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The Honorable Edmund G. Brown Jr
Governor of California
State Capitol, First Floor
Sacramento CA 95814

The Truth About Delta Levees
Or
The Shaky Justification for the BDCP

Dear Governor Brown,

You must be aware that one of the principal reasons that is advanced for the need for an isolated conveyance as part of the Bay Delta Conservation Plan (BDCP) is that the Delta levees are in a pathetic condition and that there will be multiple failures in a major earthquake followed by saltwater intrusion that will curtail exports from the Delta by the State Water Project and the Central Valley Project for up to three years, forcing up to 25 million people to drink and bathe in whiskey for that period of time. While I think I understand your desire to announce a "preferred project" for the BDCP within the next month, you should not do this without understanding that this reason for constructing an isolated conveyance with intakes in the North Delta is based on a series of misrepresentations and falsehoods - in other words, that the supporters of the BDCP are lying. And they are deceiving themselves - the threat to reliable water supply, the Delta ecosystem and both recreational and commercial fishing posed by a six-year drought is much greater than any threat posed by earthquakes, yet the BDCP does not include storage and does little or nothing to address the drought issue.

The implication that 25 million people are solely dependent on water exported from the Delta is of course false, but that is a relatively minor issue. The two more important issues that I want to focus on in this letter are the repeated use of the doomsday scenario for Delta levees as a scare tactic and the contention that exports might be interrupted for as much as 3 years, both of which are false.

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Examples of Scare Tactics by BDCP Proponents

The July 8 editorial in the LA Times, "California's Way Forward on Water," concludes with the following sentence: "Engineers warn that in the event of a major earthquake, Clifton Court could fail and the aqueduct could run dry, leaving much of the state without that water for three years or more."

Another recent example reported by KMTS radio is from the Santa Clarita City Council meeting on June 26th: "The delta is in danger of collapse. If you've ever driven or flown over Northern California and looked at that thing. It's a little terrifying," said City Manager Ken Pulskamp. "It's a 100 year old man-made agricultural levy system that could explode very easily, particularly in an area that's prone to earthquakes, floods, and some of the rising sea levels that we've been seeing," said Pulskamp.

Yet, another example was contained in the letter to John Laird, Ken Salazar and Mike O'Connor dated May 24, 2012, by eighteen members of the California State Legislature "as each day passes, the threat of a major earthquake in the Delta region and the impact of weather changes threaten the water supply …"

While threats to the Delta levees from floods, earthquakes and possible more rapid sea-level rise are real, statements like this greatly exaggerate their importance. At least, that is my opinion as a registered civil and geotechnical engineer with over 40 years of experience and national and international standing in earthquake geotechnical engineering. As far as I know, neither the editors of the LA Times, the City Manager of Santa Clarita nor the eighteen members of the legislature have any qualifications in these fields, so where do they get their information from? Some clue is provided by the next two examples.

One is a blog posted on the Southern California Water Committee (SCWC) web site http://socalwater.org/news/scwc-water-blog which reads in part: "The U.S. Geological Survey says there's a 63 percent chance of a magnitude 6.7 quake in the next 30 years in the Bay Area, home of the Delta—California's water supply hub. Those are some pretty high odds. So what would a seismic event of that size mean for the Delta and those who depend on its water? A 6.7 quake could create a Katrina-like collapse of the 100-year-old levees that channel Delta water, causing saltwater to flood in and contaminate the supply for 25 million people. Water deliveries from the Delta could be interrupted for as long as 1 ½ years. Until we make the needed investments to protect our infrastructure against this scenario, we are simply not prepared for this very real possibility."

The statement by USGS is correct but is being used inappropriately. The 63 percent chance of a magnitude 6.7 earthquake in the next 30 years in the Bay Area is in the right ballpark but it includes possible events on three main sources, the Peninsula San Andreas fault, the Hayward fault and the Rogers Creek fault. Only the Hayward fault is of much interest to the Delta and even the Hayward fault is 45 km from the western tip of Sherman Island. The Bay Area is not normally said to be "the home of the Delta". At least the SCWC is now talking about a supply interruption of only 1½ years, down from 3 years in some other articles, but the latest DWR studies suggest that even a very extreme 50 levee breaches, 20 flooded islands scenario would likely only disrupt water exports for several months and in the worst case for six months. And of course the impact is only on a relatively small fraction of the supply for 25 million people.

The second example of a possible source for these scary statements is a video entitled "Seismic Risk in the Sacramento San Joaquin Delta" that can be found on the website of the Metropolitan Water District of Southern California (MWD) http://mwdh2o.com/mwdh2o/pages/yourwater/supply/Delta/index.html the introduction to which says: "There are hundreds of miles of unengineered levees that are susceptible to major failures due to flood and seismic risk. This video demonstrates the catastrophic consequences to homes, businesses, farms and habitat in the Delta from a 6.7 magnitude earthquake and how Southern California's water supply could be cut off for up to two years." Note that the interruption is now back to two years in spite of the fact that MWD actually initiated the studies now being conducted by DWR and follows those studies closely.

A further example of exaggeration was given by Dr David Sunding in reporting his preliminary findings of the economic benefits of the BDCP at a public meeting on June 20th. Dr Sunding evaluated the economic impact of outages of six months, one year, two years and three years, even though the scope of work for his contract only specified that he would do this for outages of six months and one year. I will return later to the substance of his evaluation but where did these unrealistic durations of outage come from?

None of this is to say that the Delta levees are in perfect condition. They are not and they need more work, but let's get realistic about their current and likely future condition.

An Independent Assessment of the Condition of Delta Levees

The basis for many of the pessimistic assessments of the condition of Delta levees and their probabilities of failure come from the Delta Risk Management Strategy (DRMS) conducted by outside consultants but tightly managed by DWR. Although led by very competent principal investigators, the DRMS effort was always hampered by being schedule-driven rather than quality driven. The DRMS Phase One report was extensively reviewed, including a review by an independent review panel (IRP) assembled by the Cal-Fed Science Program. The reviews were generally critical of the study. After revisions had been made to the initial report, the IRP review concluded that "the revised DRMS Phase 1 report is now appropriate for use in DRMS Phase 2 and serves as a useful tool to inform policymakers and others concerning possible resource allocations and strategies for addressing risks in the Delta." But the IRP expressed concerns: "*This conclusion, however, is subject to some important caveats. First, the IRP cautions users of this revised DRMS Phase 1 report that future estimates of consequences must be viewed as projections that can provide relative indicators of directions of effects, not predictions to be interpreted literally ...*"

Although the DRMS developed a nice framework for assessing risks to the Delta levees, the effort had data gaps that were never filled, as acknowledged in the note on page 1-1 of the report. Gaps such of these in data and knowledge tend to drive the estimates of fragilities down, and the risks up. However, despite the warning from the IRP, the numerical results from the DRMS Phase 1 report are widely quoted and used in other studies, painting a more pessimistic picture of the Delta levee system than is warranted. In addition, there are on-going improvements to the levee system under the Delta levees subventions and special projects programs and these improvements are not reflected in the DRMS Phase 1 assessment which was based on 2005 conditions.

The first, and to date only, significant independent study of the condition of Delta levees is included in the Economic Sustainability Plan (ESP) of the Delta Protection Commission, completed in 2011. This study was conducted by the writer and Michael J. Conrad Jr., former commander of the Sacramento District of the Corps of Engineers. Col. Conrad and I had some familiarity with the Delta but our broad engineering experience had been largely accumulated outside the Delta. We conducted extensive interviews with DWR staff and consultants and with reclamation district engineers who work in the Delta. Because DWR at that time had no up-to-date maps of the Delta levee system, with the cooperation of DWR staff who made available various GIS data sets and the results of 2007 LiDAR surveys conducted for DWR, we developed our own map of the Delta levee system and made an assessment of the current condition of the Delta levees. Subsequent to the completion of the ESP, DWR has released the initial version of their own maps which are, not surprisingly because they are based on the same data, generally similar to the ESP map and assessment.

When we commenced our study, there were basically two schools of thought about Delta levees. One, that relied in part on DRMS, that said there were 1,100 miles of levees in poor condition that would fail in a large earthquake, and the other, advanced by engineers who work for reclamation districts, which said that since 1982 significant improvements had been made to many Delta levees and that they were now in reasonably good shape. Col. Conrad and I found, amongst other things, that there are in fact only about 1,000 miles of permanently maintained Delta levees, but our principal finding was that both schools of thought had some merit. We found that the reclamation district engineers were correct in claiming that the Delta levee system was now in reasonable condition overall, but that the "doomsday school" was also correct in asserting that the levee system was still not adequately designed to cope with more extreme flood events, large earthquakes or possible more rapid sea-level rise. The reclamation district engineers had never disputed this second conclusion and it turned out that the difference between the two schools was mostly one of emphasis.

In order to provide at least some detail about the current condition of the Delta levees it is necessary to refer to three different levee standards, the HMP "standard", the Delta-specific PL 84-99 standard, and a higher standard suggested in the ESP that has come to be referred to as the "fat levee" standard.

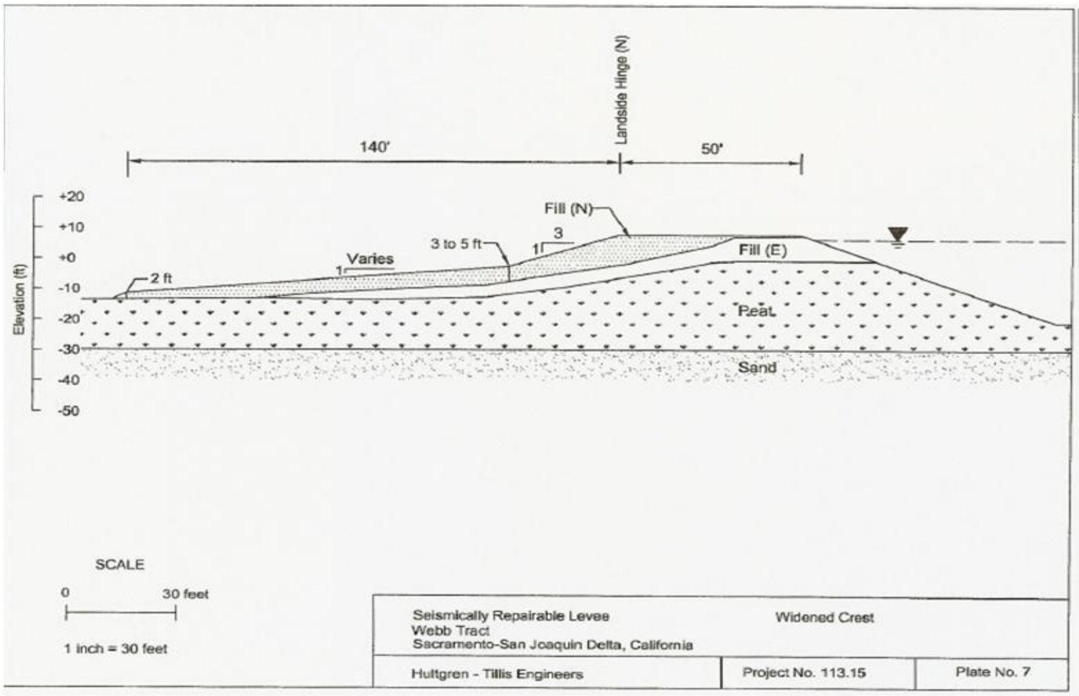
The HMP "standard" is not an engineering standard but is the minimum geometry specified in the "Short Term Mitigation Plan" as defined in "*State of California, FLOOD HAZARD MITIGATION PLAN, 180- Day Report Prepared in Accordance with Section 406 of Public Law 93-288, August 21, 1986*". The same report includes a "Long Term Mitigation Plan" based on DWR Bulletin 192-82 and the U. S. Army Corps of Engineers (USACE) companion document, "*Sacramento-San Joaquin Delta, California, Draft Feasibility Report and Draft Environmental Impact Statement, October 1982*". The Short Term HMP levee geometry was negotiated among FEMA, DWR, and the Delta reclamation districts following Delta disaster declarations resulting from the 1982-83 and 1986 floods. It was rationalized as an interim step with the objective of mitigating and rapidly improving Delta levees on islands (that were then in much worse shape than they are now) so they would be less likely to overtop, or be substantially damaged in the event of another federal disaster event. There was no pretention that the HMP geometry was an adequate long-term technical design standard. The HMP Criteria was solely for the purpose of meeting FEMA Public Assistance eligibility. Levees must protect against water flowing over the levee and water seeping through or below the levee. The HMP "standard" provides a measure of protection against water flowing over the levee but provides no safety requirements for seepage. While the State has been very slow in helping the local reclamation districts complete this interim step, thanks to funding authorized by Propositions 84 and 1E, this goal in now within reach. In fact DWR is currently in the process of administering a round of funding which is expected to bring all Delta levees up to this interim "standard".

The Bulletin 192-82 Long-Term Mitigation Plan evolved into the USACE Delta-specific guideline for non-project levees to qualify for Public Law 84-99 post-flood rehabilitation assistance that was issued in 1987. The PL 84-99 design criteria, which do constitute an engineering standard, are very similar to those in Bulletin 192-82. Under the multi-agency CALFED Bay-Delta Accord (1995 to 2000), the integrity of Delta levees was addressed as a major program area. Part of the resulting Levee System Integrity Program was improvement of all Delta levees to a "base level of protection." The final EIS/EIR stated this commitment as follows: "The CALFED Levee Program will institute a program that is cost-shared among the beneficial users, to reconstruct Delta levees to the Corps' PL 84-99 Delta Specific Standard." This commitment was then reflected in the Record of Decision (ROD) in August, 2000 and was to be implemented through a Memorandum of Understanding between the Corps and DWR executed in July, 2001. While CALFED fizzled out, funds that were generally adequate to cover the State share of improving all Delta levees were included in Propositions 84 and 1E, approved by the voters in 2006. Disbursement of that funding has been delayed for various reasons, including the State's fiscal crisis, but much progress has been made. Details of the expenditures on Delta levees through 2011 are included in the ESP but total spending since 1982 is approaching $700 million. After current projects are completed, only about 350 miles of levees will remain that need to be brought up to the PL 84-99 standard. The funds remaining from Propositions 84 and 1E, together with funds from the USACE Levee Stability Program, an outgrowth of CALFED, should be sufficient to upgrade most Delta levees to the PL 84-99 standard, finally achieving a goal that was first set by the State and federal governments thirty years ago.

However, the PL 84-99 standard does not explicitly address seismically-resistant design, or design for greater than 100-year water surface elevations and makes no accommodation for possible sea-level rise. The 1983 Delta Levees Investigation did suggest that Delta levees should be designed for 300-year water surface elevations but that suggestion has not been included in subsequent standards or revisions. Likely, adoption of the new requirement for urban levees of three feet of freeboard over the 100-year water surface elevation coupled with superior flood-fighting would effectively provide 500-year flood protection. Building to this standard and increasing the crown width to a minimum of 22 feet would increase the cost only marginally over the cost of complying with the Delta-specific PL 84-99 standard and this "PL 84-99 plus" standard may be sufficient for many Delta levees long-term. If the levee in question does not contain or is not underlain by loose sands that are susceptible to liquefaction, these "PL 84-99 plus" levees should be considered to be seismically robust. However, in order to more fully address earthquake loadings, possible sea-level rise and to provide the option for adding vegetation on the water side of levees, a higher Delta levees standard is required. This standard should particularly be applied to most of the lowland levees which face the biggest hazard due to possible sea-level rise and are also the most critical to salinity intrusion, but it might be selectively applied to other Delta levees.

As an example of a levee with increased seismic resistance that also meets other objectives, the cross-section of a proposed seismically-resistant levee taken from a report by Hultgren-Tillis Engineers (HTE) for Reclamation District 2026 (Webb Tract) is shown in Figure 1.

Figure 1 - Example "Fat Levee" Cross Section



Even when assuming that some liquefaction might occur both in the embankment and the foundation, this study indicated that deformations would be limited by the addition of a landslide buttress, as shown in the figure. A key feature of the design shown in Figure 1 is the wide crest. Wider crests not only provide a more robust levee, but also allow for more efficient emergency levee patrol and response when it includes an all-weather traffic surface. The fact that the levee section is overbuilt also means that material could be borrowed from the toe as necessary to quickly rebuild the crests of any levees that actually deform during an earthquake. Levees with wider crests are also the most economical way to provide for possible sea-level rise. While it is the policy of the state to plan for 55 inches of sea-level rise by the year 2100, the probability of that magnitude of sea-level rise is actually very small. While it is not cost-effective or rational to construct levees to those elevations today, the provision of a wider crest with an all-weather traffic surface today has at least three benefits: providing a more robust levee immediately; allowing more room and accessibility for patrol, flood-fighting or emergency response following earthquakes; and allowing a choice of methods for raising the crest elevation in the event of need in flood events and in the long term case of actual sea-level rise. In addition, the provision of a wider crest also allows for retaining or planting of appropriate vegetation on the waterside of the levee. Such planting, creating shaded riverine habitat, should be an essential component of any comprehensive plan to repair the Delta ecosystem.

HTE estimated that this design would cost approximately $2 million per mile in 2009. HTE also looked at more elaborate designs which included either or both of a slurry trench wall or an internal drain. Those designs added up to $5 million per mile to the incremental cost but I believe that the additional features are not generally required and that an average cost of $2-3 million per mile is a reasonable estimate at this time.
If it is assumed that anywhere from 300-600 miles of levees need to be upgraded to this standard, the basic engineering and construction cost would be in the order of $1-2 billion although the overall program cost might well be higher and the ESP suggested an overall program budget of $4 billion.

This higher Delta-specific levee standard might be referred to as a “seismically repairable levee” or a “seismically-robust levee” but because it also addresses other issues it has come to be known by the popular name of “fat levee”. The first “fat levees” addressing these multiple issues were constructed on Upper Jones Tract in 2011 as a result of outstanding cooperation between the local reclamation district, the East Bay Municipal Utility District, DWR and the Department of Fish and Game.

Figure 2 – “Fat Levee” on Upper Jones Tract

While the cost of further improving Delta levees to this "fat levee" standard is non-trivial, as explained in the ESP, that cost can easily be justified because of the value of the infrastructure that the levee system protects and because of the multiple benefits of improved levees. Not only would such a program generate jobs more quickly than the BDCP, but it would reduce the risk to life and property throughout the Delta, protect and enhance the Delta as a place, contribute to ecosystem restoration, and reduce the risk to many kinds of energy and transportation infrastructure in addition to water conveyance.

Are Delta Levees Really Vulnerable to Earthquakes?

The short answer is yes, but not very vulnerable. The two reasons that are normally given for questioning the performance of Delta levees under earthquake shaking are: (1) that they are founded on peat which is a poor foundation material; and (2) that they are founded on or composed of loose sands that are susceptible to the phenomenon of liquefaction.

The first of these assertions is completely wrong. Peat is very compressible under static loads but under cyclic loads peats generate even less excess pore pressures than clays and thus show little or no loss of strength and stiffness. In fact, to the extent that the Delta levees are largely composed of peat, they may be expected to perform better than levees in general under earthquake loadings. Not only is peat expected not to lose strength under earthquake loadings, but, because it is relatively soft, it also might be expected to attenuate ground motions with peak accelerations in the order of 0.2g or more. The relatively good performance of peat under even large amplitude cyclic loadings was demonstrated by a recent test carried out on Sherman Island by researchers from UCLA with funding from the National Science Foundation's NEES program.

Liquefaction might be a problem if loose sands were pervasive in either the foundations or the constructed portion of the Delta levees, but they are not. There are three different situations where loose sands that may be susceptible to liquefaction are found in and under the Delta levees. One possible source of loose sands is the natural levees that underlie some of the present-day levees. The extent of this condition is believed to be limited because few of the present day levees overlie historic natural levees. The second possible source of sands that may be susceptible to liquefaction is hydraulically placed clean sand that has been dredged from the main river channels and placed in adjacent levees without compaction. The actual extent of these materials is unclear and it may be that these materials are sufficiently well drained that most of the excess pore pressures that are generated by earthquake shaking would quickly dissipate so that any deformations would be limited. The third source is the topmost sand layer that underlies the peat. From a geotechnical engineering point of view, the sands that underlie the

Delta can, with the possible exception of the top 10 feet, be characterized as dense to very dense, and actually constitute a good foundation. Meticulous work by Drexler and others at the USGS indicates that the oldest peat deposits are in the order of 7,000 years old so that the underlying sands are at least this old. That age, when combined with the penetration resistances cited by Hultgren-Tillis Engineers in their report on Webb Tract, suggest that even the surficial sands are not particularly susceptible to liquefaction. Even under the 500-year return period ground motions estimated in DRMS, which range from 0.2 to 0.4g in firm soils, significant or widespread deformations from any of these three kinds of sands should not be expected. The repeated citing of levee deformations that were sustained in the Kobe and Christchurch earthquakes, which had higher ground motions and where levees were founded on very loose and recent alluvial soils, is not particularly helpful. However, although these case histories are not directly applicable to the Delta, they do illustrate that levees do not necessarily breach and release water, even when they are quite badly deformed.

Thus, a fair summary would be that the risk of failure of Delta levees due to earthquake shaking cannot be completely dismissed, but that more detailed studies are required to determine whether it even rises to significant levels. What is clear, even without further study, is that the argument that a peripheral canal is needed because of the threat to Delta levees posed by earthquakes, rests on a very shaky foundation.

The Economic Impact of Conveyance Outages

The economic impact of possible conveyances outages caused by earthquakes has been discussed in a recent report by Dr. Jeffrey Micheal of the University of the Pacific and in the presentation by Dr David Sunding at the public meeting on the BDCP on June 20th.

It is unfortunate that Dr. Sunding's presentation had an alarmist focus on a worse than worst case scenario, and just talked about water supply and ignored the bigger picture that must be discussed in any Delta earthquake discussion. For example, Dr. Sunding was trying to sound reasonable in saying that an earthquake wouldn't result in a "refugee" situation due to water shortages. However, the low-probability catastrophic quake and flood he is discussing would result in widespread homelessness and loss of life in the Delta itself, not to mention interruptions of energy and transportation. There would, in fact, be refugees and the water conveyance tunnels would do nothing to prevent it. "Fat" levees are the only viable proposal that truly protects the lives and the economy from a major seismic catastrophe in the Delta.

However, as acknowledged by Dr. Sunding in his verbal comments, for the more realistic periods of outage there is little difference between his estimates and Dr.

Michael's estimates. Limiting the discussion to the more realistic but still conservative outages of 6 to 12 months, Dr. Sunding presented an expected present value of $722 million to $2,093 million for these outage durations. This can be converted to an expected annual value that can be compared to Dr. Michael's annual estimate of $50 million. If the effect of discounting is eliminated, the expected values for 6 and 12 month outage increase to $970 million and $2,812 million. For an expected annual value, this would be multiplied by an annual probability of such a seismic event and failure occurring. According to DRMS Phase 1, the annual probability of 10+ islands failing from earthquake is about 3%, and the annual probability of 30 or more islands failing is about 1%. These failure probabilities are far too high, but I use them to make a point. The expected annual values if you apply a probability range of 1-3% to the expected costs of a 6-12 month outage are as follows:

Annual Probability	6 Month Outage	12 Month Outage
.03	$29.1 million	$84.4 million
.02	$19.4 million	$56.3 million
.01	$9.7 million	$28.1 million

These values are very comparable to the $50 million annual earthquake risk reduction benefit Dr. Michael included in his June 14 report – in fact the median value in the table is only about $30 million. So that even if you use conservative estimates of the likely length of any outage and very conservative estimates of the probability of those outages, the economic impact of an earthquake-induced outage is less than one-twentieth of the estimated annual financing and operating costs of the BDCP, which is over a billion dollars. This goes beyond shaky. It is ludicrous that it is put forth as a principal argument for the BDCP.

Conclusion

There is a real need for an improved system to convey any surplus water from the Sacramento River to users in the San Joaquin Valley and Southern California, but it is not the BDCP as presently planned. If the BDCP as presently planned was justified, it would not be necessary to resort to phony arguments such as there will be widespread failure of Delta levees in a major earthquake and supply will be interrupted for up to three years. Even using very conservative values for the expected duration of outages and the probability of those outages, the economic impact of those outages is trivial when compared with the cost of financing and operating the BDCP.

Furthermore, since the probability of these outages given the current and expected future condition of the Delta levee system is likely characterized by a return period of something greater than 1000 years, why are the lobbyists and flacks for the San Joaquin /Southern California Water Lobby more concerned about earthquakes than they are about a six-year drought which has a return period in the order of 100 years. A six-year drought would decimate farmers and fishermen alike, and force very tight rationing for urban water users, but the BDCP includes no storage and makes no provision for a six-year drought.

I am a professional engineer rather than a politician, but even if I do not fully understand California politics, it seems to me that you are not getting the best possible advice on this important issue and I would urge you seek input from a wider circle of advisors so that you can make a decision about the BDCP based on facts rather than misinformation.

Let's get California working again!

Sincerely.

Robert Pyke Ph.D., G.E.