Anticipating California Levee Failure: The State of the Delta Levees and Government Preparation and Response Strategies for Protecting Natural Resources from Freshwater Oil Spills

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ABSTRACT

Seismic activity and other natural and human forces significantly threaten the structural integrity of Delta levee systems. Breached levees appreciably impact fresh water resources, damage crops and livestock, destroy homes, schools, public works, businesses and wild species habitat, among other vital, sensitive areas. Levee failure often leads to oil and petroleum contamination of freshwater resources, particularly in dense residential, agricultural and commercial areas protected by levee systems that depend upon such water resources for drinking, irrigation and industrial uses.

San Joaquin Delta to illustrate selected impacts to a freshwater region jeopardized by levee failure, this paper will: 1) discuss the current state of the Delta levee systems and detail the fragility of the system and the potential consequences of major impacts - earthquakes and floods likely to jeopardize this system; 2) review issues concerning levee breach preparedness, including practices to maintain levee structure and promote levee rehabilitation; and 3) suggest a coordinated federal, state and local response to contain damage caused by a levee breach, with particular focus on oil and hazardous materials spill impacts.

As with many levee systems, the issues presented by a levee breach to the Sacramento-San Joaquin Delta region are complex and require close, concerted federal, state and local participation, not only to rapidly and effectively respond to impacted areas, but to anticipate and

avoid more massive levee failure. Employment of these levee protection and breach response measures will help defend, among other vital resources, domestic, agricultural and industrial water for use from oil, petroleum and other hazardous contaminants.

Sacramento-San Joaquin Delta Photo by brothergrimm (CC)

I. Levee Systems and Freshwater Spill Issues

A. Introduction

Natural and artificial levees are an essential component for flood protection and river flow confinement to protect natural and man-made resources, as well as to hold back the hydrostatic force of water and the frequency of tides. Levee failure is usually associated with the size and condition of the levee and height of the water exerting force upon it; levee vulnerability increases with either subsidence under the dam or length of the levee on which water pressure is acting. When levees are breached, obvious consequences are flooding of protected areas that could destroy residential, agricultural and industrial areas, wreak havoc on natural habitats, and threaten human lives. Oil and hazardous materials can get dispersed in floodwaters and significantly harm previously protected areas as the floodwaters pour through the damaged levees.

Even with advances in engineering and technology over the past century, levee failures occur frequently, especially when politics, economics and property disputes interfere with proper maintenance, rehabilitation and repair of outdated, crumbling levees. The devastating effects of

levee failure in New Orleans, during Hurricane Katrina in 2005, galvanized public attention on the fragility of the Sacramento-San Joaquin Delta Levee System ("Delta" or "Delta Region") in Northern California. New Orleans provides a cautionary tale for public and private interests which must maintain the integrity and viability of levees they own or control. (Schwartz, John, 2006.)

This paper focuses on the structural integrity and viability of the Delta Region levee system, and identifies the ability of federal, state and local governments' responsibilities to challenges of rehabilitating and maintaining the current levee system. This paper also mentions the plans federal, state and local authorities have in place to respond to levee failures, noting how agencies are prepared to protect resources when Delta levees are breached, including protecting against oil and hazardous materials spills or contamination by resulting floodwaters.

B. Structural Integrity of the Sacramento-San Joaquin Delta's Fragile, Fundamental Levee System

The Sacramento-San Joaquin River Delta is a unique, expansive, thousand square-mile inland river delta and estuary in Northern California in the United States. At the confluence of the Sacramento and San Joaquin rivers lies a complex system of over 1,100 miles of levees – longer than California's coastline. Many levees are a century old, lying just east of where the rivers enter Suisun Bay — an upper arm of San Francisco Bay. The Delta includes 57 islands and hundreds of thousands of acres of marshes, mudflats and farmland — most below sea level.

The Delta levee system is of vital importance for many reasons. Freshwater flowing from mountains to the east feeds this hub of California's water system. Freshwater is destined for points south — farms in Central Valley and the thirsty population of Southern California. Delta levees keep the saline seawater of San Francisco Bay from mixing with the Region's freshwater which, if it contaminated potable and irrigable freshwater, would lead to serious impacts. Delta Region freshwater provides a significant portion of drinking water for 25 million Californians, nurtures a $31 billion agricultural economy, and functions as a vital habitat for 750 plant and animal species. (CALFED Bay-Delta Program, *Bay-Delta Levees Information* 2010; Environmental Defense Fund, 2010.) Today, the Central Valley Project (CVP) – a U.S. Bureau of Reclamation water project – dampens over 10% of the country's irrigated farmland and enables California to produce half the nation's fruits, vegetables and legumes. (Bourne, Joel, 2010.)

Delta Region levees protect farmland, towns, population, water supply, energy infrastructure and ecosystem functions. (Public Policy Institute of California, August 2008.) Water in the delta is distributed to wildlife refuges, consumed for power plant cooling and other industrial uses, and utilized for commercial purposes. In addition, the Delta serves as a transportation corridor in which highways, pipelines, power lines, railroads and ships merge. (California Department of Water Resources, November 2005.)

Ownership and control of Delta levees fall into two categories: "non-project levees" and "project levees." Non-project levees, which comprise approximately two-thirds of Delta levees, are owned and maintained by local reclamation districts on behalf of private landowners. (California Department of Water Resources, November 2005.) These levees are subject to a range of federal and state-mandated standards. Local levees were constructed, enlarged and maintained over the last 130 years by local reclamation districts. In general, levee maintenance by these districts was financed by landowners within the levees. In past 30 to 35 years, California has provided supplemental financing for levee maintenance and emergency response. (California Department of Water Resources, *Delta Risk Management Strategy Overview*, 2010; California

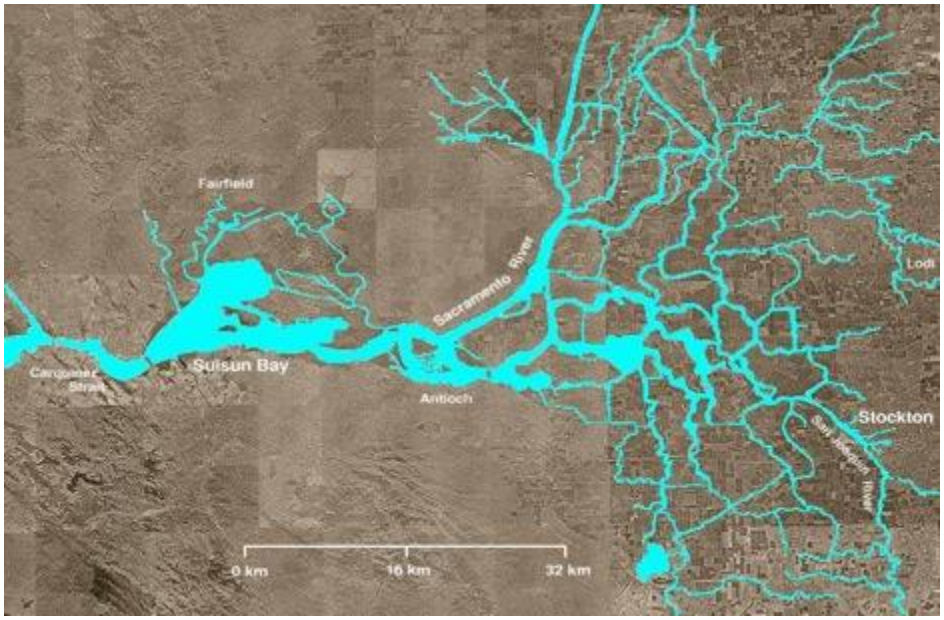
Department of Water Resources, *Delta Risk Management Strategy Executive Summary*, February 2009.)

The remaining one-third of Delta levees — project levees — are part of the Sacramento-San Joaquin Flood Control Project, and eligible for U.S. Army Corps of Engineers (ACE) rehabilitation, if needed. Following significant floods in the Delta in 1986, the federal government compelled the state to set new standards for Delta levees to reduce frequency of island flooding. (Public Policy Institute of California, August 2008.)

In late 1800s, large-scale agricultural development in the Delta Region required levee building to prevent frequent flooding of vast wetlands reclaimed for farming. Levee and drainage systems were largely completed by 1930. (U.S. Geological Survey, April 2000.) Thus, most levees were built without the benefit of modern engineering practices, e.g., soil mechanics, sophisticated equipment, and better forecasting. The underlying foundation of most Delta levees still retains original materials including dredged riverbed sands, soil and organic matter. Over time, the weight of levees has compressed and displaced soft organic soils beneath, and organic soils within island interiors behind the levees have oxidized and been removed by wind, resulting in significant subsidence. Delta Region islands behind the levees continue to shrink at a rate of one to three inches per year.

Reclamation and agriculture have led to land surface subsidence in many parts of the Delta Region. (California Department of Water Resources, 2009.) Delta levees today are commonly 15 to 20 feet high, and many islands in the Central Delta are presently 10 to 25 feet below sea level. The dominant cause of this subsidence is decomposition of organic carbon in peat soils. (U.S. Geological Survey, April 2000.)

Delta levee tracts and islands help to protect water-export facilities in the southern Delta from saltwater intrusion by displacing water and maintaining favorable freshwater gradients. Ongoing subsidence behind levees reduces levee stability and threatens to degrade water quality in the massive north-to-south water transfer system. (U.S. Geological Survey, April 2000.) After years of governmental and private rebuilding/patching Delta levees, of diverting water, of drought and other natural forces, the system is understood to be vulnerable to breach. Evaluations of current maintenance practices of Delta levees demonstrate that high-water conditions could cause about 140 levee failures in the Delta over the next 100 years. Levees throughout the Delta region are vulnerable to failure due to earthquakes, subsidence, flooding, inadequate engineering, soil conditions, storm surges, burrowing, inappropriate vegetation, lack of maintenance, and sea level rise due to global warming (Association of Bay Area Governments, 2011). There have been 162 Delta levee failures during last century, in most cases leading to flooding of islands, costly disasters for Delta residents, businesses and farmers. (California Department of Water Resources, 2010.) Levee failures have caused flooding of Delta islands 158 times since 1900. Estimates of damages are not readily available, but would be considered significant (California Department of Water Resources, February 2009.)



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C. Potential Consequences of a Levee Breach from Earthquakes and Floods

The Delta Region's levee integrity and flood prevention planning is at a critical stage:

- The U.S. Geological Survey (USGS) estimates that an earthquake of magnitude 6.7 or greater has a 62% probability of occurring in the Bay Area between 2003 and 2032. (California Department of Water Resources, 2009.) A USGS study a year earlier states that California faces a greater than 99% probability of a 6.7 or greater magnitude earthquake in next 30 years. (U.S. Geological Survey, 2008.);
- An ACE study predicts a 99% chance of flooding within next 50 years on 13 Delta islands (Yang, Sarah, 2010); and
- California Department of Water Resources (DWR) projects that a one-foot rise in sea level (a mid-range prediction from Intergovernmental Panel on Climate Change) would increase frequency of a 100-year peak tide to a 10-year event. DWR found a 40% probability of an earthquake of magnitude 6.7 or higher causing 27 or more islands to flood at the same time in next 25 years. Anticipated flooding of 20 islands could interrupt freshwater flows through the Delta for well over a year, and emergency repairs could cost up to $2.3 billion and take three years to complete. (California Department of Water Resources, February 2009.)

Earthquakes present a drastic and obvious danger to the Delta's levees, particularly because the Delta is near active earthquake faults. A major earthquake could cause multiple levee failures and several islands to be flooded simultaneously. Earthquake dangers to the Delta Region are not solely due to major fault lines. A small earthquake centered at the heart of the Sacramento-San Joaquin Delta occurred on October 15, 2010. While this earthquake did little damage, it struck under the Delta where no fault lines are known to exist. (Weiser, Matt, 2010.)

In early 2009, DWR completed the first of two phases of Delta Risk Management Strategy Project (DRMS) analyzing risks and consequences of levee failure to local and state economies, public health and safety, and the natural environment in the Delta Region from earthquakes, floods and other high-water conditions, climate change, subsidence and seepage, among other considerations. DWR's analysis reinforces what many already know – under

current practices, the Delta Region is unsustainable. A seismic event is the greatest risk to levee integrity in the region. The DRMS analysis shows that a major earthquake would cause levees to fail and likely flood as many as 20 Delta islands simultaneously, resulting in economic costs and impacts of at least $15 billion. (California Department of Water Resources, 2009.) The second phase of DRMS, not yet completed, will consider various scenarios to reduce risks and consequences of levee failure.

Other studies completed in the past 10 years suggest there is a two-thirds chance of a levee failure in next 50 years due to seismic activity or a catastrophic hydrological event. (Mount, Jeffrey & Twiss, Robert, March 2005.) A 2005 study demonstrates that a 6.5 magnitude earthquake in the Delta region would likely cause levee failures in the Delta — failures that would result in $30 to $40 billion loss to California's economy over five years after the event. (CALFED Bay-Delta Program, 2011.)

Jack R. Benjamin and Associates, Inc., a California-based engineering consulting firm specializing in natural phenomena hazards analysis, structural and earthquake engineering, produced a simulated seismic model of the earthquake, illustrative of major levee damage coupled with loss of structural integrity. (Benjamin, Jack R., and Associates, Inc., June 2005.)

Under this case scenario, the earthquake would cause 50 levee breaches in the Delta Region, flooding 21 islands; breaching 20 levees on Sherman Island alone. Levee breaches create an inrush of water onto breached islands, and form a flow gradient from San Francisco Bay to the Delta. Islands flood with saline water, and a high level of salinity persists because of the lack of freshwater to flush out salt. (Benjamin, Jack R., and Associates, Inc., June 2005.) Flooding sets off a chain reaction of failures in adjoining infrastructure systems that have a ripple effect throughout the state. Three hundred billion gallons of salt water flow into the Delta within the first few days, and water supply south of the Delta shuts down. (California Department of Water Resources, Nov. 2005.) Water exports for both State Water Project (SWP; a water storage and delivery system for urban and agricultural water suppliers in Northern California) and Central Valley Project would cease because of salt water intrusion. All levee breaches are assumed to be 500 feet to 1,600 feet wide, due to liquefaction and inertial failure. A breach of 500 feet requires 115,000 tons of material to close it. (Benjamin, Jack R., and Associates, Inc., June 2005.)

This simulated earthquake is projected to cause disruption of water delivery from the Delta that could last up to 28 months. Pumping Delta water could not occur for one year as breach repairs and removal of saline water would be needed (Benjamin, Jack R., and Associates, Inc., June 2005). Economic impacts would include loss of revenue from up to 85,000 acres of agricultural land as crops are flooded, and costs associated with repairing as many as 3,000 homes inundated with flood water. After one year, damage is estimated to reach at least $6 billion. (California Department of Water Resources, November 2005.)

Several key aspects of Delta infrastructure are highly vulnerable to oil and hazardous material releases into the Delta system: transportation corridors, including highways, waterways and railways; pipelines carrying oil products; agricultural and residential sources (including storage tanks, household utilities and oil products); and gas stations and other fuel sources related to Delta urbanization. Should 30 to 50 levees breaches occur simultaneously or sequentially, the containing of pollutants – particularly oil products – would be nearly impossible even though tidal influence from San Francisco Bay and flows from the Sacramento and San Joaquin rivers will help naturally facilitate dispersal of hazardous materials. As the Delta is an integral part of California's complex water supply system, dispersing hazardous materials could adversely affect drinking water supply for 23 million citizens who depend on this system.

Contamination would seriously impact agricultural interests, which support California's economy. (Benjamin, Jack R., and Associates, Inc., June 2005.)

Approximately 400 miles of oil and hazardous liquid pipelines operated and maintained by Conoco-Phillips, Chevron, Shell, Pacific Gas and Electric and others run alongside or across the Delta. Martinez, located west of Bethel and Sherman Islands, contains several major oil refineries. In 2004 and 2005, the U.S. Environmental Protection Agency (EPA) led drills in four facilities in the Delta considered "substantial harm" facilities. Five facilities lie near the Port of Stockton and four in Sacramento/West Sacramento, which include Tesoro, Conoco Phillips and BP West Coast Products. Subsurface hazardous liquid pipelines, containing products such as nitrogen and liquefied natural gas, cross the Delta and are adjacent to seismic faults. Density of oil is less than the density of water. Thus, when soil liquefies, pipes have a tendency to rise. If they rise too far, they can rupture. In event of major earthquake in the Delta, pipelines are vulnerable to rupture, leading to release of crude oil, gas and other hazardous liquids. (Benjamin, Jack R., and Associates, Inc., June 2005.)

Reclaimed tracts and islands in the Delta sustain regional agriculture. Farmers often store fuel for tractors and other farm equipment in storage tanks on reclaimed and often subsided land. Pesticides and herbicides are abundant, and pose environmental threat if released into waterways. Residential areas contribute pollutants from fuel tanks and household and automobile products. Levee breaches and subsequent flooding of the Delta islands create a heightened risk that agricultural and household products will be released and contaminate Delta water. Increasing urbanization of Delta islands brings pollutants from cars, homes and local infrastructure to contribute to public health impacts and environmental damage in the event of a Delta levee catastrophe. (Benjamin, Jack R., and Associates, Inc., June 2005.)

Another recent concern impacting the Delta Region is the possibility of a massive storm event dubbed "ARkSTorm," after the atmospheric rivers that draw warm, moist air from Pacific Ocean and turn moisture into rain and snow when it reaches the West Coast. Like the earthquake scenario mentioned above, such a storm would produce heavy rains that would cause flooding in the Delta Region and may breach as many as 50 levees. This would force evacuation of 1.5 million residents. Conservative cost estimates of such a storm's devastation are $300 billion. (U.S. Geological Survey, 2010.)

Because of the subsidence of Delta levee islands, sea level rise due to climate change, and increases in flooding severity and seawater intrusion caused by earthquakes and other forces, stakeholders need to implement proactive measures to rehabilitate and reinforce Delta levees, as well as prepare for protecting people, property and the Region's wildlife during disasters, and find alternate ways to preserve the freshwater integral to California's population and economy.

II. Preparedness: Levee Breach Prevention

A. Maintaining Levee Structure and Promoting Levee Rehabilitation

The Sacramento-San Joaquin Delta levee system is in danger of failure. This failure jeopardizes people, wildlife, industry and infrastructure of the Delta Region, as well as freshwater destined for the state's Central Valley and Southern California. Stakeholders are attempting to find ways to repair and strengthen the levee system, as well as attempting to protect Delta freshwater in spite of the levee system. Government continues to plan for levee collapse to minimize flood damage that will impact freshwater and the inevitable oil and hazardous materials contamination that will flow in with the floodwaters.

The U.S. Army Corps of Engineers (ACE) is the primary federal agency tasked with repair and rehabilitation of levees involved largely in public projects. This includes some Delta

levees. To address both known and developing deficiencies in the Delta system, ACE evaluated 1,059 miles of levees in Sacramento River Flood Control Project between 1986 and 2003. This multi-year evaluation found 89 miles of levees that needed significant repairs at an estimated cost of $145 million. While most repairs have been completed, evaluation was performed using criteria that are now outdated and did not include all potentially deficient levees. ACE has recently developed new seepage design criteria that will require more stringent field exploration than earlier guidance. These new criteria are likely to result in identifying many more deficient areas that will lead to significantly greater levee repair costs. (California Department of Water Resources, January 2005.)

ACE commissions an annual national survey of critical levee erosion repair projects. For example, the 2005 survey reported 174 erosion sites in need of critical repairs. Critical sites, of highest priority, are those where further erosion could result in a bank failure, near or into a levee crown. On February 24, 2006, the Governor's State of Emergency State's Levee System made an emergency declaration for state levees at 24 critical erosion sites on project levees and 9 other sites, for a total of 33 repair sites (Department of Water Resources, February 2007). Of the 33 sites, 22 critical erosion sites were under the Department of Water Resources' jurisdiction and the remaining 11 critical erosion sites were under the Army Corps of Engineers' jurisdiction. A Federal emergency declaration is needed before federal emergency assistance. Other needs include state-federal cost share, cooperation and assistance from ACE, and an expedited process for federal permits. (U.S. Army Corps of Engineers, December 2005.)

Materials created by ACE in conjunction with the U.S. Department of Homeland Security detail how best to strengthen levees and mitigate damages. These plans include solutions for earthen dam protection, long or shallow breach seals, and narrow or deep breach seals. ACE's best practices for maintaining levee safety consist of: 1) levee safety portfolio management; 2) a national levee database; 3) levee inspection system tools (including data collection and reporting); 4) levee screening tools; and 5) risk classification. (Halpin, Eric, U.S. Army Corps of Engineers, March 2010.)

In partnership with ACE, the Central Valley Flood Protection Board works to control flooding along the Sacramento and San Joaquin Rivers and their tributaries. Together these parties have provided protection to the existing levee and flood control facilities, known as the Sacramento River Bank Protection Project, since the passage of the Flood Control Act of 1960. Meanwhile, erosion continues and new erosion sites are anticipated. (Central Valley Flood Protection Board, 2010.)

Another avenue for cooperative levee repair and rehabilitation resides in landmark CALFED Bay-Delta legislation signed in 2004. This legislation authorizes the Secretary of the Army to expend $90 million of the estimated budget of $9.2 billion dollars from the CALFED Bay-Delta Program in 2004 for construction and implementation of levee stability projects for flood control, ecosystem restoration, water supply, water conveyance, and water quality objectives (Legislative Analyst's Office, February 2004). Existing authorization of this $90 million should help ACE support objectives the sponsor is seeking to achieve with this legislation. While the CALFED Bay-Delta Program (CALFED) contains federal and state agencies within its purview, ACE and the California Department of Water Resources (DWR) lead efforts like the CALFED Levee Stability Program along with local reclamation districts and other concerned stakeholders. CALFED's Levee System Integrity Program is designed to provide long-term protection of vast resources in the Delta by maintaining and improving the integrity of the estuary's extensive levee system. This aspect of federal-state partnership is designed to reduce the risk to land use and associated economic activities, water supply, agriculture and residential use, infrastructure, and the ecosystem from the effects of catastrophic

breaching of Delta levees. (CALFED Bay-Delta Program, *Levee System Integrity Program*, 2011.) Unfortunately, CALFED has only moderately met the program's levee system integrity goals at this point due to funding challenges and difficulty of stabilizing existing Delta levees — an action that ultimately might not be cost-effective. (CALFED Bay-Delta Program, August 2007.)

DWR inspects and evaluates the maintenance of California's federally-designated project levees. Most project levees are maintained by local agencies, such as reclamation and levee districts. (California Department of Water Resources, January 2005.) Ongoing subsidence of levees causes more damage than can be repaired by state or local reclamation districts using normal maintenance programs. During a typical 30-year mortgage period, there is a 26% chance that homeowners living behind a levee will experience a flood larger than the 100-year flood event—the Federal Emergency Management Agency's (FEMA) minimum acceptable level of flood protection as specified by the National Flood Insurance Program (NFIP). Local resources are not adequate to address floods of this magnitude, requiring state, and likely federal, assistance. (California Department of Water Resources, March 2007.)

ACE and DWR are involved in a Delta Islands and Levees Feasibility Study to address flood risk management problems, water quality, and water supply, among other things, in the Delta and Suisun Marsh area. Results will help define problems, opportunities and specific planning objectives. (U.S. Army Corps of Engineers, June 2006.)

Another avenue by which California is addressing levee integrity is through Bay Delta Conservation Plan (BDCP), collaboration by federal, state and local water agencies, state and federal fish agencies, environmental organizations, and other stakeholders. As part of this plan, ACE will continue to work with non-federal sponsors to identify opportunities to reduce flood risk by improving flood capacity of the Delta system while restoring and protecting floodplain and environmental features of the Central Valley, as well as identifying levee stability needs for potential reconstruction efforts. (U.S. Department of the Interior, November 2010.)

Advancements in state of the art engineering are available to rehabilitate and fortify Delta levees, but since, due in part to their having been created long ago, most have serious design, construction and operational inadequacies, costs will be enormous. The National Committee on Levee Safety (NCLS) was created by Congress to develop a strategic plan and recommendations for a national levee safety program. A key issue is finding funding necessary for federal, state and local levee rehabilitation and improvement. The NCLS has recommended that Congress authorize and fund an estimated budget for $1 billion in funds for a National Levee Rehabilitation, Improvement and Flood Mitigation Fund, which would also provide financial support for publicly-owned levees not federally operated and maintained (National Committee on Levee Safety, 2009). Levee rehabilitation under these efforts is limited, focusing at this stage on urban-area levees in critical need of repair. (National Committee on Levee Safety, June 2010.)

Even with the efforts of the U.S. and state governments and other stakeholders to repair and rehabilitate Delta levees, the vast majority of levees and flood control structures are owned, operated and maintained by local levee and reclamation districts, or are privately owned – requiring private maintenance. It is widely accepted that most levee districts are under-funded and unable to maintain the system to meet current federal standards. As for private levees, their quality and repair needs are largely unknown. Emergency flood-fighting efforts by state and local teams have been responsible for saving many leaking levees during major flood events. Without these emergency response actions, more levee failures, loss of life and property damage would have resulted. There will likely be more flooding through distressed levees and fewer

resources available to save these levees and prevent further flooding. (California Department of Water Resources, January 2005.)

Circumstances surrounding Hurricane Katrina's levee preparation are instructive to all parties working to fortify Delta levee system from flooding and protect the region's resources. A direct hit from a major hurricane in New Orleans had been predicted for years prior to Katrina, and days before Katrina hit on August 29, 2005, specific warnings had been given. The city's emergency preparedness before Katrina included a hurricane evacuation plan that identified at-risk populations such as people living outside of levee protection areas. New Orleans' levee system was prepared for Category 3 storm, and Katrina was Category 5 at its strongest. (Handwerk, Brian, 2005.) In July 2004, FEMA conducted a five-day exercise to respond to a hurricane. City officials had planned to release a DVD in September urging residents to prepare for a hurricane as the city did not have resources to evacuate everyone. (Drobnyck, Josh, 2005.)

Hurricane Katrina put 80% of New Orleans under water, mostly due to levee failures from nearby Lake Pontchartrain. (ScienceDaily, Aug. 2006.) The 350-mile levee system breached in about 50 places. Subsequent evaluation showed Katrina caused dozens of breaches throughout the levee system rather than a few breaches through the floodwalls. Levees, made of highly-erodible materials, failed due to scour erosion caused by overtopping, seepage, soil failure, and piping (internal erosion). (Independent Levee Evaluation Team, 2006.) Weak soil embankments or foundation soil and displaced soil contributed to some levee failures. High water pressure may have caused internal instability in structures. Connections among levee sections were problematic, with inconsistent crest heights, materials, and levee types. Funneling of the surge, from storm and winds, into channels of water resulted in overtopping levees. Differences in degree of damage depended on types of levees and the materials from which they were made. Most heavily damaged or destroyed levees were made of easily erodable sand or "shell fill." (Nicholson, Peter, November 2005.)

In the Sacramento Delta, stakeholders should develop strategies to minimize impact from natural hazards. Furthermore, design and construction of key infrastructure should be reviewed, such as port and harbor installations, pipelines, pump stations to draw flood water from streets, wastewater and drinking water plants, airports, waste management facilities, mass transit, and roads and bridges. Coordination among federal, regional, state and local entities on flood risk management and community planning must improve. (Medlock, Sam Riley, July 2010.)

B. Levee Failure Response and Spill Cleanup: Federal, State and Local Governmental Preparation for and Response to Levee Breaches

Many federal and state agencies and inter-agency teams respond to flooding in the Delta Region, regardless of cause. Additional assistance exists for responding to and containing an oil or hazardous materials spill. This section discusses the agencies and their duties responding to spills in the Delta region.

EPA is lead federal agency responsible for preparing for and responding to oil spills occurring in and around inland waters. The U.S. Coast Guard (USCG) is lead federal agency responsible for these functions for oil spills in coastal waters and deepwater ports. Among oil spill priorities are the: 1) Facility Response Plan (FRP) Rule (certain oil storage facilities must submit plans to respond to worst-case discharge of oil and to substantial threat of such discharge); 2) National Contingency Plan (NCP) Subpart J - Product Schedule (a schedule of spill-mitigating devices and substances that may be authorized for use on oil discharges); 3) Reporting Requirements for Oil Spills and Hazardous Substance Releases; and 4) Spill Prevention, Control, and Countermeasure (SPCC) Rule (certain facilities must prepare, amend,

and implement SPCC Plans to address the potential for discharge of oil). (U.S. Environmental Protection Agency, 2011.)

The Delta is connected to the San Francisco Bay, considered coastal water; the Delta by extension is coastal water, thus allowing USCG to become the lead federal agency responding to spills in the Delta Region. USCG has operational units located throughout California and the Bay Area. One of three special USCG Strike Teams is based in the Bay Area. Strike teams are comprised of a unique, highly trained cadre of USCG professionals who maintain and rapidly deploy with specialized equipment and incident management skills to any place or hazard. (U.S. Coast Guard, 2011.)

The key "super-agency" for emergency response to oil or hazardous material spills in the Delta Region is the Regional Response Team for Region IX (RRT). RRT is composed of tribal, state and federal agencies, co-chaired by USCG and EPA. RRT plans for and responds to incidents covered by a National Contingency Plan (NCP) and may engage in consultation, planning, training, stakeholder outreach and coordination to support the Federal On-scene Coordinator (FOSC). A Regional Contingency Plan (RCP) for Region IX supports deployment of response resources and development of agency response relationships and support mechanisms for emergency responses. Federal agencies, notably the U.S. Fish and Wildlife Service and USGS, would offer assistance to RCP response. The RCP is intended for use by emergency response personnel for obtaining resources to respond to an oil or hazardous materials incident. For the Delta Region, the RCP is used in coordination with an inland Area Contingency Plan (ACP) for the San Francisco Bay and Delta, which covers: 1) discharge or threats of discharge of oil into or upon navigable waters of the U.S. and adjoining shorelines or which may affect natural resources; and 2) releases or substantial threats of releases of hazardous substances into the environment or of pollutants or contaminants that may present a danger to the public health or welfare. This ACP was developed to protect sensitive and valuable resources of the San Francisco Bay and Delta Estuary and associated coastline in the event of an oil spill. The RRT believes that ACPs should be adequate to respond to a worst-case discharge and to mitigate or prevent a substantial threat of such discharge. RRT members are encouraged to take every opportunity to exercise the RCP. (Federal Region IX Regional Response Team, October 2005.)

The National Oceanic and Atmospheric Administration (NOAA) would become involved in emergency response as well. In event of a major emergency in the Delta Region, NOAA's Scientific Support Coordinator, part of its Office of Response and Restoration, would be immediately deployed in conjunction with USCG response efforts. (U.S. Department of Commerce, July 2010.)

The California Emergency Management Agency (California EMA; formerly the Governor's Office of Emergency Services) is also involved in emergency response, primarily to assist local government and the public through emergency management including the ACP. California EMA, responsible for coordination of overall state agency response to major disasters in support of local government, produces the State Emergency Plan which outlines the organizational structure for state management of response to disasters. DWR would work with California EMA in this instance, providing general assistance in life-saving operations, provision of state funds and other resources, and salinity tracking necessary due to inflows of saltwater from San Francisco Bay. (California Emergency Management Agency, January 2011.)

The California Department of Fish and Game's Office of Spill Prevention and Response (OSPR) would join response efforts as well. OSPR has its own San Francisco Oil Spill Contingency Plan and can provide extensive local and regional knowledge, including of native plant and animal species, water patterns and unique aspects of the Delta ecosystem. OSPR would provide expertise for containing and mitigating harmful effects of oil and hazardous

materials spills due to large earthquake and/or massive flooding. (California Dep't of Fish and Game, *OSPR Contingency Plan Program Overview*, 2011; California Dep't of Fish and Game, *San Francisco Oil Spill Contingency Plan*, 2011.)

Ultimately, limited resources could hinder response efforts and impede quick levee repairs. Levee repair materials, barges to transport such materials to the Delta Region, and other repair equipment would be difficult to procure during a geographically widespread catastrophe. Federal assistance would mitigate lack of regional resources but might not be timely. The response community must address these shortfalls and plan for them accordingly.

Adequate resources, especially at the local level, are a major issue. If a large earthquake or massive flood hits the Delta Region, competing interests in need of the state's resources would quickly exhaust California's ability to respond effectively and timely to any one area. At the local level, law enforcement could be involved in emergency response efforts, depending on the location of the incident, its severity, and the county's resource-level ability to respond. In case of emergency in the Delta, local reclamation districts in Contra Costa, Sacramento, and Solano Counties, for example, have general emergency response plans, and county sheriff's offices, fire departments, and emergency services departments which would be among first responders during a large-scale emergency such as earthquake. These counties are unlikely to possess adequate resources for extensive emergency response, and constrained budgets probably will not allow for programs specifically aimed at the Delta levee system. State and federal agency coordination with localities is essential for emergency planning in the Delta, and will be crucial to supplement local efforts. (California Delta Protection Commission, June 2008.)

The Association of Bay Area Governments (ABAG) has established a Technical Working Group to Evaluate Bay Area Levee Hazards and Planning Options in response to statewide analyses of serious threats to water supplies from earthquake and flood hazards in the Delta. The working group's priorities will be to assess funding and technical resources and identify collaborative opportunities for emergency planning as part of a mitigation plan to address predicted hazards. (Association of Bay Area Governments, 2011.)

The aforementioned agencies implementing response measures to a massive earthquake or flood probably would be overtaxed due to the enormity of such an event. The experience of disaster relief during Hurricane Katrina is, again, instructive. Federal agencies prepared for the hurricane's arrival, providing critical infrastructure assessments, predicting possible points of impact, and beginning pre-storm staging of personnel. New Orleans' mayor ordered the city's evacuation 24 hours before the hurricane hit, in contrast to the 72-hour time provided in the city's emergency management plan. The city initiated its emergency plan with city officials providing transportation at announced pick-up points and opening schools, the Superdome, and the Convention Center as shelter. Unexpected flooding prevented rescuers from responding immediately. It took days to get food, water, and medicine to tens of thousands of displaced residents who chose not to evacuate or had no means to do so. (Drobnyck, Josh, 2005.)

Katrina flooding due to levee breaches destroyed oil and gas infrastructure in addition to hurricane-protection levees, bridges, homes, and industrial facilities in Louisiana. Agencies – including USCG, EPA and the Louisiana Department of Environmental Quality, among others – were notified of nearly 400 incidents of hazardous materials release, more than 70 salvage operations, and other materials releases that were potentially hazardous. Hurricanes Katrina and Rita destroyed or damaged more than 100 oil platforms, damaged 100 oil pipelines and caused 211 minor pollution incidents involving fewer than 500 barrels of oil. (Pine, John C., June 2006.)

The hurricane scattered barrels of antifreeze and synthetic oil on lawns and roadways, submerged oil operations, grounded or sank watercraft that carried petroleum products, capsized fishing boats, and damaged or dislodged oil storage tanks protected by levees. An oil tank could

be as long as 20 feet tall and 280 feet in diameter. Petrol and oil from 250,000 submerged cars and gas stations also contributed contaminants, as did suspected leakage from area toxic waste dumps. (Borger, Julian and John Vidal, September 2005.)

A total of 11 million gallons of oil were released into the ground and waterways from Katrina and Rita (540 spills from broken pipelines and failures in storage structures)—about the same amount as was released during the 1989 Exxon Valdez spill. (Schleifstein, Mark, August 2010.) About 500 specialists focused on the 44 most serious spills from industrial plants, storage depots, and other facilities. Transportation and movement of cleanup crews, such as from the state's oil spill response task force, and materials were challenged by hurricane damage such as downed power lines and flooded roads, as were workers focused first on human lives in search and rescue. Logistical challenges included lack of electricity, water, food, sewage, fire department and emergency services, phone lines, and shelter. (Llanos, Miguel, September 2005; Sever, Megan, February 2006.) We expect that the Delta will have similar infrastructure disturbances with the advent of flooding, due to its critical role in the state for roads and water deliverance.

USCG and EPA both responded to cleanup: EPA oversaw inland spills, and USCG oversaw spills in coastal areas and waterways. ACE set up barriers to prevent spills from reaching Lake Pontchartrain. Besides government agencies, local officials and responsible parties worked together during the cleanup as well as in restoration. Marine Spill Response Corporation, an industry-funded nonprofit oil spill cleanup organization, brought in seven vessels that served as command and control centers in response to 32 incidents. The ships had sleeping and mess halls, logistical and staging support, communications facilities and spill cleanup headquarters. (Sever, Megan, February 2006.)

The technology available to assist with Katrina spill cleanup included widely-used mechanical tools to contain the oil and chemicals that disperse oil. One is a mechanical boom, a floating barrier with a skirt to surround a tanker or oil slick. Oil collected on the surface of the water was then scooped up by skimmers or absorbed using sorbents (made from natural materials such as peat moss, straw, or clay, or synthetic materials such as plastic). Chemical dispersants break down and distribute the oil in the body of water, biological agents such as plants and bacteria speed up degradation, and in situ burning on the water surface prevents oil spread. Oil on the shoreline can be pressure washed, vacuumed, and suctioned. In addition, companies and agencies have available computer models for tracking and surveilling spills according to weather conditions and environmental properties; radar or satellite imagery can track oil at night, under ice, or in cloudy conditions, helping to determine the type of spill, and prioritize and direct response to most severe spill areas first. (Sever, Megan, February 2006.) While chemical measures are not pre-approved for use in the Delta, the Regional Response Team would advise the FOSC

If the Sacramento-San Joaquin Valley had river diversion structures, controlled flooding to specific basins or floodways may be effective in protecting residents, property, and natural resources in event of an oil spill contaminating Delta water. (Israel, Brett, June 2010.)

III. Conclusion & Future Considerations

After recent events in New Orleans, the Gulf Coast, and predicted storms, earthquakes and climate change impacting California, the threat of levee breaches and the resultant impact of oil and hazardous materials is on the minds of the media and the public. California depends upon a complex water system that requires Sacramento-San Joaquin Delta freshwater for personal consumption, irrigation and industry. What does the future hold for the Delta Region? The technical examples discussed above, used in New Orleans' response to Katrina and considered or

implemented for the Delta Region, are important pieces to prepare for and respond to levee breaches and flooding. As the Katrina experience demonstrates, advanced engineering and technological fixes cannot completely resist the force and unpredictability of Mother Nature, but appropriate planning relevant to the magnitude of the disaster can abate some issues. Thus, public and private stakeholders are considering other options to protect Delta freshwater, while continuing to rehabilitate and fortify the region's levee system. One major consideration is construction of an "isolated facility" — a vehicle to take freshwater from its source and move it through or around the Delta in a way which isolates it from the Delta and then exports it downstate. One concept for the isolated facility – once rejected – has resurfaced and is gaining steam: the peripheral canal. This canal or tunnel system would move freshwater around the Delta Region and on to Central Valley and Southern California destinations. The tunnel system would be capable of carrying 15,000 cubic feet per second – big enough to carry the entire Sacramento River. Problems persist, however. U.S. Department of the Interior biologists have cautioned that existing diversion proposals may cause more environmental harm than good for wildlife depending on the system, and cost remains a hurdle – for an aqueduct system to tunnel water to Southern California, latest figure is $13 billion. (Taugher, Mike, 2010; Bacher, Dan, 2010.)

Other concepts have been put forth for improving Delta water and Delta levee health and longevity, including general maintenance of existing levees, erecting a permanent or moveable seaward saltwater barrier to keep saltwater at bay, and massive investment in fixing existing, or erecting, new levees to protect urban areas, infrastructure and water supply exports. (Public Policy Institute of California, February 2007.) Other concepts for broader long-term management of Delta Region islands and water quality include shallow flooding of islands to mitigate subsidence by slowing peat oxidation and allowing growth of wetland vegetation that contributes biomass accumulation, or shallow flooding combined with thin-layer mineral deposition; continued use of agricultural areas with shallow peat or low organic-matter content (assuming additional subsidence by such use will not destabilize levees); addition of thick layers of mineral soil, possibly using controlled levee breaches, to slow peat oxidation and raise land-surface elevation; or deep flooding to create freshwater reservoirs. (U.S. Geological Survey, Apr. 2000.)

Finally, new developments on Delta islands create greater risk for oil and hazardous materials releases and for residents and their surrounding environment. Developments on subsiding islands surrounded by weakened levees in an area with potential seismic activity do not provide for safe human habitation. Use of planned exercises with participation from all Delta Region stakeholders, whether their interests are environmentally focused, agriculturally focused, politically focused or homeowner focused, is a necessity. To safeguard all interests, cooperation and participation from those involved is necessary and the only sufficient means to adequately address the dangers of impending levee failure and subsequent environmental damage.

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