Chapter 6. Levee Stability and Seepage

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

This chapter presents information, developed since the 1995 DEIR/EIS was published, on potential Delta Wetlands Project effects on levee stability and seepage. The 1995 DEIR/EIS described Delta Wetlands' proposed preliminary levee design and seepage control system; that system includes operational measures developed by Delta Wetlands to avoid or reduce potential effects of project construction and operation on levee stability and use of adjacent islands for agriculture. In response to testimony presented at the Delta Wetlands water right hearing, the lead agencies determined that new information should be presented in this REIR/EIS to augment the evaluation presented in Chapter 3D, "Flood Control", of the 1995 DEIR/EIS.

Delta Wetlands' Proposed Levee Design and Seepage Control System

As described in Chapter 3D of the 1995 DEIR/EIS, Delta Wetlands proposes to improve the levees surrounding the reservoir islands. Under existing conditions, levee conditions are greatly variable. A typical present levee condition is a 20-foot-wide crest at an approximate elevation of +8.5 feet above mean sea level with an exterior (water-side) slope of 2:1 (horizontal to vertical) and an interior (land-side) slope of 4:1. Under the proposed project, a typical improved levee would have an exterior slope of 2:1, a crest about 22 feet wide (including the thickness of erosion protection on the interior slope) at an elevation of about +9 feet, a 3:1 or steeper initial interior slope down to an elevation near -3 feet, and wide land-side toe berms to buttress the levee. Alternatively, the interior slope may be inclined at about 5:1 and may not have toe berms. Figure 6-1 shows examples of potential initial levee improvements on levees with a 3:1 existing interior slope. The new slopes would meet or exceed criteria for Delta levees outlined in DWR Bulletin 192-82. Levee-improvement materials would be obtained primarily from sand deposits on the project islands. Each borrow area would generally be located more than 400 feet inward from the toe of a levee so that the borrow excavation would not cause structural impacts on the levee and would be at least 2,000 feet inward from the final toe of an improved levee where a greater setback is necessary to control seepage.

The interior slopes of these perimeter levees would be protected from erosion by conventional rock revetment similar to that used on existing exterior slopes, or by other conventional systems such as soil cement or a high-density polyethylene liner. In areas where final design studies indicate that wave splash and runup could potentially erode the levee crest if it is unprotected, the levee crest would be hardened or the erosion-protection facing would be extended up as a splash berm.

The proposed project includes a seepage-control system that would consist of interceptor wells installed in the exterior levees of the reservoir islands in locations where substantial seepage to adjacent islands through subsurface materials is predicted to occur (Figure 6-2). Water captured by the interceptor wells would be pumped back into the reservoirs. The interceptor wells would be used to maintain the hydraulic heads in subsurface materials within preproject ranges at distances of 500 to 1,000 feet from the project island perimeters (i.e., beneath levees of adjacent islands).

Delta Wetlands would implement a seepage monitoring program to provide early detection of seepage problems caused by project operations (Figure 6-2). A network of wells (i.e., piezometers) located immediately across the channels from the reservoir islands would be used to monitor seepage; background wells at distant locations would establish water-level changes that typically occur without project operations. Delta Wetlands has proposed seepage performance standards for the project that would be used to determine the amount of interceptor-well pumping needed to ensure that seepage is reduced to acceptable levels. The seepage-control system and seepage performance standards are described fully in Chapter 3D of the 1995 DEIR/EIS.

1995 Draft EIR/EIS Evaluation, Comments, and New Information

1995 Draft EIR/EIS Evaluation

The evaluation of project effects presented in the 1995 DEIR/EIS was performed by comparing the proposed levee improvement design with existing conditions as described in the results of the preliminary investigations performed by Delta Wetlands' geotechnical consultants. These investigations included numerous field studies, monitoring, modeling, and levee stability analyses (see Appendix D1 of the 1995 DEIR/EIS for a listing). The impact analysis concluded that because of the elements and operational measures incorporated into the project design, the project would have no significant impacts on levee stability and seepage.

New Information Developed for This Evaluation

Several commenters on the 1995 DEIR/EIS and protestants against Delta Wetlands' water right applications questioned the adequacy of Delta Wetlands' proposal with regard to levee stability and seepage to adjacent islands. To address this issue regarding the project's potential effects, an additional independent analysis of levee stability and seepage issues has been performed to provide information to supplement the 1995 DEIR/EIS discussion.

The analysis of these issues, performed by URS Greiner Woodward Clyde (URSGWC), is included as Appendix H of this REIR/EIS, "Levee Stability and Seepage Analysis Report for the Delta Wetlands Project Revised Draft EIR/EIS". This chapter updates the assessment of potential

Delta Wetlands Project effects presented in Chapter 3D of the 1995 DEIR/EIS by summarizing the findings of the URSGWC analysis and, as requested by the lead agencies, presenting new information on boat-wake effects on levee erosion.

Summary of Issues Addressed in This Chapter

The REIR/EIS analysis of issues related to flood control addresses the following questions, which represent the concerns expressed at the water right hearing and in comments on the 1995 DEIR/EIS:

- Can a pumped-well system (i.e., Delta Wetlands' proposed interceptor-well system) control groundwater seepage?
- What is the long-term reliability of the proposed interceptor-well system of seepage control?
- Would the proposed seepage monitoring program be adequate and effective?
- Could operation of the seepage-control system result in substantial water diversion onto the reservoir islands?
- Would the proposed setbacks for borrow-pit areas be adequate to prevent excessive seepage increases in the underlying sand aquifer?
- Would rapid changes in the reservoir water level cause additional stresses on underlying soil layers and additional settlement of the levees and interiors of reservoir islands?
- Would Delta Wetlands operations reduce the levees' dynamic or static stability?
- Would the construction and operation of the interceptor-well system reduce levee stability?
- What potential damage to adjacent islands could result if a reservoir island's levee failed or if the owner abandoned the project?
- Would increased wave action from Delta Wetlands Project-related boat use in Delta channels contribute to levee erosion and adverse effects on channel island habitats?

The information presented in this chapter adds more detail to the impact evaluation presented in the 1995 DEIR/EIS; however, the analysis does not address every extreme of conditions that could be encountered during project implementation. The discussion below is based on a proposed preliminary design of flood- and seepage-control features of the project and represents a general evaluation of the environmental feasibility of these features. Specific design issues, including site-specific geotechnical evaluations, will be addressed in detail as the lead agencies and the applicant proceed through the permit approval processes. Nonetheless, the level of detail presented below is adequate for purposes of CEQA and NEPA impact analysis and for determining the general feasibility of Delta Wetlands' proposal for levee stability and seepage control.

Definition of Terms

The following are definitions of key terms as they are used in this chapter:

- *Aquifer:* A porous soil or geological formation lying between impermeable strata that contains groundwater; yields groundwater to springs and wells.
- *Bearing Capacity:* The maximum load that a structure can support, divided by its effective bearing area (the part of the structure that carries the load).
- *Borrow Area:* An excavated area or pit created by the removal of earth material to be used as fill in a different location.
- *Buttress:* To steady a structure by providing greater resistance to lateral forces to prevent failure.
- *Design Response Spectrum:* The specified range of ground motion in response to seismic activity that is assumed for an analysis based on historical data and local soil conditions.
- *Dynamic and Static Stability:* The stability of levees under seismic movement or without seismic movement.
- *Factor of Safety for Slope Stability (FS):* A calculated number representing the degree of safety of a slope against instability. The FS is expressed mathematically as the ratio of stabilizing effects (forces or moments) and destabilizing effects acting on a potentially unstable soil mass in a slope. When the FS is greater than 1, the soil mass in the slope is, in theory, stable; when the FS is less than 1, the slope is, in theory, unstable. For a given slope geometry and soil conditions, a calculated FS is associated with a unique slope failure configuration. The most critical failure configuration is associated with the minimum FS calculated in a slope stability analysis. Several agencies (such as the Association of State Dam Safety Officials and USACE) have developed criteria that provide different design FSs stipulated for various slope conditions (e.g., under long-term loading, shortly after construction, etc.). These FSs are typically above 1 and are minimum values to be achieved for the slope to be considered stable.
- *Freeboard:* The vertical distance between a design maximum water level and the top of a structure such as a levee, dike, floodwall, or other control surface. The freeboard is a safety margin intended to accommodate unpredictable rises in water level.

- *Hydraulic Conductivity:* A measure of the capacity of a porous medium to transmit water, often expressed in centimeters per second. The hydraulic conductivity is equal to the rate of flow of water through a cross section of one unit area under a unit hydraulic gradient.

- *Hydraulic Gradient:* The rate of change in total hydraulic head per unit distance of flow measured at a specific point and in a given direction, often resulting from frictional effects along the flow path.

- *Hydraulic Head:* The force exerted by a column of liquid expressed as the height of the liquid above the point at which the pressure is measured (the force of the liquid column being directly proportional to its height).

- *Interceptor Well:* In the context of the Delta Wetlands Project, a pumped well located on an island levee for controlling groundwater flow off the island.

- *Interceptor-Well System:* A seepage-control system that would consist of actively pumped wells installed in the exterior levees of the reservoir islands in locations where substantial seepage to adjacent islands is predicted to occur.

- *Levee Crest*: The top of a levee.

- *Liquefaction:* The process in which loose saturated soils lose strength when subject to seismic activity (i.e., shaking).

- *Overtopping:* Passing of water over the top of a levee as a result of wave runup or surge action.

- *Passive-Flow Relief-Well System:* A system of wells that passively relieve elevated hydrostatic pressures in an aquifer by allowing flow to the surface. (Hydrostatic pressure is the pressure exerted by a liquid, such as water, at rest.)

- *Phreatic:* Of or pertaining to groundwater.

- *Phreatic Surface:* The surface of a body of unconfined groundwater at atmospheric pressure.

- *Piezometer:* A sandpipe monitoring well used to measure the depth to the groundwater surface in the aquifer.

- *Piping:* The removal of fine soil particles from the soil mass by high hydraulic gradients. For example, excessively high exit hydraulic gradients at the surface may cause upward transport of soil, resulting in sand boils.

- *Rock Revetment:* A stone covering used to protect soil or surfaces from erosion by water or the elements. Also referred to as riprap.

- *Seepage:* A slow movement of water through permeable soils caused by increases in the hydraulic head (see "hydraulic head" below).
- *Seepage Flux:* The rate of flow of water across a given line or surface, typically expressed in gallons per minute (gpm) or cfs.
- *Settlement:* The sinking of surface material as a result of compaction of soils or sediment caused by an increase in the weight of overlying deposits, by pressure resulting from earth movements, or by the removal of water from the soil or sediment.
- *Slope Deformations:* Changes in the shape or size of a slope.
- *Splash Berm:* An extended area of facing on an island levee designed to protect against erosion of the levee crest by wave splash and runup.
- *Stratigraphy:* The composition, characteristics, distribution, and age relation of layered rocks and soils.
- *Toe Berm:* The section projecting at the base of a dam, levee, or retaining wall.
- *Wave Runup*: The vertical height above stillwater level to which water from an incident wave will run up the face of a structure.
- *Wind Fetch:* An area of water over which wind blows, generating waves.
- *Yield Acceleration:* Pseudostatic horizontal force that will give a calculated factor of safety of 1 in slope-stability analyses.

NEW INFORMATION

Information used to prepare the discussion of levee stability and seepage in this chapter is summarized from URSGWC's report of new technical analyses of Delta Wetlands' proposed levee design and seepage-control system (Appendix H of this REIR/EIS) and from testimony presented at the water right hearing. Information on boat-wake-induced erosion is based on a literature review and discussion with knowledgeable individuals.

Results of the New Analysis of Delta Wetlands Project Effects on Seepage

As described in Chapter 3D of the 1995 DEIR/EIS and confirmed by the URSGWC seepage analysis, Delta Wetlands Project operations would increase the potential for seepage onto islands adjacent to the reservoir islands. These seepage effects would occur because deep sand aquifers underlie the reservoir islands and adjacent islands, as well as the channels or sloughs separating them. Storing water on the reservoir islands would increase the elevation of the phreatic (i.e., groundwater) surface and the hydraulic pressure on the aquifer, thereby inducing seepage through the sand aquifer onto the neighboring islands.

Delta Wetlands considered several technically feasible methods for controlling seepage onto the adjacent islands. These measures include pumping from reservoir island levees, pumping from levees of adjacent islands, using passive or active relief wells or trenches on adjacent islands, and using a continuous cutoff wall in the reservoir island levees. Installing seepage control measures on the adjacent islands may be hydraulically more efficient because it would require less pumping; however, these potential solutions were eliminated from consideration because of concerns about land ownership and access. A continuous cutoff wall was likewise eliminated by Delta Wetlands from consideration because it would be cost prohibitive. Delta Wetlands has therefore proposed to install a system of interceptor wells on the reservoir island levees to control seepage.

The following discussions summarize URSGWC's seepage analysis methodology and the findings of the analysis; where appropriate, references are given to specific sections of URSGWC's analysis (Appendix H).

Seepage Analysis Methodology

Previous analyses prepared by Delta Wetlands' consultants (Hultgren and Tillis, Harding Lawson Associates, and Moffat & Nichols) used plan-view modeling techniques to estimate seepage conditions. Plan-view modeling considered only horizontal seepage within the sand aquifer, where most seepage would occur. This approach does not include seepage through other elements of the subsurface strata or the effects of vertical infiltration from the storage reservoirs or adjacent channels. Consequently, the plan-view modeling approach does not adequately simulate the localized seepage conditions near the proposed interceptor-well system.

To better evaluate the performance of the proposed interceptor-well system, URSGWC used a two-dimensional finite element model (SEEP/W) (Geo-Slope International Ltd. 1994) for two cross sections each of Bacon Island and Webb Tract. The cross sections were selected based on available data to be conservative and reasonably representative of relatively high seepage conditions that would be encountered on the reservoir islands. The two-dimensional modeling approach considers all major elements of subsurface stratigraphy and vertical infiltration from the reservoir islands and channels.

The following parameters deemed critical for the evaluation of seepage effects of reservoir operations were considered in the URSGWC analysis:

- average total hydraulic head in the sand aquifer near the levee centerline on a reservoir island,
- seepage flux (seepage flow through a vertical section) near the project-island levee centerline,

- average total hydraulic head in the sand aquifer at an adjacent-island levee,
- seepage flux at the centerline of the adjacent-island levee, and
- water-table level at the far inland toe of the adjacent-island levee.

No site-specific investigation or testing was performed as a part of the URSGWC analysis. The lead agencies considered the previously collected soil profiles adequate for the level of analysis presented in this REIR/EIS. The characterizations of soils, levee properties, seismic setting, and hydraulic and hydrologic conditions were based on available data, publications, and professional engineering judgment and experience. As discussed in Appendix H, significant additional detailed predesign soil profiling and analysis will be required before construction.

The model input parameters, calibration, and sensitivity analyses are described in Section 2, "Seepage Issues", of Appendix H.

Ability of a Pumped-Well System to Control Groundwater Seepage

Using the SEEP/W model, URSGWC evaluated three conditions:

- existing seepage conditions,
- a full reservoir with no interceptor well pumping, and
- a full reservoir with pumping.

The analysis determined that a pumped-well system (i.e., the proposed interceptor-well system) with wells spaced at 160 feet on center and a pumping rate of 5 to 12 gpm, depending on local conditions, would be adequate to maintain seepage at existing levels beneath the levees on adjacent islands (Table 2.3.2 of Appendix H). For both Webb Tract and Bacon Island, URSGWC notes that the interceptor well system should extend to the bottom of the sand aquifer, the pumping well should be screened over the entire length of the aquifer to achieve the required drawdown at the well, and the pumps should be sized to efficiently handle the required pump rate.

URSGWC concluded that the interceptor-well system of seepage control as proposed by Delta Wetlands "appears effective to control undesirable seepage effects" and that "a properly functioning interceptor well system can be used to minimize the effects of the proposed reservoirs on adjacent islands, including the potential for rises in the groundwater table or flooding". The summary of findings also notes that the proposed spacing of 160 feet between interceptor wells appears to be adequate. The findings indicate that spacings and pumping rates will be more precisely defined for each levee section during the final design of the project and note that adjustments in the design of the interceptor-well system will be required to accommodate varying site-specific conditions. Following detailed investigations of subsurface conditions, adjustments in the well interceptor system design will be required to accommodate varying conditions, ranging from areas where little or no pumping may be needed to areas where pumping rates may be much higher than is typical (e.g., along localized gravelly portions of the aquifer). For example, previous studies have shown variations in the hydraulic conductivity of the sand aquifer up to five to six times those used in the URSGWC analyses. Such a higher conductivity could require pumping rates of as much as 50 to 60 gpm in some portions of the reservoir levee pump field for wells spaced at 160 feet to maintain seepage at existing levels. (See Sections 2.3.5 and 4.1 of Appendix H.)

Long-Term Reliability of the Proposed Interceptor-Well System

As described in Chapter 3D of the 1995 DEIR/EIS, Delta Wetlands' geotechnical consultants conducted a series of demonstration projects on McDonald Island in 1990 to show the effectiveness of a pumped-well system and a passive-flow relief-well system in lowering the hydraulic head in the sand aquifer. Mildred Island, located immediately west of McDonald Island, has been flooded since 1983. The analysis showed that both a pumped-well system and a passive-flow relief-well system reduced the hydraulic head, but that the passive-relief system resulted in less drawdown. Evidence was presented in water right hearing testimony that McDonald Island land became saturated and unfarmable after the demonstration projects were completed. Delta Wetlands' geotechnical consultant Ed Hultgren testified, however, that the relief wells became less effective with time as they became clogged with silt. Hultgren added that the demonstration wells were constructed for the demonstration project only, not for long-term use, and that when the demonstration projects were complete, the wells were not maintained.

URSGWC reviewed the previously prepared reports and generally concurred with their findings that the drawdown test on McDonald Island showed:

- the interceptor-well system could be effective in controlling seepage, and
- an interceptor-well system installed on the perimeter of the reservoir islands could be a viable system to control the seepage into the neighboring islands.

URSGWC also concluded, however, that the McDonald Island demonstration projects show that final design and proposed maintenance programs must address the potential migration of fine materials from the sand aquifer to a pumped-well system (Section 2.2.7 of Appendix H). Migration of fine materials from the sand aquifer could decrease the efficiency of the wells and could result in subsidence or slumping of the levees (see "Effect of the Interceptor-Well System on Levee Stability" below.) Regular performance monitoring, maintenance, and "redevelopment" (cleaning) of the wells will be required to ensure long-term effectiveness of the proposed interceptor-well system. The report states the following (Section 2.5 of Appendix H):

- The design of the well screen and surrounding gravel pack will need to accommodate the grain sizes of the aquifer.
- The perforated section of the well casing should stay submerged (i.e., should not extend above the elevation of the deepest expected drawdown of the water table) to minimize the possibility of fouling of the screen by organic growths.

- It would be useful for the individual wells to be equipped with flow meters so that any dropoff in output can be identified.

- It would be necessary, during the final design, to evaluate the likelihood of power outages and their consequences on seepage control and to consider whether providing standby generators would be advisable.

Adequacy and Effectiveness of the Proposed Seepage Monitoring Program

Delta Wetlands has proposed a monitoring program to ensure that there is no net seepage onto adjacent islands. The proposed monitoring program includes hourly measurements of water levels in seepage monitoring wells (i.e., piezometers), background monitoring wells, and adjacent sloughs and channels. The seepage and background monitoring wells are located on the levees of islands adjacent to the reservoir islands; the locations proposed by Delta Wetlands are shown in Figure 6-2. Delta Wetlands proposes to implement additional seepage control measures if the monitoring data indicate that water levels in the seepage monitoring wells have exceeded performance standards (see Chapter 3D of the 1995 DEIR/EIS) and the increased seepage is attributable to reservoir-island filling. URSGWC reviewed the monitoring program and determined that it is appropriate in concept, but recommends modifying the program as follows (Section 2.4 of Appendix H):

- The background monitoring wells should not be more than 1 mile from the seepage monitoring wells.

- More than one background monitoring well should be used for each row of seepage monitoring wells.

- At least 3 years of data should be used to establish reference water levels in the background monitoring wells and in at least half of the seepage monitoring wells before reservoir operations begin.

- A running straight-line mean from the monitoring well data should be used in the application of the seepage performance standards.

- The seepage performance standard of 1 foot should be reduced to 0.5 foot for the single-well condition.

- The seepage performance standards should be reevaluated periodically after reservoir operations begin.

Additionally, URSGWC notes that the proposed seepage monitoring system does not account for the relationship between groundwater elevations and seasonal or local variation within each adjacent island. Local conditions could include changes in groundwater levels attributable to local pumping for farming operations. To monitor trends in groundwater management on the neighboring islands, URSGWC recommends that Delta Wetlands supplement the proposed background well system with shallow background wells (10 to 20 feet deep) installed across each neighboring island. These additional background wells would be placed one-half mile to 1 mile apart, beginning near the levee adjacent to the reservoir island and continuing across the adjacent island, so that groundwater levels at increasing distance from the reservoir island can be compared. During final design, the specific location and spacing of these wells should be finalized based on groundwater conditions in each neighboring island.

Water Diversion onto the Storage Islands through Interceptor-Well Pumping

Under certain water-level conditions in the reservoir islands and adjacent channels, water from adjacent channels could be inadvertently diverted onto the reservoir islands through operation of the interceptor-well system or direct seepage. Using the SEEP/W model, URSGWC evaluated the volume of seepage and the rate of interceptor-well pumping under full-reservoir conditions. For this evaluation, it was assumed that water pumped from the interceptor wells would be returned to the reservoirs. The study concluded that if Delta Wetlands operated the seepage-control system at the minimum rate necessary to prevent net seepage on adjacent islands, the simulated flux of water from the slough toward the reservoir islands would be about the same as the flux under simulated existing conditions for most locations and would constitute approximately 8% of the total water pumped from the wells (Section 2.6 of Appendix H). The proposed seepage monitoring program could be used in conjuction with pumping-rate monitoring to determine the volume of channel water being pumped onto the reservoir through the interceptor-well system or through direct seepage.

Adequacy of Borrow-Area Setbacks

URSGWC used the SEEP/W model to evaluate whether Delta Wetlands' proposed borrow-area setbacks would be adequate to prevent excessive seepage increases in the underlying sand aquifer. URSGWC concluded that borrow areas located 400 feet from the toe of the reservoir island levees would have an insignificant effect on the total hydraulic head conditions within the sand aquifer near the levees or the required pump rate at the interceptor-well system. The modeling showed that setting the borrow area back 800 feet from the levee in accordance with USACE standards would result in no effects (i.e., no additional benefit) on seepage conditions or operation of the interceptor-well system (Section 2.3 of Appendix H).

Effects of Rapid Changes in Reservoir Water Levels on Settlement of Island Interiors

URSGWC evaluated the conceptual mechanisms that would lead to land-surface subsidence on the interiors of the reservoir islands and concluded that additional settlement caused by operation of the Delta Wetlands Project would be nominal. The weight of water stored on the reservoir islands would compact the soil and lead to settlement of the reservoir island interiors. The evaluation determined that project operations would result in approximately 1 foot of additional settlement over the life of the project, with most soil compaction occurring during the first year of water storage operations. This predicted settlement is only a fraction of the land-surface subsidence that would be expected to occur if the existing agricultural practices are continued in the future. Under existing agricultural practices, land-surface subsidence would continue until all peat materials have oxidized, which would result in a long-term lowering of the ground surface of approximately 15 feet on Webb Tract and 10 feet on Bacon Island. (Section 2.7 of Appendix H.)

Results of the New Analysis of Delta Wetlands Project Effects on Levee Stability

The four Delta Wetlands islands are bounded by "nonproject" levees. Federal "project" levees are maintained to USACE standards by the State of California or by local landowners under state supervision; nonproject levees are defined as levees constructed and maintained by local landowners and reclamation districts. Delta Wetlands' proposed improvements to its levees are described in Chapter 3D of the 1995 DEIR/EIS and are summarized above under "Delta Wetlands' Proposed Levee Design and Seepage Control System". Placement of toe berm fill and fill on the levee slopes and crest would take place in stages to allow for consolidation of material. Delta Wetlands' proposed project includes regular inspection and maintenance of the levees.

The main objective of the levee-stability analysis performed by URSGWC was to evaluate Delta Wetlands' proposed levee-strengthening method for the reservoir islands. The analysis focused on the static and dynamic slope stability of the proposed levee configuration. Other performance conditions were studied as well, including:

- load bearing capacity;
- slope deformations and settlement and their effects on levee stability; and
- potential effects associated with geologic and seismic hazards, such as liquefaction.

The following discussions summarize URSGWC's methodology for analyzing levee stability and the findings of the analysis; where appropriate, references are given to specific sections of URSGWC's analysis (Appendix H).

Methodology Used for the Levee Stability Analysis

For the evaluation of Delta Wetlands project effects on levee stability, URSGWC reviewed published literature on peat soil as well as the geotechnical studies, including slope-stability analyses, previously prepared for Delta Wetlands by its own consultants. URSGWC reviewed the assumptions and results of these studies and used information from these reports to develop the soil parameters included in its analysis.

The URSGWC analysis considered both the dynamic and static stability of the proposed levee improvements by using four cross sections, two for each of the reservoir islands. The cross sections were selected to be reasonably representative of conditions that would be encountered on the reservoir islands, and that would represent conservative estimates for stability issues. (Some cross sections were therefore different from the cross sections used for the seepage analysis, which were selected to allow for conservative analysis of seepage effects.) The analysis considered the potential for failure of the slope toward the island and the slope toward the slough. For both slopes, the following cases were considered:

- existing conditions;
- the end of construction (i.e., soil-consolidation condition);
- long-term conditions;
- sudden drawdown (i.e., an emergency evacuation of stored water); and
- pseudostatic conditions (i.e., the stability of the slope during seismic loading, which is analyzed to determine yield acceleration and estimate earthquake-induced deformation).

Static Stability Analysis. URSGWC analyzed the static stability of levees using the limit equilibrium method based on Spencer's procedure of "slices" using the computer program UTEXAS3 (Wright 1991). The program iteratively balances the FS and the side force inclination until both force and moment equilibrium forces are satisfied. The UTEXAS3 model can simulate rapid undrained loading that follows a period of soil consolidation (end of levee construction) and rapid drawdown (emergency evacuation of stored water). Section 3, "Slope Stability Issues", of Appendix H details the review of previous studies and describes selected parameters and methods used in this analysis.

Dynamic (i.e., Seismic) Stability Analysis. For the evaluation of seismically induced levee deformations and geologic hazards, URSGWC reviewed previous ground-motion studies for the project area, developed and updated dynamic soil parameters based on recent findings and published data, and developed design earthquake ground motions based on horizontal earthquake acceleration time histories recorded during the 1992 Landers and 1987 Whittier Narrows earthquakes. Results from the recent CALFED study on seismic hazards and probability of levee failure in the Delta (CALFED Bay-Delta Program 1999b) were used to construct the design response spectrum.

The design earthquake ground motions developed for the analysis used a hazard exposure level corresponding to a 10% probability of exceedance in 50 years; this level corresponds to a return period of about 1 in 475 years and is consistent with the requirement adopted by the 1997 Uniform Building Code. Dynamic responses and deformations of the levee induced by the design earthquake motions were computed for the long-term levee conditions at two cross sections each for Webb Tract and Bacon Island. The seismically induced geologic hazards assessed for the analysis included liquefaction, loss of bearing capacity, settlement, and levee overtopping. The evaluation also considered wave-height estimates and erosion, borrow requirements, and the effect of interceptor wells on slope stability. The literature reviewed and methods used for this analysis are described in Appendix A to the URSGWC report (see Appendix H of this REIR/EIS).

Effect of Delta Wetlands Operations on Levee Stability

In the1995 DEIR/EIS, levee improvements were estimated to increase the long-term FSs in comparison with existing conditions, resulting in a beneficial effect. Independent review of levee stability issues by URSGWC verified that Delta Wetlands' proposed levee improvements would increase the long-term FS toward the reservoir islands in comparison with existing conditions but determined that the long-term FS toward the slough would decrease (Table 6-1).

The URSGWC evaluation also found that, compared with existing conditions, the FS toward the reservoir islands would decrease for both the end-of-construction case and the sudden drawdown condition. (Section 3.5 of Appendix H.)

The "end-of-construction" results presented in Table 6-1 represent conditions after construction of levee improvements in a single stage; the single-stage analysis was conducted to demonstrate that the levees cannot be constructed in a single stage. Delta Wetlands has proposed to construct the levees in multiple stages to facilitate consolidation of levee materials. Delta Wetlands has proposed two conceptual land-side levee slope configurations—a 3:1 initial slope flattening to a 10:1 slope or a uniform 5:1 slope (Figure 6-1). The uniform 5:1 slope fill configuration results in a lower end-of-construction FS than the 3:1-to-10:1 fill configuration, so Table 6-1 presents the FS results for the uniform 5:1 slope configuration to provide the most conservative estimates of levee stability.

The seismic-stability evaluation of the reservoir island levees indicated that as much as 2 feet of deformation on the reservoir side of the levees and 4 feet on the slough side could be experienced during a probable earthquake in the region (Section 3.6 of Appendix H). Stability is improved from existing conditions on the reservoir side and is less than existing conditions on the slough side.

With regard to levee stability, URSGWC concluded that the "levee strengthening measures conceptually proposed by Delta Wetlands are generally appropriate and adequate to provide stability of the reservoir islands' levees". The report notes that construction of the levee-strengthening fills must be implemented in carefully planned staged construction to prevent stability failures to the new fill loads. URSGWC estimated that construction of the levees could take 4 to 6 years, depending on final levee design. The report also outlines conceptual measures that would improve the long-term stability of the slough side of the levees, improve stability under sudden drawdown conditions, and mitigate slough-side deformation under seismic conditions. Delta Wetlands plans to implement detailed subsurface exploration programs along the reservoir island levees, stability evaluations, and site-specific design and construction methods as part of final design. The report concludes that these steps will be essential to achieving safety and effectiveness of the proposed levee system. (Section 4.2 of Appendix H.)

Effect of the Interceptor-Well System on Levee Stability

As discussed previously, a network of interceptor wells would be used to control seepage onto adjacent islands. Delta Wetlands has suggested that these wells would probably be 6 inches in diameter and spaced approximately 160 feet on center. A 6-inch-diameter well could require drilling a 12-inch-diameter space to accommodate the well and packing. URSGWC determined that the wells would not substantially affect stability of the levees or the supporting levee foundation because the area occupied by the wells is so small compared to the area occupied by the levees.

A high rate of continuous pumping in the interceptor wells can result in the migration of fine materials from the sand aquifer, which can cause internal erosion or piping in the levee material, and over time, lead to weakened levee foundations and potential settlement and stability problems. URSGWC recommends that to minimize the risk to levee stability from excessive migration of fine-grained material from the aquifer, Delta Wetlands should:

- monitor individual wells' flows to judge well pumping efficiency (an indicator of internal soil erosion);
- redevelop (i.e., clean) the wells periodically or in response to flow monitoring that indicates a drop in well efficiency; and
- in severe cases, abandon and rebuild the well. (Section 3.10 of Appendix H.)

Delta Wetlands may be required to identify the criteria by which they would judge when an interceptor well would need to be replaced.

Wave Runup and Erosion

The 1995 DEIR/EIS evaluated levee erosion and overtopping as a result of wind and wave runup. The proposed flooding of reservoir islands could result in wave runup on the interior levee slopes because of the long wind fetch across the islands, the water depths during storage, and wind conditions. Longer wind fetch, deeper water, and faster winds increase wave height. Delta Wetlands estimated wave runup on the reservoir islands and is proposing to include erosion protection on the interior levee slopes. These slopes would be protected from erosion by conventional rock revetment (i.e., riprap) or other conventional systems, such as soil cement or high-density polyethylene liner. During final design, site-specific requirements for erosion protection will be evaluated and riprap or other suitable erosion protection measures will be designed for each levee section. Delta Wetlands is also proposing an erosion monitoring program, which includes weekly inspections of levees and maintenance measures to address potential erosion problems (see Chapter 3D in the 1995 DEIR/EIS).

URSGWC completed an independent analysis of wave runup to evaluate freeboard and erosion potential of the reservoir island levees (see Section 3.8 in Appendix H). The analysis used the most severe wind conditions in the area (i.e., 60 miles per hour in fall), the longest wind fetch on Bacon Island and Webb Tract (i.e., 3.15 miles and 2.83 miles, respectively), and full storage conditions to represent worst-case wave runup potential. Both the 3:1 and 5:1 levee slope configurations were evaluated. The results of the analysis are shown in Table 6-2. URSGWC concluded that these results are consistent with the wave runup estimates published in DWR Bulletin 192-82. The proposed reservoir island levees will have an interior slope freeboard of 3 vertical feet (Figure 6-1) and, as described above, will include placement of riprap on the interior slopes. As shown in the table, the estimated worst-case runup could result in overtopping if a 3:1 levee design is used. However, the analysis concludes that the proposed flatter (5:1) levee slope would reduce wave runup and avoid overtopping under the worst-case conditions. The final design of the levee will consider the potential for wave runup, and Delta Wetlands will implement a final levee design according to those site-specific conditions. Additionally, during project operations, the erosion monitoring program would be implemented. In conclusion, wave runup will not result in substantial erosion or overtopping of the proposed levees on the reservoir islands.

Potential Damages to Adjacent Islands in the Event of a Reservoir Island Levee Failure

Although a worst-case, or catastrophic-failure, analysis is not required under CEQA or NEPA, the lead agencies asked URSGWC to evaluate the potential for damages to neighboring Delta islands in the event that a reservoir island levee failed.

URSGWC's levee stability analysis indicates that failure of a Delta Wetlands Project levee is unlikely, but that the most probable types of failure are:

- failure of a reservoir island levee toward the adjacent channel or slough with a full reservoir,
- failure of the levee into the reservoir island with the reservoir low or empty, and
- failure of an adjacent island's levee caused by seepage effects attributable to reservoir operations.

To evaluate the potential effects of a levee breach under full reservoir conditions, URSGWC performed hydraulic analyses assuming breach widths (i.e., lengths of failed levee) of 40, 80, 200, and 400 feet. Assuming that the reservoir was full at the time of a breach, URSGWC determined that the maximum velocity of water on the bank opposite the breach would be 2, 9, 12, and 16 fps, respectively. The maximum breach width of 400 feet would result in a maximum discharge rate of 123,000 cfs. Figure 3.5.47 of Appendix H shows the velocity distribution of flows under this failure scenario. The maximum velocity on the opposite bank would be approximately 16 fps for 30-40 minutes. It is expected that the riprapped levee would be able to withstand these velocities, although floating structures and moored boats might be damaged (Section 3.5.4 of Appendix H).

The analysis concluded that the proposed conceptual levee design would provide adequate protection against failure of the reservoir levee with the reservoir empty, with high FSs for long-term failure into the reservoir island and adequate FSs for sudden drawdown at most locations. The report notes that adjustments to levee geometry may be needed at some locations to provide an adequate FS during sudden drawdown (Section 3.5.4 of Appendix H).

Failure of an adjacent island's levee caused by seepage effects attributable to reservoir operations is addressed by the seepage analysis.

New Information on Erosion Effects of Boat Wake

After the 1995 DEIR/EIS was released, the lead agencies received comments from several parties about the impacts on Delta island levees of increased boat wake that could result from increased boating activity if the proposed project were implemented. Consequently, the lead agencies believed it would be helpful for REIR/EIS reviewers to be given information about this subject, and directed that such information be included in this revised chapter on levee stability and seepage. Concerns about potential boat-wake impacts relate to the potential contribution of increased wake action to significant levee erosion and the erosion of channel islands and water-side habitats.

A literature search and conversations with knowledgeable individuals indicates that there are no current data related to wake-action impacts on channel islands. In the 1970s, the California Department of Navigation (now the California Department of Boating and Waterways) and DWR conducted two studies; however, these studies were based on unsubstantiated assumptions and reported conflicting findings, and are not reliable sources of information. The California Department of Boating and Waterways is currently conducting a 6-year study with Scripps Institute of Oceanography that addresses wake-action impacts; the study had not been completed as of the date of release of this REIR/EIS.

Margit Aramburu, executive director of the Delta Protection Commission; Don Waltz, chief of the Facilities Division of the California Department of Boating and Waterways; and Ron Flick, research associate at Scripps Institute of Oceanography and staff oceanographer for the California Department of Boating and Waterways, were each contacted for information on this issue during April and May 1999. Each indicated that impacts of boat wakes on Delta islands are difficult to generalize. They explained that impacts vary according to several factors related to boat use, including boat size, boat speed, proximity of boats to the islands, and type of boating activity, and that these factors should be considered with others such as currents and the presence of wind-blown waves.

Because of the lack of data to quantify the relationship between boating and wake effects, it is not currently possible to estimate the erosion or habitat effects of increased wake action resulting from increased boating use of Delta waterways under the proposed project. However, the lead agencies recognize the potential for such effects. This issue was considered during the endangered-species consultation between the lead agencies and DFG, NMFS, and USFWS. As a result, the FOC terms developed in the consultation process include a measure (number 53) specifically intended to mitigate boat-wake effects. Under this term, Delta Wetlands is required to contribute a set fee for each boat berth added to any of the project islands beyond pre-project conditions; these funds would be used for aquatic habitat restoration (see also page 55 of the DFG biological opinion in Appendix C). This measure is in addition to the requirement that Delta Wetlands mitigate the effects of project construction and operations on aquatic habitat and shallow shoal habitat. The FOC terms have been adopted as part of the federal and state biological opinions for Delta Wetlands Project effects on listed fish species, and Delta Wetlands is required to incorporate these terms into the proposed project. No additional mitigation is recommended in this REIR/EIS.

IMPACT ASSESSMENT METHODOLOGY

Analytical Approach and Impact Mechanisms

Impacts on seepage and levee stability were assessed based on the ways in which construction and operation of the Delta Wetlands project alternatives would affect seepage on adjacent islands and levee stability. Effects of the project alternatives on seepage and levee stability were based on previous work prepared by Delta Wetlands' consultants and new technical analyses prepared by URSGWC (Appendix H).

Criteria for Determining Impact Significance

An alternative is considered to have a significant impact on seepage or levee stability if it would:

- induce additional seepage on adjacent islands when compared to no-project conditions,
- decrease levee stability on the Delta Wetlands Project islands during or immediately following project construction,
- decrease long-term levee stability when compared to existing levee conditions, and
- cause property damage in the event of levee failure.

Levee Standards and Significance Criteria

During and subsequent to the water right hearing, parties expressed an interest in using existing levee standards as a significance criterion in the levee stability analysis or in identifying which standard or standards would be applied to the Delta Wetlands Project. Table 6-3 summarizes standard FSs for various levee or dam conditions, as adopted or recommended by USACE, DWR, and the Division of Safety of Dams (DSOD). FSs are only one element used to regulate levees and dams; other design considerations are also used. Figure 6-3 compares different levee standards for minimum freeboard, maximum slopes, and crest width. As shown in Table 6-3 and Figure 6-3, USACE has published standards and guidelines for project and nonproject levees; DWR has published guidelines for levee rehabilitation in the Delta; and DSOD establishes standards for dams.

The purpose of the impact assessment is to determine the difference in levee stability between existing conditions and with-project conditions. The relative change in the FSs between the project and existing conditions is used as the basis for evaluating the impact of the proposed project. Because the analysis evaluates the *change* in levee conditions, a given FS standard cannot be used to determine the significance of the change. However, these standards would be considered during project approval and final design.

The lead agencies can choose to adopt a given standard to be applied to the final levee design for the Delta Wetlands islands. Because the Delta Wetlands levees are nonproject levees, rehabilitation of those levees under existing conditions would follow DWR and USACE's recommendations for nonproject levees. Delta Wetlands has committed to improving levees on all four project islands to meet levee design criteria for Delta levees identified in DWR Bulletin 192-82; Bulletin 192-82 does not include FS but requires a given levee design (Figure 6-3). The lead agencies, however, may include more conservative standards or guidelines for the reservoir island levees in the terms and conditions of project approval.

Additionally, if the levees are determined to be "dams" as defined by the California Water Code (Sections 6002 through 6008), Delta Wetlands would be required to meet DSOD's standards and design review requirements. DSOD has oversight and approval authority for structures that are considered dams under the Water Code. Dams under jurisdiction are artificial barriers that are at least 25 feet high or have an impounding capacity of at least 50 af. However, Water Code Section 6004(c) provides the following exclusion for structures in the Sacramento-San Joaquin Delta:

> The levee of an island adjacent to tidal waters in the Sacramento-San Joaquin Delta, as defined in Section 12220, even when used to impound water, shall not be considered a dam and the impoundment shall not be considered a reservoir if the maximum possible water storage elevation of the impounded water does not exceed four feet above mean sea level, as established by the United States Geological Survey 1929 Datum.

Therefore, if the Delta Wetlands levee structure is built to impound water to a level of 6 feet above mean sea level as proposed in the 1995 DEIR/EIS and evaluated in this REIR/EIS, it would be considered a dam within DSOD jurisdiction and would be subject to DSOD review and permit approval. The levees would be required to meet DSOD standards for dams (Table 6-3). Delta Wetlands would submit final design drawings, specifications, geotechnical reports, survey data, and an application to DSOD for approval before levee construction (Driller pers. comm.).

ENVIRONMENTAL CONSEQUENCES

The following section addresses project impacts on seepage and levee stability. The text addresses the four criteria listed above that are used to determine significance. Table 6-4 compares the 1995 EIR/EIS and REIR/EIS impact conclusions.

Potential Seepage on Adjacent Islands Resulting from Project Operations

As described in the1995 DEIR/EIS, operation of the Delta Wetlands Project would induce seepage on adjacent islands if seepage control measures were not implemented. The Delta Wetlands Project includes a network of pumped wells to control seepage and a seepage monitoring program. It also has a set of seepage performance standards that, if exceeded, would trigger implementation of other measures to control seepage, including drawdown of the reservoir islands' water levels. Independent review of the seepage control program, seepage monitoring program, and performance standards by URSGWC (Appendix H) indicated that the proposed seepage control program could effectively control the seepage onto adjacent islands. However, the review also indicated that the seepage monitoring program and performance standards might not provide adequate warning that an adverse effect was about to occur and might not trigger additional mitigation measures in a timely enough manner to prevent adverse effects on adjacent islands. Therefore, potential seepage on adjacent islands is considered significant and the following mitigation is recommended.

Mitigation Measure: Modify Seepage Monitoring Program and Seepage Performance Standards. URSGWC has recommended that the seepage monitoring program and the seepage performance standards be modified to include the following requirements:

- Locate the background monitoring wells no more than 1 mile from the seepage monitoring wells.
- Use more than one background monitoring well for each row of seepage monitoring wells.
- Use at least 3 years of data to establish reference water levels in all the background monitoring wells and in at least half of the seepage monitoring wells.
- Use a running straight-line mean from the monitoring-well data when applying the seepage performance standards.
- Reduce the seepage performance standard for the single-well condition from 1 foot to 0.5 foot.
- Reevaluate seepage performance standards 2, 5, and 10 years after reservoir operations begin and then every 10 years.

Implementing the recommended changes to the seepage monitoring program and seepage performance standards would reduce this impact to a less-than-significant level.

Potential Decrease in Levee Stability on the Delta Wetlands Project Islands during or Immediately after Project Construction

As described in the1995 DEIR/EIS, levee improvements would be completed in layers or lifts less than 5 feet thick and allowed to settle to ensure that an appropriate FS would be maintained. Delta Wetlands estimated that it would take several years to complete levee improvements. Independent review of levee stability issues by URSGWC (Appendix H) verified that levee improvements could not be completed in a single lift. As shown in Table 6-1, if the levees were constructed in a single lift, the FSs would be less than 1, indicating that the levees would not be strong enough to support their own weight. The levee construction methods described in the 1995 DEIR/EIS are adequate to maintain an appropriate FS; therefore, this impact is considered less than significant and no mitigation is required.

Potential Decrease in Long-Term Levee Stability on the Delta Wetlands Reservoir Islands

In the 1995 DEIR/EIS, levee improvements were estimated to increase the long-term FSs when compared to the existing conditions, resulting in a beneficial effect. Independent review of levee stability issues by URSGWC (Appendix H) verified that levee improvements would increase the FSs toward the reservoir islands when compared to the existing conditions. As shown in Table 6-1, the long-term FS toward the reservoir islands at the cross sections evaluated would increase by 27 to 36 percent. However, the long-term FS toward the slough would decrease by 10 to 17 percent when compared to existing conditions. URSGWC suggests that slough-side levee improvements would achieve an appropriate FS with the proposed levee design. However, slough-side levee improvements would have substantial adverse environmental effects (e.g., significant fishery habitat and water quality impacts); consequently, although slough-side levee improvements would be technically feasible, they would not be environmentally feasible or practical. Therefore, this impact is considered significant and the following mitigation measure is recommended.

> **Mitigation Measure: Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure.** Delta Wetlands' final levee design shall provide a minimum FS of 1.3 in accordance with DWR's requirements for rehabilitating levees in the Delta (Table 6-3). This recommended FS is more conservative than USACE's recommended 1.25 FS for nonproject levees. After detailed geotechnical studies have been completed to support the levee design efforts, it is anticipated that the conceptual levee design will be modified (e.g., change in slope, crest width, lift compaction, and other levee design and construction factors) to achieve the desired FS without affecting the existing levees' slough faces and incurring the significant environmental impacts.
>
> Alternately, at locations where there are no practical design options to achieve this FS, measures could be implemented to reduce the risk of catastrophic levee failure. URSGWC has recommended increasing the width of the levee cross section to provide additional buffer

if the slough side of the levee fails. The buffer would provide sacrificial material that could be allowed to erode until emergency action could be taken to restore levee integrity. Although this option would not improve the factor of safety, it would greatly reduce the risk of catastrophic failure.

Potential Levee Failure on Delta Wetlands Project Islands during Seismic Activity

By improving the reservoir island levees, the stability of reservoir island levee slopes under seismic conditions would increase toward the reservoir island and would decrease toward the slough. Results of the dynamic stability analysis concluded that as much as 4 feet of levee deformation could occur under seismic conditions. This impact is considered significant. The following mitigation measure is recommended to reduce this impact to a less-than-significant level.

Mitigation Measure: Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure.

This mitigation measure is described above.

Potential Property Damage Resulting from Levee Failure

Implementing the Delta Wetlands project would increase the levees' FS toward the reservoir islands and decrease their FS toward the adjacent sloughs when compared to existing conditions. Levee failure is unlikely, however, because the long-term FSs exceed 1 (Table 6-1). Failure into the reservoir island with the project would have no greater effect on property than a failure under the existing conditions, although the risk of failure would be somewhat less because of increased long-term FSs.

URSGWC evaluated the potential effects of a worst-case levee failure, a levee breach toward the slough when the reservoir islands are full. Hydraulic analyses were completed assuming breach widths of 40, 80, 200 and 400 feet. The maximum likely breach of 400 feet would result in a maximum discharge rate of 123,000 cfs. Figure 3.5.47 of Appendix H shows the velocity distribution of flows under this failure scenario. The maximum velocity on the opposite bank would be approximately 16 fps. Assuming the reservoir was at full storage (+6 feet) and the channel was at a relatively low tide (-2 feet) when the levee failed, the adjacent levees would experience the 16 fps velocity for approximately 30-40 minutes. The adjacent riprapped levee would be expected to withstand these velocities for the limited amount of time. Because the potential risk of a levee failure is very small, this impact is considered less than significant and no mitigation is required.

Cumulative Impacts

Levee stability conditions in the Delta are expected to improve in the future through the implementation of levee improvements using existing and future state and federal funding and implementation of proposed projects under the CALFED Bay-Delta Program. Since 1988, federal, state, and local agencies have completed more than $160 million in improvements to Delta levees using Senate Bill (SB) 34 funds, Assembly Bill (AB) 360 funds, emergency levee repair funds for work performed by USACE under Public Law (PL) 84-99, and local funds (CALFED Bay-Delta Program 1999a). Improvements to Delta levees are ongoing. The CALFED Bay-Delta Program's Long-term Levee Protection Plan outlines a long-term strategy to reduce the risk of catastrophic breaching of Delta levees. The CALFED Levee Program includes a cost-sharing program to reconstruct Delta levees, the "Special Flood Control Projects" program to provide additional flood protection for key Delta levees that protect public benefits of statewide significance, improvements to existing emergency response capabilities, and development of a risk management strategy in response to the threat that earthquakes pose to Delta levees (CALFED Bay-Delta Program 1999c).

Implementing the Delta Wetlands Project would not contribute significantly to cumulative flood hazards in the Delta. The proposed project would improve long-term levee stability on the habitat islands and would improve long-term stability of the levee slope toward the reservoir islands. As described above, long-term stability toward the slough would be reduced on the reservoir islands; however, because the resulting FS still would be greater than 1, the likelihood of levee failure under the proposed project is low. Additionally, analysis indicates that neighboring levees would not be significantly damaged if the levee failed when the reservoir was full. Therefore, the cumulative effect on levee failure in the Delta is considered less than significant and no mitigation is required.

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

As described in Chapter 2, the difference between Alternative 1 in the 1995 DEIR/EIS and Alternative 2 (the proposed project) is water discharge operations. Consequently, the levee system and proposed seepage control plan are the same under Alternative 1 as under the proposed project. The impacts and mitigation measures described above would also apply to Alternative 1.

Under Alternative 3, water would be stored on all four islands, so levee improvements and seepage control measures would be implemented on all islands. Although the REIR/EIS did not analyze levee stability and seepage for Bouldin Island and Holland Tract, it can be reasonably assumed that the levee stability and seepage impact conclusions presented above for the proposed project would be similar to the findings for the other reservoir islands under Alternative 3.

Table 6-1. Summary of Factors of Safety

Cross Section	Factor of Safety							
	Existing Conditions		End of Construction[a]		Long-Term		Sudden Drawdown[b]	
	Toward Island	Toward Slough	Toward Island	Toward Slough	Toward Island	Toward Slough	Toward Island	Toward Slough
Webb Tract (Station 160+00)	1.24	1.29	0.62	1.29	1.57	1.12	0.88	1.12
Webb Tract (Station 630+00)	1.40	1.34	0.89	1.34	1.82	1.12	1.18	1.12
Bacon Island (Station 25+00)	1.23	1.48	0.90	1.48	1.63	1.33	1.07	1.33
Bacon Island (Station 265+00)	1.21	1.49	0.86	1.49	1.64	1.23	0.98	1.23

Notes:

[a] Represents conditions after construction of levee improvements in a single stage. It was assumed that at the end of construction, the toward-slough factor of safety would be the same as under existing conditions.

[b] Under the sudden-drawdown scenario, the toward-slough factor of safety would be the same as the long-term toward-slough factor of safety.

Source: Section 3, "Slope Stability Issues", of Appendix H of this REIR/EIS.

Table 6-2. Summary of Results from the Worst-Case Runup Analysis

	Bacon Island		Webb Tract	
	5:1 interior levee slope	3:1 interior levee slope	5:1 interior levee slope	3:1 interior levee slope
Wave runup without riprap (feet)	4.0	6.4	3.8	6.1
Wave runup with riprap[1] (feet)	2.2	3.5	2.1	3.4
Reservoir setup[2] (feet)	0.4	0.4	0.3	0.3

Assumptions:

- Wind speed = 60 mph
- Fetch on Bacon Island = 3.15 miles
- Fetch on Webb Tract = 2.83 miles

Notes:

[1] If riprap is used on the bank slopes, the runup would be reduced to 55% of the estimated runup values.

[2] Reservoir setup is defined as a general tilting of the reservoir due to sheer stresses caused by winds.

Source: Appendix H.

Table 6-3. Stability Criteria Adopted for Levees and Used for Dam Safety Evaluations

	Design Condition Factor of Safety		
Criterion	End of Construction	Long Term	Sudden Drawdown
U.S. Army Corps of Engineers minimum factors of safety for "project" levees[a]	1.3	1.4	1.0
U.S. Army Corps of Engineers guidelines for nonfederal levee rehabilitations in the Delta under PL 84-99[b]	–	1.25	–
California Department of Water Resources criteria for "nonproject" levee rehabilitations in the Delta[c]	–	1.3	–
Factors of safety for dam safety evaluations under DSOD jurisdiction[d]	–	1.5	1.25

Notes:

[a] U.S. Army Corps of Engineers 1978.
[b] U.S. Army Corps of Engineers 1988.
[c] California Department of Water Resources 1989b.
[d] Association of State Dam Safety Officials 1989.

Definitions:

"Project" levees = Levees maintained to USACE standards by the State of California or by local landowners under state supervision.

"Nonproject" levees = Levees constructed and maintained by local landowners and reclamation districts.

Table 6-4. Comparison between Delta Wetlands Projects on Flood Control
in the 1995 DEIR/EIS and the 2000 REIR/EIS

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
CHAPTER 3D. FLOOD CONTROL	
Impact D-1: Increase in Long-Term Levee Stability on Reservoir Islands (B) • No mitigation is required.	**Potential Decrease in Long-Term Levee Stability on the Delta Wetlands Reservoir Islands.** Independent analyses by URSGWC indicate that the levee's long-term factor of safety would increase by 27 to 36 percent toward the reservoir islands but would decrease by 10 to 17 percent toward the sloughs. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure (LTS)
----	**Potential Decrease in Levee Stability on the Delta Wetlands Project Islands During or Immediately After Project Construction.** Independent analyses by URSGWC verified that the levee construction methods described in the 1995 DEIR/EIS are adequate to maintain an appropriate factor of safety. Therefore, the impact is considered less than significant and no mitigation is required. (LTS)
Impact D-2: Potential for Seepage from Reservoir Islands to Adjacent Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	**Potential Seepage on Adjacent Islands Resulting from Project Operations.** Analyses by URSGWC indicate that seepage control measures proposed by Delta Wetlands would be adequate to control seepage; however, the seepage control performance criteria were not adequate to detect adverse impacts. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Modify Seepage Monitoring Program and Seepage Performance Standards (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

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Table 6-4. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
Impact D-3: Potential for Wind and Wave Erosion on Reservoir Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	**Potential for Wind and Wave Erosion on Reservoir Islands.** Analysis by URSGWC confirmed that the levee design and erosion protection measures proposed by Delta Wetlands would be adequate to address the potential for erosion and overtopping of the levees under worst-case wave runup conditions. This impact is considered less than significant. (LTS)
Impact D-4: Potential for Erosion of Levee Toe Berms at Pump Stations and Siphon Stations on Reservoir Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	These effects were not reevaluated in the REIR/EIS. The impact conclusions and mitigation remain the same as presented in the 1995 DEIR/EIS.
Impact D-5: Decrease in Potential for Levee Failure on Delta Wetlands Project Islands during Seismic Activity (B) • No mitigation is required.	**Potential Levee Failure on Delta Wetlands Project Islands during Seismic Activity.** Analyses by URSGWC indicate that deformation of as much as 4 feet of the reservoir island levee slopes would be experienced during a probable earthquake in the region. Compared to existing conditions, levee stability on the reservoir islands would be greater on the reservoir side and would be less on the slough side. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 6-4. Continued

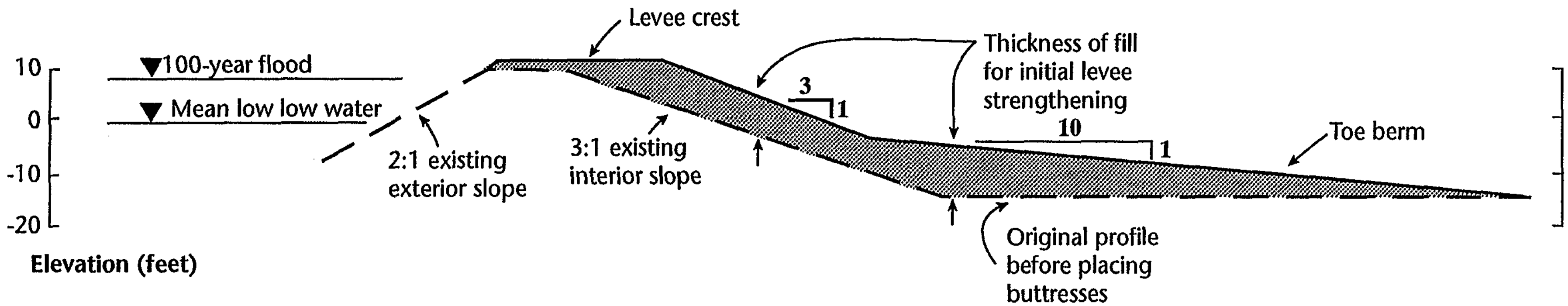
Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
----	**Potential Property Damage Resulting from Levee Failure.** The project would have no effect on property compared to existing conditions if a levee were to fail into a reservoir island. There would be potential for property damage to occur if a levee failed toward the slough under full reservoir conditions, but the effect is considered less than significant because the risk of levee failure is very low. (LTS)
Impact D-6: Increase in Long-Term Levee Stability on Habitat Islands (B) • No mitigation is required.	These effects were not re-evaluated in the REIR/EIS. The impact conclusions and mitigation remain the same as presented in the 1995 DEIR/EIS.
Cumulative Impacts	
Impact D-12: Decrease in Cumulative Flood Hazard in the Delta (B) • No mitigation is required.	**Cumulative Effects on Delta Flood Hazard.** Implementation of the Delta Wetlands Project would not significantly contribute to cumulative flood hazards in the Delta. This impact is considered less than significant and no mitigation is required. (LTS)
Impact D-13: Decrease in the Need for Public Financing of Levee Maintenance and Repair on the Delta Wetlands Project Islands (B) • No mitigation is required.	This impact was not re-evaluated in the REIR/EIS. The impact conclusion remains the same as presented in the 1995 DEIR/EIS.

Notes:

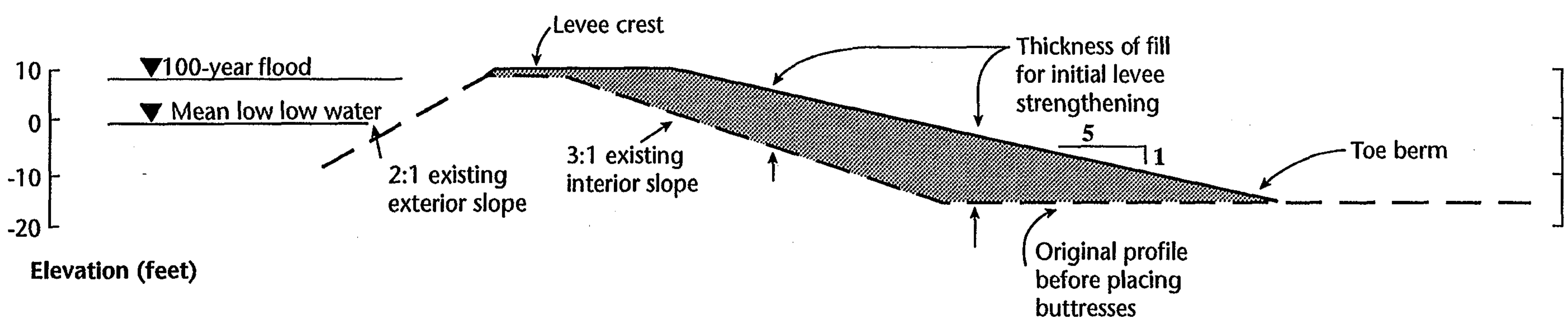
Impacts D-7 through D-11 of the 1995 DEIR/EIS describe impacts of Alternative 3, the four-reservoir-island alternative. The REIR/EIS does not analyze levee stability and seepage for Bouldin Island and Holland Tract. However, it can be reasonably assumed that the impact conclusions shown here for the proposed project would also apply to these islands under Alternative 3.

S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Example A: Broken-Slope Buttress



Example B: Constant-Slope Buttress



Source: Harding Lawson Associates 1993.

Jones & Stokes

Figure 6-1
Examples of Initial Levee Strengthening on Reservoir Islands

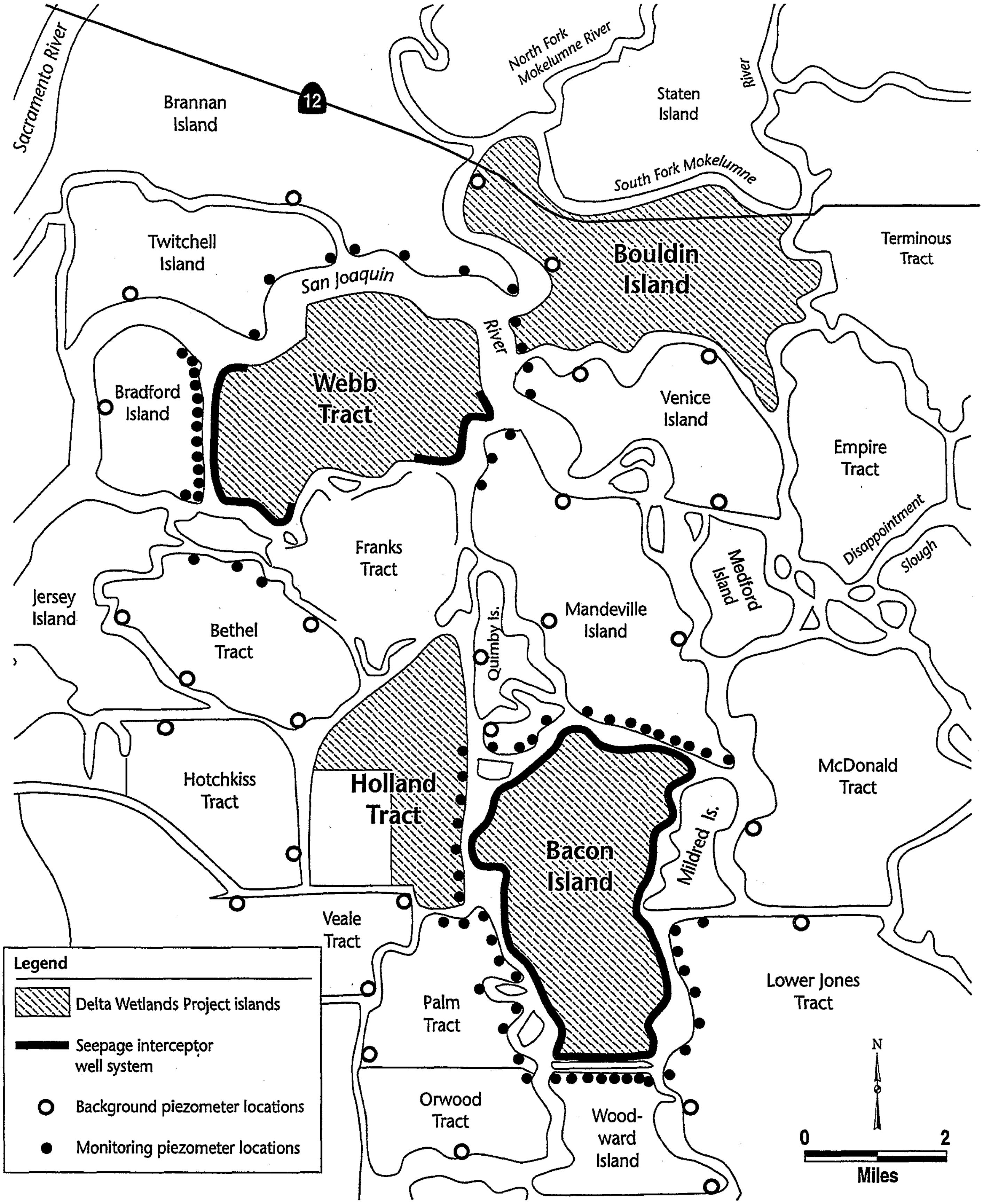


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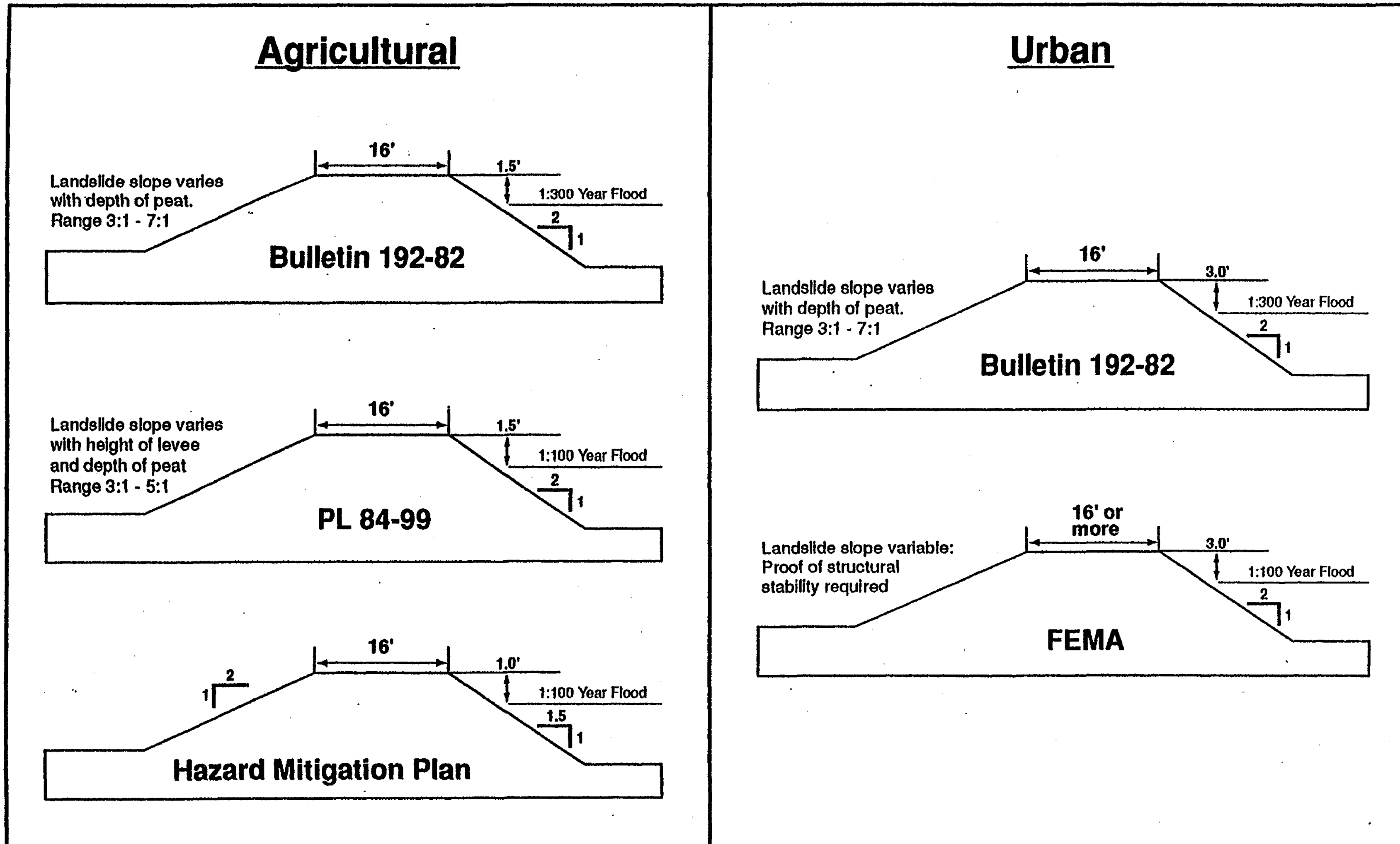
Figure 6-2
Seepage Interceptor Well System and Proposed Locations of Seepage Monitoring Piezometers under the Proposed Project

C-062891



C — 0 6 2 8 9 2

Jones & Stokes

Figure 6-3
Levee Geometric Standards