UNIVERSITY OF THE PACIFIC
Eberhardt School of Business

December 15, 2011

Mark W. Cowin
Director
California Department of Water Resources
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Sacramento, CA 95814

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Dear Director Cowin:

I am writing as the principal researcher on the Delta Protection Commission's Economic Sustainability Plan (ESP). We are seeking information developed for DRMS Phase 2 regarding Seismically Improved Levees that is needed to successfully complete the Economic Sustainability Plan. In a 2008 report to the Legislature required by AB 1200 (Laird),[1] a Seismically Improved Levees building block was reported to be one of three high-ranking building blocks that was the basis for the trial scenarios analyzed in DRMS Phase 2. However, the final DRMS Phase 2 report (released in June 2011) does not include the Seismically Improved Levees building block, and it is not part of the "Improved Levees" trial scenario as it was in the January 2008 report.

For the Delta Protection Commission's ESP, our engineering consultants recommended seismically resistant and repairable upgrades to most lowland Delta levees as an effective way to sustain and enhance the Delta economy, and further the co-equal goals while protecting other critical energy and transportation infrastructure that crosses the Delta. The Delta Science Program organized an independent review panel of the ESP. The panel found that the ESP "substantiates the importance of lowland levees" and with respect to the recommendation for larger, seismically improved levees stated that the ESP "provides a potentially viable alternative to improve reliability of lowland levees." However, the review panel expressed concerns that levee upgrade costs needed further substantiation and that the effectiveness of the strategy had not been formally modeled as in the DRMS studies, and requested further substantiation of these areas in the final, revised ESP.

In our search for additional information in response to the independent review, we discovered the January 2008 report to the Legislature. There appears to be significant similarities between the ESP recommendation and the Seismically Improved Levees building block described briefly on page 20. The "Improved Levees" scenario illustrated on page 21 of the January 2008 report shows seismically improved levees for islands in the southern and central Delta that were not included in the "Improved Levees" scenario in the final report. Page 24 of the January 2008 report gives a qualitative summary of DRMS findings noting that "Improved Levees" scenario that includes seismically improved levees is the least costly strategy, and ranks highest in the category "Preserve lands and protect levees" which includes highways, and other utilities and infrastructure.

To assist our efforts in completing the ESP, we request the following specific preliminary results from DRMS that were described in summary form in the January 2008 report.[1]

- Full description of the Seismically Improved Levees building block including cost estimates.
- Quantitative results for the modeling of the "Improved Levees" scenario described in the January 2008 report, and

I have attached two figures that show how the "Improved Levees" scenario changed between the January 2008 report to the Legislature and the final version of DRMS Phase 2. Seismically improved levees are a component of the January 2008 scenario (Attachment 1), but are not included in the final "Improved Levees" scenario (figure dated December 2008) described in the final DRMS phase 2 report released in June 2011 (Attachment 2).

We understand that these are preliminary results from analysis conducted in 2007, but we have been unable to locate more updated information regarding this important strategy in more current sources. We understand that the Armored Pathway building block in the final DRMS Phase 2 report included seismically resistant setback levees as a component of the pathway, but these are very different than seismic upgrades to existing levees that protect complete islands. We have discussed our request with Dave Mraz and Sean Bagheban at DWR. They have been very helpful in answering our questions regarding the DRMS Phase 1 and Phase 2 reports, but recommended that we direct our specific request for additional modeling results and data to you.

Because of the short-time frame we have to complete our work, I hope you are able to respond quickly to this request. If you or your staff have additional questions, feel free to contact me at 209-946-7385 or jmichael@pacific.edu.

Sincerely,

Jeffrey A. Michael, Ph.D.
Principal Investigator, Economic Sustainability Plan
Director and Associate Professor, University of the Pacific

Enclosure

cc: Mike Machado
Dave Mraz
Todd Ferraro

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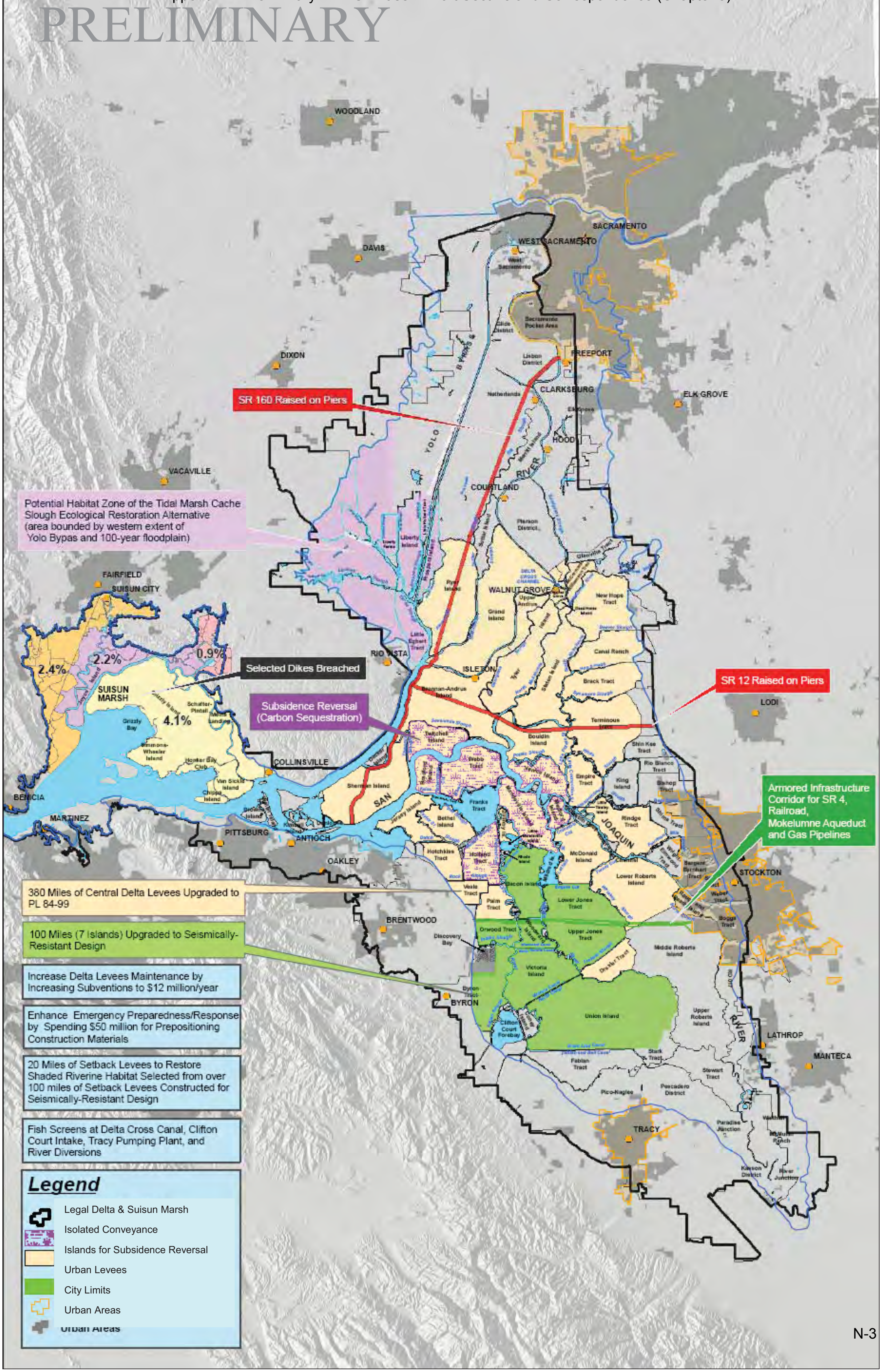
[1] "Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin Delta." A Report Pursuant to Requirements of Assembly Bill 1200, Laird. Department of Water Resources & Department of Fish and Game. January 2008.
http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/AB1200_Report_to_Legislature.pdf


PRELIMINARY
SR 160 Raised on Piers
Potential Habitat Zone of the Tidal Marsh Cache Slough Ecological Restoration Alternative (area bounded by western extent of Yolo Bypass and 100-year floodplain)
Selected Dikes Breached
Subsidence Reversal (Carbon Sequestration)
SR 12 Raised on Piers
Armored Infrastructure Corridor for SR 4, Railroad, Mokelumne Aqueduct and Gas Pipelines
380 Miles of Central Delta Levees Upgraded to PL 84-99
100 Miles (7 Islands) Upgraded to Seismically-Resistant Design
Increase Delta Levees Maintenance by Increasing Subventions to $12 million/year
Enhance Emergency Preparedness/Response by Spending $50 million for Prepositioning Construction Materials
20 Miles of Setback Levees to Restore Shaded Riverine Habitat Selected from over 100 miles of Setback Levees Constructed for Seismically-Resistant Design
Fish Screens at Delta Cross Canal, Clifton Court Intake, Tracy Pumping Plant, and River Diversions
Legend
Legal Delta & Suisun Marsh
Isolated Conveyance
Islands for Subsidence Reversal
Urban Levees
City Limits
Urban Areas
Urban Areas
2.4%
2.2%
0.9%
4.1%
WOODLAND
DAVIS
SACRAMENTO
WEST SACRAMENTO
DIXON
FREEPORT
CLARKSBURG
ELK GROVE
HOOD
VACAVILLE
COURTLAND
YOLO
RIVER
FAIRFIELD
SUISUN CITY
WALNUT GROVE
RIO VISTA
ISLETON
SUISUN MARSH
LODI
COLLINSVILLE
BENICIA
MARTINEZ
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STOCKTON
BRENTWOOD
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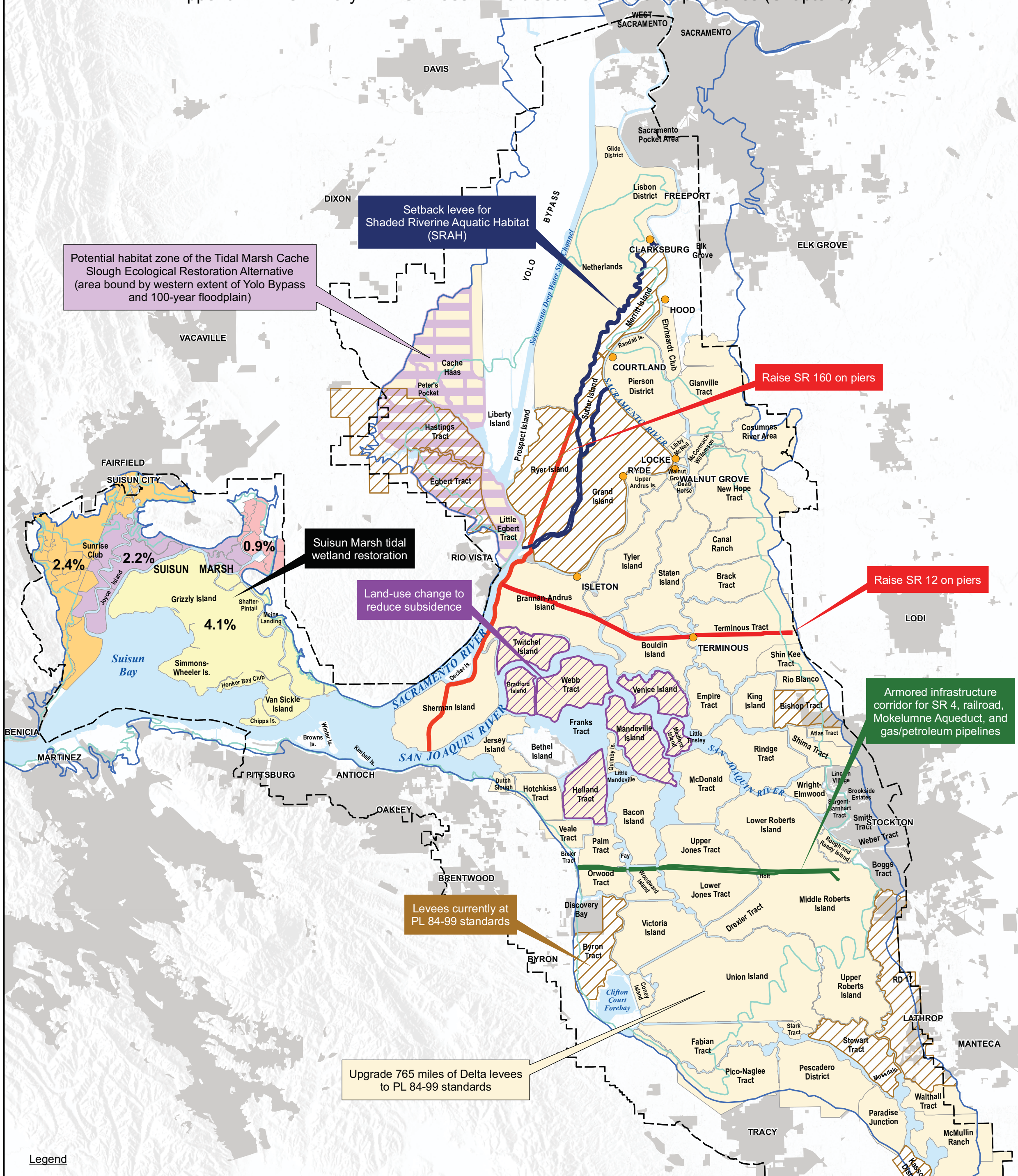

Project description	Captial cost ($M)
Improved levee maintenance ($12M/year)	
Upgrade Delta levee to PL 84-99 standard (768 miles)	1,158
Enhance emergency preparedness/response	50
Land-use change to reduce subsidence	60
Raise SR 12 and SR 160	4,400
Construct Armored Infrastructure corridor	3,300
Suisun Marsh tidal wetland restoration	167
Cache Slough tidal marsh restoration	410
Fish screens at river diversions	165
Setback levee for SRAH (30 miles)	720
Total	10,430

URS

Project No. 26815935

Delta Risk Management Strategy (DRMS) Phase 2
10 Dec 2008

Trial Scenario 1: Improved Levees

Figure 18-1

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY
EDMUND G. BROWN JR., Governor

DEPARTMENT OF WATER RESOURCES
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JAN 09 2012

Mr. Jeffrey A. Michael, Ph.D
Principal Investigator, Economic Sustainability Plan
Director and Associate Professor, University of Pacific
Business Forecasting Center
3601 Pacific Avenue
Stockton, California 95211

Dear Mr. Michael:

Thank you for your December 15, 2011, letter to Director Mark Cowin. In response to your request for additional information from Delta Risk Management Study Phase 2 Report (DRMS Phase 2) regarding cost estimates for seismically improved levees and quantitative modeling results, staff researched and located the corresponding section in a preliminary draft pertaining to your request. The information is included as an attachment to this letter.

Please note the information dates back to 2007 and is stamped as preliminary. It was also not part of the DRMS Phase 2 public draft, because it was not further considered for in-depth analysis in Phase 2. Therefore, I do not recommend using this information for either planning or design purposes. With these caveats in mind, we hope you still find the attached information useful.

If you have any questions regarding this information, please contact Sean Bagheban, Senior Engineer, DRMS, at (916) 651-0870, seanb@water.ca.gov.

Sincerely,

Dale K. Hoffman-Floerke

Dale K. Hoffman-Floerke
Deputy Director

Attachment: Delta Risk Management Strategy, Phase 2, August 20, 2007 Draft
Section 18: Scenario Evaluation

As described in Section 2, building blocks are combined to define scenarios that offer risk-reduction benefits to more than one asset or resource in the Delta and Suisun Marsh and statewide. The three scenarios considered in Phase 2 were identified in Section 2, "Building Blocks and Scenarios," in terms of the building blocks that are included in each. This section describes the results of the evaluation.

The first section describes the scenario evaluation steps. The remaining sections describe the results of the scenario evaluations.

18.1 SCENARIO EVALUATION

As described in Section 2, a scenario is a collection of building blocks that is intended to provide risk-reduction benefits to the Delta and the state. Each scenario, which is a conceptual-level development, is evaluated to assess its risk reduction potential. The steps in this process consist generally of the following steps:

- Evaluate the frequency of levee failures and island flooding for seismic, flood, and sunny-day events for scenarios that offer some benefit or improvement to the reliability of Delta levees.
- Assess the emergency response and repair of Delta levees for the evaluation cases considered in Phase 1 (URS and JBA, 2007e). This analysis takes into account the emergency response and preparedness building block and an alternative strategy for levee repairs.
- Evaluate the hydrodynamic response of the Delta in the evaluation cases to determine if there is a change (from Phase 1) in the disruption to water exports.
- Determine the economic costs for each evaluation case taking into account the building block changes (i.e., elevating state roads, reductions in water export disruptions, etc.)
- Determine the risk-reduction benefit of a scenario in terms of the difference in risk costs between the base case (Phase 1 results) and the scenario results and determine the net present value of the risk reduction (NPV).

In considering each scenario, the functional/physical interface of the building blocks as they are joined in a scenario is considered. These considerations include the physical layout of different building blocks, potential cost savings, and ultimately the combined risk benefit. As an example, Scenario 1 includes seismic upgrading of selected southern Delta islands. Also included in Scenario 1 is the development of an armored infrastructure corridor. Because the armored corridor under consideration traverses many of the islands that are being seismically upgraded, it is redundant to build the armored corridor on those islands. As a result, a considerable cost savings (relative to the sum of the costs of the two individual building blocks) is realized if the armored corridor is built only on islands that are not being seismically upgraded.

At the other end of the spectrum, a building block that offers individual benefits to an area where it is implemented (seismically upgrading 20 miles of levees), may in the context of a scenario (the larger picture) offer relatively small benefits when viewed in the context of the Delta and state.

18.2 SCENARIO 1: IMPROVED LEVEES

The elements of Scenario 1 are shown in Figure 18-1. Table 18-1 lists the building blocks that are combined to form Scenario 1, which focuses on improving levee performance to mitigate the high likelihood of failures due to seismic events and floods. As part of this scenario, the second option for seismically upgrading levees (see Section 4) was selected for this scenario because the upgrade of southern Delta islands has a greater advantage with respect to reducing salinity intrusion into the Delta and disrupting water exports (see Section 6).

Other highlights of this scenario include enhanced emergency preparedness, raising state highways to minimize the impact to state transportation, an armored infrastructure corridor, and a number of environmental actions, including tidal marsh Cache Slough restoration, installation of fish screens, and construction of setback levees.

18.2.1 Scenario 1 Evaluation

The DRMS Phase 1 risk model is used to evaluate the risk-reduction benefits of Scenario 1. The re-evaluation of Delta risks considers the effect of building blocks on the likelihood of levee failure and island flooding, and the reduction in the consequences of levee failures.

As discussed in Section 5 on emergency preparedness, an alternative strategy to that used in the Phase 1 analysis (which was based on a Business-as-Usual) approach is used. In Scenario 1, when levees are breached or damaged following a seismic event, a strategy for repair is followed where by breaches are closed first, before all other damages are repaired. The order of breach closures proceeds with the southern Delta islands being addressed first, moving systematically northward. This strategy has the benefit of minimizing the tidal mixing of salt water, thus reducing the water salinity near the pumps. Once all the islands that have been breached are closed, resources are then focused on the flooded islands (whose breaches have been repaired) to repair non-breach damage due to the seismic event and levee interior wave erosion[1]. Lastly, the damaged non-flooded islands are repaired.

This strategy is coupled with the stockpiling of rock in the Delta, which has the advantage of increasing rates of repair in the early stages following an event.

The analysis of levee repairs, Delta hydrodynamic response, and economic consequences is carried out for the same evaluation cases considered in Phase 1. For the seismic evaluation, the islands that are seismically upgraded are eliminated from the number of flooded and damaged islands. This is a reasonable assumption in view of the fact the seismically upgraded islands have considerably lower conditional probability of failure.

18.2.1.1 Levee Failure

A number of building blocks implemented in Scenario 1 are designed to improve the reliability of Delta levees including the improvement of levee maintenance, seismically upgrading levees and improving Central Delta levees to meet PL84-99 standards. These building blocks have been considered in the Delta risk model and the likelihood of flooding Delta islands re-evaluated.

[1] Depending on the number of breaches and the rock production rates, repairs on non-breached sections and interior erosion protection may start prior to the closure of all breaches.

Figure 18-2 shows a comparison of the Phase 1 and Scenario 1 results for frequency distribution on island flooding due seismic events. The comparison indicates the reduction in the frequency of island flooding is relatively low (less than a factor of 1.5) for less than about 50 islands. Above about 50 islands, the reduction in the frequency of failure steadily increases. Whereas only nine islands are seismically upgraded, the frequency of having a large number of islands flood because of a seismic event does not change significantly. However, as the number of flooded islands increases and some of the upgraded islands are part of the mix of islands that mail fail, the conditional probability of the seismically upgraded island failing is low, thus lowering the joint probability of island failures that include the upgraded islands.

The upgrade of central Delta islands to meet PL84-99 has a moderate (greater than a factor of 1.5 and less than a factor of 5) benefit with respect to the reduction in the frequency of island failures during flood events. For sunny-day failures, the improvement in levee maintenance was estimated to reduce the frequency of occurrence levee failure of a factor of 1.5 or less. With these changes in the frequency of island flooding associated with the different hazards, seismic events have a greater relative contribution to risk than in Phase 1.

18.2.1.2 Emergency Response and Water Export Disruption

The duration and cost of levee repairs for Scenario 1 are summarized in Table 18-2a. The costs are generally comparable to those in Phase 1, although there are differences from one case to the next. The similarity in costs is due in part to the repair strategy, which focuses less on interior levee damage. As a result, there is additional repair to the levee interiors that must be made due to the additional erosion that takes place.

Table 18-2b shows the disruption of water exports due to salinity in the Delta. As in Phase 1 other water quality issues (organic carbon) that may impact water treatment and use are not evaluated.

As the number of flooded islands increases, there is an increasing reduction in the length in the period of disruption and the amount of water that is not exported. For example for case 6, the period of disruption ranges from 6 to 9 months, where as in Phase 1 the disruption ranged from 16 to 23 months. The difference between Phase 1 and Scenario 1 in terms of the amount of water that is not exported is a factor of 2.6 (i.e., 9.3 MAF vs. 3.6 MAF).

18.2.1.3 Consequences

The consequences associated with levee failures and island flooding events are evaluated for the seismic cases listed in Table 18-2a. Table 18-3 summarizes the economic costs of the six cases for the three combinations of event month and hydrologic years considered (similar to Phase 1).

As in Phase 1, the main elements of in-Delta costs are emergency response and repair cost, infrastructure repair cost, lost use of structures and services, agricultural losses, and lost recreation. About 90% of in-Delta costs are from the emergency response and repair cost, and infrastructure repair cost, and 5% are from lost recreation. Compared to Phase 1 there is a significant reduction in the statewide economic costs. This is difference is attributed to the reduction in the export disruption that occurs. For example, in case 6 the maximum reduction in the economic costs between Phase 1 and Scenario 1 is about $20B.

18.2.1.4 Scenario Costs

Table 18-4 lists the costs of implementation for Scenario 1. The costs listed are based on the individual building block cost estimates, taking into account efficiencies of combining different building blocks (such as the reduced cost of the armored infrastructure corridor where it crosses islands that have been seismically upgraded), and annual costs (increased annual funding for levee maintenance).

18.2.1.5 Risk-Reduction Benefit

A measure of the risk reduction can be made by comparing the average annual damages associated with Phase 1 results and those for a Phase 2 scenario. Table 18-5 shows these results as well as the estimate of net present value of the risks and an estimate of the risk reduction benefit for Scenario 1.

18.3 SCENARIO 2: ARMORED PATHWAY

The elements of Scenario 2 are shown in Figure 18-3. Table 18-6 lists the building blocks that are combined to form Scenario 2, which focuses on improving the reliability of water export capability by creating an armored pathway through the Delta to mitigate the high likelihood of failures due to seismic events and floods.

Other highlights of this scenario include enhanced emergency preparedness, raising state highways to minimize the impact to state transportation, creating an armored infrastructure corridor, and a number of environmental actions, such as breaching dikes in Suisun Marsh, Cache Slough restoration, and the placement of fish screens.

18.3.1 Scenario 2 Evaluation

The following subsections define the evaluation of this scenario.

18.3.1.1 Levee Failure

The building blocks implemented in Scenario 2 are designed to improve the reliability of Delta levees that define the armored pathway. The levees that define the armored pathway are seismically upgraded and will meet or exceed urban levee standards. As a result, these levees are considerably more reliable than individual Delta islands by a factor of 10 or more with respect to seismic events. The levees that define the armored pathway make up a fraction of the total length of levees on the individual islands where they exist. As a result, the likelihood of island flooding will decrease. However, since the improvement on each island has been partial, the reduction in the frequency of island flooding due to seismic events in particular is small.

On balance the risk of islands flooding due to seismic events is slightly lower than the Phase 1 result (approximately 10 percent of the Delta levees are upgraded and a large fraction of each island that has some length of upgraded levee is as vulnerable). As a result, the overall risk of island flooding due to seismic events and floods is assumed here to be approximately the same.

By comparison, the likelihood that levees which make-up the armored pathway fail is more than a factor of ten lower. As a result, for the seismic events (ground motions less than 0.20g PGA) that important to levee failure and Delta risks, the armored pathway will remain functional.

18.3.1.2 Consequences

The consequences associated with Scenario 2 will be similar to those in Phase 1 In-Delta. Since the armored pathway is anticipated to remain functional, there will be no disruption of water exports and therefore no south of Delta urban and agriculture losses.

Table 18-7 summarizes the economic costs for the six cases for the three combinations of event month and hydrologic years considered (similar to Phase 1).

18.3.1.3 Scenario Costs

Table 18-8 lists the costs of implementation for Scenario 2. These costs are based on the individual building block cost estimates, efficiencies of combining different building blocks, and annual costs (increased annual funding for levee maintenance).

18.3.1.4 Risk-Reduction Benefit

A measure of the risk reduction can be made by determining the difference in the average annual damages associated with Phase 1 results and those for a Phase 2 scenario. Table 18-9 shows these results as well as the estimate net present value of the risks and an estimate of the risk reduction benefit for Scenario 2.

18.4 SCENARIO 3: ISOLATED CONVEYNACE FACILITY

The elements of Scenario 3 are depicted in Figure 18-4. Table 18-10 lists the building blocks that are combined to form Scenario 3, which focuses on improving the reliability of water export capability by construction of an Isolated Conveyance Facility (ICF) around the Delta to mitigate the high likelihood of failures due to seismic events and floods.

Other highlights of this scenario include enhanced emergency preparedness, raising state highways to minimize the impact to state transportation, and a number of environmental focused actions.

18.4.1 Scenario 3 Evaluation

By constructing an ICF the capability to convey water to the SWP and CVP pumps in the south Delta is no longer dependent on the performance of Delta levees. Further, since the seismic vulnerability of Delta levees remains unchanged, the frequency of occurrence of levee failures and island flooding remains the same as estimated in the Phase 1 analysis. Similarly, the In-Delta consequences for Scenario 3 also remain essentially the same.

The significant benefit of the ICF is two-fold. First, the reliability of water conveyance to the pumps in the south Delta will be considerably higher than that of the Delta levees. The ICF would have a seismic design that is comparable to that of the seismically upgraded levees (see Section 4). Further, the ICF will not be vulnerable to flooding of Delta islands or floods less than the 100-year flood event. As a result, the likelihood of ICF damage or failure will be considerably less than Delta levees.

A second benefit of the ICF concerns repairs that would be required if damages were incurred, in particular from a seismic event. Due to its location, repairs to the canal, structures and equipment can be land based. In this analysis of Scenario 3 it is assumed that repairs that are required to return the ICF to service can be made in a short period (3 months or less in most cases, possibly a bit longer in others). If the period of repair is 3 months or less to return the ICF to service, the economic costs of an event will be limited to In-Delta costs.

The economic costs for this case are the same as those for Scenario 2; these costs are listed in Table 18-7.

18.4.1.1 Scenario Costs

Table 18-11 lists the costs of implementation for Scenario 3. These costs are based on the individual building block cost estimates, efficiencies of combining different building blocks, and annual costs (increased annual funding for levee maintenance).

18.4.1.2 Risk-Reduction Benefit

A measure of the risk reduction can be made by determining the difference in the average annual damages associated with Phase 1 results and those for a Phase 2 scenario. Table 18-12 shows these results as well as the estimated net present value of the risks and an estimate of the risk reduction benefit for Scenario 3.

18.4.1.3 Scenario Summary

The estimates of the risk-reduction benefit for the three scenarios can be broadly compared to their conceptual level capital costs as shown in Table 18-13. For each of the scenarios, the capital costs are at least 2.5 and up to 6 times larger than the estimated reduction in economic risk. Note however the only way to determine whether any of the scenarios are worthwhile from an allocative efficiency perspective would be to compare **all** project benefits and **all** project costs in a benefit cost analysis. Such an assessment was beyond the scope of the Phase 2 analyses.

Tables

Table 18-1 Scenario 1 Building Blocks

No.	Building Block	Option
1.1	Improved Delta Levee Maintenance	Delta Levee Subventions increased to ~$12 million/year (2 x current level)
1.2b, 1.2d	Upgraded Delta Levees	All Central Delta Levees (~500 miles) upgraded to PL84-99
		Seismically upgrade southern Delta islands (Bacon, Byron, Jones Tract, Orwood, Woodward, Union, Victoria)
1.3	Enhanced Emergency Preparedness/Response	Spend ~$50 million for pre-positioning rock, sheetpiles, etc.
1.5	Land Use Changes to Reduce Island Subsidence	Change land use from farming to wetlands/carbon seq. (rice growing, fish food farm, etc.) for all islands projected to have more than 3 feet of additional subsidence by 2100
2.1a-c	Raise State Highways and Place on Piers (similar to I-80 across Yolo Bypass)	Highways 12 and 160 are raised.
2.2a-d	Construct Armored Infrastructure Corridor Across Central Delta	Mokelumne Aqueduct, Burlington-Northern Santa Fe Rail Line, Highway 4, Natural Gas Pipelines
3.1	Breach dikes in Suisun Marsh	Breach dikes in Suisun Marsh
3.2	Cache Slough Restoration	Cache Slough Restoration
3.3a-d	Fish Screens	Delta Cross Channel, Clifton Court Intake, Tracy Pumping Plant, River diversions
3.4a	Set back levees to Restore Shaded Riverine Habitat	10 miles

Table 18-2a Duration and Cost of Repair for Seismic Cases

Seismic Case	Number of Flooded Islands	Duration of Repairs (months)	Cost of Repairs ($billion)
1	1	Up to 20	Up to 0.6
2	2	20	1.4
3	2	35	1.7
4	8	45	3.4
5	15	64	6.2
6	23	69	5.8

Table 18-2b Duration of No Export Pumping for Seismic Cases

Seismic Case	Number of Flooded Islands	Duration of No Pumping (months)[1]	Water Not Exported (maf[2])
1	1	Up to 2	Up to 0.7
2	2	0 to 2	0.01 to 0.8
3	2	0 to 2	0.01 to 0.8
4	8	1 to 4	0.3 to 1.1
5	15	4 to 8	2.0 to 2.9
6	23	6 to 9	2.4 to 3.6

[1] Export disruptions will continue for an additional period, depending on the severity of the scenario, while only partial pumping is possible.
[2] million acre-feet

Table 18-3 Summary of Economic Costs of Seismic Failure for Scenario 1

Seismic Failure Case	No. of Flooded Islands	No. of Non-Flooded, Damaged Islands	Spring, Wet Water Year			Summer, Average Water Year			Fall, Dry Water Year		
			In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)	In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)	In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)
1	1	2	1,290	325	1,615	1,290	325	1,615	1,290	325	1,615
2	2	0	1,676	143	1,818	1,674	143	1,817	1,725	493	2,218
3	2	0	1,980	154	2,134	1,977	155	2,131	2,031	505	2,535
4	8	0	4,096	265	4,361	4,107	267	4,374	4,156	699	4,855
5	15	6	5,944	1,056	6,999	5,949	966	6,914	5,938	2,143	8,080
6	23	7	7,960	2,455	10,415	7,866	1,454	9,320	7,896	3,013	10,910

Table 18-4 Scenario 1: Levee Improvement Costs

No.	Building Block	Costs	
		Capital	Annual
1.1	Improved Delta Levee Maintenance	-	$12M
1.2b	Upgraded Delta Levees to PL 84-89	$2.1B	-
1.2d	Upgraded Delta Levees to Seismic Resistant	$6.6B	-
1.3	Enhanced Emergency Preparedness/Response	$50M	-
1.5	Land Use Changes to Reduce Island Subsidence	$600M	$0.5M
2.1	Raise SR 12 & 160 and Place on Piers (similar to I-80 across Yolo Bypass)	$4.4B	-
2.2	Construct Armored Infrastructure Corridor Across Central Delta[1]	$880M	-
3.1	Breach dikes in Suisun Marsh	$1.2B	-
3.2	Cache Slough Restoration	$921M	-
3.3	Fish Screens at DCC, Tracy PS, Banks PS, and Ag. River Diversions	$1.7B	-
3.4	Set back levees to Restore Shaded Riverine Habitat (20 miles)	$1.2B	
	Total	$20.0B	$12.5M

[1] Armored infrastructure length reduced due to comparable levee seismic upgrades on Orwood, Woodward, and Jones Tract.

Table 18-5 Scenario 1: Risk-Reduction Benefits

Scenario	Average Annual Damages (AAD) $M	Net Present Value (3% over 50 yrs) $M	Net Present Value of the Risk-Reduction Benefit (3% over 50 yrs) $M
Base Case	$676	$17,394	NA
Scenario 1	$369	$9,499	$7,894

Table 18-6 Scenario 2: Building Blocks

No.	Building Block	Option
1.1	Improved Delta Levee Maintenance	Delta Levee Subventions increased to ~$12 million/year (2 x current level)
1.2a	Upgraded Delta Levees	All Central Delta Levees (~500 miles) upgraded to PL84-99
1.3	Enhanced Emergency Preparedness/Response	Spend ~$50 million for pre-positioning rock, sheetpiles, etc.
1.5	Land Use Changes to Reduce Island Subsidence	Change land use from farming to wetlands/carbon seq. (rice growing, fish food farm, etc.) for all islands projected to have more than 3 feet of additional subsidence by 2100
1.6	Armored "Pathway" Through Delta Conveyance	Seismically upgraded levees along "Pathway". Also, a series of five gates are installed in the southern Delta and sections of channel must be dredged.
2.1b, c	Raise State Highways and Place on Piers (similar to I-80 across Yolo Bypass)	Highways 12, and 160
2.2a-d	Construct Armored Infrastructure Corridor Across Central Delta	Mokelumne Aqueduct, Burlington-Northern Santa Fe Rail Line, Highway 4, Natural Gas Pipelines
3.1	Breach dikes in Suisun Marsh	Breach dikes in Suisun Marsh
3.2	Cache Slough Restoration	Cache Slough Restoration
3.3a-d	Fish Screens	Delta Cross Channel, Clifton Court Intake, Tracy Pumping Plant, River diversions
3.4a	Set back levees to Restore Shaded Riverine Habitat	10 miles

Table 18-7 Summary of Economic Costs of Seismic Failure for Scenarios 2 and 3

Seismic Failure Case	No. of Flooded Islands	No. of Non-Flooded, Damaged Islands	Spring, Wet Water Year			Summer, Average Water Year			Fall, Dry Water Year		
			In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)	In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)	In-Delta Cost ($M)	Statewide Cost ($M)	Total Cost ($M)
1	1	2	1,373	-	1,373	1,373	-	1,373	1,373	-	1,373
2	2	0	2,209	-	2,209	2,212	-	2,212	2,280	-	2,280
3	2	0	2,537	-	2,537	2,539	-	2,539	2,628	-	2,628
4	8	0	5,221	-	5,221	5,212	-	5,212	5,218	-	5,218
5	15	6	8,315	746	9,061	8,228	706	8,935	8,476	1,030	9,506
6	23	7	12,370	1,089	13,459	12,219	935	13,154	12,233	1,373	13,605

Table 18-8 Scenario 2: Armored Pathway Costs

No.	Building Block	Costs	
		Capital	Annual
1.1	Improved Delta Levee Maintenance	-	$12M
1.2	Upgraded Delta Levees to Urban Levees[2]	$10.1B	-
1.3	Enhanced Emergency Preparedness/Response	$50M	-
1.5	Land Use Changes to Reduce Island Subsidence	$600M	$0.5M
1.6	Armored Pathway (15,000 cfs)	$9.8B	-
2.1	Raise SR 12 & 160 and Place on Piers (similar to I-80 across Yolo Bypass)	$4.4B	-
2.2	Construct Armored Infrastructure Corridor Across Central Delta	$3.3B	-
3.1	Breach dikes in Suisun Marsh	$1.2B	-
3.2	Cache Slough Restoration	$921M	-
3.3	Fish Screens at Armored Pathway, DCC, Tracy and Banks Pumping Stations and in-Delta Agriculture River Diversions[2]	$2.0B	-
	Total	$32.4B	$12.5M

[1] Urban Levees reduced by 21 miles. These levee sections are included in Armored Pathway.
[2] Fish screens required at all facilities.

Table 18-9 Scenario 2: Risk-Reduction Benefits

Scenario	Average Annual Damages (AAD) $M	Net Present Value (3% over 50 yrs) $M	Net Present Value of the Risk-Reduction Benefit (3% over 50 yrs) $M
Base Case	$676	$17,394	NA
Scenario 2	$454	$11,685	$5,709

Table 18-10 Scenario 3: Isolated Conveyance Facility Building Blocks

No.	Building Block	Option
1.1	Improved Delta Levee Maintenance	Delta Levee Subventions increased to ~$12 million/year (2 x current level)
1.2a	Upgraded Delta Levees	All Central Delta Levees upgraded to Urban Levees
1.3	Enhanced Emergency Preparedness/Response	Spend ~$50 million for pre-positioning rock, sheetpiles, etc.
1.5	Land Use Changes to Reduce Island Subsidence	Change land use from farming to wetlands/carbon seq. (rice growing, fish food farm, etc.) for all islands projected to have more than 3 feet of additional subsidence by 2100
1.7	Isolated Conveyance Facility	Construct a full capacity conveyance facility along the eastern edge of the Delta
2.1a,b, c	Raise State Highways and Place on Piers (similar to I-80 across Yolo Bypass)	Highways 4, 12, and 160
3.1	Breach dikes in Suisun Marsh	Breach dikes in Suisun Marsh
3.2	Cache Slough Restoration	Cache Slough Restoration
3.3a-d	Fish Screens	Delta Cross Channel, Clifton Court Intake, Tracy Pumping Plant, River diversions
3.4a	Set back levees to Restore Shaded Riverine Habitat	10 miles

Table 18-11 Scenario 3: Costs

No.	Building Block	Costs	
		Capital	Annual
1.1	Improved Delta Levee Maintenance	-	$12M
1.2	Upgraded Delta Levees to Urban Levees	$10.6B	-
1.3	Enhanced Emergency Preparedness/Response	$50M	-
1.5	Land Use Changes to Reduce Island Subsidence	$600M	$0.5M
1.7	Peripheral Canal (15,000 cfs)	$4.4B	-
2.1	Raise SR 4, 12 & 160 and Place on Piers (similar to I-80 across Yolo Bypass)	$6.1B	-
3.1	Breach dikes in Suisun Marsh	$1.2B	-
3.2	Cache Slough Restoration	$921M	-
3.3	Fish Screens at Peripheral Canal, Delta Cross Channel, and in-Delta Agriculture River Diversions[1]	$711M	-
3.4	Set back levees to Restore Shaded Riverine Habitat (20 miles)	$1.2B	
	Total	$25.8B	$12.5M

[1] Fish screens not required at Tracy PS and Banks PS. Peripheral Canal design includes fish screen at inlet facility near Hood.

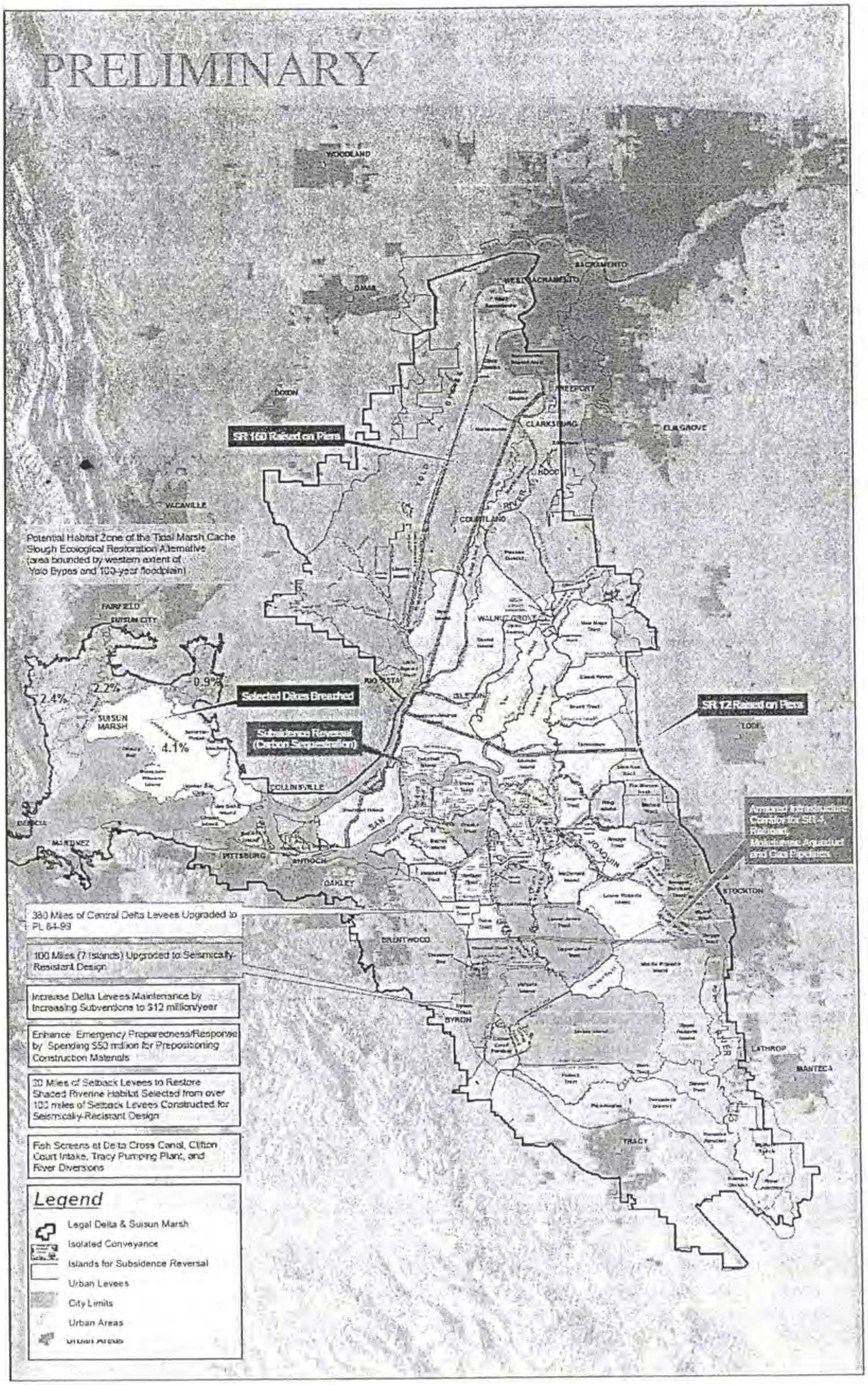
Table 18-12 Scenario 3: Risk-Reduction Benefits

Case	Average Annual Damages (AAD) $M	Net Present Value (3% over 50 yrs) $M	Net Present Value of the Risk-Reduction Benefit (3% over 50 yrs) $M
Base Case	$676	$17,394	NA
Scenario 3	$454	$11,685	$5,709

Table 18-13 Summary of Scenario Costs and Risk Reduction Benefit

	Scenario	Capital Cost (B)	Net Present of the Risk-Reduction Benefit (3% over 50 years) $B
IMPROVED LEVEES	1	$20.0	$7.9
ARMORED PATHWAY	2	$32.4	$5.7
ISOLATED CONVEYANCE	3	$25.8	$5.7

Figures



URS	26815935 Delta Risk Management Strategy (DRMS) Phase 2	SCENARIO 1: IMPROVED LEVEES	Figure 18-1

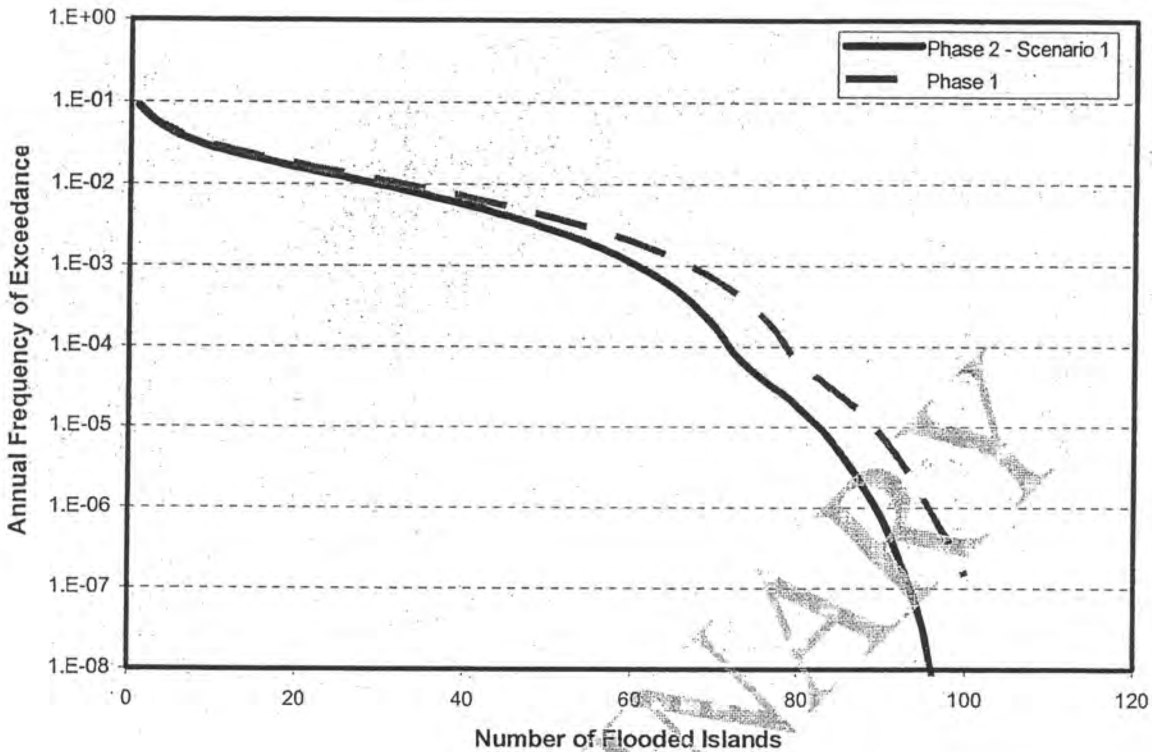
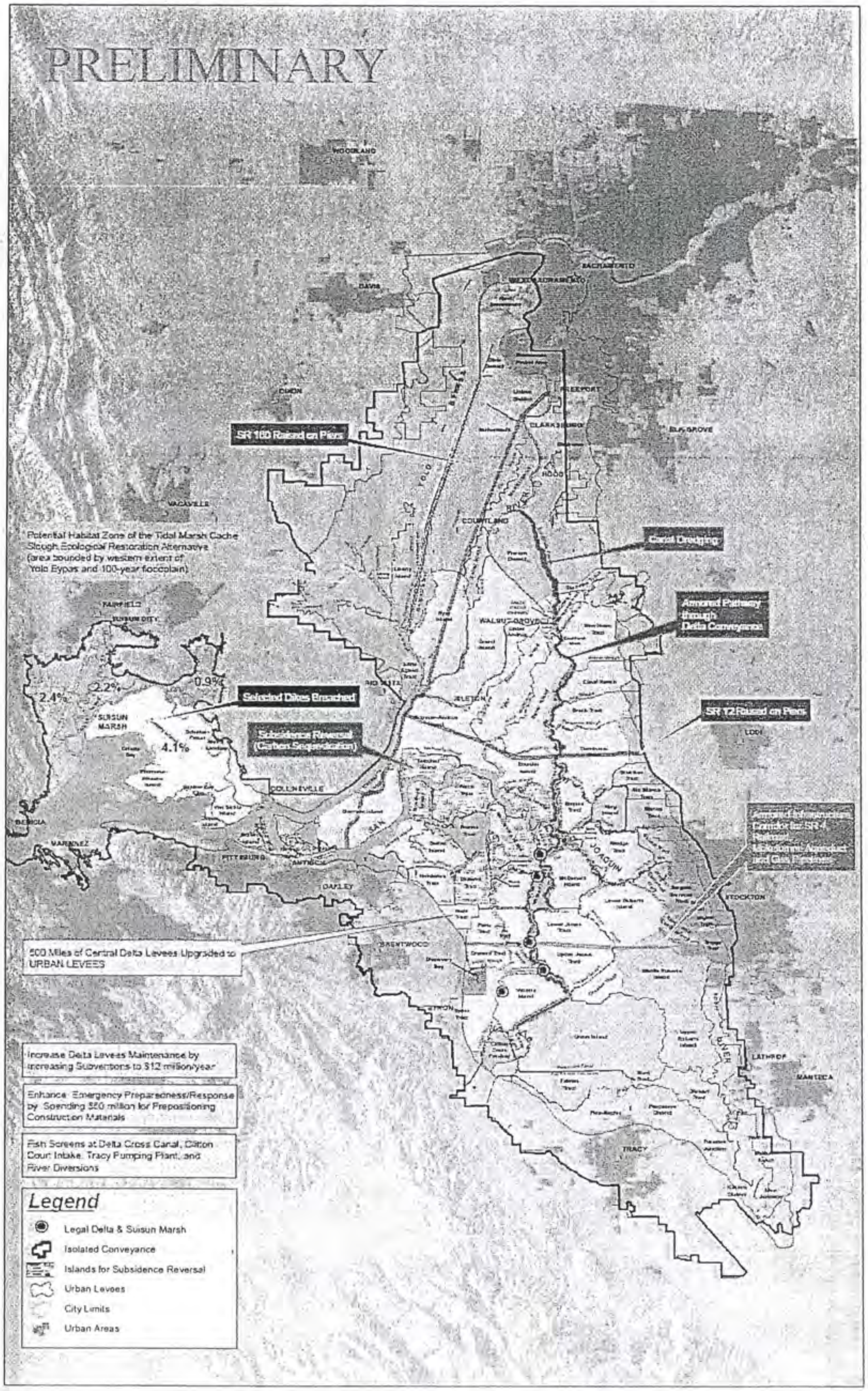
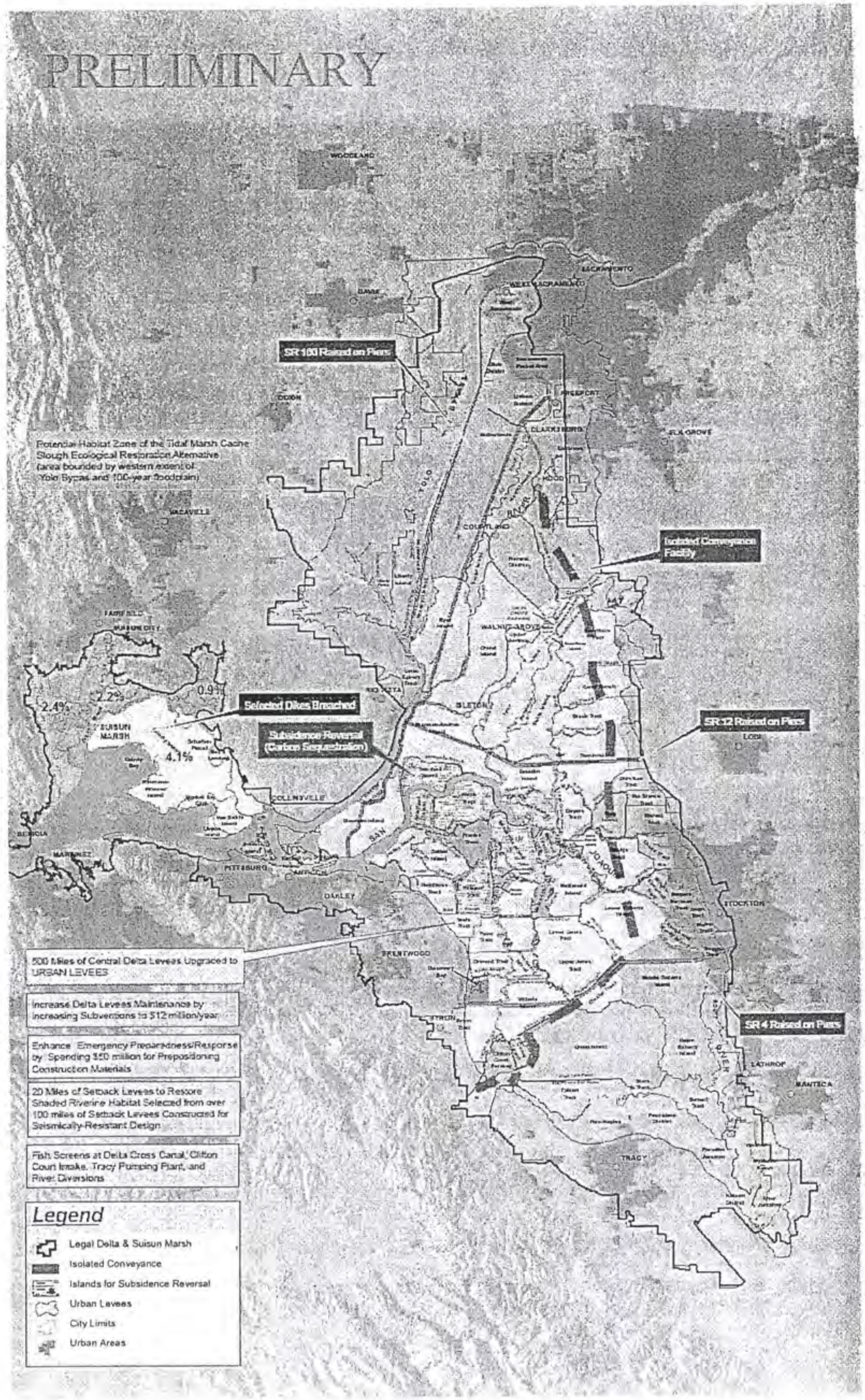


Figure 18-2 Comparison of the mean frequency distribution on the number of flooded islands due to seismic events for Phase 1 and Scenario 1



URS	26815935 Delta Risk Management Strategy (DRMS) Phase 2	SCENARIO 2: ARMORED PATHWAY	Figure 18-3



URS	26815935 Delta Risk Management Strategy (DRMS) Phase 2	SCENARIO 3: ISOLATED CONVEYANCE FACILITY	Figure 18-4