Delta Vision

Context Memorandum: Flooding and Delta Levees

This context memorandum provides critical information about flooding and Delta levees to support policy making. As they are developed, the context memos will create a common understanding and language about the critical factors in establishing a Delta Vision.

This is an iterative process and this document represents the beginning of a dialogue with you about how best to understand flooding and Delta levees and to inform recommendations by the Delta Vision Blue Ribbon Task Force. You have two weeks to submit comments that may be incorporated into the next iteration.

You may submit your comments in two ways: either online at dv_context@calwater.ca.gov or by mail. If you are using mail, please send your comments to: Delta Vision Context Memo: Flooding and Delta levees, 650 Capitol Mall, 5th Floor, Sacramento, CA 95814.

Your attributed comment will be posted on the Delta Vision web site (http:www.deltavision.ca.gov). Please cite page and line number with specific comments; general comments may be keyed to sections.

Your participation in this iterative process is valuable and important and is greatly appreciated. Thank you for your comments.

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Section 1. General Policy

Flooding is the most common and damaging natural disaster in California and has caused more economic damage to the state than all other natural disasters combined. All 58 counties have been declared under a state of emergency because of flooding at least three times since 1950.

The floodwaters in the state are mostly managed through artificial systems. In the large Central Valley, watersheds drain to the Delta. Flows are confined with levees to minimize the damages caused by flooding. These levees work on a “part time” basis since they are necessary to provide protection only during high flows. In contrast, the Delta is shaped by levees that provide constant protection from flooding due to the fact that most lands in the area have subsided and the ground is below mean sea level. Therefore Delta levees commonly work “full time” retaining water at all time.

More than 90% of the land in the Delta is included in FEMA’s flood zones. Virtually all existing services in the Delta are dependent on Delta levees. Levees shape the Delta the way we know it today, with levee failures causing damages to farming, infrastructure, and interruption of water exports. Eleven hundred miles of levees protect “islands” in the Delta and an additional 200 miles of levees are in Suisun bay and marsh.

The 1,300 miles of levees were originally built only to reclaim the rich Delta soil and protect it from flooding. Therefore, levees were built with varying standards, mostly by local districts to protect agricultural uses; but 35% (385 miles) are part of the Sacramento River Flood Control Project and eligible for US Army Corps of Engineers rehabilitation. Delta levees are designed to provide protection against hydrologic flooding and are not designed and built to resist earthquakes. A small fraction of Delta levees (101 miles) have been improved to better standards, mostly to protect urban areas. Levees require regular maintenance to remain effective in flood management.

For most of the history of the Delta the levee maintenance was performed and paid for by the owners of the land protected on individual islands. Despite that maintenance, virtually all levees in the Delta have failed at least once over the past 100 years; about 75 percent have failed at least twice. The average number of failures per year in the last 100 years is 1.6.

Despite the fragility of the levees in the Delta, they are the backbone of the Delta as we know it today. Levees shape all the waterways and protect most islands, infrastructure and services in the Delta.

Over time, the state and local governments as well as private industry built significant infrastructure in the Delta, including the State Water Project. This

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infrastructure is protected by the levee system and the state determined that it was in their best interest to improve the maintenance of the levee system. In 1973, the state started providing supplemental funding to local agencies to assist with Delta levee maintenance and improvement. In the past five years a total of $55 million in State funding was spent on such maintenance. In recent years, the average number of levee failures has dropped to less than 1 per year, in part, because of the public/private partnership between the State and Delta levee maintaining agencies. However, both the state and local agencies have found it increasingly difficult to carry out adequate maintenance programs due to funding and environmental issues.

Additionally, global climate change effects like sea level rise and stronger storms threaten the stability of the Delta levees. On the legal side, a recent court ruling, *Paterno v. State of California*, holds the state liable for flood-related damages caused by failure of a project levee, where the State has provided assurances of levee integrity, even when the levees were built and are maintained by local districts. Approximately 1/3 of the levees in the Delta are Project levees; the remainder levees are non-project levees which may not have the same level of state liability.

The current system for construction, maintenance and repairs of levees is highly fragmented among state, federal and local authorities and results in significant separation of decisions from responsibility of payment and of liabilities. Historically the state has repaired levee breaches to prevent salinity intrusion, with local reclamation districts bearing the expenses of pumping the water out of the islands and restoring it for agriculture.

Current practice is to repair Delta levees at costs above the assets protected, justifying the expenses with the value for water exports. Other practice is to reinforce levees to allow increased urbanization with some risks shifted to other governments and those who purchase property behind those levees.

Virtually all proposals for the future sustainability of the Delta require levees to achieve desired environmental, water supply and quality, infrastructure and disaster preparedness goals, among others. The policy questions to be addressed regarding levees are critically determined by the goals desired. In short, policy questions regarding levees are appropriately addressed in the context of achieving desired policy results, not independently.

Five policy questions are:

- Which levees are of long-term importance?
- What is the appropriate standard to which they should be built and maintained?

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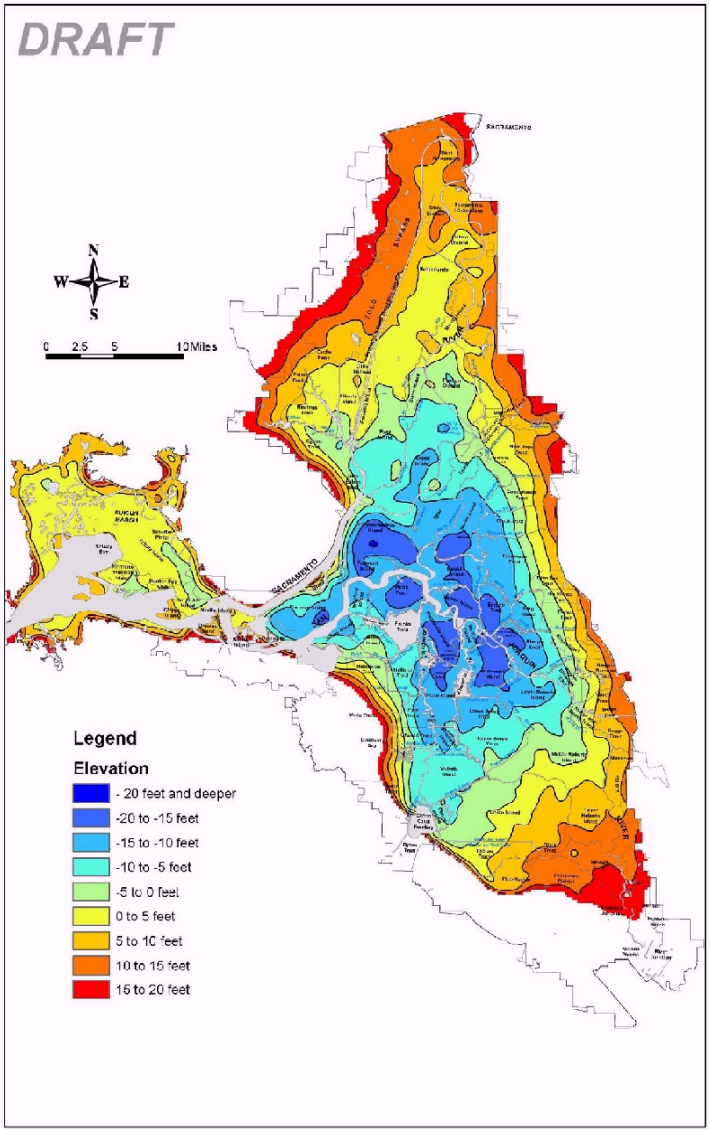
- How and by whom will decisions about levee reinforcement and maintenance be made?
- How shall levee construction and maintenance be financed?
- How shall the consequences of levee failure be distributed?

Scientists and engineers identify the following factors affecting the protection provided by levees:

- Design (including foundation, materials, width and slopes, facing materials…)
- Height differential between water side and land side
- Height and duration of water pressure, including tidal, flood and wind generated wave variations

Current policies affecting the design, construction, maintenance and repair of levees include:

- Design standards
- State levee subvention policies
- Paterno decision
- FEMA standards and regulations



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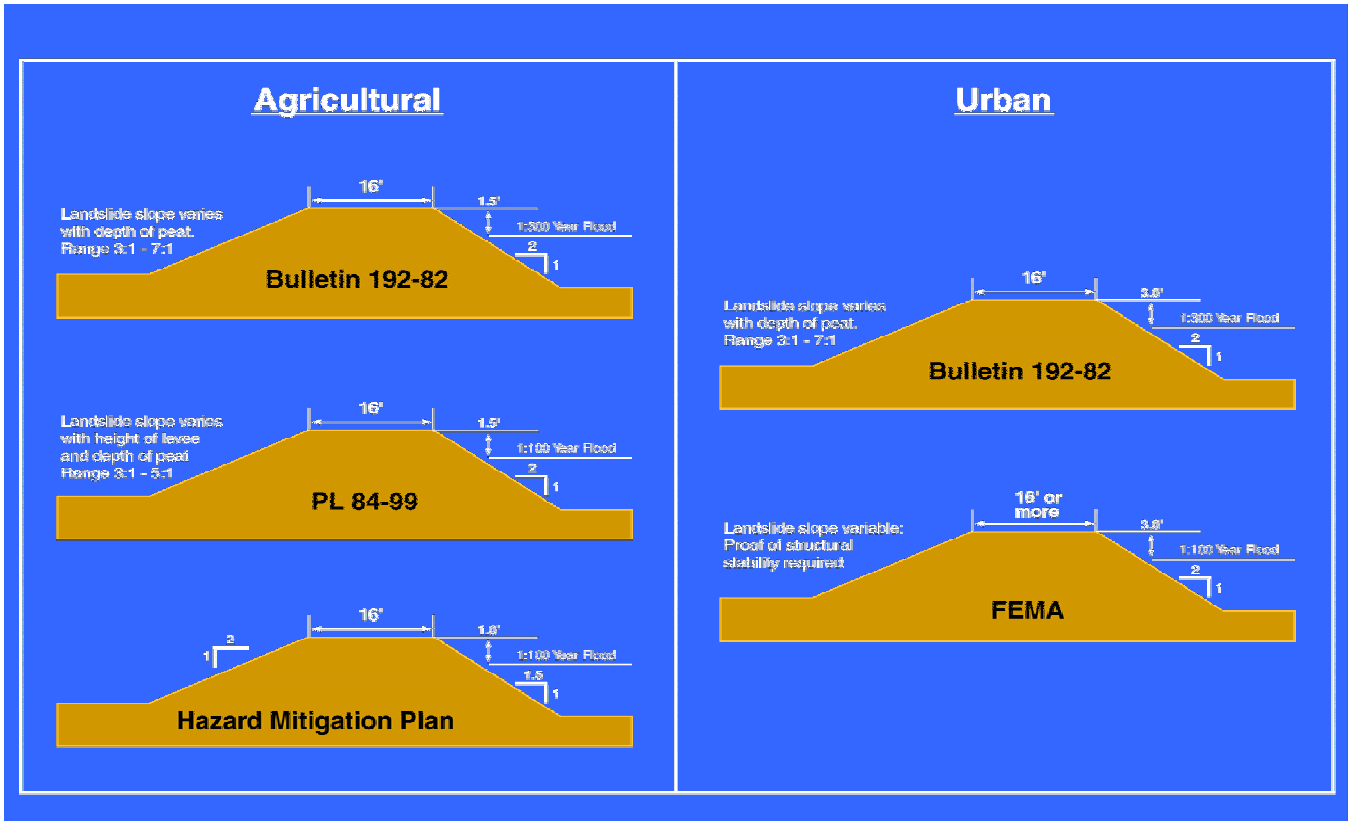
Section 2. Conceptual Models and Related Science and Engineering

Levee Standards. More than 700 miles of levees in the Delta are maintained locally to comply with the Hazard Mitigation Plan standard (HMP). This is standard for agricultural land protection. In 2000, the CALFED Program through its Record of Decision identified the federal "Public Law 84-99" standard (PL84-99) as the standard all levees in the Delta should meet. This is called Base-Level Protection. The PL84-99 standard is also a standard for agricultural land protection. Only 101 miles of levees have achieved this new standard as a minimum during the last seven years, many of them due to the need to improve levees for urbanization. Many locally maintained levees do not even meet the HMP standard at this time.



Achieving the base level of protection standard will require many steps, including placement of a significant volume of material over compressible foundation soils. The weight of this new material will stress the foundation and may cause significant settlement and cracking. Therefore geotechnical evaluations on cracking, high seepage, and levee failure must be performed on an individual basis.

Levee Stability. Levee stability is dependent on the characteristics of the material that make up the levee and its ability to withstand the forces of the water pressure and, as is the case in the Delta, seismic activity. Seepage and tunneling, erosion, and

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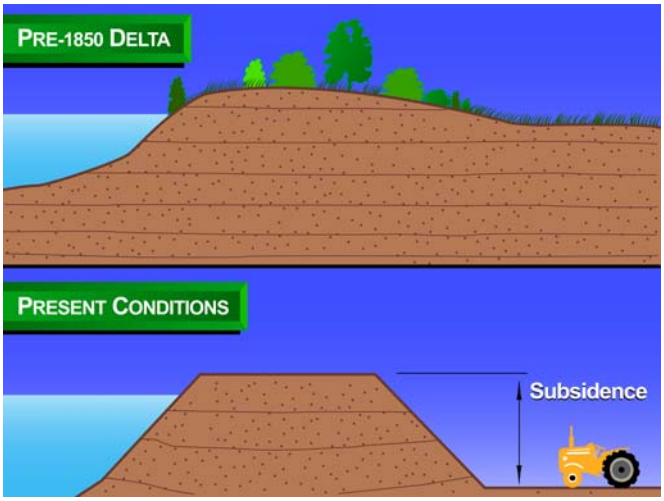
physical encroachments on the levee are all ways that reduce the ability of the levee to withstand the force of the water and cause levee failure. Earthquakes are, also, a concern because they can cause the levee material to become weaker, and can also cause liquefaction and settling of the foundation or embankment soil under the levee – causing levee failure. A stable foundation and continuing levee maintenance are important for maintaining adequate levee stability.

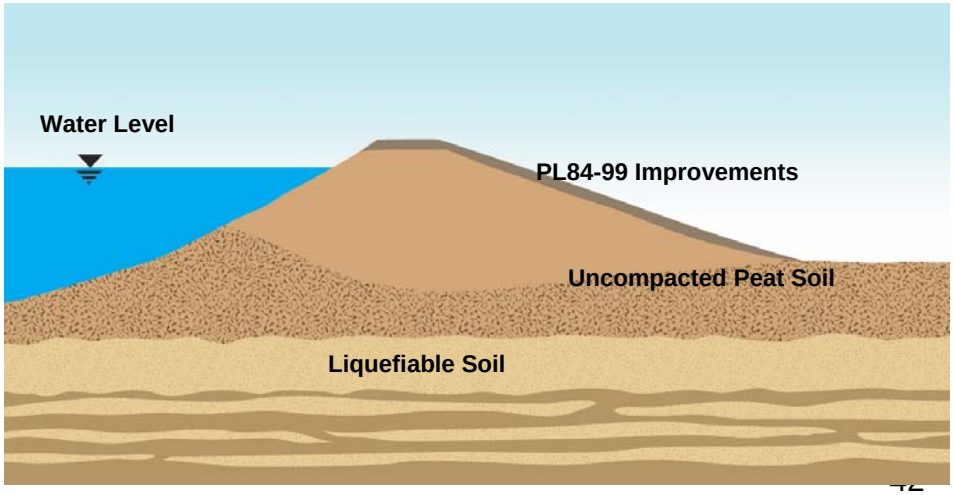


In general Delta levees are not designed and constructed in accordance with today's standard engineering practices. Levees have been shaped through time due to land subsidence inside the islands. Most levee failures have occurred because of seepage and tunneling (water flowing under levee foundation), but there are other factors that cause levees to fail:

Levee failures caused by water-related pressures:

- Tides
- Storm water runoff
- Weather (wind and rain)
- Climate change effects (stronger storms, higher sea level)
- Caused by earthquake
- Liquefaction
- Cracks

Seismic related failures include liquefaction (when the sandy soils behave as fluid - 85% of the cases) and non-liquefaction damages like cracks (15%). It is important to note that levees remain susceptible to earthquake damages even after PL84-99 improvements are made since the foundation is still liquefiable.



Global Climate Change and Seal Level Rise. Global climate change will increase the stresses on Delta levees. Sea level rise, believed to be a foot or greater in

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the next 100 years, in combination with continuing subsidence, will add more water pressure on levees increasing the risk of seepage and tunneling. Another damaging factor will be the effect of the combination of winds associated with stronger storms and higher tides.

Recent peer-reviewed scientific studies indicate that global climate change is not just a possibility but a current reality that is already affecting temperatures, rainfall patterns and ocean levels. Although much uncertainty remains, the state may be facing a rise in sea level of several inches within the next few decades. The potential impacts in the Delta of some ocean-rise scenarios include increased levee failures and even massive flooding throughout the Delta.

The last world-wide consensus of the Intergovernmental Panel of Climate Change states that a two-foot level raise in sea level is expected by 2100. However, recent research and availability of new information have changed that prediction to as much as four feet, with the two-foot raise expected bay 2050.

Mitigation for Levee Failure. There are three ways to mitigate for levee failures:

- Reduce failure probability (levee reinforcement; meet higher standards)
- Improve emergency response
- Improve catastrophe tolerance

Local reclamation districts have been maintaining and reinforcing Delta levees for several decades and will be able to keep pace with raising levees until the cost of maintenance outweighs the value of the protected lands. The state, through the Subventions Program, reimburses part of the maintenance cost to qualifying districts.

There is a disparity of opinions about the effectiveness of maintaining levees and their future stability. There is also debate about the probability of a seismic event that would be strong enough to cause major damages in the Delta. The Delta Risk Management Strategy is an effort that will determine, in a probabilistic way, the risk Delta levees will be facing in the next decades.

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Section 3. History, Institutions, Policies and Economics of Flooding and Delta Levees

Delta Reclamation. Delta reclamation occurred in several phases. The first phase (1850-1868) of reclamation projects were small-scale efforts using manpower and horses to build levees on top of existing natural levees.

In part due to the lack of government involvement and to the abolition of individual land ownership limitations, large-scale reclamation began in 1868. During this time levee building was more aggressive and was accomplished with both hand labor and mechanical equipment. Dredgers, a mechanical device, would scoop out submerged Delta soil and pile it on dry land to form levees. This period of development ended around 1900 with most of the lands with mineral-organic soils reclaimed. With the exception of Bouldin Island, the lands with peat soils in the central Delta were generally not reclaimed.

Large amounts of sediment began flowing into the Delta as a result of hydraulic gold mining during the 1850s. Although the federal government stopped this form of mining in the 1884, the residual transport of sediments continues today. In addition to sediments, mercury used to extract gold also made its way into the Delta. In some Delta channels, the sediment filled the river bottom channels to the point where navigation was impossible. Also, sediments reduced the capacity for the Delta to contain floodwater and thus enhanced the need for levee protection.

The final period of Delta reclamation occurred between 1900 and 1920 on lands in the Delta's interior. These lands contain mostly organic soils and although the soils are very agriculturally productive, they are not suitable for levee construction due to their high organic matter. In addition, when exposed to air organic soils oxidize (conversion of organic matter to carbon dioxide) due to biological processes. Oxidation of organic soils has resulted in as much as a fifteen-foot loss in elevation in places. Due to the drop in land elevation, there is increased pressure on the levees during flooding events.

The result of the reclamation efforts is largely what is seen in the Delta today - approximately 700 miles of meandering waterways and 1,100 miles of levees protecting over 538,000 acres of highly productive farmland and millions of dollars in homes and other structures.

Water Development and Flood Control. Since 1900, there have been 166 levee failures leading to island inundations. In 1921 the state initiated the first water plan to address water supply and flooding issues. Because of California's inability to obtain financing for the plan the federal government implemented components of it as the

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Central Valley Project (CVP) in 1933. California began building the State Water Project (SWP) in 1951. The operation of both projects relies on the use of Delta channels and sloughs to convey fresh water from the tributaries to the export facilities located in the southern Delta. The construction of these facilities was predicated on a commitment to maintain suitable water quality for beneficial uses within the Delta as well as the water export areas.

In 1960, the Sacramento River Flood Control Project was completed by the U.S. Army Corps of Engineers. This project incorporated and improved flood control for much of the Sacramento Valley and a portion of the Delta. About a third of the Delta levees (385 miles) are part of the Sacramento River Flood Control Project and eligible for US Army Corps of Engineers rehabilitation. This leaves the vast majority of Delta levees, over 730 miles, to be maintained by locals. Local levees were constructed by local landowners, reclamation companies, and reclamation districts that enlarged the levees over the last 130 years without the benefit of significant engineering or quality control. Almost all of the local levees are maintained by local public agencies such as reclamation districts.

Legislative and Regulatory Actions and the Subventions Program. In the 1970s, the California Legislature recognized that the Delta levee system benefits many segments and interests of the public and approved a preservation plan. The Delta Levee Maintenance Subventions Program was established in 1973 and amended by the Delta Flood Protection Act of 1988. The Delta Flood Protection Fund was created to provide for local assistance under the Delta Levee Maintenance Subventions Program (Subventions Program), and for Special Delta Flood Protection Projects (Special Projects).

Currently, the Subventions Program and Special Projects are being carried forward under funding provided by the Safe, Clean, Reliable Water Supply Act, Division 24 of the California Water Code (Proposition 204, 1996). In 2006, voters approved Propositions 1E and 84, which provide funds for these programs for the next two decades.

Economics of Levees. The potential impacts on people and communities of a single failure or multiple failures are catastrophic. These risks tend to be disproportionately higher in rural and economically disadvantaged communities that are often unable to invest in flood control improvements. The 1997 floods forced more than 120,000 people in the state from their homes. More than 55,000 were housed in 107 shelters, the largest sheltering operation in California's history. An estimated 30,000 residential and 2,000 business properties were damaged or destroyed.

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California voters approved nearly $300 million for Delta levee maintenance and improvements through Proposition 84 last November, with potentially more funds available through Proposition 1E. Therefore, levee maintenance is assured for at least the next decade. However, these funds do not include an emergency response fund, which could be very costly.

Repairing a levee breach in the Delta is mainly performed to maintain water quality for beneficial purposes. The value of the protected island and its infrastructure is seldom greater than the repair cost. For example, the recent levee break cost on Upper Jones Tract in the South Delta was nearly $100 million for emergency response, damage to private property, lost crops, levee repair, and pumping water from the island. There were also significant costs associated with losses in water supply and conveyance.

Following the break, Delta pumping was curtailed for several days to prevent seawater intrusion at the State and Federal pumping plants, and water shipments to Southern California were continued only through unscheduled releases from San Luis Reservoir. Releases were also increased at Shasta and Oroville reservoirs, sending more fresh water to the Delta for salinity control.

It is important to note that the state's response to the Jones Tract levee break does not have a precedent. In the past, the state has limited its emergency response efforts to close the breach. Local reclamation districts would then pump the water out and restore the flooded island to continue farming. Frank's Tract and Mildred Island are two examples of islands that were not recovered after levee breaches.

4. Ongoing Studies Related to Delta Levees

Delta Risk Management Strategy. The Delta Risk Management Strategy (DRMS) is a study being performed as an outgrowth of the management program element described in the August 2000 CALFED Record of Decision (ROD). The study will analyze the risk of levee failures and is intended to provide a set of alternative risk reduction plans that would be considered in subsequent decision and implementation phases such as the Delta Vision and the USACE's CALFED Levee Stability Program. Risk reduction measures that would be common to all alternative plans would be recommended for immediate implementation.

This study is important to pending decisions on Delta levee management because it will provide important technical information on not only the probability of levee Delta failures but also the consequences of failed levees on the Delta and water export regions.

Schedule: The DRMS is expected to be completed by January 2008.

Delta Long-Term Management Strategy. The Delta Long-Term Management Strategy (DLTMS) being performed by the USACE is studying the best options for the reuse of dredged material for beneficial purposes. There are five areas that the DLTMS is focusing on:

- Compile a 20-year projection for sediment generation in the Delta.
- Identify and prioritize projects suitable for use of dredged material (with priority given to levee reconstruction and ecosystem restoration).
- Document economic impacts,
- Refine cost estimates for dredging, placement, storage, and treatment.
- Established a standardized testing and treatment protocol for dredged material.

This study is important to pending levee management decisions because dredged material that the ports of Stockton and Sacramento need to remove on a regular basis could be used in the future for levee improvements.

Schedule: This study is being conducted in coordination with DRMS and the Delta Vision, and is expected to be finished in six years.

CALFED Levee Stability Program, California Sacramento-San Joaquin Delta. In response to US Congress CALFED Bay-Delta Authorization Act (Public Law 108-361), the US Army Corps of Engineers is preparing a report that describes the levee stability reconstruction projects and priorities that will be carried out under the Act. The report provides both short- and long-term strategies to address levee stability in the Delta. No decision document will be included in this report. The report prioritizes the projects and presents the USACE long-term strategy for levees in the Delta.

This study is important to pending levee management decisions because it will provide guidance for Congress to direct the USACE to participate in the improvement of specific Delta Levees.

Schedule: This study is being conducted in coordination with DRMS and the Delta Vision, and is expected to be finished by 2012.

5. References

Governor's Flood Emergency Action Team (FEAT), 1997, Final Report

USACE's Post – Flood Assessment, Sacramento and San Joaquin River Basins, California, 1999, Final Report