DELTA RISK MANAGEMENT STRATEGY

INITIAL TECHNICAL FRAMEWORK PAPER

EMERGENCY RESPONSE AND REPAIR

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Emergency Response and Repair

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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 describes the objectives, methodology, required inputs, anticipated outputs, and project tasks for completing the emergency response and repair analysis.

A set of scenarios, each comprising levee failures (breaches) and/or non-breach damage, that could occur and their likelihood of occurrence will be determined by the levee fragility module and provide the input to the emergency response and repair analysis. The results of the emergency response and repair analysis will feed into the hydrodynamic modeling task to determine the salinity effects associated with the set of levee failure scenarios. These results will be combined with the rest of the probabilistic risk assessment to evaluate the risk of different levee failures to water export capability.

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1.0 INTRODUCTION

This Initial Technical Framework (ITF) paper is prepared as part of the Delta Risk Management Strategy (DRMS) project. It describes the objectives, methodology, required inputs, anticipated outputs, and project tasks for completing the emergency response and repair analysis.

A set of scenarios, each comprising levee failures (breaches) and/or non-breach damage, that could occur and their likelihood of occurrence will be determined by the levee fragility module and provide the input to the emergency response and repair analysis. The results of the emergency response and repair analysis will feed into the hydrodynamic modeling task to determine the salinity effects associated with the set of levee failure scenarios. These results will be combined with the rest of the probabilistic risk assessment to evaluate the risk of different levee failures to water export capability.

2.0 OBJECTIVE

The objective of the emergency response and repair analysis is to develop a model to estimate the time and material requirements and costs associated with a scenario that involves an identified number of levee breaches and/or the extent of non-breach damage. In addition, in the case of flooded islands where levees have been breached, the model must also estimate the time for island dewatering. The model must be applicable for the range of sequences that will be modeled in the DRMS study as well as address the need to protect the interior side of levees on flooded islands and consider the effect on emergency response and capability resulting from flood fighting activities during the winter months. The range of sequences will be defined in the following terms:

- Flooded Islands:
  - The number and size of breaches that have occurred.
  - The number and size of damaged levee segments within the flooded island.
- Non-Breach Damage:
  - The number and size of damaged levee segments on other, non-flooded islands.

Although the State has improved its pre-event emergency preparedness, and will likely continue such improvements as a result of lessons learned from the recent Jones Tract levee breach, as well as the findings of the DRMS, it is believed such measures will have a limited effect on overall emergency response and repair durations calculated by this model since this model already presumes an effective emergency preparedness status is in place. Furthermore, as the magnitude of scenario damage increases, it is believed the effect of emergency preparedness on overall repair durations diminishes. Therefore, the model does not quantitatively account for such emergency preparedness preparations beyond the assumption that such preparations enable the model to meet the emergency response and repair production rates presumed within.

3.0 PHYSICAL SYSTEM

3.1 Event-Related Response and Repair

As part of the DRMS study, a risk model will be developed which will model the potential occurrence of events (floods, earthquakes, etc.) that may lead to levee failures and/or damaged levee segments. The risk model will consider the complete set of levee damage and/or failure sequences that could occur and their likelihood of occurrence.

Following an event, there may be a number of islands that are flooded as a result of one or more levee breaches on that island. In addition to levee breaches, there may be sections of the levee that have been damaged, but which have not been breached. These levee sections will require some degree of remediation in order to avoid a breach at a later time. Furthermore, each island that is flooded is susceptible to interior levee slope erosion as a result of exposure to wind-driven wave action. Erosion may occur on damaged or non-damaged sections of the levee. Erosion rates depend on the wind vulnerability of a particular section ("segment") of levee, which is based on the fetch and exposure of that particular section of levee to the predominant wind direction.

A non-flooded island is one that does not experience a levee breach following an event. However, there may be sections of the levee that have been damaged, which require some degree of remediation in order to avoid a breach at a later time.

3.2 Non-Event Related Response and Repair

Depending on the time of year, there may be other flood fighting activities taking place in the Delta, which are not related to an event. These activities may detract resources from the event-related response activities.

3.3 Scenario Definition

A particular scenario is defined by the following:

Event related, flooded islands:

- The number of islands that are flooded, the number of breaches that have occurred on each island, and their size (length);
- Identification of the levee segments that have been damaged, but have not been breached; and
- Exposure level of each levee segment to erosion from wind-driven wave action.

Event related, non-flooded islands:

- Identification of the levee segments that have been damaged, but have not been breached.

Non-event related, non-flooded islands:

- Ongoing flood-fighting activities that depend on time of year.

Each levee breach within a scenario will be identified by:

- Island;
- Location on each island;
- Levee geometry (as defined by vulnerability class);
- Initial breach size; and
- Time-varying rate of breach growth.

Each incidence of levee damage within a scenario will be identified by:

- Island;
- Location (segment) on each island;
- Levee geometry (as defined by vulnerability class);
- Damage state, a number from 0 to 2, where 0=no damage, 1=implies a certain percentage of the levee cross section is lost and that a breach will occur in the levee segment if remediation is not carried out within x days of the event; and 2=breached; and
- Breach size and time-varying rate of breach growth, if a breach occurs.

Wave erosion within a scenario will be identified by:

- Island;
- Location (segment) on each island;
- Levee geometry (as defined by vulnerability class);
- Wind vulnerability; and
- Breach size and time-varying rate of breach growth, if a breach occurs.

The formulation for the time-varying rate of breach growth will be developed by the levee vulnerability group and will be included in the emergency response and repair model.

Given a scenario that identifies a set of levee breaches and/or damage distributed throughout the Delta, an assessment must be made of the ability to respond. The assessment will address the following factors key to estimating the amount of time required for achieving a return to normal operations (i.e., normal water exports):

- Emergency response organization and initiation of actions;
- Prevention of continuing damage (i.e., remediation of damaged sections of levee and capping of breach levee ends with rock);
- Remediation and breach closure productivity and progress; and
- Dewatering of islands.

The analysis will consider gross quantities of material required for repairing damage and closing breaches and will not differentiate between material types.

Levee segments will be defined in order to facilitate (1) identification of levee damage and (2) susceptibility to erosion. Each island has a unique geometry. For each island a geometrical center will be determined and lines will be drawn from this center at equal angles to delineate the eight sectors: N, NE, E, SE, S, SW, W, and NW. The levee segments will be defined as the perimeters of each of these eight sectors.

3.4 Prioritization

The following prioritization scheme will be adopted in the emergency response and repair model:

- Prevent flooding on any unflooded island
  - The first priority will be to prevent flooding on any unflooded island; i.e., repair post-event, non-breach damage to levee sections.
- Prevent or lessen continuing damage on flooded islands
  - Prevent wind/wave damage to the levee interior slopes on flooded islands.
  - Repair post-event, non-breach damage to levee sections on flooded islands.
  - Stabilize breached levees by capping the levee ends at breaches.
- Breach Closure on flooded islands
  - Breach closure.

Breach closures are given lowest priority, since they are assumed stabilized once they have been capped. Dewatering operations will commence at the time when an island has been closed.

Seasonal flood fighting activities on unflooded islands are assumed to be ongoing during emergency operations, thus detracting resources and reducing response capacity during a limited time of the year.

A separate module is being developed that will prioritize each damaged island on the basis of assets, infrastructure, community, role in salinity balancing, etc. This island priority will be passed into the ER&R module, which will apply the given island priorities in conjunction with the repair prioritization scheme outlined above, to determine an overall strategy for the repair work.

4.0 ENGINEERING/SCIENTIFIC MODELS

The primary objective of the emergency response and repair model is to estimate the time and material requirements to close each levee breach and dewater the island following a sequence of levee breaches, while at the same time repairing non-breach damage and continuing flood-fighting efforts in order to avoid further breaches and flooding. For purposes of providing the input required by the hydrodynamic and water quality modeling task, the emergency response and repair model must evaluate:

- The time, following the event, at which remediation efforts will be initiated, which will repair levee damage resulting from the event or from wind-wave erosion;
- The time required to repair damaged levee sections and to cap the ends of each breach (at which point the breach no longer grows);
- The time, following the event, at which each breach closure will be initiated;
- The time required to close each breach; and
- The time required to dewater the island.

The model will determine these times based on a strategy for responding to multiple levee damages and breaches that is based on the response prioritization scheme outlined in Section 3.

In addition, the emergency repair and response model will calculate the material demands and cost (in 2006 dollars) for repairing each levee breach as well as dewatering each island. While the model will have the capability to handle inflation, the scenarios will be run with no allowance made for inflation. The cost and time to restore the interior of the island will not be calculated in this analysis.

In order to develop emergency repair and response model it was necessary to quantify the resources available and estimate production rates for the available resources. In order to perform these analyses, discussions were held with representatives of The Dutra Group (Dutra), the primary supplier of quarry products for the Delta (Stewart 2006a, 2006b; Walker 2006).

4.1 Resources

During this stage of the study, it will be assumed that rock placement will be exclusively utilized as a means of stabilizing damaged levees and breaches. The outcome of this study will indicate whether other technologies, such as salinity control structures or dredging from adjacent waterways should be considered in order to reduce material requirements, cost and time required to return to normal operations (water export).

Currently, the San Rafael Rock Quarry (SRRQ) located in San Rafael, California, and owned by Dutra, is the primary supplier of quarry products for the Delta. This situation exists due to the unique physical advantage the SRRQ possesses over other local quarry sites. The SRRQ is the only quarry located in northern California with direct loading access to barges. Consequently, the quarry possesses a significant advantage over competing quarries in its ability to directly load barges with product for delivery to the Delta and the economy of scale this advantage offers. For purposes of this analysis, it is assumed that all material will initially come from the SRRQ.

The following equipment necessary for levee repair is either owned by Dutra or available from sources identified below:

Rock Mining

Drills, loaders, haul trucks, scalpers (i.e., screening devices used for sorting rock). The current rock mining equipment at the quarry can yield material at a rate of approximately 10,000 tons per day (tpd).

- Material Loading at the Quarry: One conveyor/barge loading facility. The conveyor is capable of moving 1,000 tons per hour. Assuming it runs 20 hours per day, the conveying capacity at the quarry is approximately 20,000 tpd.
- Material Transport: One tug (1,300 horsepower), 14 barges with average capacity of 2,000 tons, and 4 dump scows with capacities ranging between 3,800 and 7,200 tons. The complete fleet of 14 barges yields an effective hauling rate of 8,000 tpd. In order to achieve this rate, it is further assumed additional tugs (either owned or rented) are utilized to facilitate barge loading operations at the Quarry as well as for barge distribution to project sites within the Delta. Along with Dutra’s dump scows, additional rock barges could potentially be obtained from the Connolly-Pacific Company quarry, located on Catalina Island in Southern California. Inclusion of the dump scows and additional barges increases the total hauling rate to 36,000 tpd.

- Rock Placement: Dutra presently has two dedicated rock placing rigs operating within the Delta. They possess two additional rock placing cranes for which they only need to obtain suitable spud barges on which to place these cranes in order to increase their primary rock placing fleet to a total of four rigs. In addition to their primary rock placing rigs, Dutra owns and operates four additional derrick barges that can be utilized for rock placement operations.

  The primary fleet of four rock placing rigs is capable of placing rock at a rate of 800 to 2,000 tons per 8-hour shift per rig, depending on whether or not material is being "placed" (i.e., placing riprap slope protection, lower rate applies) or "hogged" (i.e., closing a levee breach, higher rate applies). Furthermore, Dutra's four dump scows have a cumulative daily capacity of approximately 20,800 tpd, though they are primarily restricted to placement operations in water depths greater than 12 feet. Thus, Dutra's total daily placement capacity is approximately 9,600 to 44,800 tpd.

  Based on the foregoing analysis, the rate of material loading (i.e., 20,000 tpd) is anticipated to be the constraint. For this reason, quantification of resource demands, such as manpower and equipment, will not be included in the model since they are presumed to not represent a parameter in the analysis.

  Total material reserves at SRRQ are estimated at approximately 52 million tons. The maximum quarry load-out capacity is estimated to be 10,000 tpd based on their current mining equipment fleet (i.e., drills, loaders, haul trucks, scalpers) and barge loading configuration, but within approximately 10 days the quarry can increase capacity to approximately 20,000 tpd with the addition of more mining equipment. To increase capacity beyond this level, it will take approximately three months to upgrade the quarry to a load-out capacity of 40,000 tpd due to the need to construct an additional barge loading facility. Commensurate with this point in time (i.e., three months), it can be assumed that other material sources have been secured and are now able to contribute to the effort. It is believed these sources could include quarries ranging from upland sources, Catalina Island, Mexico, and British Columbia. Based on the logistical demands associated with each of these longer-range sources, it is assumed these sources would be capable of providing an additional 10,000 tpd, thus increasing the total response capability to a maximum of 50,000 tpd.

  For interior levee wind/wave protection efforts, depending on access to the flooded island, material may be able to be sourced from quarries other than SRRQ and delivered by truck. The benefit of this would be to avoid the placement of any additional resource demands on SRRQ. However, two significant constraints may negate this approach: 1) if there is no vehicular bridge access to the island, trucking will not be possible; and 2) during periods of elevated water levels in the Delta, the operation of trucks on levees would most likely be prohibited owing to concerns related to the potential for damage to the levees caused by heavy truck traffic.

4.2 Production Rates

Since the rate of material supply is anticipated to be the governing constraint, the production rates (i.e., repair rates) are typically equal to the material loading rates. Furthermore, it is assumed that one-half day will lapse before the contractor arrives at the initial levee failure and commences repair work. It is further assumed that another 2.5 days will lapse during which contracts for levee repair are put in place, although it is assumed that the contractor will start repair work during this period. Tables 1 and 2 summarize the assumed production rates by time at the SRRQ and at other quarries local to the Delta. Table 3 summarizes the production rates by activity for each phase of the repair and breach closure process. It is important to note that during a multi-damage and/or multi-breach scenario the maximum production rates will be limited by the material supply rates stated in Tables 1 and 2 in combination with the possible placing rates stated in Table 3; however, the priority for repairing damage, protecting interior slopes versus capping levee ends and closing breaches must be specified in order to properly allocate the fixed resource of material supply (see Section 4.3).

Table 1
Production Rates by Time (SRRQ and Others, Marine-Based)

Days	Production Rate (tpd)			Remarks
	Low	Expected	High	
0 to ½ day	0	0	0	Time required for contractor to commence work
½ to ~3 days	2,000	4,000	8,000	
~3 to 10 days	4,000	10,000	12,000	Maximum SRRQ capacity with current equipment and configuration.
10 to 90 days	8,000	20,000	24,000	Addition of more mining equipment.
90+ days	20,000	40,000	48,000	Additional barge loading facility.
90+ days	30,000	50,000	58,000	SRRQ plus other sources

Table 2
Production Rates by Time (Local Quarries, Land-Based)

Days	Production Rate (tpd)			Remarks
	Low	Expected	High	
0 to ½ day	0	0	0	Time required for contractor to commence work
½ to ~3 days	2,400	4,800	9,600	
~3 to 10 days	4,800	12,000	14,400	Maximum combined capacity (local quarries) with current equipment and configuration.
10 to 90 days	9,600	24,000	29,000	Additional mining equipment.
90 to 180 days	24,000	48,000	58,000	Configuration modifications.
180+ days	36,000	60,000	70,000	Further configuration modifications & additional mining equipment.

Table 3
Production Rates by Activity

Activity	Production Rate [1] (tpd)	Remarks
Levee Repair	2,400	rate of 1 placing rig; max 1 placing rig per 400 ft
Interior Levee Protection		
Marine Access	2,400	rate of 1 placing rig; max 1 placing rig per 400 ft
Land Access (trucking)	5,280	1 truck (22 tons) every 5 minutes (50 min-hr)
Interior Levee Protection Marine Access	2,400	rate of 1 placing rig; max 1 placing rig per 400 ft
End Capping	4,000	per breach
Levee Closure	4,000	rate of 1 placing rig; max 1 placing rig per 200 ft

Notes: (1) Production rate varies with weather.

4.3 Repair Prioritization

The model will be able to handle any type of ordering of repairs within a scenario based on the prioritization scheme outlined in Section 3. This scheme prioritizes island and levee repair as follows:

1. Prevent flooding on any unflooded island; i.e., repair post-event, non-breach damage to levee sections.
2. Prevent wind/wave damage to the levee interior slopes on flooded islands.
3. Repair post-event, non-breach damage to levee sections on flooded islands.
4. Stabilize breached levees by capping the levee ends at breaches.
5. Breach closure.

Within this scheme of prioritization, island prioritization is based on amount of damage that has been sustained; that is, islands with least damage (else, smallest island) will be dealt with first.

4.4 Required Material Quantity

The emergency response and repair model will determine (provide as output) the required material to repair non-breach damage, to close a breach and to close an island. In order to determine the required material and the repair durations, a typical levee cross section has been developed. The typical levee and its parameters are shown in Figure 1.

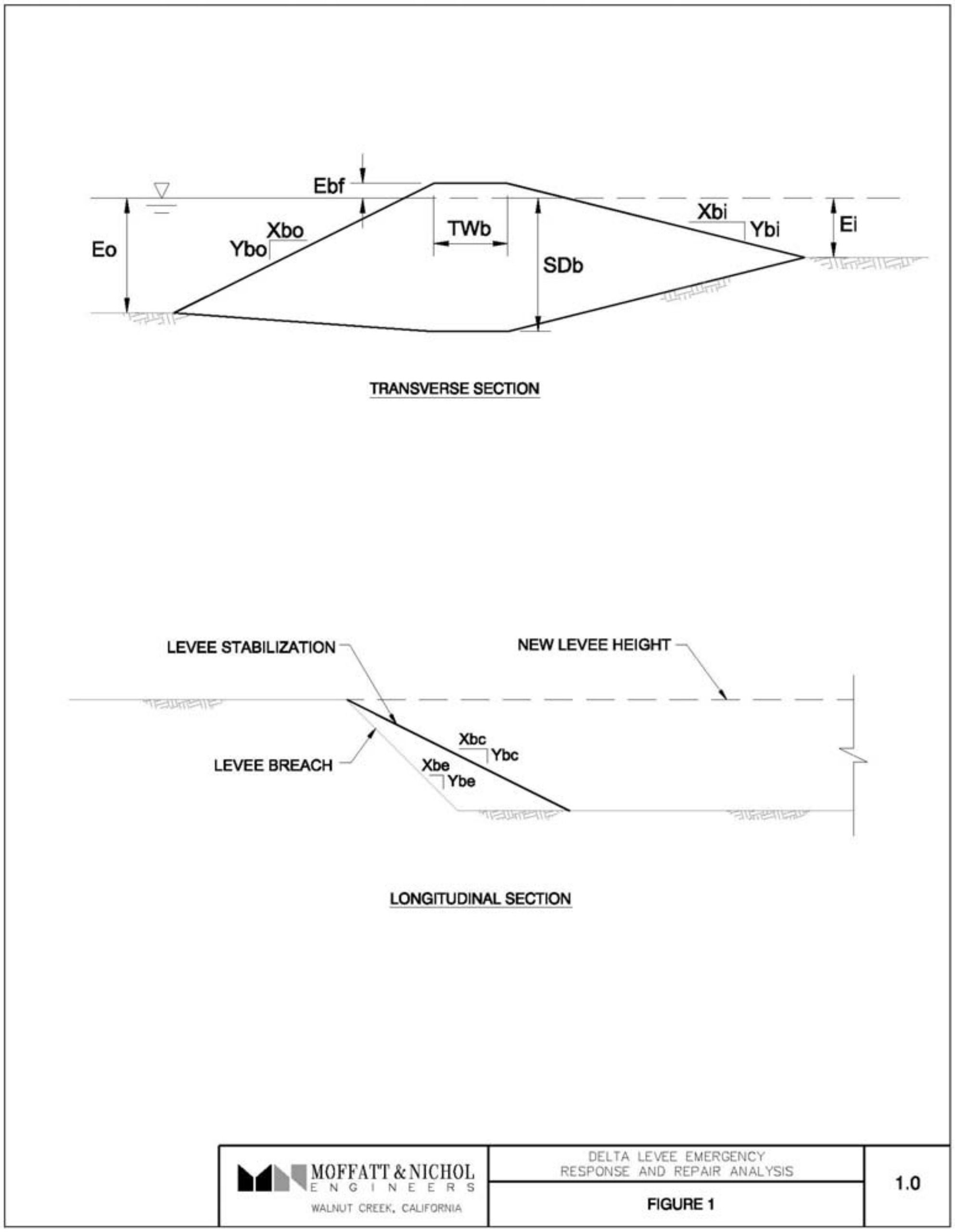

Figure 1: Illustration of a Typical Levee Section
(see Table 4 for an explanation of the symbols/dimensions).

4.5 Breach Repair Process

Contracting and Mobilization

Immediately following an event, damage assessments will be required throughout the Delta-wide levee system to ascertain the extent of damage sustained. Damaged levees will require prompt identification and the responsible authorities notified so as to enable repair efforts to begin. For this assessment, we have assumed that within the first three days immediately following a seismic event, these inspections will be conducted and the results forwarded to the appropriate responsible authorities. It is assumed that an emergency response plan will be in place that enables the immediate decision on the needed response level and execution of contracts for appropriate repair services.

Repair of Levee Damage
Levee damage following an event will be identified by the levee segment (as defined in Section 3.3) and its “damage state.” The levee segment automatically defines the length of levee that is damaged. The “damage state” is a number ranging from 0 to 2, where 0=no damage, 1=implies a certain percentage of the levee cross section is lost and that a breach will occur in the levee segment if remediation is not carried out within x days of the event, 2=breached. In the case of a damage state “1”, the levee is assumed to breach if remediation is not <u>initiated</u> before day x. The quantity of rock that will need to be placed on the levee varies with the damage state and levee segment length.

Stabilization of Levee Erosion
After an island is breached and flooded, erosion on the interior levee slope may occur as a result of wind-wave action. Levee erosion on flooded islands will be identified by the levee segment and its wind wave vulnerability. Each levee segment will have an associated fetch for each wind direction. An hourly time-history of wind direction will be used to integrate wave height and duration over time. An erosion rate determined by the levee vulnerability team in conjunction with the wave height-duration accumulated will then enable modeling of the erosion of the interior slope. The erosion rate is assumed to reduce to zero as soon as interior levee slope stabilization is initiated. Island elevation will be required, as there is a threshold value for depth of flooding below which wind waves that lead to interior slope erosion will not be generated.

Exposed Levee Ends
When a levee breach occurs, the breached section will leave two levee faces exposed to the erosive effects tidal exchange and waves. If these ends are not protected promptly, the length of the breach will continue to grow. The condition of the exposed levee faces will likely be irregular due to the random nature of erosive forces acting on it immediately following the initial breach. For analysis purposes, the breach growth rate, the slope for the post-breach condition prior to placement of erosion control materials and the interim slope after rock placement to stabilize the levee must be provided as inputs.

Breach Closure
Once the exposed levee ends have been protected for a breach, closure of the breach can commence. We believe the general process for closure will entail commencing breach filling operations from one or both ends working across the breach.

5.0 PROBABILISTIC APPROACH
A number of factors will contribute to randomness in the emergency response and repair process. These include:

- The probability and magnitude of the event that leads to levee damage and/or failure, the severity of the damage (damage state), and the number and severity (breach length and scour depth) of levee breaches occurring as a result of this event. Note that the type of water year and time of season may also impact the severity of the levee breaches.

- Weather may impact the repair time because of its potential to slow down transport and rock placing activities. Weather also has an impact on erosion of levee interior slopes, and thus affects repair time and material requirements.
- Equipment capacities may lead to variations in the production rates. During the three day ramp-up period in operations, towing capacity will likely be the controlling factor, since not all of Dutra's barges may be in the vicinity right after an event. After the three day ramp-up period, the quarry mining equipment is the likely constraint. The expected production rate of the equipment is 10,000 tpd, but with breakdown of equipment, this could be significantly less. After 10 days, it is assumed that more mining equipment has been sourced. As a result, the barge loading facility becomes the constraint. A maximum of 24,000 tpd is possible if the conveyor is operable 24 hours per day. However, it is expected that it will operate 20 hours per day to allow for maintenance, etc., thus the expected production rate is 20,000 tpd. Breakdowns in the conveyer will lead to lower rates. Variations in SRRQ and local quarry production rates were presented in Tables 1 and 2. These tables give the range (low and high value) and the expected rate.
- The levee damage (non-breach) state (damage state "1") will be treated as a lost volume that is a random variable uniformly distributed.

A set of simulations for a single levee breach scenario (consisting of 10 levee breaches, no non-breach damage, and no levee interior slope erosion) was run to provide a preliminary assessment of the impact the variation in parameters might have on the repair times. Because the simulations are for only one sequence of levee breaches, the breach and scour size are by definition not variables. Additionally, weather variation was not included at this stage, since the variation in production rates are expected to have a significantly larger impact.

The results indicate that the variation in total time required to close all 10 levee breaches is substantial. Given the expected values for the production rates during the various stages identified in Table 1, the expected time to closure of all 10 levee breaches is 107 days. When randomness is introduced into the simulation, the total time for repair works varies between 100 and 141 days. A distribution of the results for 100 simulations that each use a different, random combination of the production rates listed in Table 1 is presented on Figure 2.

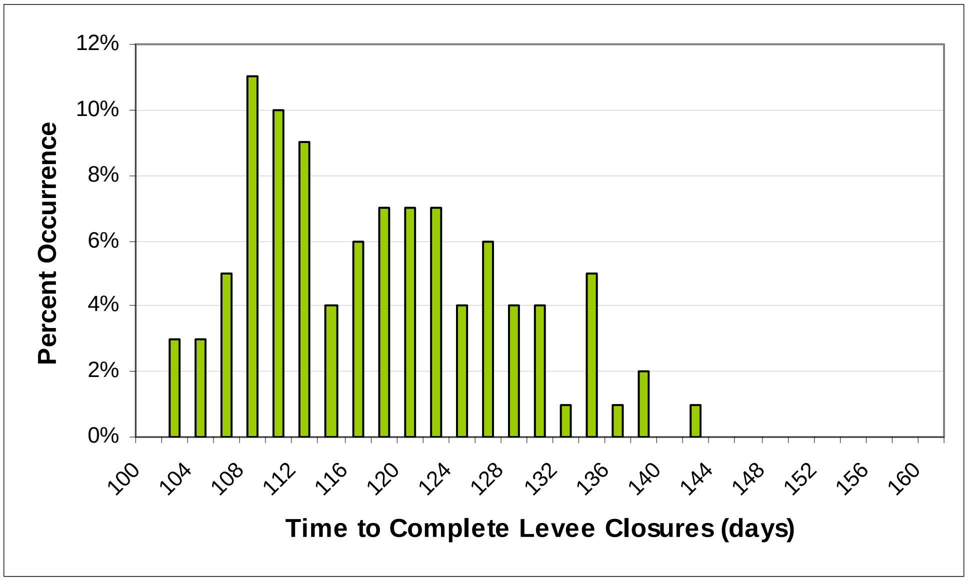

Figure 2: Simulation Distribution Results: Effect of Production Rate Variability

6.0 ASSUMPTIONS, CONSTRAINTS, AND LIMITATIONS

The following are some of the assumptions that will be made in the emergency response and repair analysis:

- The SRRQ will be in operation for the next 200 years even though their rock supply is more consistent with approximately 52 years of continued operation.
- The SRRQ will remain operational after a seismic event.
- All material will initially come from the SRRQ.
- Within days of a sequence of levee breaches, local regulations will be eased or set aside to allow the SRRQ to operate on a 24-hour basis.
- Sufficient transportation equipment (i.e., deck barges, scows, and tugs) can be made available immediately, so that material supply capacity remains the constraint.
- Resources (i.e., materials and equipment) are assumed to be available and will not be compromised by demands outside the Delta that occur as a result of the same seismic event. Damage which occurs to assets other than levees will not put a demand on resources required to support levee breach repairs.
- Additional damage resulting from after-shocks is not considered.
- There are no constraints on dewatering resources.

The following factors are not explicitly accounted for in the emergency response and repair model, yet they may impact the results of the analysis:

- The time required to put contracts into place may be significant and will vary from event to event.
- It may not be possible for Dutra to obtain permits to build a second loading facility in within 90 days. State/Federal officials may need to step in to waive the typical permitting process

(CEQA/NEPA). Additionally, SRRQ neighbors may hold up the process if they do not see events in the Delta as an impact on them.

- The longevity of the quarry.
- It may take longer than 180 days to bring other sources of material on line. The State will probably have to make the decision when to call in help from non-local sources, such as Catalina Island, Canada, or Mexico.
- After a seismic event there will be numerous projects that will be competing for the same resources. The State may have to make the call on prioritization of competing projects.
- After a seismic event in the Bay area, there may be access constraints for the barges if bridges have collapsed.

7.0 INFORMATION REQUIREMENTS

The following are the inputs required to carry out the emergency response and repair analysis.

For each scenario:

- Number of damaged levee sections;
- Location (island and island segment) and damage state of each damaged levee section;
- Number of breaches;
- Location (island) of each breach;
- Initial breach size;
- Rate of breach growth in terms of breach length per unit time (e.g., ft/day);
- Typical levee section geometric parameters, as outlined in Figure 1 and Table 4;
- Island acreage, perimeter length, segment lengths, and elevation; and
- Erosion rate (e.g., feet per wind wave-duration exposure).

In addition, an hourly time history of wind speed and direction is required in order to assess erosion of levee interior slopes on flooded islands, and the impact on work progress.

Table 4
Levee Section Parameters

Nb	Breach Number
Lb	Length of breach (ft)
Xbe	Slope of breach exposed ends component parallel to sea floor (ft)
Ybe	Slope of breach exposed ends component perpendicular to sea floor (ft)
Xbc	Slope of breach covered ends component parallel to sea floor (ft)
Ybc	Slope of breach covered ends component perpendicular to sea floor (ft)
SDb	Scour Depth (ft)
Ebf	Elevation of levee after fill (ft)
TWb	Top width of breach (ft)
Eo	Outboard Toe Elevation (ft)
Xbo	Slope of outboard toe component parallel to sea floor (ft)
Ybo	Slope of outboard toe component perpendicular to sea floor (ft)
Ei	Inboard Toe Elevation (ft)
Xbi	Slope of inboard toe component parallel to sea floor (ft)
Ybi	Slope of inboard toe component perpendicular to sea floor (ft)

Note: Elevations and depths are measured with respect to a defined vertical datum.

8.0 ANTICIPATED OUTPUT/PRODUCTS

The following are the outputs from the emergency response and repair analysis:

- Time (duration and dates), materials, and cost to repair damaged levee sections;
- Time (duration and dates), materials, and cost to protect interior levee sections;
- Time (duration and dates), materials, and cost to cap both ends of each breach;
- Time (duration and dates), materials, and cost to close each breach;
- Time (duration and dates), materials, and cost to close up an island; and
- Time (duration and dates) and cost to dewater an island.

9.0 RESOURCE REQUIREMENTS

None.

10.0 PROJECT TASKS

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

- Task 1: Compile Data: We will compile cost and production rate data necessary for model development. Additionally, a database of island parameters will be developed for inclusion in the model as a lookup table. Parameters such as: acreage; perimeter levee length and elevation; interior elevation; perimeter levee top width; perimeter levee interior and exterior slopes; and island access methods will be collected for each Delta island.
- Task 2: Modify Existing Simulation Model: A simulation model has been developed that computes required material quantities and estimates durations for capping failed levee ends and closing the breaches. The model will need extensive modification to:

- Incorporate repair of non-breach damage and levee interior slope protection (against wave action) before these damages become secondary breaches;
- Predict when a secondary breach would occur in the absence of timely repair efforts;
- Incorporate a repair prioritization scheme, as outlined in Section 3.4;
- Incorporate cost data;
- Compute the time and cost required to dewater an island; and
- Include factors that contribute to randomness in the emergency response process, in order to apply a probabilistic approach to the determination of the time required to return to normal operations. The factors to be explicitly included in the model are listed in Section 5.

- Task 3: Develop Weather Database and Add Weather Impact to Model: Impacts to interior and/or adjacent levees, as well as the ability to work productively on levee repair, may be impacted by winds and wind-generated waves. Weather hindcasts will be used to determine multiple year wind time-histories that will be incorporated into the model. A subroutine will be written to vary daily production rates based on wind conditions. Another subroutine will be developed to determine the exposure level to wind-driven wave erosion for each levee interior slope segment from the time that the event occurred to the time when protection of the interior slope is initiated.
- Task 4: Run Simulation Test Cases – Model Validation: A number of test cases will be devised which will enable us to validate the model. Results will be checked against hand or spreadsheet calculations.
- Task 5: Compile Draft Report: The report will completely outline the procedures, equations, unit cost data, and production rates that define the emergency response and repair simulation model. A description will be provided at a level of detail which will enable the risk analysis team to encode the model as part of the risk analysis algorithm.
- Task 6: Interface with Risk Analysts and Compile Final Report: It is expected that significant interface between the emergency response and repair team and the risk analysis team is required for the transfer of modeling details to function smoothly. Revisions to the report may be required at this stage and this will be issued as a Final Report.

11.0 REFERENCES

Walker, Chuck. 2006. Telephone conversation with Chuck Walker, The Dutra Group, April 14.

Stewart, Harry. 2006a. Telephone conversation with Harry Stewart, The Dutra Group, April 14.

Stewart, Harry. 2006b. Telephone conversation with Harry Stewart, The Dutra Group, April 18.