DELTA RISK MANAGEMENT STRATEGY

INITIAL TECHNICAL FRAMEWORK PAPER

DELTA INFRASTRUCTURE

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Delta Infrastructure

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Foreword

The purpose of the Delta Risk Management Strategy (DRMS) Initial Technical Framework (ITF) is to guide the analysis of specific technical topics as they relate to assessing potential risks to Delta levees and assets resulting from various potential impacts (e.g., floods, earthquakes, subsidence, and climate change). These ITFs are considered "starting points" for the work that is to proceed on each topic. As the work is developed, improvements or modifications to the methodology presented in this ITF may occur.

This ITF paper identifies the methodology that will be used to assess damage to Delta infrastructure and resulting cost and schedule needed to repair the damage that could occur as a result of, or concurrently with, inundation from levee breaches due to the hazards that are considered in the DRMS study, and potential secondary hazards that may occur (e.g., chemical spills). The output from the work covered under this ITF paper will be used by the Economic Consequences group to estimate revenue losses to various businesses, utilities, and transportation entities.

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1.0 INTRODUCTION

A large amount of infrastructure is located within the Delta. Some of the infrastructure crosses the Delta to other parts of California and provides vital resources such as water, gas, power, communications, shipping, and railroad freight transportation. Levee failure would cause direct physical damage to residential, commercial and public assets, and environmental impacts. Rupture of petroleum pipelines and resulting spills would cause further environmental losses. Disruption of these In-Delta resources due to levee failure has the potential to cause extreme economic losses to the State and nation as a whole.

The scope of this Initial Technical Framework (ITF) paper addresses the likelihood of damage to Delta infrastructure assets due to levee failure, the cost of repairs to and restoration of the damaged infrastructure, and the estimated time required to make the repairs. The output from the work covered under this ITF paper will be used by the Economic Consequences group to estimate revenue losses to various businesses, utilities, and transportation entities.

In this ITF paper, we consider damage to infrastructure assets that results from, or occurs concurrently with, levee breaching and island flooding, whatever the initiating (stressing) event may be (seismic, flooding/overtopping, etc.). Infrastructure assets that are damaged or fail as a result of an earthquake, for example, without levee breaching and flooding, is not within the Delta Risk Management Strategy (DRMS) study purview. Infrastructure assets that fail as a result of, or concurrently with, flooding caused by levee breaching from an earthquake is within the DRMS study scope.

2.0 OBJECTIVE

This ITF paper identifies the methodology that will be used to assess damage to Delta infrastructure and resulting cost and schedule needed to repair the damage that could occur as a result of, or concurrently with, inundation from levee breaches due to the hazards that are considered in the DRMS study (e.g., seismic and flood), and potential secondary hazards that may occur (e.g., chemical spills). As stated above, the output from the work covered under this ITF paper will be used by the Economic Consequences group to estimate revenue losses to various businesses, utilities, and transportation entities.

3.0 PHYSICAL SYSTEM

The “Delta” includes the following geographic areas:

- Suisun Marsh east of the Benicia-Martinez Bridge on Interstate 680; and
- Legally defined Sacramento-San Joaquin Delta as defined in Section 12220 of the Water Code.

For discussion purposes in this ITF paper, the term “Delta” will be used to describe both the Suisun Marsh and the legally defined Sacramento-San Joaquin Delta.

The Delta infrastructure can be divided into linear and point assets. Linear infrastructure includes railroads, highways, shipping channels, transmission lines, fiber optic lines, sewers, aqueducts, and gas and petroleum pipelines. Point infrastructure includes bridges, marinas, natural gas fields/storage areas, housing tracts, pump stations, and farmland.

An inventory of Delta assets will be obtained from existing resources, including the Sacramento-San Joaquin Delta Atlas (DWR 1995) and a GIS database being developed under a separate Department of Water Resources (DWR) contract for the DRMS project. The inventory of infrastructure assets will be supplemented by other sources such as other consultants (e.g., PBS&J), utilities, and businesses. Another source of data to describe the Delta assets is system upgrades such as capital improvement projects (CIPs). Utilities will be contacted to gain such information.

An important component to assess vulnerability to damage of infrastructure is the type of foundation support system. Infrastructure supported on deep foundations would have less vulnerability to damage and failure than would infrastructure supported on shallow foundations. Heavy structures such as bridges and aqueducts (e.g., the Mokelumne Aqueduct) are typically founded on deep foundations where they are located on peat and soft ground. Thus, they are less likely to fail as a result of flooding than assets that are founded on shallow foundations.

To the extent available, we intend to have a complete inventory of individual structures such as residential, commercial, and others. However, we will not attempt to provide data to fill gaps in the asset inventory. A list of the known assets at this time, organized by category of asset and by island, was provided by DWR.

A summary of the currently available data from PBS&J follows:

- URS GIS group categorized the infrastructure information that we received from PBS&J and produced nine maps as follows:

  1. Utilities, oil, and gas (tank farm, gas and oil well, transmission lines etc.)
  2. Water (points of diversion, public water supply, wells, etc.)
  3. Sewer (solid waste facilities and sewage treatment plant)
  4. Communication (cell towers)
  5. Transportation (airports, rail roads, bridges, highway, etc.)
  6. HAZUS (police stations, fire stations, schools, nuclear facilities, etc.)
  7. Business data
  8. Miscellaneous data (prison, buildings, etc.)
  9. Parcels and reclamation, district boundaries

- A total of 256 attribute tables are available and most of the cells on these data tables are populated. The types of data available in these attribute tables vary, depending on the type of infrastructure. Some examples are shown in Table 1.

4.0 APPROACH

The general approach to the work covered under this ITF paper is outlined in this section. The overall description of the approach includes the following topics:

- Assess damages/failure due to island flooding.
- Estimate cost of island (agricultural land)/infrastructure restoration after dewatering of the island has occurred.
- Estimate schedule (duration) for island repairs and restoration.

These topics are further discussed is the sections that follow.

Table 1
Examples of Data Available in Attribute Tables

Type of Asset	Attributes
Buildings	Building name, address, use
Businesses	Company name, address, sales volume, number of employees
Utilities	Company name, city, zip code, sales volume, number of employees
Tank Farms	Area (NP*), perimeter (NP), zip code, owner, plant name, contact information, capacity
Transmission Lines	Owner, voltage, category, circuits, type, length
Solid Waste Facilities	Site name, place name, operator, owner, inspection frequency, category, activity
Sewage Treatment Plants	Area (NP), perimeter (NP), address, name, and a several other columns that are populated

* NP = not populated

4.1 Response of Infrastructure to Stressing Events and Island Flooding

Two categories of infrastructure assets will be considered in estimating damage: co-located water system assets in the Delta and infrastructure facilities within Delta islands and sloughs. For the water system assets (such as pump stations) damage will be assessed for each stressing event considered in the levee fragility analysis. Screening-level methods using judgment will be employed to evaluate response of these assets to the stressing event. Also, available broad regional earthquake and flood loss estimation models will be used. These may include CCWD and EBMUD system seismic vulnerability and reliability improvement programs to estimate potential damage and losses.

For infrastructure facilities within the Delta islands/sloughs, damage will be assessed assuming each island and adjoining sloughs are flooded. Approaches to assess damage are outlined below:

- Use existing methods to estimate flood inundation losses (such as FEMA's HAZUS and the USACE's flood loss estimating models (see for example, see http://www.hec.usace.army.mil/software/hec-fda/hecfda-hecfda.html). These models can be used for residential construction, commercial buildings, etc.
- Residences, buildings, and similar assets will be assumed to be destroyed if islands are inundated. Inundation will be assumed to be at mean sea level. Other assets (e.g., pipelines) may be damaged if inundated (e.g., Mokelumne Aqueduct was damaged during the June 2004 Jones Tract levee failure). Assets near levees that fail may be damaged or fail themselves, depending on foundation systems and depth of scour. Depth of scour will be estimated from historical data from Delta levee failures. Table 3 summarizes the format for presenting the estimated cost and time to repair different types of assets.
- Utilize studies that utilities and others have used for their assets to assess damage potential.

- Hold a half-day meeting with the major commercial and public entity asset owners to make them aware of this effort and to elicit their support (i.e., guidance, documentation, etc.).
- Infrastructure assets will also be evaluated for 50, 100, and 200 years. Input will be needed from other groups to provide asset density for these years to make this evaluation.

4.2 Cost Estimation

Unit costs to repair various infrastructure elements will be estimated. These unit costs will be for cost per linear foot of pipe, per square foot of bridge deck, per linear foot of roadway, per linear foot of railroad track, per acre of crop land, etc. The unit prices will be estimated from readily available cost data and repair costs from historical failures (e.g., the June 2004 Jones Tract failure) (URS 2005). Where such cost data are unavailable, costs will be estimated from construction industry costs. Utilities may also provide repair cost data. Environmental clean-up costs will include cleaning up petroleum product spills, other chemical spills, and disposal costs for toxic wastes. Where possible, such costs will be based on historical costs (e.g., petroleum product spill in Suisun Marsh). Loss of crops would be estimated by the Economic Consequences group.

4.3 Repair Schedule Requirements

Repair duration/schedule requirements are needed for the Economic Consequences Group to estimate revenue losses to various businesses/utilities during the time when infrastructure is out of service following a levee failure event. Schedule is measured from time when access can be gained to repair damaged infrastructure until completion of repairs. This information will be provided from historical failures (e.g., the June 2004 Jones Tract failure) (URS, 2005). The Emergency Response and Repair Group will provide information on the time required to pump out flooded islands.

A catastrophic failure of the Delta levees (e.g., following a major Bay Area earthquake) would affect the response time to repair infrastructure in the Delta. This response time would be longer than for an isolated failure of a levee. This longer response time would result from competition for resources following catastrophic events. To address this longer response time, a scaling factor would need to be applied to estimate times from historical data. Also, the lessons learned from the New Orleans levee failures following hurricane Katrina will be used.

5.0 PROBABILISTIC APPROACH

The project team will assess the probability of failure/damage of various infrastructure assets at risk from each initiating event. Existing data/models and engineering judgment will be used for this assessment. For each failed/damaged asset, the team will also develop estimates of the time out of service and the cost of repair or replacement using FEMA’s HAZUS and/or the USACE’s models as stated above. The failure/damage analysis will be performed for two categories of assets: (1) water system assets in the Delta whose failure would impact water supply interruption and (2) statewide infrastructure assets in the Delta that would be impacted by levee failures and resulting flooding of islands. The following sections describe approaches to assessing the probabilities and impacts of failure/damage of the two categories of assets.

5.1 Water System Assets in the Delta

This category includes co-located water system assets in the Delta, that is, those water system assets that could be impacted by the same initiating event that could cause levee failures and whose failure or damaged state would impact the duration of water supply interruption. The specific assets that belong to this category are identified in Section 3.0. For each initiating event considered for the levee fragility analysis, the probability of failure of each water system asset will be assessed using available data and models. The time out of service and cost of repair or replacement will be estimated based on experience and engineering judgment.

5.2 Statewide Infrastructure Assets

This category includes infrastructure assets that would be damaged by levee failures and resulting flooding of islands. Section 3.0 identified the specific infrastructure assets or asset types that will be included in this analysis. For each island in the Delta, the project team will estimate probability of failure/damage to each asset within the island assuming that the island is flooded. This estimation will be made using existing data and engineering judgment. Using available GIS data on delta resources, the team will also estimate the quantity (lineal feet, acres, etc.) of each asset that would be damaged. A unit cost of repair or replacement of the damaged asset will be defined based on experience with similar projects. The total cost impact then will be calculated as the product (probability of damage x quantity x unit cost).

6.0 ASSUMPTIONS, CONSTRAINTS, AND LIMITATIONS

The following are some assumptions that will be made in evaluating the vulnerability of Delta infrastructure:

- Infrastructure maintained at present levels (i.e., no deterioration of infrastructure over time).
- Available loss estimation models will be applicable for future years.
- Available data is complete and accurate (i.e., satisfactorily represents existing conditions).
- Responses to the Team’s data requests from infrastructure owners are timely.

7.0 INFORMATION REQUIREMENTS

This section describes the data needs that are required to implement the Delta infrastructure evaluation and also the information needed from other Risk Groups.

Key data requirements are:

- GIS maps of infrastructure assets (to be prepared by others)
- Inventory of infrastructure assets
- General definition of foundation systems, from infrastructure owners and based on engineering judgments
- Depth of flooding of the Delta islands
- Scour extent and depth from historical data (air photos, etc.)

- Unit costs

Information required from other Risk Groups is:

- Definitions of stressing events and resulting loading levels in the Delta
- Response time to pump out islands – from Emergency Response and Repair Group
- Infrastructure asset density at 50, 100, 200 years.

8.0 ANTICIPATED OUTPUT OR PRODUCTS

The following items will be the primary output from the infrastructure analysis:

- Cost of repairs
- Time to repair
- Island restoration cost and timing

9.0 RESOURCE REQUIREMENTS

The following are some of the resources that will be required to implement the infrastructure analysis:

- Structural engineering input to define infrastructure damage/failure based on deformation or load limits.
- Obtain information on broad regional earthquake and flood loss estimation models.

10.0 PROJECT TASKS AND SCHEDULE

The specific project tasks for this analysis module will be as follows:

- **Task 1: Review of Data on Delta Infrastructure Types and Locations**
  GIS maps of inventory of Delta assets/infrastructure will be collected and reviewed. The results of this review will be compiled in tabular and GIS map format.
- **Task 2: Review Data on Features that Affect Infrastructure Performance (Vulnerability Levels)**
  This data review will focus on items that affect the performance of infrastructure. Foundation materials (e.g., peat and liquefiable soils) for the various infrastructure assets will be categorized for evaluating potential for damage to infrastructure. Historical data on scour depths and extent resulting from levee breaches will be reviewed. These data will be used to identify infrastructure that could be undermined by scouring. Types of foundations (deep or shallow) will be reviewed to assess vulnerability of infrastructure to failure due to stressing events.
- **Task 3: Develop Estimates to Define Infrastructure Damage and Estimate Cost and Time Required to Repair Infrastructure**
  Using the data from Tasks 1 and 2, we will assess the response of the various Delta infrastructure assets to stressing events (seismic and flooding). Evaluation of response of infrastructure to stressing events will be done by simplified approaches as described in Section 4.1. Unit costs will be developed for infrastructure assets as described in Section 4.2. The amount of assets requiring repair will be evaluated so

that repair costs can be estimated. Likewise, the time to repair the assets will be estimated as described in Section 4.3.

- **Task 4: Assess Probability of Failure/Damage**
  We will assess the probability of failure of the various Delta infrastructure assets as a function of the stressing event as described in Section 5.0.
- **Task 5: Summarize Results of Analysis**
  In this task, the project team will summarize the results of the analysis. For each stressing event, a summary table will be prepared to list water system assets at risk (see Table 2). For each asset at risk, the table will display the probability of failure, the cost of repairs and restoration, and the estimated time required to make the repairs. A second summary table (see Table 3) will be prepared to display the infrastructure/resource impacts of flooding each island in the Delta. The probability of failure of each point facility and the estimated quantity (e.g., lineal feet, acres, etc.) impacted for each linear/areal infrastructure facility/resource will be shown along with the unit cost of repairs/ restoration and time required to make the repairs.

Table 2
Impacts to Co-Located Water System Assets

Stressing Event	Water System Asset at Risk	Probability of Failure	Repair/Restoration Cost ($000)	Repair/Restoration Time (Days)

Table 3
Impact of Flooding Delta Islands

Island	Area (Acres)	Infrastructure Facility or Resource at Risk	Probability of Failure or Damage*	Unit of Measure	Quantity Impacted	Unit Cost of Repair/Restoration	Repair/Restoration Cost ($000)	Repair/Restoration Time (Days)

* Accounts for infrastructure location within an island.

- **Task 6: Compile Report**

The project team will describe the methodology and summarize the results of the analysis in a draft topical memorandum and submit to DWR for review.

11.0 REFERENCES

California Department of Water Resources (DWR). 1995. Sacramento-San Joaquin Delta Atlas, August.

URS Corporation (URS). 2005. In-Delta Storage Program, Risk Analysis, Draft Report, May 31.