DELTA RISK MANAGEMENT STRATEGY

INITIAL TECHNICAL FRAMEWORK PAPER

ECONOMIC CONSEQUENCES

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Economic Consequences

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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 addresses economic consequences methodologies for the Delta Risk Management Strategy. Economic consequences are the adverse economic effects of Delta levee failures. There are many possible and related measures of economic consequences. We propose to estimate certain economic costs and damages, lost personal income, and employment effects. Also, we will qualitatively assess the potential for permanent economic effects that might be caused by the relocation of industries and resources to areas outside of California.

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1.0 INTRODUCTION

This Initial Technical Framework (ITF) paper addresses economic consequences methodologies for the Delta Risk Management Strategy (DRMS). Economic consequences are the adverse economic effects of Delta levee failures. There are many possible and related measures of economic consequences. We propose to estimate certain economic costs and damages, lost personal income, and employment effects. Also, we will qualitatively assess the potential for permanent economic effects that might be caused by the relocation of industries and resources to areas outside of California.

To undertake this task, the Economic Consequences team needs to define the problem in a tractable way. To develop this scope of work, the team has made a number of assumptions. The key assumptions in this paper relate to:

- The maximum duration of the disruption
- The likely “points of inflection” in a loss function curve
- The time periods for which there exist the necessary data
- The regions likely to be affected
- The work product that will be made available from others

As the task progresses, these assumptions may need to be revised.

There are several categories of economic damages that will be estimated outside of the economic consequences group. These categories are:

- Levee repair and dewatering costs
- Infrastructure repair costs
- Private property repair and replacement (including structural and equipment damage to homes, businesses, and agriculture)
- Emergency response costs

These costs will be provided by other groups. The Economic Consequences Group will work closely with these groups to coordinate the scope of the two efforts.

2.0 OBJECTIVE

The objectives of the methodology are to quantify economic impacts, including economic damages and costs, caused by a wide range of Delta levee failure events. The economic impacts will be measured relative to an economic baseline to be defined in the methodology. The methodology must be flexible enough to consider a full range of baseline and event conditions involving level of development, season, water supply conditions and event scenarios. In the case of seismic events, the types and duration of other (non-Delta levee) infrastructure damages must be considered.

The team has identified five general types of economic costs.

1. In-Delta Losses: these include:
    - Lost use of structures and businesses in the Delta (for example, loss of use of homes, and loss of business incomes)
    - In-Delta agricultural losses
    - In-Delta recreation losses
2. Disruption to water supplies that transit the Delta, including water delivered by the State Water Project (SWP), Central Valley Project (CVP) and the conveyance facilities crossing the Delta (Mokelumne Aqueduct and Hetch Hetchy Aqueduct)
3. Statewide impacts resulting from loss of infrastructure located in the Delta that provide services to the state as a whole: These include impacts from disruption of facilities such as:
    - Major roads crossing the Delta,
    - Electric transmission lines, gas fields, pipelines and storage, telecommunications facilities, railways and ports,
    - Potential losses to ocean fishery industries, both commercial and sport fishing.
4. The impacts resulting from changed operation of reservoirs, including the loss of hydroelectric generation and recreation opportunities. This will be most evident in reservoirs south of the Delta, but will also be considered for reservoirs north of the Delta.
5. The economic effects from changed ecological values, including that of changes to species abundance and habitat in the Delta and Suisun Marsh.

The costs outlined above are those net costs to the state in the form of lost production or increased spending that result from the disruption, and the estimate developed by the team will be a measure of the net loss in gross state output.

In addition to this, the economics consequences team will measure the economic impacts that will result from the disruption. The impacts include additional items where the economic damage to one party has been counterbalanced by an economic advantage for someone else in the state. For example, state spending on repair work in the Delta would count as a cost to the state that resulted from the disruption. However, to the extent that same state spending is used to purchase goods and services from within the state, there are both positive and negative impacts on the state's economy. The impact to the state's economy will spread beyond these direct impacts, as both losses of production and increased repair spending ripples through the economy and has indirect and induced effects. The team will develop estimates of short-term employment and personal income impacts that result from the disruption.

In addition to these costs, the economics team will consider the extent to which any changes in environmental conditions (gains or losses) that are identified by the environmental team can be given an economic evaluation.

Lastly, the team will provide a descriptive analysis of the long-term economic consequences that might result from the economic dislocations and physical changes resulting from the disruption.

There are limited tools and data available for the analysis of economic consequences. Additional data collection would be helpful, but would be expensive both in time and money so is not envisioned for this analysis. Therefore, the methodology will rely to the extent possible on published models and data, literature and expert opinion.

3.0 PHYSICAL SYSTEM PROBLEM

This section describes generally the types of economic effects that will be counted by reference to the physical impacts that cause the economic effects. The methodologies to estimate economic effects are discussed in Section 5.0.

A delta levee failure has many types of economic implications. First, there is the emergency response and the direct costs of removing people and valuables from the flood zone. Next, levee breaches must be repaired and flooded islands dewatered, and damaged structures and infrastructure must be repaired or replaced. These types of damages and costs will be estimated and provided by the Emergency Response and Repair Group.

The economic consequences analyzed by this group will include all other costs, damages, and economic impacts that follow from the levee failure. These costs may occur as a result of disruption of activities within the Delta, or of activities outside the Delta that rely on infrastructure within the Delta. The specific costs included are discussed by category below.

3.1 In-Delta Losses

In-Delta Lost Use Costs

These lost use costs apply to structures within the Delta that cannot be put to their normal use because of Delta levee failure. These costs apply to homes, agricultural infrastructure, and businesses in the Delta that cannot be used or operated because of the levee failure.

In-Delta Agricultural Losses

In considering in-Delta agricultural losses, two distinct areas must be considered. The first area is that likely to be inundated when levees fail. In this region crops may be destroyed by inundation. However, the Delta service area (which is slightly different than the legal Delta) is a second area that will not be subject to inundation, but may be adversely affected because of declining water quality in the Delta. The effect on both of these areas must be investigated.

Following a levee failure, any crops growing on inundated islands, including trees and vines, are very likely to be destroyed. Many Delta islands are used for livestock grazing; there is a potential for drowning of livestock, and surviving livestock must be rounded up and relocated, and planted crops may be destroyed. We expect that physical damages, excluding the replacement costs of trees, vines, and livestock, will be assessed by others. Our task will include the assessment of these replacement costs as well as the value of the lost agricultural production.

Following inundation, the Delta lands will be unusable for agriculture until the land is dewatered and returned to a productive condition, and normal farm operations can resume. The time required to return to production will depend on the time required for cleanup, and the time required to return the farm infrastructure to its useful state, including farm roads, ditches and canals, pumps, power lines, etc. We expect this to be provided by the Delta infrastructure and repair group. For trees and vines, years may pass before full production is restored. The value of all agricultural production lost while land is inundated and being restored will be assessed, including the losses incurred until permanent crops can be returned to full production.

Farmland in the Delta Service Area that is not inundated may incur direct damages from saline water supply. The surface water available for irrigation may be too saline for irrigation. Existing crops may be lost, or yields diminished. In addition, crops may not be planted until water quality returns to an acceptable level; additional irrigation management may be required to maintain adequate leaching. The additional losses caused by poor water quality will also be assessed.

In-Delta Recreational Losses

Recreational use of the Delta would be impaired by Delta levee failures. Boating in channels near the levee failures might be prohibited. Seawater intrusion would substantially impact game fish species. Reduced recreational use would impact recreational businesses as well as recreationists. The lost net income of recreation businesses, and the lost value to recreationists will be counted. As part of this segment, we will need to obtain the impacts on fisheries from the environmental group.

3.2 Costs of Water Export Disruptions

Delta levee failures could reduce water quality in the Delta. For any levee failures scenario, a number of decisions about water supply operations must be addressed. These decisions may involve temporary in-Delta water routing, operations of eastside facilities, and operations of upstream storage. Some scenarios may include permanent abandonment of some islands, and permanent re-routing of Delta water for export. The economic consequences team will not develop these scenarios, but we can contribute by considering what may be economically reasonable.

Exports might continue, but with degraded water quality. For a multiple breach scenario, water quality might be reduced to the point that the downstream water quality would not be acceptable for municipal and industrial (M&I) or agricultural purposes. In this case, exports must cease. As water quality at the point of export improves over time with restored conveyance and upstream water management, some exports may be practical, but water quality may be degraded.

The major costs of water export disruptions derive from additional water supply costs and shortages experienced by the ultimate users. Shortage and water supply costs depend on duration of the outage, the amount of water available once exports can resume, the water supplies available from project storage south of the Delta, the level of demand, and amounts and costs of water available to local agencies from other sources, including local storage. Under some conditions, the available supplies might be enough to meet most of the demand for an extended period. Under others, the shortages will be more severe. In some cases, supply shortages may extend beyond the period of the Delta disruption because local supplies will be depleted.

Other costs may occur as the result of decreased water quality. If local water supply conditions are extreme, it may be judged necessary to resume water exports even if those export supplies are of impaired quality. The use of this lower quality water may result in additional costs.

Urban Water Agencies

Losses to urban water agencies will depend on the shortages they incur, the mix of end-uses within the water agencies, and the options those agencies have for emergency responses. Water shortages could occur to CVP and SWP contractors south of the Delta, for direct industrial diverters, and also possibly for deliveries through the North Bay aqueduct.

In the Bay Area, water shortages from a disruption to the project supplies may be somewhat mitigated by existing or emergency interconnections with agencies supplied through the Mokelumne and Hetch Hetchy aqueducts. Some of these interconnections are currently under development. Therefore, East Bay MUD and the City and County of San Francisco might have water supply impacts. If, in addition, either of the two aqueducts has failed, either because of levee failure or other occurrence, the economic losses caused by Delta levee failure will be more severe than if the aqueducts are unaffected because the overall shortage level will be larger. However, the treatment of those costs must be careful to distinguish between those costs caused by levee failure, and those costs caused by, for example, seismic failure. Losses to the entire Bay Area caused by Delta levee failures and seismic failures together, minus losses caused by seismic failures alone, equals losses attributable to Delta levee failures.

San Joaquin Valley Agricultural Users

These include south-of Delta contractors to the SWP and CVP. It is possible that Friant Division CVP contractors will be affected if Reclamation releases water to the San Joaquin River for its Exchange Contractors. Other San Joaquin Valley regions may be affected if reservoirs on tributaries to the San Joaquin are used as sources of water for flushing the Delta.

For agricultural contractors in the San Joaquin Valley, the loss estimates will be affected by the amount of water they would have received absent the disruption. Agricultural production in some parts of the Valley varies according to the annual water allocation received from the projects. In wet years, when high allocations are available, acreage in agricultural production increases; in dry years, when lower water allocations are available, the acreage in production is lower. Therefore, for a given length of disruption, an event that prevents water deliveries during wet years will result in higher losses than one occurring in dry years. In addition, the types of crops, the number of harvests, and the productivity of the land affected by a disruption in surface supply are likely to differ based on year type.

Local water supplies may be adversely affected even when Delta exports are restored to their pre-failure condition because local groundwater and surface water supplies will be depleted. The increased costs of groundwater pumping to replace the lost surface supply during the shortage event will be a significant source of economic losses. In addition, costs will be incurred to restore storage levels. The economic consequences team will develop an estimate of additional costs caused by pumping and storage depletion.

3.3 Losses from the Disruption of Infrastructure of Statewide Importance that Crosses the Delta

Many assets that are important components of the state's infrastructure are located in or near the Delta, or cross the Delta. This includes important natural gas fields, electric transmission lines, natural gas storage and transmission mains, highways, and railways. Any of these assets may be put out of service by levee failure, or if they are put out of service by other action, (such as seismic activity) their return to service may be delayed by the results of levee failure. In addition, access to the ports of Stockton and Sacramento may be blocked by levees slumping into the channels, and access may not be restored until neighboring levees have been stabilized and the channels have been dredged.

In addition, ocean salmon fisheries (both commercial and sport) may be negatively impacted by a disruption to Delta habitat. The Sacramento chinook is a mainstay of much of the ocean fisheries in the California/Oregon region, and if this fishery is disrupted by Delta conditions there could be extensive impacts on coastal employment and incomes.

3.4 Losses from Changed Reservoir Operations

During the disruption, recreation and hydroelectric generation will be affected in south of Delta reservoirs, and potentially in north of Delta reservoirs. This analysis will develop an estimate of the economic losses related to the disruption.

For south of Delta reservoirs (both project reservoirs and local agency reservoirs), the Delta levee failure will cause water storage and conveyance to be reduced. This could have the following effects:

- Hydroelectric production from southern reservoirs and penstocks could be reduced;
- The use of electricity for pumping could be reduced;
- The water level in southern reservoirs will be reduced, adversely affecting recreation.

The situation for north of Delta reservoirs is less clear. The disruption may result in more or less water being released for flushing than would otherwise be released for export. This may result in less or more hydroelectric generation, and improved or deteriorated conditions for recreation.

3.5 Losses from Environmental Damage

Any extensive damage to the Delta, or inundation of Suisun marsh will have an effect on species in those regions. These areas contain numerous species, including those of particular interest because they are listed as being of special concern. At this time, it is not obvious whether the net effects of a disruption will be positive or negative. For example, the initial incident could result in loss of some habitats, and increased turbidity and contamination in both water and soils. As the situation stabilizes, additional habitats will be created, and water flows may change in a way that is beneficial to fish. Other recovery actions may be less beneficial. To the extent that the environmental group can specify changes in environmental quality, the Economics Consequences team will develop an estimate of economic losses or gains.

3.6 Short-Term Employment and Personal Income Impacts

The loss of agricultural and industrial production will have ripple effects that spread throughout the economy, depressing other economic activity. The net result will be loss of employment and personal income that spreads beyond the directly affected sectors outlined above.

At the same time, additional spending will be undertaken to repair the levees and restore services. This spending will have a positive effect on economic activity, employment, and personal income. However, someone must pay for this spending. The positive effect of repair and restoration spending is offset to the extent that the money cannot be spent elsewhere in California. The net effect on the economy will depend on the extent to which the recovery effort is paid for by outside sources such as the federal government and outside insurance companies. Given that the proportion of payments from those sources are extremely difficult to predict over the time period to be investigated, we will assume for this analysis that all repair and restoration costs will be borne by in-state entities. Therefore, the net effect of repair and restoration spending is zero, and we will count only the personal income and employment losses caused directly and indirectly by reduced agricultural and industrial production.

3.7 Longer-Term Structural Changes to the Economy

Structural change refers to any permanent change to the California economy resulting from levee failures. These changes could include: a permanent loss of agricultural land and production, permanent infrastructure changes and business costs, increased taxes, and prices (particularly for project water supplies, electricity and natural gas), loss of industry, employment and population.

4.0 ENGINEERING/SCIENTIFIC MODELS

The economic analysis will develop cost functions that relate the physical, institutional, and operational responses to a levee failure event to the level of economic consequence. For example, the cost of lost use of housing will be related to the number of houses lost, the duration for which they are lost, and availability of replacement housing. Likewise, the cost of inundated agriculture will be related to the number of acres inundated, the duration of inundation and recovery, and the mix of crops grown on the inundated land. Further descriptions of the causative relationships are provided later in this section.

There are several existing economic models we are proposing to bring into the analysis. We propose to examine DWR's LCPSIM model's approach to modeling local water supplies and costs. We will also examine the use of IMPLAN, and DWR's agricultural IO model (DWR 2002), to estimate economic impacts in terms of jobs and personal income. Useful information may be included in the Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) computer program (HEC 2006), and in FloodEcon, a flood damage estimation software program under development by the National Water and Climate Center, among others.

For most categories of losses discussed below, the team will search for applicable information in the following priority: 1) models that are readily applicable or can be modified, 2) information from published literature regarding parameters or data for the cost functions, and 3) expert opinion. The work will include obtaining opinions and information from knowledgeable experts within each industry. This will enable the team to use information that is not otherwise published, and will allow for increased credibility for the final results.

4.1 Loss Categories and Approaches for Loss Estimates

In-Delta Losses

In-Delta Lost Use Costs
These losses will be estimated through the use of loss functions that relate the value of lost use to the number of homes and businesses inundated, and the duration of the inundation and repair period.

In-Delta Agricultural Losses
To estimate the losses through inundation of farmland, the economic consequences team will need to be told the additional time after pump-out before farm land can be returned to agricultural uses, and develop direct loss functions to estimate lost agricultural production from inundated Delta farmland. We will investigate dividing the Delta acreage into subregions to provide increased accuracy to the estimate of losses through this cause. Losses will vary according to the area flooded, the season of inundation, and the duration of inundation and recovery. The season relates to how much of the annual crop year expenditures have already occurred at the time of inundation and what crops in the ground would be lost. The duration determines how many crop seasons would be lost. If a full season is lost, the direct economic cost will be the lost net return from the crop. Crop production cost and revenue data will be drawn from recent available data provided by the University of California Cooperative Extension and County Agricultural Commissioner reports. Economists at the California DWR have recently gathered data on agricultural activity on Delta islands.

To investigate losses on other agricultural land within the Delta, the economic consequences team will work with Delta water users to develop rules regarding what water quality may allow the water to be used for irrigation. Then a loss function will be developed that relates lost agricultural production from lack of suitable irrigation water to the acreage of farmland not inundated and the duration of time before the irrigation water returns to satisfactory quality. The analysis will also assess the costs of returning agricultural land to production with irrigation water of lower quality, by additional irrigation management to assure adequate leaching of salts. Relationships between applied water salinity, leaching, and yields will be based on U.N. FAO Irrigation and Drainage Paper No. 48. Losses from crops lost or not planted will be estimated using the same approach as described above for inundated land.

In-Delta Recreational Losses
For Delta recreation, the duration of restrictions on boating in the Delta and potential effect on fisheries will be used to develop an estimate of reduced recreational usage in

terms of recreation days. We expect this information will be provided by the levee response and repair unit, which would identify the reaches in which repair work is being undertaken, and where boating would be prevented to minimize wave action on unrepaired breaches. Unit day values from the literature will be used to develop the losses, and cost functions will be developed where costs are a function of the proportion of the Delta in which recreation is restricted, and the effect on sport fisheries.

Losses From Water Export Disruptions
The economic consequences team will investigate the allocation of south of Delta supplies between project contractors. They will rely on input from project operators and contractors to develop this allocation. They will also work with available models, project operators and local agency planners to develop relationships between the season and duration of outage, water in project and local storage, water from other supply sources, and the level and duration of shortage incurred by urban and agricultural water users. We will also explore the opportunities for emergency actions to mitigate the effect of these shortages. For example, some agricultural areas will be able to substitute a certain level of groundwater pumping for the loss of project supplies. Within the agricultural districts and service areas, water transfers may be used to minimize the loss to high-value and permanent crops. However, any transfers that depend on SWP and CVP deliveries from the Delta to move water "uphill" (i.e., from south to north) along the aqueduct via in-lieu operations are likely to be curtailed. For urban water users, emergency conservation programs may help reduce shortage costs, as may shortage policies that protect industry and jobs, and temporary interconnections to regions with lower shortage levels. While these actions will reduce the overall shortage costs, the costs of those programs must also be included in the costs of levee failures.

Our initial plan for the development of the loss functions is to consider local agency responses to hypothetical 6 month, 2 year and 4 year disruption of supplies. These values were chosen because initial analysis suggests that the loss functions may not be smooth, but that these durations may approximate points of inflection on the cost curve. However, we will review these levels of disruption with other team members and water supply agencies early in the process to determine whether this initial plan is appropriate. In addition, the analysis will investigate the cost of a return to a significantly lower level of supplies after a 4–year disruption. This scenario would reflect a temporary through-delta channel to protect water supplies in the event of cascading levee failures in the Delta. Any later permanent fix for cross Delta supplies would not be part of this analysis.

San Joaquin Valley Agricultural Users
The agricultural analysis will consider costs resulting from crop acreage reduction and crop shifting, crop losses as a direct result of supply interruption, and increased groundwater pumping. Movements of other agricultural surface supplies and groundwater within each agricultural region will be evaluated. Water transfers between regions will also be considered, but are likely to be unavailable or insignificant as a result of the large reductions in regional surface supplies and the competition from urban areas looking to purchase transfers.

Loss functions for agriculture will be developed by affected groups (see below), and will be based on the season, extent, and duration of the shortage. These loss functions will take into account the availability and cost of groundwater supplies, project actions taken to allocate water supplies, and the amount of water that would have been available to agriculture absent the supply disruption.

Potentially affected agricultural users include all CVP and SWP agricultural users south-of-Delta who can receive export water or who would be affected by outage-related water delivery decisions. The following groups of potentially affected agricultural water users will be considered:

- CVP agricultural users in the Delta-Mendota and San Luis Units (water service contractors in the Central Valley)
- San Joaquin River exchange contractors
- CVP agricultural users in the San Benito service area
- Eastside San Joaquin Valley users and Friant Unit contractors affected (including those affected by interrupted deliveries on the Cross Valley Canal, those potentially affected by releases of San Joaquin River water to replace deliveries to the exchange contractors, and those affected by releases from eastside reservoirs for delta flushing, if any)
- SWP contractors in Kings and Kern Counties
- Other SWP contractors potentially affected
- Other, non-project areas affected by water transfers, emergency allocations, or price effects.

Urban Water Users

Loss functions will be developed to represent 2005 and 2020 time periods, with extrapolations from those points forward and interpolations between those two points. A modified version of LCPSIM may be used for this analysis, or a new model may be developed. In the Bay Area, different versions of the model will be developed to handle scenarios that reflect differing potential states of other water supply infrastructure (Hetch Hetchy and the Mokelumne Aqueduct).

The economic consequences team will need to obtain information from local water supply agencies about their reaction to an extended water supply outage, and to gage what shortage may continue even after imported supplies are restored because local supplies will be depleted. We will meet with Metropolitan and the six Bay area agencies, if possible. We will request information by letter or other means from SWP North Bay Aqueduct water users, SWP Central Coast Aqueduct water users, SWP M&I water users in southern California outside of the south coast, and CVP Central Valley M&I export users (Tracy, Coalinga, Avenal, Huron).

Loss functions for urban areas will be developed separately for the following categories:

The South Coast Region

This water user group includes M&I use within the Metropolitan Water District of Southern California (MWDSC) and certain other SWP contractors within the South Coast region. This group will be defined as that water use included in DWR's south coast LCPSIM model.

The South Bay Area

This group may include water use included in DWR's south bay area LCPSIM model, with the exception of Contra Costa Water District. The water use to be included may change for specific scenarios depending on assumptions about which districts are affected and how they share water in a crisis. This group includes water use within Santa Clara Valley Water District, Alameda County Water District, and Alameda County Zone 7.

Contra Costa Water District

Because of its isolation from south of Delta facilities, and because it takes water directly from the Delta at a location different from other agencies, the duration of a given disruption, the level of shortage, and the options for alternative supplies will be different for this water district, and so it will be analyzed separately. The effects on other industries in Contra Costa County that currently take water directly from the Delta will be included in the analysis of CCWD water supply impacts.

City and County of San Francisco, East Bay Municipal Utility District

These two areas will be analyzed separately, under a number of different scenarios. For example, if the aqueducts supplying these agencies remain intact, the agencies' customers will likely still experience shortages as part of a region-wide effort to minimize costs.

Other M&I Users

This group includes:

- SWP North Bay Aqueduct water users
- SWP Central Coast Aqueduct water users
- SWP M&I water users in southern California outside of the south coast
- CVP Central Valley M&I export users (Tracy, Coalinga, Avenal, Huron)

Separate loss functions that specify the amount of the loss as a function of the severity and duration of the shortage will be developed.

Other Infrastructure Losses

The economic team will obtain the available literature and work with the industries and agencies involved to develop estimates of the economic losses that will result from disruptions to key infrastructure such as electric transmission, natural gas production, storage and transmission, telecommunications, railways, roads and ports. Once again, loss functions will be developed that relate the cost of the disruption to its duration, and, in some cases, to the season of the disruption.

Losses from Changes in Reservoir Operations

The economic consequences team will develop functions that express economic costs as a function of reservoir conditions south of the Delta with and without the Delta levee failure. These economic costs will be a function of changing recreation opportunities as the water is drawn down in those reservoirs, and the net effect of the decreases in electricity used and electricity generated because of the reduction in water "throughput" as a result of the supply disruption.

At this stage, it is not clear whether the overall effect on northern reservoirs would be significant enough to be included in the analysis. However, we will investigate the results of the water management group's analysis of project operations to determine whether this is likely to result in a significant economic impact. If necessary, we will develop loss functions associated with changes in operations at the northern reservoirs.

Short-Term Employment and Personal Income Impacts
The main output of the analyses above will be economic costs, and these costs can be added to the Levee Repair and Dewatering costs, Infrastructure Damage and Repair Costs, and Emergency Response Costs to obtain total costs. However, costs are just one economic measure of interest. The economic consequences team will also provide information about economic impacts; in particular, employment and personal income losses that arise from the loss of economic activity that results from the levee failure/

Economic activity will be lost directly because of reduced industrial and agricultural production. Lost production caused by infrastructure outages and reduced output in other industries will be identified where possible. Economic functions will be developed to estimate economic output losses by industrial segment as a function of the duration and severity of water shortage. IMPLAN, an economic modeling tool and database, will be used to estimate the loss of jobs and personal income associated with reduced output. Functions will be developed that result in estimates of lost production, jobs and personal income that will result from the duration of disruptions described above, and from extent of urban and agricultural water supply shortages.

Structural Change
The economic consequences team will describe any permanent economic impacts caused by permanent changes such as abandonment of Delta islands. We will also explore the potential for types of permanent structural change related to the duration of the disruption and severity of water supply conditions, and will describe qualitatively what the permanent changes may be.

Matching the Analysis to the Time Period of the Disruption
The analyses described above will be undertaken for two points in time, currently expected to be 2005 and 2030. The team will then need to develop extrapolations and interpolations from these two points to match the losses to the time of the particular disruption under analysis. Finally, all dollar values will be discounted to a current year (expected to be 2005) so that losses from different time periods may be compared or aggregated in a meaningful way.

5.0 PROBABILISTIC APPROACH

5.1 Epistemic Uncertainty
Economic modeling and estimation necessarily involves a great deal of epistemic uncertainty. This can arise in the following general areas:

- Uncertainty related to the state of the economy. Even the current state of the economy is imperfectly known. The uncertainty arises both from the lack of precision in measuring the economy at any one time, plus uncertainty as to how the economy will change over time. The state of the economy in future years becomes even more uncertain, and over the time-frame we are investigating, this uncertainty becomes extremely large.

- Uncertainty related to the effect of water shortages on the economy. Existing studies suggest that the relationship between the water supply and the level of economic activity is non-linear, but little else is known of the functional form of the loss function.
- Uncertainty related to future investment in infrastructure. To the extent possible, we will be relying on existing plans for future investment. However, these plans will be subject to revision over time, and cannot be expected to reflect future infrastructure investments with any certainty. Once again, over the time-frame of this study this uncertainty will become extremely large
- Uncertainty related to responses to the inundation event. At the time of the inundation triggering event, and in the recovery period, a number of decisions will be made that may have strong effects on the economic consequences. At this time, even the possible range of these decisions cannot be known with certainty. We will investigate the consequences of what we believe will be the most likely of these responses, but we will limit those responses to those currently foreseen by the likely actors.
- Uncertainty related to the crisis management of local and non-project supplies. There are a number of actions that agencies could take to manage these supplies. We will be making assumptions about the actions the agencies will take, but these must be considered speculative. However, the speculation will be informed by discussions with the local agencies.

The range of epistemic uncertainties is so large that there is no clear approach to determining the size of these uncertainties. The economics team will use its best professional judgment, and information gathered from experts, to develop an estimate of this uncertainty.

5.2 Aleatory Uncertainty

There are a few categories of uncertainty that are random in nature. The economics group intends to investigate the distribution of these factors to develop an estimate of the related uncertainty. The random factors that will be investigated include the following:

- Damages in relation to crop mix inundated in the Delta. For example, losses will be much higher if most of the acreage inundated is in permanent crops (orchards) than if it is range land.
- Availability of alternative water supplies. The amount of South of Delta project water and local (non-project) water supplies and storage at the time of the inundation event will have a strong influence on the economic consequences. This will be related to hydrology in the multi-year period before the inundation occurs. The historical record will be used to develop a range of possible initial states for these variables.
- Hydrology during the disruption period. The through-Delta project water supplies that would have otherwise been available if the disruption had not occurred will influence the level of production that would have occurred without the disruption, and thus the

level of losses resulting from the disruption. The historical record will be used to develop a range of possible values for this variable.

6.0 ASSUMPTIONS/CONSTRAINTS/LIMITATIONS

The major limitations on this analysis are expected to arise from the following:

- The wide range of emergency actions that could be taken to reduce demands or increase water supplies in the face of the emergency, and a lack of knowledge of the effectiveness of those efforts;
- Uncertainty about how farmers and local water agencies would manage in an emergency condition;
- The lack of a recent characterization of the industrial demand for water, and how industries would be affected by reductions in water supplies;
- A lack of information about use costs associated with infrastructure damage
- Uncertainty about how game fish populations might respond to a levee failure event, and how recreation might be limited.
- The assumptions made regarding the future growth of California. Our analysis will be based on either Department of Finance forecasts. However, in some cases we will be relying on analyses made by other groups. Many of these will also rely on Department of Finance forecasts, but they may not be consistent. For example, some analyses may be of different vintage than others.

In addition, the possible family of loss curves is large. We will be modeling a multitude of decisions that will be made by individuals and agencies, at different points in time. At every decision point there will be differing antecedent conditions, and different resulting following decisions that will lead to a different set of losses. We plan to approximate these loss functions by analyzing situations representing 2005 and 2030 time periods, with extrapolations from those points forward and interpolations between those two points. These points in time were chosen because we believe there are existing CALSIM runs available for those points in time. CALSIM runs are necessary because they will provide the range of possible storage levels in south of Delta reservoirs. DWR is developing 2005 and 2030 databases, which are expected to be available shortly. In addition, we expect that all urban agencies will have existing plans (that define the "business as usual" situation through 2025, because this is required under the Urban Water Management Planning Act (California Water Code Division 6 Part 2.6.) In contrast, it is expected that very few will have completed plans through 2030.

These loss curves will also be developed based on four disruption scenarios for water supply -- 6 month, 2 year and 4 year disruption of supplies. In addition, the analysis will investigate the cost of a return to a significantly lower level of supplies after a 4 –year disruption. Increasing the number of disruption scenarios could improve the loss curve estimation, but the disruption scenarios identified above are all that can be developed in the time frame foreseen.

We have decided to use a straight line interpolation and extrapolation for other time periods throughout the period required. It is likely that this straight line approximation will overstate losses in the early years and understate losses in the later years.

7.0 INFORMATION REQUIREMENTS

While the general outline of the analysis has been described above, particular aspects of the analysis may not be clear until the task is underway. In the section below, we have developed a summary of the information we expect to need, but other information may be identified during the course of the project.

From the DRMS Team:

- General
  - Year (date) of disruption
  - Season of disruption
- In Delta Lost Use
  - The number of housing units lost and the duration of that loss (i.e., until reconstruction is completed).
  - Information on the number and types of businesses whose premises are lost and the duration of that loss. Any other information available on business losses.
- Delta Agriculture
  - Agricultural acreage inundated
  - Value and categories of agricultural property included in emergency response and repair costs (for coordination purposes)
  - Location of inundation, or crop mix on acreage inundated (it may be preferable to handle crop mix probabilistically – see below)
  - Schedule of acreage drained and land restored to productive condition
  - Duration until specified salinity levels reached in specified Delta locations (to be determined)
- Delta Recreation
  - Proportion of Delta where boating is restricted and duration of restriction
  - Temporary and permanent effect on fisheries
- Water Supply Disruption

For each of the major delta diversion points:

- Amount of pumping without any Delta levee failure
- Duration of complete outage
- Amount and timing of project deliveries during ramp-up after delta diversions are restored

- Duration of, timing for and amount of, opportunistic water available
- Amount of pumping with impaired water quality and quality of impaired water

For other water sources:

- Disruption status for Mokelumne Aqueduct, duration of any outage, duration of outage attributable to seismic failure alone
- Disruption status for Hetch Hetchy aqueducts, duration of any outage, duration of outage attributable to seismic failure alone
- Any water used for flushing purposes taken from reservoirs that could be used to supply south-of-Delta agencies.

For each upstream reservoir:

- Final storage volume with and without the disruption

- Other Infrastructure Disruption
  - The infrastructure disrupted by levee failure, or the disruption compounded by levee failure.
  - The period of the disruption, or the period the disruption is extended because levee failure inhibits repair.
  - The season the disruption/disruption extension occurs.

The economic consequences team will have to confer with the client and the structural team to develop a list of the infrastructure failures whose consequences will be investigated.

- From Other Sources
  - Literature search for models, parameters and data
  - Meeting with USACE and other economic model experts to acquire and interpret use loss parameters and data
  - Meetings with water project operators to determine assumptions to be used for downstream water operations.
  - Meetings with Delta water users, as discussed, to develop estimates of water quality at which irrigation diversions will continue
  - Meetings with water users to identify "business as usual" conditions, likely emergency responses, develop water allocation scenarios, estimates of when impaired water would be taken, parameters and data.
  - Meetings with operators of other infrastructure to determine how the loss of the infrastructure would impact system operations
- Coordination Issues

  The economic team has identified a number of issues that will need to be resolved early in the project to ensure that our deliverable is consistent with those developed by others. In particular, we will need to know the following:

- What reservoirs the Water Management group is considering using to provide flushing water for the Delta
- What information for future land use will be developed by other groups
- How immediate damages to agriculture – such as loss of livestock – will be assessed

In addition, there are a number of issues that need to be addressed by someone, but it is not clear whether these are best addressed by the Economic Consequences Group or others. For example, the Water Management Group will be developing an estimate of north of Delta reservoir storage. To identify lost recreation impacts the volume of water stored will need to be translated to surface area of water in the reservoir. This can be done through the use of reservoir-specific algorithms, but it is not yet obvious whether this should be undertaken by the Economic Consequences Group or the Water Management Group.

Other issues are bound to arise over the course of the project, so we see a need for an established process to address the needs for intergroup consistency.

8.0 REFERENCES

Department of Water Resources (DWR). 2002. IO model.

Hydrologic Engineering Center (HEC). 2006. Hydrologic Engineering Center's Flood Damage Analysis computer program.