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February 6, 2006

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[Letter transmitted electronically only]

Dear Lynn,

As we discussed, I am writing to propose that the Corps consider investing a bit of its growing stream of funding for efforts to improve the security of California's Sacramento-San Joaquin Delta towards targeted research and development efforts.

Each time we have gathered over the past 25 years to begin the next set of studies for the Delta, we have faced short timelines and the need to deliver the best possible engineering and scientific insights possible, usually within a two-year time frame (or similar), and that generally requires using the "best available" technology and augmenting this with solicitation of leading experts in selected fields. Each time we perform this sort of exercise, we are left with the knowledge that a bit of targeted research and/or development, in a few selected areas, would pay off handsomely in terms of: (1) providing improved tools and insight for the next coming rounds of study and eventual design, (2) which would, in turn, provide improved outcomes with regard to selection of better mitigation schemes, (3) provide for the ability to optimize the design of such mitigation, likely saving orders of magnitude more monies than the initial investment in research and development, and (4) would in some cases also provide much-needed tools for emergency response and management of emergency repairs as well (and at no additional cost).

This would represent a magnificently cost-effective investment, either by the State or by the Federal Government. Unfortunately, in a program plagued by two-year rushed cycles, investment in a three to four year development effort is never quite within the scope of the current allocations. To make such an investment would require us to be forward-looking; not easy within the current system!

We currently face this problem, yet again, within the current two-year DRMS effort, and we will face it again in the more detailed decision-making and design studies that will follow in the wake of DRMS.

It is time to stop this wasteful cycle.

Accordingly, I would like to propose that some small fraction of the currently looming allocation of approximately $93 million be directed toward prudent investment in a series of narrowly targeted R & D initiatives certain to pay for themselves many times over both in terms of improving our ability to make intelligent decisions and to design more effective, and more cost-effective, mitigation schemes to resolve the currently unacceptable levels of risk in the Delta.

Based on previous studies of risk in the Delta over the past 25 years, and the meetings and discussions of the Technical Advisory Committee for the current Delta Risk Management Studies (DRMS), a number of recurring issues warrant research and/or development efforts that will, once again, not be feasible within the current two-year timeframe of the DRMS studies. Principal among these, in my opinion, are the following. I list and explain these in order of my own sense of priority in terms of both need and likely payoff relative to cost. These are brief descriptions only, but they can certainly be expanded with regard to detail if a promising mechanism can be found for support of these.

1. Development of Improved, Rapid Hydrodynamic Modeling Capability for Study of Delta Hydrodynamics, and for Rapid Response and Management of Delta Levee Failures

There are, currently, no fast and efficient hydrodynamic models for analysis of the movements of waters, salt concentrations, contaminants, heat, etc. through the Delta system. Recently improved models run very slowly, and take a week and more to model and cycle through two or more water years.

Yet even these slow-running models have already provided tremendous insights for the current phase of risk assessment studies. Our previous experience with actual failures of levees in and near the Delta had involved either single levee failures, or at most a few failures during a single storm/flood event. It turns out that "lessons" from these relatively localized and manageable situations do not extrapolate well to scenarios associated with multiple simultaneous levee failures from a major earthquake or flood event. Only a few detailed analytical "runs" have been able to be performed to date, owing to the slow and computationally cumbersome analytical system currently available, but these have already begun to revolutionize our views of how the system works, the levees most important to protect against failure, and the optimal sequence of repair priorities, etc., in the case of a major levee disaster.

Specifically, cycling through a variety of previously recorded "water years" (including inflows, snow pack, reservoir volumes available, and full modeling of recorded daily tides), with the ability to model decisions regarding upstream reservoir management and releases, and "downstream" pumping to export water from the Delta from a number of locations, has shown original hypotheses with regard to prioritization of islands and levees "to be protected", and the prioritization of islands and levees to be repaired in the wake of catastrophic damages, to be incorrect. The ability to track the influx of salt from the Bay during the initial levee failures ("the big gulp"), and then to track the movements of salt concentrations through many months of daily tidal cycling and seasonal through-flows has already been extremely valuable; quite likely the largest recent advance in our overall understanding of Delta risk and its mitigation.

In addition, it has become clear that management of the boundary conditions (management and timing of upstream reservoir releases, and management and timing of pumping outflow volumes and temporary cessation of these) can be very useful in responding to major levee failure scenarios, as well as to emergency repairs and eventual flushing out of the Delta system.

With the current, slow-running model, we will have only limited ability to make use of this important technology during the current DRMS studies. We will, of course, maximize this by starting immediately and keeping several computer systems humming. In the end, however, we will only be able to model a limited sub-set of the many failure scenarios we would like to examine, and only a limited sub-set of the interactions of each of these with "good', "average" and "poor" water years. We will also have only a limited ability to model the effects of various strategies regarding operation of reservoirs and pumps.

There will be more Delta studies on the heels of DRMS. Further studies will next be performed to further refine the risks, and the benefits of various mitigation alternatives to be developed by DRMS. Additional studies will then follow even those, as detailed project design will eventually be required.

For all of those studies, it would be tremendously valuable to have an improved, and much faster-running, computation hydrodynamic model.

This can be accomplished. Dr. Jon Bureau, of our DRMS Technical Advisory Committee, has investigated this and has located a computational solver (currently proprietary software) that can perform the calculations several orders of magnitude faster than the "solver" used in the current analysis tools. In addition, recent high resolution LIDAR surveys are available to provide an improved overall topographic characterization of the Delta's principal features with regard to island ground elevations, etc., and that would improve the accuracy and reliability of the modeling and analyses. And the current technology can also relatively easily be modified to incorporate the ability to better model initial levee failures and also the effects of scour and tidal actions as they progressively exacerbate the original levee breaches, as well as the effects of management of reservoirs and pumps, etc.

It is proposed that a comprehensive Delta hydrodynamic model be developed, for use by both Federal and State agencies for: (1) improved assessment of current Delta risk and fragility, (2) improved assessment of the benefits of various risk mitigation alternatives, and (3) improved effectiveness and cost-efficiency in eventual design and implementation of mitigation alternatives.

In addition, the same model would also provide an invaluable tool for emergency response to levee failures, and to management of the water system during extended repair periods in the wake of a major (multiple failure) event. The ability to run multiple scenarios, testing various reservoir management, pump management, and levee repair prioritization schemes in the immediate aftermath of major failures would be invaluable, and this application alone (Emergency Response Management) should more than fully justify the cost of this proposed effort.

It is proposed to create an analytical hydrodynamic model for the Delta and its environs (through Suisun Bay) capable of accurately modeling all of the variables and boundary conditions discussed above, and capable of running through a simulated "water year" within a few minutes, rather than a few days. The model would be calibrated and verified using data from recent levee failure events, and also using data regularly accumulated regarding salt concentration transport, etc.

It is proposed that Dr. Jon Bureau assemble the necessary team, to include experts from a number of organizations and institutions (those who might otherwise have been expected to bid, with some chance of success, on this work if it had been opened for competitive bidding.) This would be expected to include representation from both the USACE and DWR. Dr. Bureau has contacted the owners of the core solution code, and it would be necessary to move this code into the public domain in order to provide transparency and full portability for the eventual model. The cost for purchase of rights to the solver, and moving it to the public domain, is estimated at $500,000. The overall research and development program, including analytical development as well as field calibration and verification, are estimated as an additional $700,000 (assuming contribution of time from USACE and Calif. DWR personnel to advise and review the work as it progresses.) The overall project would then be estimated as a three-year effort, at a cost of approximately $1,200,000 (not counting overhead, etc.) It is estimated that a deal can be made to handle this effort through one of the California universities, and that overhead can be negotiated as low as 25 to 40% for this effort.

2. Unresolved Seismic Geotechnical Issues Affecting Delta Levee Security

There are two sets of unresolved seismic geotechnical issues that will continue to be important in all phases of Delta work over the coming years. The first of these is uncertainty regarding the performance of Delta levees with regard to the effects of potential seismically-induced liquefaction of the levee embankment soils and/or the underlying foundation soils. The second issue is the current lack of definitive methods for evaluation of the seismic response of the very deep alluvial basin deposits within the Delta, and also of the organic soils that dominate much of the upper strata. Together, these two issues; (1) introduce significant uncertainty into analyses of current levels of risk and levee fragility, and (2) introduce significant uncertainty with regard to development and evaluation of potential mitigation alternatives.

Simply put, they make it difficult to determine exactly how seismically unsafe the current levees are, and no one has yet developed a reasonably cost-effective design for reduction of this seismic levee risk that can be shown likely to actually work. These are pivotal issues.

(a) Liquefaction-Related Levee Vulnerability

There have been major advances over the past decade with regard to development of improved analysis tools for probabilistic assessment of the likelihood of liquefaction for a given level of seismic loading. Current DRMS studies are expected to provide an improved basis for evaluation of the seismicity of the region, and thus the likelihood of such loadings.

What is missing is a well-calibrated set of analytical tools for analysis/assessment of the effects of soil liquefaction on the stability on the complex system of levees and highly variable foundation soils distributed across the Delta. Such tools are fairly well developed for large dams, but we lack similar calibrated and proven tools for the levees.

It is proposed to devote three years to the development, verification and calibration of these needed analytical and design tools. The computer code FLAC has many variants, and is now increasingly widely used for analyses of liquefaction induced deformations and instability of major dams. This program will take one of the current versions best-calibrated for liquefaction analyses of dams, and will further modify this code as necessary and cross-calibrate and verify the resulting analysis tool by means of analyses of previous liquefaction-related levee embankment case histories (from California, Japan, and Taiwan.)

The resulting code will then also be exercised to help to evaluate the current levels of seismic liquefaction risk for existing Delta levees, and also to develop and evaluate a suite of design alternatives for mitigation of this type of risk for selected "representative" Delta levee sections.

The availability of this analytical capability should pay for itself many times over at two stages in the coming years:

1. It will facilitate a far better evaluation of current seismic levee risk, and also the real benefits of proposed mitigation alternatives, and thus improve our ability to make the best choices among alternatives. It will also foment a far more accurate evaluation as to just how must risk is effectively mitigated by the alternative(s) that are eventually selected.

2. It will permit much more refined design, and evaluation of design, of seismically improved levee sections. With approximately 1,100 miles of levees to be considered in the Delta, and in the City of Sacramento area, and the looming likelihood of billions of dollars in likely mitigation efforts, saving a percentage of the actual costs of implementing seismic levee mitigation could be expected to result in many millions in savings. A bargain given the cost here.

This is proposed to be a three year effort, at a projected cost of approximately $375,000 (not counting overhead, etc.) Again assuming that the work can be negotiated at an overhead rate of between about 25 to 40% for this effort, the total cost would be on the order of about $500,000 or less. This work would be performed at U.C. Berkeley, likely under the direction of Prof's. Jon Bray, Juan Pestana and myself. Contributions for cost-sharing should be sought from non-Federal sources including Calif. DWR, The State legislature, and the University of California itself (e.g. from the CITRIS or PEER Research Center programs, etc.) This project would ideally involve the participation of Dr. Michael Beatty (Calif. DWR), whose own doctoral work contributed to the development of the use of the FLAC-type codes for similar analyses of dams (including back-analyses for verification and calibration), and also an expert from the USACE familiar with dynamic deformation-based analyses of liquefaction-induced displacements of dams (you have several suitable experts within USACE on this topic.)

The availability of such analytical capability, and the understanding through calibration against field case histories, would represent a major advance and would provide a valuable tool for seismic analysis and design of levees not only in California, but also in the St. Louis, Charleston and Washington and Oregon state regions.

(b) Seismic Response Evaluation of Deep Alluvial Deposits and Organic Peaty Soils

Studies to date show that approximately 75% to 85% of seismic risk to levees in the Sacramento and Delta regions is associated with soil liquefaction hazard. The remainder is associated with inertial "lurching" levee displacements and deformations. For both types of hazard, it is the levels of seismic shaking at and just below the bases of the levees that are of principal concern. Unfortunately, this too is an area requiring additional study in order to reduce currently unacceptable levels of uncertainty in evaluation of these shaking levels.

Major advances have been made over the past decade in evaluation of the effects of deep sedimentary basin deposits as the seismic energy propagates upwards towards the surface and near-surface soils of principal interest. It turns out that we had long over-estimated the "damping" provided by the deeper soils, and so had underestimated these critical near-surface shaking levels.

Little had been known about the dynamic properties of the peaty organic soils that underlie the levees throughout much of the Delta. Recent work by Boulager et al. at U.C. Davis has led to major progress here, but this work has characterized these peaty soils largely as they exist near the toes of the levees (where they can most easily be accessed and sampled with little disturbance), and corollary programs by Calif. DWR to instrument full levee sections and to compare measured vs. calculated seismic response from recordings for small earthquakes suggest a need to continue this work to also characterize the dynamic properties of peaty soils under the heavy overburdens beneath the centers of levees.

In addition, these comparisons between field instrumented levee sections and analyses also show soil/structure interaction (SSI) to be an important issue at and just below the bases of the levees. In simple terms; the stiffness and mass disparities between the relatively stiff and heavy "hockey puck" of the levee embankment section, and the generally much softer upper foundation soils below it, has a major effect on the shaking and on the cyclic shear stress levels in the critical regions at and just below the bases of the levees.

With advances of the past decade we now know much more about the critical regions within which the shaking and cyclic shear stress levels need to be evaluated. Recent work through the joint California (CALTRANS) and Federal (NSF) sponsored ROSRINE research program have led to major advances in the analysis of dynamic response of deep basin soils. Coupling these advances with improved experimental work to characterize the seismic response of peaty soils under larger overburden loads, and then generalizing these analyses to include important SSI effects, would greatly improve our ability to perform both liquefaction-related and non-liquefaction-related (seismic "lurching") seismic stability and deformation-based analysis and design of levees. As with Part (a) above, this would in turn permit far better evaluation of current risk, better assessment and selection of alternatives for mitigation, and optimization of actual design of mitigation.

Again, the availability of this analytical capability should pay for itself many times over at two stages in the coming years:

1. It will facilitate a far better evaluation of current seismic levee risk, and also the real benefits of proposed mitigation alternatives, and thus improve our ability to make the best choices among alternatives. It will also foment a far more accurate evaluation as to just how must risk is effectively mitigated by the alternative(s) that are eventually selected.

2. It will permit much more refined design, and evaluation of design, of seismically improved levee sections. With approximately 1,100 miles of levees to be considered in the Delta, and in the City of Sacramento area, and the looming likelihood of billions of dollars in likely mitigation efforts, saving a percentage of the actual costs of implementing seismic levee mitigation could be expected to result in many millions in savings. A bargain given the cost here.

This is also proposed to be a three year effort, at a projected cost of approximately $425,000 (not counting overhead, etc.) Again assuming that the work can be negotiated at an overhead rate of between about 25 to 40% for this effort, the total cost would be on the order of about $575,000 or less. The slightly higher cost of this work, relative to that proposed previously in Part 2(a), is due to the expected expenses associated with field sampling and laboratory testing. This work would be performed jointly at U.C. Davis and U.C. Berkeley, likely under the direction of Prof's. Ross Boulanger (U.C. Davis) and Jon Bray, Mike Reimer and Juan Pestana (U.C. Berkeley.) Contributions for cost-sharing should be sought from non-Federal sources including Calif. DWR, The State legislature, CAL-FED and the University of California itself (e.g. from the CITRIS or PEER Research Center programs, etc.) In addition, assistance either from the USACE or DWR would be sought for some of the boring and sampling.

3. Evaluation of the Character and Potential Seismicity of the Coastal Range Central Valley Fault Feature

Another significant source of uncertainty in current assessments of seismic Delta risk is the feature known as the Coastal Range/Central Valley (CRCV) fault. This is a fault-like feature that passes beneath the western edge of the Delta, and also passes close to the City of Sacramento. This feature can be clearly seen in remote geophysical imaging, but it is not known with any certainty whether this is simply a contact feature between two disparate major geologic units, a formerly active fault that is now "locked" and which has no history of seismicity in recent geologic time, or a potentially seismically active fault feature.

This range of possibilities has a major impact on current assessments of seismic risk in both the Delta and the Sacramento metropolitan areas.

Overall, seismicity has been unusually well studied and well characterized in the greater San Francisco Bay area. This is due, in part, to the fortuitous location of a number of leading world experts and research institutions in this area, and they have done an unusually good job of seismicity characterization "on their own turf." Unfortunately, the northeast portion of the Bay Area is the least well characterized, and this is the portion that most directly affects seismic risk to both Sacramento and the Delta.

The CRCV fault lies beneath thousands of feet of sediments, and thus cannot be "trenched" or accessed by other simple means for inspections (as with most of the other Bay Area Faults.) Remote imaging, and very deep borings through the feature, would thus represent the most promising means to better evaluate this feature.

The USGS has its major "seismic" research office in the south Bay Area (in Menlo Park), and experts there are well-suited to a study of this important and difficult-to-access feature. The USGS has its own intramural research funding programs, and would be able to fund and perform a study of this feature. They might be induced to do so simply based on our urging, and an explanation of the importance and timeliness of the answers. It is far more likely, however, that USGS prioritization of funds for such a study could be enhanced by a partial "match" from other (non-USGS) sources.

I have not had the time this past week to contact the people at USGS who would ideally lead such an effort (e.g. Dr. Paul Spudich, and others), nor to check with those who would fund it, or to go over the likely costs in any detail. I have had prior conversations with some of them, however, and expect that the USGS could be convinced to spend the monies necessary to perform deep borings through this feature, to image it with geophysical methods, and to have a team of expert seismic geologists perform a formal assessment of the seismic potential of this feature.

It is therefore proposed that USGS be contacted, and that an attempt be made to persuade them to undertake a formal investigation of the seismic potential of the CRCV Fault feature in the vicinity of the west Delta and Sacramento area. Setting aside $250,000 from the current Delta and Sacramento levee funding, as partial matching funds for an effort intended to be funded primarily from within the USGS, would likely be very helpful here. If the USGS cannot find the additional funds necessary to perform this work, then the $250,000 would be returned to the USACE and they would again be available for other, more conventional levee work.

Summary

The three proposed initiatives are summarized in Table 1. Estimated costs are approximate, but the proposed work can be performed within the budgeted amounts shown. Some minor additional economies may be feasible when preparing more formal cost proposals.

Both the Pacific Earthquake Engineering Research Center (PEER) at U.C. Berkeley, and the Center for Catastrophic Risk Management (CCRM) at U.C. Berkeley have expressed an interest in hosting and supporting work associated with both the Sacramento and Delta levee systems. Both centers have access to additional discretionary funds of their own, and it may also be feasible to either negotiate lower overhead rates, or to garner additional direct matching funds, as additional contributions here.

The three efforts proposed were selected for their necessity, for the cost-effectiveness of the proposals relative to the funding sought from the current allocation, and because they are not feasible within the normal "two-year or less" timeframes within which efforts to address current hazard levels for both the Sacramento and Delta levee systems continue to advance. It is my hope that we can find a creative way out of this "short-cycle" box, and perform studies of three to four year duration in order to develop tools, knowledge, and analytical methods to provide improved tools and insight for the next coming rounds of study and eventual project design. These would

1. Provide improved outcomes with regard to evaluation and eventual selection of better mitigation schemes.

2. Provide for the ability to optimize the design of such mitigation, likely saving orders of magnitude more monies than the initial investment in research and development.

3. And in some cases also provide much-needed tools for emergency response and management of emergency repairs as well (and at no additional cost).

This would represent a very prudent and cost-effective investment at this stage of the process. We have not, typically, been previously able to make prudent and cost-effective investments for these works, and this may provide a valuable opportunity to change that.

There are additional issues that can (and have been) identified as warranting similar longer-term (three to four year) efforts in parallel with the ongoing two-year DRMS effort. Many of these deal with either environmental, water quality, or economics analysis, however, and these areas have traditionally been better able to garner adequate separate support within the overall scope of Delta programs (including CAL-FED, etc.)

Accordingly, I have singled out several critical issues directly related to the risk and fragility of the levees themselves. As you are aware, levee-related issues have received an appallingly small fraction of the overall CAL-FED support to date (less than 2%).

As we discussed, these proposals are rather simple and the budget details are not well developed. If the support of such work appears feasible, then it would be easy to mobilize the necessary teams, to rapidly develop more refined cost estimates and scopes of work, and to make the necessary arrangements for matching funds, etc. These are much needed efforts, and the people likely to be involved have long been waiting for an opportunity to get this work performed.

If you have any questions, or I can provide further information, please feel free to E-mail me, or to call me on my cell at (925) 899-6101 or at home at (925) 930-8692. We are working long days right now on the New Orleans levee studies, so evenings and weekends are fine too.

Yours sincerely,

Raymond B. Seed
Professor of Civil and
Environmental Engineering

cc: Dr. Les Harder, Calif. DWR

Table 1: Proposed Research and Development for Sacramento and Delta Levee Risk Mitigation

	Estimated Cost	Est. ~35% Overhead[1]	Total Cost	Matching Funding[2]	Total Funds Requested
1. Delta Hydrodynamic Modeling for Hazard Analyses and Emergency Response	$ 1,200,000	$ 420,000	$ 1,620,000	$ 400,000[3]	$ 1,220,000
2. Seismic Geotechnical Development and Field Verification of Seismic Response and Liquefaction Analysis Methods for Risk Evaluation and Design	$ 800,000	$ 280,000	$ 1,080,000	$ 250,000[4]	$ 830,000
3. Assessment of Potential Seismicity of the CRCV Fault Feature	$ 750,000	$ 260,000	$ 1,010,000	$ 760,000[5]	$ 250,000
			$ 3,710,000	$1,410,000	$ 2,300,000

Notes:

[1]Estimated overhead rates. It may also be possible to negotiate lower overhead rates as an additional "match in kind" to save additional costs.
[2]Matching Funding may come from a variety of sources, depending on the project details.
[3]Matching funding to be sought from the California Department of Water Resources (DWR), and from the CAL-FED Program.
[4]Matching funds to be sought from CAL-FED, DWR, and also from the Pacific Earthquake Engineering Research Center (PEER).
[5]Principal funding to be sought from the U.S. Geological Survey (USGS).