**
1016	2004	Drexler Tract	7/2004	DRE-TRA	Non-Project Ag	Subventions-Ag	There were active boils all along other side of Trapper Slough during the summer of 2004 while Upper Jones was inundated
1004	1983	Twitchell	7/30/1983			Subventions-Ag	Near -miss, boil was flowing 200 gal/min of material laden material, usually enough to lead to evacuation, but CCC and Rd was able to stop the boil with classical methods
1020	2007	Wright-Elmwood				Subventions-New Urbanization	Many places where broken concrete was dumped as rip-rap, not acceptable now because of the high pH of concrete, and such a surface makes great squirrel habitat. In 2006 or 2007, the district had a dozer working on other parts of the levee and they say an
1019	2006	Staten				Subventions-Ag	We were fighting a boil, water was flowing through the levee slope, we were out there with this big Blue Iron rig to drive piles and they were driving the piles that a 18 wheeler delivered to the island levee and the pulled them off and dropped the piles
1006	1984	Bouldin	12/9/1983	BOU-POT	Non-Project Ag	Subventions-Ag	Seep started flowing on south side on Potato Slough from flooded Bradford, dredge pulled up and dump, gravel, muds and rock on water side of levee to stop leakage
1022	2009	Bradford	8/27/2009	BRD-SAN	Direct Agreement	Agriculture, Subventions-Ag	Ship moving up to Stockton ran into levee

				APPENDIX P	Continued		
Inc #	YEAR	Island or tract	Date	Levee Seg.	Classification	Subvention ?	Notes
1007	1997	Tyler	1/7/1997	TYL-MKN	Non-Project Ag	Subventions-Ag	200 Workers sent to Isleton to fight seepage and boils on surrounding islands, including Tyler where Squirrel holes apparently caused a lot of seepage at location noted by S Mello on map
1000	1981	Tyler		TYL-MKN	Non-Project Ag	Subventions-Ag	A human built cave was discovered in the levee by the R.D. board president around 1981, complete with a timber beam supported roof structure, intent of the cave and who built it never determined Levee repaired immediately.
1017	2006	Tyler	1/15/2006	TYL-GEO	Project	Subventions-Ag	Boils develop near duck club field, flowing material, added to berms to stop boil flow
1015	2004	Tyler	2/2004	TYL-GEO	Project	Subventions-Ag	900' section of levee with multiple boils, repaired with expansion of landside berm
1018	2006	Twitchell	1/1/2006	TWI-SAN	Direct Agreement	Subventions-Ag	We had lots of problem at Chevron Point which we then purchased for $3 million
1014	1998	Webb Tract	2/1/1998	WEB-FAL	Non-Project Ag	Subventions-Ag	Wind came up across from south across Franks Tract, and waves cost us half of the Webb Tract levee for about a mile very quickly during high tide, DWR got the CORPS in to make repairs and island was saved
1021	2009	Medford	1/24/2009	MED-COL	Non-Project Ag	Subventions-Ag	Sinkhole in levee turned out to be collapsed roof of beaver den that totally penetrated the levee
1003	1938	Brannan-Andrus	2/14/1938	BRA-SAN	Direct Agreement	Subventions-Ag	50 families moved from low areas to higher ground as winds washed water over levee and gravel had to be barged in to fix the levee

				APPENDIX P	Continued		
Inc #	**YEAR**	**Island or tract**	**Date**	**Levee Seg.**	**Classification**	**Subvention ?**	**Notes**
1005	1984	Tyler	8/21/1984	TYL-MKN	Non-Project Ag	Subventions-Ag	date of incident listed as 8/21/1984
1010	1997	Ryer	1/1/1997	RYE-SUT	Project	Subventions-Ag	Sutter slough levees suffered waterside sloughing
1001	1997	Brannan-Andrus	1/1/1997	BRA-SAC	Direct Agreement	Subventions-Ag	Fighting numerous boils in Upper Andrus district on Sacramento
1012	1997	Brannan-Andrus	1/1/1997	BRA-GEO	Project	Subventions-Ag	Georgiana levee high seepage rates
1013	1997	Brannan-Andrus	1/1/1997	BRA-MOK	Non-Project Ag	Subventions-Ag	On Mokelumne at Georgiana , cracking and slumping of levee Mokelumne at 165 year flood
1008	1997	Twitchell	1/1/1997	TWI-7MI	Non-Project Ag	Subventions-Ag	High seepage and cracking of 7 Mile slough levee
1009	1997	Twitchell	1/1/1997	TWI-SAN	Direct Agreement	Subventions-Ag	Cracking and slumping of San J. levee at 7 Mile slough
1011	1997	R.D. 17	1/1/1997	D17-SAN	Project	Non-Subventions	East side SJR levee high seepage and boils during high water , Also Walthall Slough levee suffer wave over wash and erosion
1023	2008	Brannan-Andrus	1/2008?	BRA-SAN	Direct Agreement	Subventions-Ag	"I went out and the waves were washing over the roadway and had eaten it away, crews came in and dumped this huge rock and repaved the roadway but I thought the levee was gone.”

APPENDIX Q

APPENDIX Q

1881	Randall	2/4/1881	N/A	Thompson 1996
1881	Randall	2/4/1881	N/A	Thompson 1996
1902	Terminous Tract	3/2/1904	N/A	*Sacramento Bee* 3/2/1904
1904	Grand	2/29/1904	N/A	*Sac Bee* 2/29/1904
1904	Lisbon District	2/29/1904	N/A	*Sac Bee* 2/29/1904
1904	Merritt	2/29/1904	N/A	*Sac Bee* 2/29/1904
1904	Bouldin	3/2/1904	N/A	*San Francisco Chronicle* 3/3/1904 p 4
1906	Roberts, Lower	7/10/1906	N/A	Thompson 1957 p. 460, 488
1906	Clifton Court	7/7/1906	N/A	*L. A. Herald*, 7/8/1906
1906	Fabian Tract	7/9/1906	N/A	*San Francisco Call,* 7/10/1906
1906	Victoria	7/10/1906	N/A	*S.F. Call* 7/11/1906
1906	Woodward	7/10/1906	N/A	*S.F. Call* 7/11/1906
1906	Lower Jones Tract	7/10/1906	N/A	*S.F. Call* 7/11/1906
1907	Merritt	3/24/1907	N/A	*Sacramento Union* 3/24/1907
1907	Grand	3/24/1907	N/A	*Sacramento Union* 3/24/1907
1909	Franks Tract	1/30/1909	N/A	*Antioch Ledger* 1/30/1909
1909	Veale Tract	1/30/1909	N/A	*Antioch Ledger* 1/30/1909
1909	Bradford	1/30/1909	N/A	*Antioch Ledger* 1/30/1909
1909	Woodward	1/30/1909	N/A	*Antioch Ledger* 1/30/1909
1936	Donlon	2/24/1936	N/A	*Pittsburg Post-Dispatch* 2/24/1936
1938	Tyler	2/13/1938	N/A	*Sacramento Bee* 2/14/1938
1938	Brannan-Andrus	2/13/1938	N/A	*Sacramento Bee* 2/14/1938
1938	Tyler	2/13/1938	N/A	*Sacramento Bee* 2/14/1938

APPENDIX Q	Continued			
Water year	**Island or tract**	**Date of Incident**	**Subvention status**	**Reference**
1938	Brannan-Andrus	2/13/1938	N/A	*Sacramento Bee* 2/14/1938
1938	Brannan-Andrus	2/12/1938	N/A	*Sacramento Bee* 2/12/1938
1938	Brannan-Andrus	2/14/1938	N/A	*Sacramento Union* 2/14/1938
1938	McCormack-Williamson Tract	2/14/1938	N/A	*Sacramento Union* 2/14/1938
1938	Webb Tract	2/14/1938	N/A	*Sacramento Union* 2/14/1938
1938	Brack Tract	2/14/1938	N/A	*Sacramento Union* 2/14/1938
1938	Jersey	2/14/1938	N/A	*Sacramento Union* 2/14/1938
1938	Egbert Tract	2/15/1938	N/A	*Pittsburg Post-Dispatch* 2/15/1938
1940	Ryer	3/2/1940	N/A	*Antioch Ledger* 3/4/1940
1956	Venice	12/26/1955	N/A	Thompson 1957 p. 466
1956	Brannan-Andrus		N/A	Thompson 1957 p. 466.
1956	Twitchell	12/26/1955	N/A	River News 12/29/1955 66:45 p
1956	Brack Tract	12/26/1955	N/A	Interview 112-2009
1956	Tyler	12/26/1955	N/A	Thompson 1957 p. 466
1956	Jersey	12/26/1955	N/A	Thompson 1957 p. 466
1965	Twitchell	12/26/1964	N/A	*River News Herald* 12/30/1964
1973	Brannan-Andrus		N/A	*River News-Herald* 1/17/1973
1982	Medford		Subventions-Ag	DWR 1983
1983	Tyler	1/29/1983	Subventions-Ag	Neudeck 1984
1983	Webb Tract	1/29/1983	Subventions-Ag	Neudeck 1984

	APPENDIX Q	Continued		
Water year	**Island or tract**	**Date of Incident**	**Subvention status**	**Reference**
1983	Jersey	1/29/1983	Subventions-Ag	Neudeck 1984
1983	King	1/29/1983	Subventions-Ag	Neudeck 1984
1983	Wright-Elmwood	1/29/1983	Subventions-New Urbanization	Neudeck 1984
1983	Bouldin	2/2/1983	Subventions-Ag	*River News Herald* 2/2/1983
1983	Twitchell	2/2/1983	Subventions-Ag	*River News Herald* 2/2/1983
1986	Walnut Grove	2/20/1986	Subventions -Legacy community	Interview 114-2009
1997	Webb Tract		Subventions-Ag	Interview 101-2009
1997	Brannan-Andrus	1/10/1997	Subventions-Ag	Interview 111-2009
1998	Sherman	1/1/1998	Subventions-Ag	Interview 117 - 2009
2006	Sherman	1/1/2006	Subventions-Ag	Interview 103-2009
2006	Twitchell		Subventions-Ag	Interview 124-2009

VITA

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