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The risk analysis was carried out, for the most part, using existing information (data and analyses). The project schedule and scope do not afford the opportunity to conduct field investigations, laboratory tests, or research. As the analysis progressed, the Delta Risk Management Strategy (DRMS) consulting team noted several data gaps that contribute to the limitations and the uncertainties of the analysis results. Consideration should be given to filling these data gaps prior to any post-DRMS evaluations or designs of Delta improvement projects. The identified gaps are as follows:

- DRMS addressed the risk of levee failures (under various hazards and stressors) and estimated the consequential impacts on life safety, the ecosystem, water exports, water quality, land use, economics, etc. DRMS does not address other stressors and their impacts on the various resources and assets in the Delta and Suisun Marsh. For example, the impact of nonnative invasive species on native species and habitat, and the impact of changes to water quality (pollutants) on the native species are not addressed. On the other hand, the impact of levee failure on the habitat, water quality, and their effects on the Delta ecosystem and water exports are addressed.
- To have a common basis for risk comparison, a business-as-usual (BAU) scenario was assumed for the current and the future Delta and Suisun Marsh. Earlier sections of the report describe the meaning and definition of BAU, the continuation of existing (2005-era) policies and management practices. This assumption offers a common basis for comparison of the present and future risks of the Delta, and allows the answer to the question of whether the current Delta status and practices are sustainable in the future. We understand that the continuation of the BAU is not likely, and changes towards a more sustainable Delta would likely occur as a result of this and other relevant studies.
- The risk model used in this study relies on input from the hazard models (seismic, flood, climate change, subsidence, and wind/wave), levee system response model, and the consequences models. The hazards, the levee response, and the life safety models have been represented probabilistically. The model development of the aquatic species impact is built on a probabilistic framework although the parameters have not been set and results have not been produced yet. The climate change model is based on ranges of possible outcomes as opposed to a full probabilistic representation. The economic model is based on best estimate values and use neither ranges nor a probabilistic representation.
- The engineering analyses conducted for this risk evaluation project were developed at a regional level using broad interpolation and smoothing of the engineering and scientific properties and parameters that are naturally highly variable across a large area such as the Delta and Suisun Marsh. These analyses were conducted at a planning level, using a coarse geographic grid, hence carrying less site-specific and locally detailed information typically required for specific engineering and design projects.
- Topographic and bathymetric base maps are essential for the development of the levee vulnerability assessment. These data are of first order importance to the entire risk analysis. The data used for the draft DRMS project (URS/JBA 2007b) relied on surveys compiled from various topographic data sets prepared at different times, with different reference datum, and by different methods and entities. However, since then, a new LiDAR survey was completed for the entire Delta and Suisun Marsh in late 2007, and the work (URS/JBA 2008h) was updated making use of this new survey.

- It is assumed that scour depth is a direct function of peat thickness (see Section 7.5 for discussion of this issue). The validity of this assumption should be further investigated to determine whether other parameters, such as island area or volume, are better predictors of scour depth.
- Breach depth is important in estimating the quantity of rock for breach closure and repair times. It is also important for estimating the volume of suspended sediments in a flooded island.
- Net Delta consumptive uses are a major source of water demand in the Delta, especially in low-flow years. Existing estimates are useful, but data and modeling limitations may contribute significant errors to the water balance in dry and critical years. Better estimates of the timing and distribution of Delta consumptive use is important for calibration of Delta models and simulation of levee breach consequences.
- The sequence and types of repairs of flooded islands have a strong effect on the time necessary to flush the Delta of intruded salinity and return to a stable salinity regime that supports normal in-Delta water use, ecosystem functions, and water exports. There are many permutations and sequences of emergency repair work for each set of levee failure outcomes. There are many sets of levee failure simulated outcomes. There are multiple permutations of repair types for each sequence of island repair, e.g., capping the breach first and coming back later to close and dewater, capping and closing the breach immediately, repairing damaged but not flooded islands first, protecting the inner slopes of the flooded islands from erosion, etc.

  The study did not exhaustively analyze this particular topic as it is outside the scope of this work and would deserve a specific research and study because of the extensive nature of its scope. The repair sequencing used in the study was based on professional judgment using one repair sequence with each simulated levee failure realization, rather than multiple repair sequences for each simulated levee failure outcome.
- Although CalSim is a powerful and useful tool, it is a limitation on how water issues can be analyzed. Two major limitations result from use of the historical hydrologic sequence to drive CalSim. The historical series is likely to trend through time, since it is now recognized that global warming and climate change have been with us for at least 30 to 40 years. Also, the historical record includes less than half of the 125 potential 3-year sequences of water year types.
- The impacts of levee breaches on Delta salinity may be more strongly influenced by the wetness or dryness of the winters after a breach event than by hydrologic conditions in the event year or in the year preceding the event. Under BAU conditions, a winter with significant San Joaquin River flows may be required to flush the southern Delta if salinity significantly intrudes the area.
- Future water demands have not been characterized in detail, but seem certain to increase. Population and demands upstream of the Delta seem likely to increase, leaving less inflow available for managing the Delta during either normal times or during levee breach incidents. Although the demands for Delta exports are limited by contract amounts and other factors, population growth will likely cause available export water to be used more intensively for

higher value uses. The effect of climate change is less certain; some indication exists that increased water demand due to increased temperatures may be counter balanced by less vegetative water requirements caused by increased atmospheric carbon dioxide.

- One of the most important outstanding questions is about the impact of unrepaired flooded islands with active tidal prism on Net Delta Outflow (carriage water) requirements. This study has not had enough time to provide conclusive quantification of flooded islands on carriage water requirements. Numerical experiments using particle tracking and salt transport simulation under a variety of flow and breach conditions provide insight, but no evident trend. The changes in tidal mixing vary by island and breach location resulting in both increases and decreases in salinity across the Delta.

  Besides changing the tidal dynamics, flooded islands act as capacitors that buffer seasonal salinity variation. In general, breached islands tend to increase mixing near the breach locations and reduce mixing away from the flooded island. Additional tidal mixing caused by flooded islands located near Sherman Island appears to be particularly effective in mixing salt into the Delta, and, therefore, is likely to have a large effect on carriage water requirements.

- Improved net (tidally averaged) flow observations (specifically at the key flow split locations of Three Mile Slough on the Sacramento and False rivers, Turner Cut, Old River near Franks Tract, and Old River at Head on the San Joaquin River) with uncertainty estimates throughout the Delta will support calibration of all Delta models as well as allowing better setting of parameters of the net flows for the WAM-HD.

- It is important to recognize the limitations inherent in the characterization of ecosystem impacts. The results presented here primarily assess the number of individuals or area of habitat impacted, which is similar to the coarse scale used to evaluate the impact of levee failure on life and safety by measuring the number of residents exposed to flooding. Therefore, these results provide a sense of the order of magnitude of the risk, primarily for the immediate impacts of levee breaches, which last for a relatively short duration but cause widespread mortality during the time they are in operation.

- The aquatic species impact model was developed solely using expert elicitation. The model was developed and presented in the Impact to Ecosystem Technical Memorandum. However, the aquatic species impact results have not been completed yet because of the project schedule limitation and the lack of availability of the experts used in the elicitation process.

- For many of the species and impact mechanisms, data were not available to support predictive response relationships to a levee failure event. Therefore, a number of assumptions were made that contribute to a high degree of uncertainty in the ecosystem risk analysis. The risk assessment model identifies assumptions and required data and provides a framework with which to incorporate new data and to evaluate the effects of alternative assumptions on the levee failure impacts on ecosystems.

- Consequences such as impacts of toxins released, water quality impacts, impacts extending across food chains, long-term levee breach impacts on organisms, and the nonlinear impacts of multiple mechanisms on organisms are examples of further effects of levee breaches that are not quantitatively assessed here but which may have far-reaching impacts on the ecosystem.

- The region queried for the purposes of measuring regional plant impacts was defined as those 12 counties that include and border the Delta and the San Francisco Bay. The results of the California Natural Diversity Database query overlaid with flooding patterns indicate that levee breaches and subsequent repair activities can greatly reduce the population size of sensitive plant species, thereby increasing the probability of species extinction. However, exhaustive surveys of rare plant locations and species-specific responses to low population size would be required to fully quantify the impact of levee breaches on species extinction.
- The DRMS Risk Analysis considered damage to infrastructure assets that could result from levee breaching and island flooding. Infrastructure assets that would not be damaged by levee failure (e.g., pumping plants and power plants) are beyond the scope of the DRMS Risk Analysis. Because some asset types lack attribute information, it was not always possible to estimate asset costs from the GIS data. In these cases, definition of quantitative attributes is insufficient to evaluate reliable replacement and repair costs, and assumptions had to be made so that damage loss could be estimated. Also, some assets were not available in the GIS database.

  Further characterization of the Delta infrastructure assets would reduce the uncertainty in the damage estimates. Because of the lack of information on repair times (due to the absence of historical experience), especially for multi-island failures, judgment and experience were used to estimate repair times.