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FILED/ENDORSED
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By: M. Pipe
Deputy Clerk

BY FAX

SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF SACRAMENTO

Coordinated Proceeding Special Title (Rule 3.550) **OROVILLE DAM CASES**	JCCP NO. 4974 Assigned to: James E. McFetridge, Dept. 30 **DECLARATION OF ROBERT G. BEA IN SUPPORT OF PLAINTIFFS' OPPOSITION TO DEFENDANT'S MOTION TO STRIKE** Date: February 15, 2019 Time: 10:00 a.m.

I, **Dr. Robert G. Bea**, hereby declare as follows:

1. This declaration is made in support of Plaintiff' opposition to Defendant California Department of Resources' Motion to Strike. I have personal knowledge of the matters set forth below and, if called as a witness, I could and would testify competently to the statements herein.

2. This declaration and the opinions I express herein are based upon my education, specialized training, skill, personal experience and knowledge of common and prevailing roles and responsibilities of parties involved in engineering, risk assessment and management, reliability, human and organization factors, construction, maintenance, and operations, and upon my consideration of materials discussed herein.

3. I received my bachelor's and master's degrees in civil engineering from the University of Florida, and obtained a Ph.D. at the University of Western Australia in 2001. I have over 48 years of experience in engineering and management of design, construction, maintenance, operation, and decommissioning marine systems. I have notably contributed engineering expertise following the 2005 levee failures in New Orleans and have weighed in on the investigation of hundreds of disasters.

4. I have served as an independent consultant, and have no present or contemplated future interest in this matter or personal bias with respect to the parties to the litigation.

5. I am currently Professor Emeritus of Engineering and Project Management within the University of California's Department of Civil and Environmental Engineering, and have been teaching at the UC Berkeley since 1989. I am also a member of UC Berkeley's Center for Catastrophic Risk Management (hereinafter, "CCRM").

6. On **May 11, 2017**, I authored the report, *Legislative Oversight Testimony Report: Oroville Dam*. A true and correct copy of this report is attached hereto as **Exhibit 1.**

7. On **July 20, 2017**, I co-authored the report, *Root Causes Analyses of the Oroville Dam Gated Spillway Failures and Other Developments*. A true and correct copy of this report is attached hereto as **Exhibit 2.**

8. On **September 5, 2017**, I co-authored the report, *Analyses of the Oroville Dam 'Wet Spots' Developments*. A true and correct copy of this report is attached hereto as **Exhibit 3.**

This report documents another example of DWR's systematic failures in the management of Oroville Dam.

9. On **January 9, 2018**, I authored the report, *Summary of the Root Causes Analyses of the Oroville Dam Gated Spillway Failures*. A true and correct copy of this report is attached hereto as **Exhibit 4**.

10. I have reviewed the complaints filed by Plaintiffs in their entirety and read all allegations made with respect to DWR's operation and maintenance of the Oroville Dam facilities.

11. I have reviewed Defendant's Motion to Strike portions of complaints and confirm that the Department of Water Resources (hereinafter, "DWR") barred me from inspecting the Oroville Dam site after the crisis, claiming potential "terrorism concerns". I advised them that I was an expert in catastrophic risk management and the head of the CCRM.

12. My root causes analyses investigations have concluded that inappropriate standards and guidelines, procedures and processes were used by DWR to evaluate and manage the risk of failure characteristics of the gated spillway. These standards and guidelines, procedures and processes failed to adequately and properly address aging, technological obsolescence, and increased risk of failure characteristics of the Oroville dam gated spillway. DWR has actively managed the gated spillway to failure.

13.. Issues with Operations and Maintenance include the following: repeated ineffective repairs were made to cracks and joint displacements; and large trees and other vigorous vegetation was permitted to grow adjacent to the spillway walls whereby roots could intrude below the base slabs and into the subgrade drainage pipes resulting in reduced flow and clogging.

14. My investigations have further concluded the root causes of the gated spillway failures are founded primarily in organizational malfunctions due to human and organizational decision-making, task performance, knowledge development and utilization as developed and propagated by DWR during the gated spillway design, construction, and operations and maintenance activities.

15. The most significant examples of organizational influence are the recently exposed existence of inspection reports dating back to 1989. Identified deficiencies were either ignored,

treated as low priority, not acted upon or a combination thereof. However, complacency, lack of industry standard level maintenance, and possibly pressure from internal DWR management and external State Water Contractors' representatives to hold down the maintenance costs were key contributors. The lack of concern and focus on the timely addressing of the dam headworks concrete spalling and cracking, missing welds, gate trunnion cable cracks, and dam abutment "wet spots", all noted deficiencies listed in the inspection reports, serve as prime examples of the DWR culture and failures.

16. The wrong standards and guidelines were being used to re-qualify critical infrastructure systems for continued service. Furthermore, a superficial "Patch and Pray" approach is not an acceptable safety and risk management process for important public infrastructure systems.

17. According to the *CEII Filing Guide* published by FERC,

> **"[The CEII] process is not intended as a mechanism for companies to withhold from public access information that does not pose a risk of attack on the energy infrastructure. Therefore, in an effort to achieve proper designation while avoiding misuse of the CEII designation, the Commission requires submitters to segregate public information from CEII and to file as CEII only information that truly warrants being kept from ready public access."**

18. However, CEII guidelines are not being properly applied by DWR. In several cases, I have been able to obtain both original and redacted documents. Comparisons of the redacted and un-redacted documents indicated in many cases information is being selectively redacted that is unfavorable or contrary to the information being provided by DWR for public access and does not have energy generation and distribution CEII security implications.

19. DWR's pattern of poor decision-making and their inability to tend to the most important of safety tasks is consistent with their attention being focused on other matters. The allegations of racism, sexism, theft, falsified books, and destruction of evidence which have resulted from a toxic organizational culture, if proven, would be consistent with the inattention to dam safety I have observed.

20. I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct. Executed this 30th day of January 2019 at Moraga, California.

ROBERT G. BEA

EXHIBIT 1

UNIVERSITY OF CALIFORNIA, BERKELEY

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Legislative Oversight Testimony Report: Oroville Dam

Dr. Robert G. Bea[a]
Emeritus Professor, Department of Civil & Environmental Engineering
University of California Berkeley
May 11, 2017

Acknowledgements

I have performed a preliminary forensic engineering Root Causes Analysis of the Oroville Dam Gated Spillway failures as an unfunded (650 pro-bono hours) volunteer Affiliate of the University of California at Berkeley Center for Catastrophic Risk Management (CCRM).

The results contained in this Testimony Report have been developed based on document and information sources cited at the end of this report and included in my Preliminary Root Causes Analysis of the Failures of the Oroville Dam Gated Spillway report dated April 17, 2017.[1],[b]

Since early February, I have received significant inputs from many retired former California Department of Water Resources (DWR) Division of Engineering engineers, Operations and Maintenance engineers, and former DWR operators and managers. These individuals were and still are highly respected, and are experienced in the design, construction, operations, and maintenance (O&M) of the California State Water Project (SWP), and in developing preparations for and responding to SWP emergencies assisted by the California Governor's Office of Emergency Services (Cal OES). These individuals received Director-level recognition and awards from the cited State organizations. At this time, these people have requested their names not be made public to help preserve their privacy. These people willingly volunteered their knowledge, experience, documentation, and advice as very important resources to be integrated into this report.

These people have demonstrated consistently their desire to contribute in positive ways to the realization of two primary objectives: 1) attempting to help improve the management,

[a] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEnd05fWUNlVXcyWFk Additional background available at - http://www.mensjournal.com/magazine/bob-bea-the-master-of-disaster-20130225 and http://discovermagazine.com/2013/june/14-master-of-disaster

[b] References cited are included in the section at the end of this report.

engineering, and operations of DWR, and 2) encouraging the State to help DWR secure other essential resources needed to develop, maintain, and improve DWR and SWP operations and the results from them.

The ultimate Goal of these two objectives has been to help reestablish and advance the capabilities of the DWR's and the associated responsible State and Federal agencies groups' to provide for the reliable delivery of a vital resource – water, and to contribute to the provision of associated infrastructure systems,[c] such as those for Flood Protection, that are able to provide essential public infrastructure services having safety[d,2], "as low as reasonably practicable" (ALARP) risks[e], and quality[f] performance characteristics for the citizens of the State of California.

In addition, I have received important inputs, guidance, and other resources to help develop my understanding of the circumstances and factors that were operative during development of the Oroville Dam Spillways from two organizations and groups of concerned citizens who established, operated, maintained, and continue to develop internet group communication websites: 1) Metabunk.org[g] and 2) FreeRepublic.com[h]. These two groups continue to develop the important information and insights that I have attempted to properly interpret and integrate into this report and into my April 17, 2017 report.

The information included in this report represents the results from my efforts to properly integrate the information I have received from these other people and organizations with the other evidence and documentation I have developed.

I would like to thank the State Legislative Oversight Water Committee for the opportunity to present this Report. The opinions in this Report are mine alone. The opinions expressed herein are a fair and accurate summary of my opinions, based upon my experience, education, training, and expertise.

Robert G. Bea

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[c] **Systems** - Interconnected, interactive, interdependent Human, Organization, Hardware, Structure, Environment, Guidelines, Standards, Procedures and Processes and Interfaces between the foregoing Components.

[d] **Safety** – Freedom from undue exposure to injury and harm including capabilities to deliver ALARP Risks.

[e] **ALARP risks** – Combinations of the Likelihoods and Consequences of major infrastructure System failures that are As Low As Reasonably Practicable (ALARP).

[f] **Quality** – combination of public infrastructure system Serviceability (provide important resources and services), Safety, ALARP Risks, Durability (freedom from undesirable, undetected, and un-remediated degradation in System Quality performance characteristics) and Compatibility (freedom significant negative impacts on the environment, public, commerce and industry, and government).

[g] **Metabunk.Org**, accessible at: https://www.metabunk.org/forums/OrovilleDam/

[h] **Free Republic.Com**, accessible at:
http://www.freerepublic.com/focus/search?q=quick&m=all&o=time&s=Oroville+Dam&find=Find , and
http://www.freerepublic.com/focus/news/3524221/posts?q=1&;page=1#1

Conclusions [1]

Results from my forensic engineering study of the failures associated with the Oroville Dam Gated Spillway are preliminary; based on currently publicly available photographic and written documentation I have reviewed.

The flaws and defects incorporated into the Oroville Dam Gated Spillway represent accumulated results from the Gated Spillways Life-Cycle Phases (1965 to February 2017). The life-cycle defects include those developed during design, construction, operations and maintenance (O&M) phases. Of particular importance in this Root Causes investigation were the standards, guidelines, procedures and processes used during the life-cycle phases of the Gated Spillway.

In my April 17th Preliminary Root Causes Analysis report[1], I cited and described specific defects and flaws I was able to identify based on the photographic evidence and documentation referenced and included this report (References section). These identified life-cycle defects, and flaws are summarized in the next section of this report.

My investigation concluded that the effects of the life-cycle flaws and defects were highly interactive and cumulative. These interactions resulted in progressive deterioration of the performance abilities of the Gated Spillway. This process continued until the Gated Spillway failed during the February 2017 Oroville reservoir discharges.

A key root cause that remains to be corroborated is to determine why the defects and resulting damage in the Gated Spillway were allowed to accumulate over such a long period of time (50 years). **My preliminary conclusion is that inappropriate standards and guidelines, procedures and processes were used to evaluate the risk[i] of failure characteristics of the Gated Spillway.** These standards and guidelines, procedures and processes failed to adequately address **aging, technological obsolescence**, and **risk of failure** characteristics of the Orville Dam Gated Spillway.

Recently, as part of the second phase of my forensic engineering Root Causes investigation, I received reports released by the DWR Board of Consultants (BOC)[3] and by the U.S. Army Corps of Engineers (USACE) Institute for Water Resources Risk Management Center.[4] My review of the causes of the Gated Spillway identified in these reports leads me to conclude that these findings substantially corroborate those identified in my April 17th Root Causes investigation report. These reports have provided important additional details and background on the physical and mechanical (engineering) root causes of the Gated Spillway failures.

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[i] **Risk** – Likelihood and Consequences associated with major failures of an engineered infrastructure System.

Defects and Flaws[1]

The following sections summarize the defects and flaws identified during the first phase of this Root Causes investigation:

Design

1. Spillway base slabs of insufficient thickness for the design hydraulic conditions: 4 to 6 inches thick at minimum points;
2. Spillway base slabs not joined with continuous steel reinforcement to prevent lateral and vertical separations;
3. Spillway base slabs designed without effective water stop barriers embedded in both sides of joints to prevent water intrusion under the base slabs;
4. Spillway base slabs not designed with two layers of continuous steel reinforcement (top and bottom) to provide sufficient flexural strength required for operating conditions; and
5. Spillway base slabs designed with ineffective ground anchors to prevent significant lateral and vertical movements.

Construction

1. Failure to excavate the native soils and incompetent rock overlying the competent rock foundation assumed as a basic condition during the spillway design phase, and the failure to fill these voids with concrete, and
2. Failure to prevent spreading gravel used as part of the under-slab drainage systems and native soils to form extensive blankets of permeable materials in which water could collect and erode.

Operations & Maintenance (O&M)

3. Repeated ineffective repairs made to cracks and joint displacements to prevent water stagnation and cavitation pressure induced water intrusion under the base slabs, with subsequent erosion of the spillway subgrade; and
4. Allowing large trees and other vigorous vegetation to grow adjacent to the spillway walls. These roots could intrude below the base slabs and into the subgrade drainage pipes, resulting in reduced flow and plugging of the drainage pipes.

February 2017 spillway release[1]

By the time of the February 2017 spillway releases from the Oroville reservoir, the Gated Spillway had become heavily undermined and the foundation subgrade eroded by previous flood releases. The first spillway release completed the undermining of the spillway slabs, allowing water cavitation to further damage the slabs and open joints and cracks and the development of stagnation pressures and foundation subgrade seepage pressures to lift the weak slabs (hydraulic jacking), breaking them into pieces.

After the almost catastrophic water release over the unsurfaced Emergency Spillway, the subsequent water releases down the gated spillway propagated the initial spillway breach until the spillway releases ceased.

Root Causes Analysis[1]

Currently available information indicates the Root Causes of the Gated Spillway failures are founded primarily in extrinsic uncertainties (due to human and organizational decision making and task performance and knowledge development and utilization) developed and propagated by DWR during the Gated Spillway design, construction, and operations and maintenance activities.[5, 6]

A key question that cannot be answered at this time is: "Why did DWR and other responsible State and Federal regulatory agencies (e.g., California Water Commission[j], Federal Energy Regulatory Commission, Federal Emergency Management Association) allow these root causes to develop and persist during the almost 50-year life of the gated spillway?"

One answer that has been offered is that the spillway was designed and constructed according to the current design standards at the time. While that answer may or may not be the case, current evidence indicates the original spillway design and construction does not meet applicable current guidelines and standards. I have concluded that DWR should have taken the steps to update its design, construction, and O&M standards and upgrade the Oroville Dam facilities. **An "Inspect and repair as best you can, watch it fail, fix it fast, and return to business as quickly as possible" is not acceptable for such vital infrastructure systems.**

Another answer that has been offered is that the spillway operated for almost 50 years, and was subjected to water discharges that exceeded those that developed during 2017 without failure. Inspections performed following these pre-2017 discharges indicated that the spillway was in satisfactory condition. Regulatory oversight (e.g., FERC) concurred that the Oroville Dam facilities were suitable for service; consequently, the facilities have not yet been relicensed for continued operation. The experiences during February and March 2017 have shown that the Oroville Dam facilities were not fit-for-purpose. **These long-term activities resulted in development of regulated failures.**

In addition, the experience prior to the DWR attempt on February 11th to use the adjacent Emergency Spillway[k] **showed that this conclusion was not valid**. The Gated Spillway partially failed (it was damaged extensively) during reservoir discharges that were of much lesser volume than the original Gated Spillway design capacity (approximately one-third) and maximum capacity (approximately one-sixth).[7]

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[j] California Water Commission at https://cwc.ca.gov/Pages/Home.aspx, Federal Energy Regulatory Commission at https://www.ferc.gov/industries/hydropower/safety/guidelines/ridm.asp#guide, Federal Emergency Management Association at https://www.fema.gov/dam-safety

[k] It is not an Auxiliary Spillway. For explanation see referenced report by Don Colson discussed herein.

My previous experiences with formal Root Causes investigations of failures of both public and private industry infrastructure systems (e.g., New Orleans hurricane flood protection system during Hurricanes Katrina and Rita, BP Deepwater Horizon Macondo well blowout, the PG&E San Bruno pipeline explosion, the San Jose Anderson Dam Coyote Creek flooding, and the Plains Pipeline Refugio oil pipeline Santa Barbara spill) lead to the conclusion that **it is likely that the wrong standards and guidelines are being used (applied) to requalify other critical infrastructure systems for continued service.** Like the Oroville Dam Gated Spillway, these critical infrastructure systems had embedded defects and flaws introduced during design, construction, and operating and maintenance life-cycle phases that were combined with aging, technological obsolescence, and increased risk effects.[1]

My reviews indicate the majority of standards and guidelines currently being used were originally intended for design, not requalification or reassessment of existing aged infrastructure systems that have experienced aging, technological obsolescence, and increased risk effects. My reviews indicate in many cases that inappropriate standards and guidelines are being used to re-qualify these infrastructure systems for continued service. **The currently available information indicates this continued long-term use of out-of-date standards, guidelines, processes and procedures is likely one of the primary Root Causes of the failures of the Orville Dam Gated Spillway.**

Short-Term Recommendations

Recommendation #1

DWR and other responsible organizations should closely examine the **current condition of the Headworks of the Gated Spillway**. I have obtained documentation and written testimony that provides plentiful evidence (e.g., DWR annual inspection reports 2008-16[1]) that there are important existing defects and damage in critically important parts of this Gated Spillway subsystem. The reported defects and damage include failed and cracked trunnion anchor rods and cracked reinforced concrete gate supporting structures. I have not been able to find any evidence that these important Gated Spillway subsystem components have been included in the current DWR Gated Spillway repair and rehabilitation planning. If my analysis is correct, these very important Gated Spillway subsystem components should be included in the current DWR Gated Spillway repair and rehabilitation planning. Reservoir releases are controlled by the

[1] These processes are similar to those people experience during their lives. They are born with flaws and defects developed during the **design phase** conducted by their mother and father. They develop additional flaws and defects during the **Construction Phase** by their mother. After birth, as they begin the long-term **operations and maintenance phases,** where the design and construction defects are combined with **aging** (damage due to high-stress demands, wear-out fatigue processes, abuse, accidents, things not done right, etc.), **Technological obsolesce** (due to healthier parents and environments developing people with increased – improved capabilities), and **increased risk** effects (likelihoods and consequences of injuries, sickness, and other hazards) develop and accumulate. The people can be repaired, rehabilitated, and change what they do until they enter and complete the last Phase – **decommissioning** – and the process starts again.

spillway gates. If the structural support and anchorages are inadequate to support the gate loadings, catastrophic failure of the gates could occur.

In addition, I have received and carefully reviewed three reports I received during my investigation.[8, 9] These reports document the investigators study of persistent "wet spots" near the abutments of the Oroville Dam. The DWR Orville Dam inspection reports I was able to obtain very early during my investigation (early February, covering 2008 – 2016 inspections) clearly showed these wet spots.[m] The cited inspection reports contain a series of photographs that show the continued development of these persistent wet spots. Recently, I have read the proceedings of public meetings where these persistent wet spots were discussed. In one case, the speaker suggested they are "natural springs."

I understand the dangers and consequences associated with the "cry wolf" syndrome: if the cry comes too often and nothing bad happens, then concerns for and awareness of the wolf decrease and eventually disappear. This will continue until the wolf shows up and eats its victims.

My assessment based on the information I have been able to obtain and access, and my previous experiences with similar structure-foundation systems threated by seepage effects with "cry wolf" early warnings of persistent potentially important challenges and consequences have taught me the *Precautionary Principle*: "Guilty until proven innocent."

I strongly recommend that DWR and the associated organizations having responsibilities and accountabilities for the safety, reliability, and quality of the Oroville Dam infrastructure system focus high quality field investigations and analyses of the results from these investigations to determine and confirm if important seepage is taking place. If such threats are confirmed, then proven effective remediation measures should be implemented to prevent being "eaten by the wolf."

Recommendation #2

Responsibility for the operation and maintenance of the State Water Project is given to DWR's Division of Operations and Maintenance (O&M). The evidence I have obtained indicates the O&M Division currently has very limited technical expertise to properly respond to all the technical problems and issues it must face.

Periodic assessments of the State Water Project facilities are conducted by the O&M Division. Field inspections and documented inspection reports generally are developed by DWR's Division of O&M's engineering staff and Division of Engineering staff.

I recommended that the many resources available to the O&M Division be more effectively utilized in the current and future repair and rehabilitation O&M developments, including those

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[m] Cited inspection reports included in my April 17, 2917 Preliminary Root Causes of the Failures of the Gated Spillway report: https://drive.google.com/open?id=0Bz1I1mIutSEnSUY5WjluQmhPXzg

of the Division of Engineering, Division of Safety of Dams, State water contractors, and qualified independent technical experts.

The O&M Division had the sole discretion to determine the scope, extent and results of the assessments it is responsible for conducting. Evidence indicates there is insufficient independent oversight or review of these assessments to ensure they include appropriate and accurate evaluation of the facilities being assessed. Advanced O&M guidelines, standards, and procedures need to be effectively utilized in development of these evaluations.

Recommendation #3

DWR, in cooperation with the Federal Energy Regulatory Commission (FERC), have developed and engaged an "*...independent forensic review team to investigate the causes of the spillway failures.*" The Forensic Review Team has initiated its work.

DWR and FERC have appointed a highly qualified and experienced "*...core group with expertise in various engineering disciplines.*" Further, DWR has proposed that "*Additional technical support will be added as required based on the ongoing investigation by the core team.*"

My review of the resumes and backgrounds of the members of the Forensic Review Team indicates that these members have very highly developed knowledge, skills, experience, and background in the technical engineering, engineering management, construction, and operations and maintenance elements essential for what needs to be accomplished. They are highly qualified engineering technical experts. I think we are very fortunate to have these people working to learn the lessons that the Oroville Dam spillway failures are trying to teach us, to develop and corroborate the facts, to learn the truths, recommend "fixes," and to document these things so that similar potential failures can be better prevented, avoided, and mitigated if they were to occur.

Based my review of the resumes and backgrounds of the members of the Forensic Review Team, I recommend that an additional member be added to the team who has formal training and experience in forensic root causes investigations of major failures and disasters involving complex engineered systems.[n] Such formal training has been provided by the American Society of Civil Engineers Forensic Engineering Committee, the U.S. National Transportation Safety Board, the U.S. Chemical Safety Board, the U.S. Nuclear Regulatory Agency, and the U.S. Federal Aviation Administration.

Also, I recommend another member, or other members, be added to the Forensic Review Team who has had formal training and experience in analysis of the human and organizational factors in root causation of major failures and disasters involving complex engineered systems. These members should have qualifications similar to those of the current Forensic Review team,

[n] If one or more of the members of the current Forensic Review Team already have such training that was not included in their resumes, then this recommendation is not needed.

except their qualifications are those of experts in human and organizational factors: psychology, organizational behavior, political and social sciences, economics, and if possible, the law. These individuals need to be added to the current Forensic Review Team because previous experience from formal Root Causes investigations of engineered infrastructure systems have clearly shown the majority (more than 80 percent) of important Root Causes are those attributed to human and organizational factors.[10]

Complex systems fail in complex ways.[6,8] The training, knowledge, and experience of the Forensic Review Team must have the requisite variety of both technical-engineering and human and organizational causative factors included in the failed system to be able to properly identify the variety of important factors involved in development of the Root Causes of the Oroville Dam spillway failures.

As stated earlier, formal Root Causes Analysis investigations generally have found human and organizational factors make up the predominant category of Root Causes of past major failures and disasters involving engineered systems. To allow such Root Causes to be included in a forensic review, DWR and FERC and other involved organizations must allow the Forensic Review Team access to relevant correspondence, records of communications, and results from interviews of personnel who were directly involved in past and current decision making and other important activities that are potentially Root Causes of the spillway failures.

Experience with results from formal Root Causes Analysis Investigations have demonstrated amply that it is particularly challenging for the organizations directly involved in causing a major failure and that have had primary responsibilities and accountabilities for the safety and acceptable performance of a complex engineered system to be able to enable a truly *independent* Root Causes Analysis investigation. This experience has shown that it is "normal and natural" for organizations and individuals directly involved in causation of major failures to be defensive and protective of their organizations and themselves. Such organizational defensive and protective influences and potentially imposed constraints associated with these influences can have important negative effects on the ability of a Forensic Review Team to be truly independent.

It is recommended that all reasonable and effective steps should be taken by DWR and FERC management and other concerned organizations to assure organizational and personnel defensive and protective influences and constraints are not allowed to degrade the true independence of the Forensic Review Team. The Forensic Review Team needs to be empowered and enabled to as accurately as possible determine, corroborate, and describe the important human and organizational factor related causes of the spillway failures so the Forensic Review Team can recommend effective ways such failures can more effectively be prevented and mitigated in the future. The objective of these analyses is not "blame and shame"; it is to learn how to implement effective measures that can provide Oroville Dam facilities that are safe and reliable and will have quality performance characteristics for the remaining service life of this very important California infrastructure system.

Recommendation #4

In my preliminary Root Cause Analysis report[1], I did not address the failures associated with and following the DWR decision to divert the Oroville reservoir discharges to the adjacent Emergency Spillway.

During the work I did to gather background documentation, photographic evidence, and other important evidence, I developed a significant knowledge database regarding the subsequent developments that resulted in the Evacuation Order and return of the Oroville reservoir discharges to the Gated Spillway.

I tracked (monitored) these developments as closely as possible. Because of earlier work I had done, I knew I was watching a very important story develop about System Risk Assessment and Management (SRAM) Crisis Management.[11, 2] After the dust settled, I thought several major things had gone wrong. The story had too many potentially avoidable unintended consequences and critically important near misses. For me, it was clear important changes were needed in how DWR and the associated organizations were managing the Oroville Dam crisis. This was an important potential "teachable moment" if the lessons could be extracted and understood.

Crisis Management is an element included in the three basic SRAM Approaches:

1) **Proactive** – work done before project completion (quality assurance, emergency training, safe work instructions and training, etc.),
2) **Reactive** – work done after project completion (emergency management, crisis response – rescue and restoration, learning, defining needed corrective actions), and
3) **Interactive** – work done while activities are being conducted (e.g., quality control, supervision, and management—including planning, organizing, leading, controlling, observing closely, diagnosing and implementing corrective actions, and crisis management).

One of the important reasons for Interactive SRAM regards one of the very important human and organizational extrinsic uncertainties; the uncertainty associated with knowledge development and utilization. This uncertainty has been organized into two basic categories:

1) **Unknown Knowables**. Often referred to as "black swans," the knowledge exists, but it has not been recognized, accessed, and properly used and understood, and
2) **Unknown Unknowables**. This category is intended to recognize an important limitation in human cognition; we cannot know all of the important things that are going to happen in the future; these things are fundamentally not knowable or predictable.

This second category of uncertainty can be addressed with real-time **"OODA looping"**:

1) **Observe** – use all of the collective group senses involved in the developing crisis to gather data and other information to help understand what is happening.
2) **Orient** – develop a realistic understanding of what is really happening, and what might be happening; assess the resources available to help control and manage what is happening and what might be happening; develop options that are practical, given the

available resources that possibly could arrest escalation and mitigate effects, include in each of these options provisions for "Plan B" activities providing for escape with minimum unintended consequences.

3) **Decide** – select the option that the collective group thinks has the best chances for success, and if success cannot be realized, then have provisions that will allow for Plan B escape.
4) **Act** – implement the chosen success option, learn the lessons from the implementation, and repeat the OODA looping until success is achieved.

The OODA looping process originally was developed by the U.S. Army Air Corps during WWII to help prepare aircraft pilots and crew for under-attack crisis management situations. The OODA looping process has been incorporated with other similar processes[o] into advanced technology for crisis (emergency) management.[8,9]

The single most important resource involved in effective crisis management are the human and organizational resources involved in the activities and the systems provided to support the crisis management activities and to provide protections (security) for those who perform the processes: **"The right stuff with the right support."** The Department of Homeland Security have published a Crisis Management Handbook intended specifically to help dam owners, operators, and regulators improve their Interactive SRAM processes.[12]

One of the unnamed colleagues I included in the Acknowledgements section of this report (Don Colson, retired DWR engineer) has written a white paper documenting his work to understand why DWR made the decision to divert the discharges from the Oroville reservoir from the damaged Gated Spillway to the Emergency Spillway.[13]

Don Colson's analysis of the available evidence concerning this important decision is that the DWR decision to divert the discharges to the Emergency Spillway could have been avoided by effective management of the discharges sent down the Gated Spillway. While Don Colson's analysis of the factors involved in development of this crisis management decision may or may not be accurate, his work highlights the importance of the decision making processes used during "high-pressure environments in which uncertainties are great."

I recommend that DWR develop an externally funded project with the University of California Berkeley Center for Catastrophic Risk Management (CCRM)[p] to gather, analyze, and document information developed by DWR during management of the Emergency Spillway Crisis, integrate this knowledge with advanced proven crisis management technology, document the results, and transfer the results to DWR in the form of project reports, group discussions, workshops, and seminars.

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[o] Example – Crew Resource Management (CRM) processes utilized by the U.S. Aviation Transportation Industry and Government (e.g. Air Traffic Control Centers).[8]

[p] University of California Berkeley Center for Catastrophic Risk Management - http://ccrm.berkeley.edu/

The Executive Director of CCRM, Dr. Rune Storesund (rune@berkeley.edu), has agreed to help organize, manage (plan, organize, lead, control), and conduct the project. Dr. Storesund was a principal investigator in the Katrina New Orleans flood protection infrastructure failures, was the Principal Investigator in a similar investigation of the 2008 Midwest flood protection systems failures, and was a senior researcher in the NSF Resilience and Sustainability – Engineered Infrastructure (RESIN) California Delta Infrastructure project. Dr. Storesund is highly qualified in the theory and practice associated with SRAM technology.

CCRM would be able to help organize a forum for highly qualified and experienced academics and practitioners (CCRM Affiliates) to perform the proposed project. Several current CCRM Affiliate members and several retired DWR—California Emergency Management Association engineers, managers, and operators—have expressed interest in participating in this project as CCRM Affiliates. If possible and if needed, I could serve as a project advisor.

The proposed project team would engage project participants and advisors nominated by DWR. This would be a project conducted at the University of California Berkeley, a public forum sensitive to infrastructure security requirements (Homeland Security, Federal Emergency Management Association), and sensitive to the needs for short-term and long-term communications with the public. This project would develop and mobilize an effective technology delivery system.[14]

Long-Term Recommendations

Recommendation #1

DWR and the other responsible organizations have demonstrated important needs for additional resources – primarily human and organizational resources – to help DWR and the other responsible organizations get the proposed spillway repairs and rehabilitation efforts completed so those parts of the Oroville Dam system can meet current applicable **SRAM-based** standards and guidelines for development of **high-reliability organizations** having **high-reliability management** able to deliver **high-reliability systems** with **ALARP risks**.[15] This development would go above and beyond the current standards and guidelines currently cited by DWR and the DWR Board of Consultants. The Oroville Dam is an extremely important part of the SWP and of California's public infrastructure systems. Going forward, the best available and safest technology should be used.

This recommendation is based on experiences and results from a four-year duration research and development project sponsored by the NSF and conducted by the Center for Catastrophic Risk Management (CCRM) at the University of California Berkeley. This project was identified by NSF as the RESIN systems project.[q]

[q] University of California CCRM NSF RESIN research and development project - http://ccrm.berkeley.edu/resin/

This project had two fundamental goals: 1) further develop and validate advanced analytical processes and procedures that could provide realistic quantitative evaluations of Risks associated with operations of complex engineered infrastructure systems—SRAM processes, and 2) apply these advanced validated SRAM analytical processes and procedures to the infrastructure systems in the California Sacramento – San Joaquin Delta.[9]

The advanced SRAM analytical procedures and processes were developed and validated with applications to past infrastructure failures.[9] Then, these validated SRAM analytical procedures and processes were applied to several specific infrastructure systems that had particular importance to continued operations in the California Delta.[9] These specific structure locations were identified with a Geographic Infrastructure System (GIS) developed specifically for the RESIN project in accordance with the guidelines provided by the Department of Homeland Security and the Federal Emergency Management Association.

The locations were identified as choke points – locations where failures would trigger failures of the other infrastructure systems that were in the same locations; these multiple infrastructure systems were interconnected, interdependent, and highly interactive. Two environmental conditions were specified: 1) potential flooding events during 2010, and 2) potential flooding events during 2100 (including potential effects from global climate changes, and continued use of the 2100 inspection, maintenance, and repair O&M processes and procedures).

The two locations chosen for the application of the advanced analytical formulations and processes were: 1) Sherman Island and 2) Natomis Basin. Representatives from local, state, and federal government agencies that had responsibilities for the infrastructure systems were involved in these developments (e.g., DWR, California Emergency Management Agency, U.S. Army Corps of Engineers, Sherman Island Reclamation Board, U.S. Coast Guard, University of California Davis, University of Colorado, Mills College). During this project, the RESIN research project team involved 35 faculty members, 73 undergraduate and graduate students in courses developed for this project, six post-doctoral researchers, and many other vital support personnel.

Results from the applications were documented extensively in public reports and reports to NSF, and published in reports, presentations, graduate and undergraduate courses, and refereed conference and journal publications. Results from the applications were presented to public and government representatives concerned with the infrastructure systems located at Sherman Island and the Natomis Basin.

The two applications of the advanced SRAM processes and procedures to the infrastructure systems at the two locations had one consistent result:[16] **The risk of major infrastructure systems failures were not "tolerable" or "as low as reasonably practicable" based on U.S. and international risk tolerability guidelines.**

The recent experiences with other U.S. infrastructure systems have served to corroborate results from these NSF RESIN Infrastructure SRAM studies (New Orleans hurricane flood protection system during Hurricanes Katrina and Rita, BP Deepwater Horizon Macondo well blowout, the PG&E San Bruno pipeline explosion, the Anderson dam Coyote Creek San Jose flooding, and the Plains Pipeline Refugio oil pipeline Santa Barbara spill). **The infrastructure SRAM challenges at the Oroville dam involve much more than the Oroville Dam infrastructure system challenge. These infrastructure SRAM challenges also are state[17] and national challenges.[18]**

Recommendation #2

DWR's Management, Division of Engineering, and Division of O&M standards, guidelines, procedures, and processes should be founded on the **proven best available SRAM** technology. This technology includes, but goes beyond, that currently documented in the U.S. Army Corps of Engineer's Dam Safety guidelines.[19, r]

The most important "goes beyond" elements concern those associated with human and organizational factor uncertainties.[9] These elements should be included in valid and validated procedures and processes required to develop "realistic" assessments of the likelihoods and consequences (risks) of major failures and for development and implementation of effective risk management barriers – standards, guidelines, procedures, and processes – used during the life-cycle of important public and private infrastructure systems. Analyses of these "human" uncertainties are combined with those included in many traditional engineering analyses: natural (inherent) variabilities and analytical model uncertainties. All four categories of uncertainties must be included to develop full-scope Risk Analyses, **thus avoiding the "E3" error of "working the wrong problems precisely."[2, 13]**

Other countries have continued, and are continuing, to implement advanced SRAM standards and guidelines to help manage, engineer, construct, operate and maintain their important infrastructure systems. Examples include those developed and implemented by the U.K. Health and Safety Executive in their Safety Case Regime developments, and by the governments of Australia and New Zealand in their Risk Management Guidelines.[20,21] The International Standards Organization (ISO) have developed and published a large number of very useful standards based on SRAM that have been incorporated into those of the U.K. Health and Safety Executive, and those of Australia and New Zealand.[22] In addition, similar standards and guidelines have been developed and implemented in Norway and the Netherlands.[23]

[r] More background provided at http://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/About-the-Program/Policy-and-Guidance/, www.iwr.usace.army.mil/...Risk-Management/Flood-Risk-Management-Program/, *and* http://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/About-the-Program/Policy-and-Guidance/Federal-Flood-Risk-Management-Standard/

In the U.S., the commercial Nuclear Power Generation and Transmission organizations and owner-operators (e.g., the PG&E Diablo Canyon nuclear power plant) and the U.S. Nuclear Regulatory Commission (NRC) for many years have applied this proven advanced technology.[s] Similarly, the commercial public air transportation organizations (e.g. United Airlines, Boeing Aircraft Company) and the U.S. Federal Aviation Administration (FAA) have applied this technology in development of their standards, guidelines, procedures and processes. These organizations have developed an admirable record for safety and reliability. The U.S. Chemical Safety Board (CSB) and Center for Chemical Process Safety have advanced a similar set of standards and guidelines for implementation of safety case regimes for high hazard chemical processing facilities.[t]

Experience during the past several decades has shown that SRAM technology, if properly implemented, can be very useful to help develop and maintain *safe* (risks are ALARP) and *reliable* (high likelihoods of delivering acceptable performance) systems. **This experience has also shown that if not properly implemented, SRAM technology can be very counterproductive.** Some of this experience has shown that improper implementation can help cause major infrastructure system failures.[2, 8]

Experience and results from analyses of 10-year duration formal efforts by seven organizations to effectively apply SRAM technology has shown that **"Five Cs"** are required to be able to develop and maintain safe and reliable systems.[24] The **Five Cs** are:

1) **Cognizance** – the involved organizations must develop an acute awareness of the hazards and threats that confront their systems. Worry and concern is constant. Awareness is crucial. Diligence to maintain systems with ALARP Risks is even more critical.
2) **Commitment** – the management and operating personnel must develop a sustained 'top down and bottom up' commitment from those involved that the necessary resources (human, organizational, monetary, knowledge, experience, physical, environmental) will be provided to enable effective application of ALARP risk management 'barriers' (integrated proactive, reactive, and interactive processes) to enable development and maintenance of systems that have ALARP risks. The commitment must be to develop high reliability organizations with high reliability management that will consistently deliver systems having ALARP risks.
3) **Culture** – The beliefs, values, feelings, and resource allocation and utilization processes of the organization must be one devoted to "Getting it right, doing it right and knowing what is right," delivering Systems that have ALARP risks, and understanding that these efforts require constant vigilance, diligence and continuous improvements.

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[s] Nuclear Regulatory Commission SRAM Probabilistic Risk Analyses (PRAs) - http://www.nrc.gov/about-nrc/regulatory/risk-informed/pra.html

[t] https://www.aiche.org/ccps/topics/elements-process-safety/commitment-process-safety/process-safety-culture

4) **Capabilities** – The human, organizational, and other parts of the systems (combinations of human operators, responsible organizations, hardware, structures, environments, standards and guidelines, and the interfaces between these interconnected, interactive, interdependent **components**) must be highly developed and "excellent" so the proven principles of SRAM technology can be properly and effectively developed and implemented. These efforts are focused on continuous improvements to enable realization of the different kinds of benefits from application of SRAM technology.

5) **Counting** – This is a very important 'C.' Counting means development of valid and validated *quantified metrics* (with numbers) that can be used by managers, engineers, and operations and maintenance personnel to help them determine system risks (likelihoods and consequences) throughout the life-cycle of a system. These valid and validated metrics serve the same purposes as an automobile speedometer; to give the diver/s dependable ways to determine the safe speed, given the road, traffic, weather, and surrounding community conditions; the safe speed (ALARP risk) depends on the local conditions. Risks that are ALARP are based on quantitative monetary cost-benefit evaluations that include proper recognition of both short-term and long-term monetary costs (direct, indirect, onsite, offsite, property, productivity, quality of human life, and environmental impacts), standards-of-practice evaluations, historic precedents, and national and international standards and guidelines for determination of ALARP risks.[25] What is effectively measured can be more effectively managed.

Reflections

During the course of my Root Causes investigation of the failures of the flood protection systems for the Greater New Orleans developed during Hurricanes Katrina and Rita, I developed an analytical formulation to express causation of major engineered infrastructure Systems:

A + B = C

- **'A'** are natural hazards that confront infrastructure systems: heat, cold, water, ice, floods, droughts, earthquakes, etc.
- **'B'** are human and organizational hazards that confront systems: hubris, arrogance, complacency, greed, corruption, ignorance, indolence, etc.
- **'C'** are major failures sooner or later.[2]

This "equation for disasters" was based on results from my 35 major in-the-field Root Cause investigations of failures involving engineered infrastructure Systems and more than 600 studies of results from other investigations.[u] My motive for this work has been to learn how and why the miserable experiences happened so I could better understand how they could be prevented, and then to communicate what I learned to my colleagues and students.

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[u] More information on these investigations available at: available at https://drive.google.com/open?id=0Bz1I1mIutSEnd05fWUNIVXcyWFk

Results from this experience have been consistent: **it is the *human factors* that are the primary challenge to being able to develop safe and reliable engineered infrastructure systems. This is the reason for emphasizing in this report the need to develop high-reliability organizations with high-reliability management that can deliver high reliability systems having ALARP risks**.

The experience of the 2017 failures of the spillways at Oroville dam have been painful for all involved in and with these failures. The word 'failure' is a cruel word. But I think the "blood, sweat, toil, and tears" experiences associated with these failures can result in future major gains—successes at Oroville Dam and elsewhere—if we will use the best available technology, knowledge, and experience.

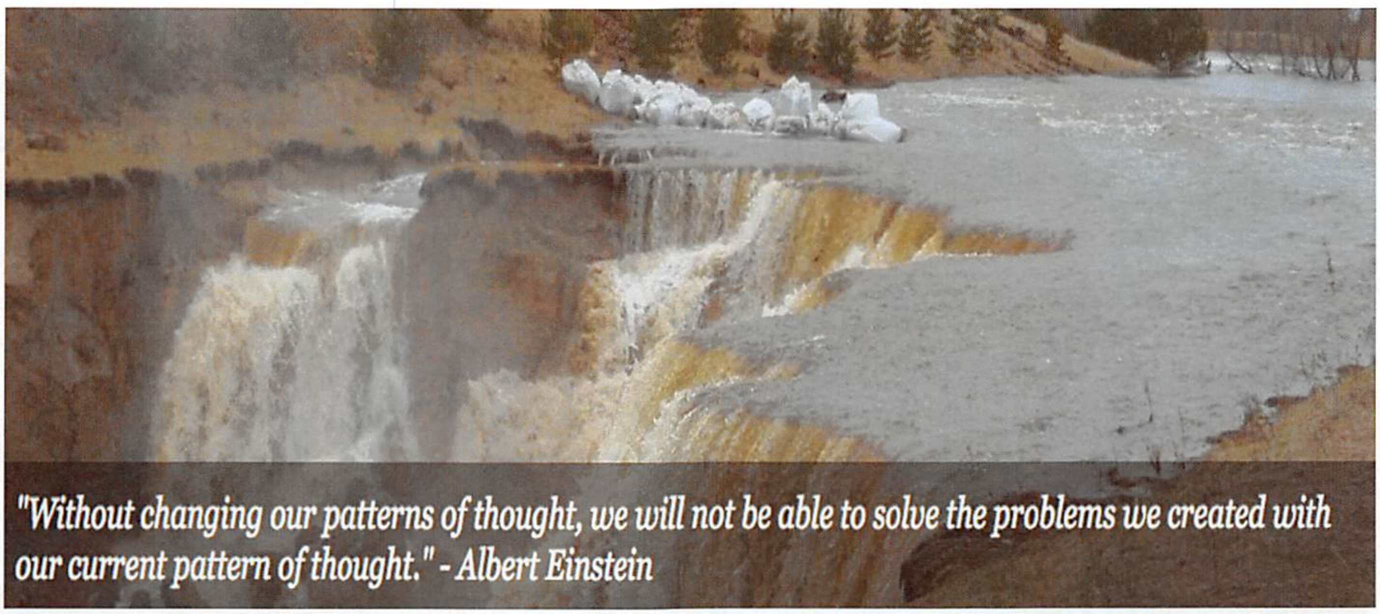

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EXHIBIT 2

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Center for Catastrophic Risk Management

Providing Solutions
for catastrophic risks to societal infrastructures

Root Causes Analyses of the Oroville Dam Gated Spillway Failures and Other Developments

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July 20, 2017

[a] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEnd05fWUNIVXcyWFk
Additional background available at - http://www.mensjournal.com/magazine/bob-bea-the-master-of-disaster-20130225 and http://discovermagazine.com/2013/june/14-master-of-disaster

[b] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEneTN6YlNKRVdZcGs

Introduction

We have performed forensic Root Causes Analyses of the Oroville Dam Gated Spillway failures and other associated developments as unfunded (approximately 3,000 pro-bono hours) volunteers of the University of California at Berkeley (UCB) Center for Catastrophic Risk Management (CCRM) Oroville Dam Advisory Group (ODAG). We initiated this work on January 27, 2017.

The results contained in this report have been developed based on the currently available public document and information sources cited at the end of this report, included in the Preliminary Root Causes Analysis of the Failures of the Oroville Dam Gated Spillway report dated April 17, 2017, and in the Legislative Oversight Report: Oroville Dam report dated May 11, 2017.[c, 1]

This report documents our analyses of the Root Causes of the initial failure of the Gated Spillway. Appendix A of this report provides summaries of the procedures and processes we used to perform the Root Causes analyses, background on the components that comprise Engineered Systems, and background on the Human and Organizational Factor malfunctions (errors) responsible for failures of Engineered Systems. Appendix B provides details of our analyses of the Physical and Organizational Root Causes of the initial failure of the Gated Spillway.

The opinions expressed in this Report are ours alone. The opinions expressed herein are a fair and accurate summary of our opinions, based upon our experience, education, training, and expertise.

Robert Bea and Tony Johnson

[c] References cited are included in the References Section at the end of this report together with Google Document links to archived copies of the available cited documents.

Acknowledgements

In January 2006, Professor Raymond Seed and the first author of this report co-founded the UCB CCRM.[d] CCRM was formed as a multi-disciplinary, multi-campus research and development center that focused on prevention and mitigation of major failures involving engineered infrastructure systems.

Starting in 2009, CCRM served as the focal point for a Research and Development Project sponsored by the National Science Foundation identified as the RESIN (Resilient and Sustainable Infrastructure Systems) Project.[e] This project developed, validated, and applied advanced System Risk Assessment and Management (SRAM) to the California Delta Infrastructure Systems.[f] During this 6-year duration project, specific infrastructure systems located in the California Delta (e.g. flood protection, emergency evacuation, Sherman Island, Natomas Basin) were studied to determine the risks associated with extreme condition storms based on 2010 and 2100 environmental conditions (including projected global climate changes).[g] Results from the RESIN project provided important starting points for this investigation.

During May 2017, the UCB CCRM Executive Director, Dr. Rune Storesund, initiated formation of the Oroville Dam Advisory Group (ODAG). The UCB CCRM ODAG was formed to provide a public source of information on the developments associated with the failures and potential developing failures of different components in the Oroville Dam System. This work included development of specific short-term and long-term recommendations for 'going forward.' Currently, the UCB CCRM ODAG has 15 members that include senior academic faculty, citizens concerned with the Oroville Dam developments, retired California Department of Water Resources (DWR) managers, engineers, and operators, and local business, environmental and government group representatives.[h]

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[d] CCRM background available at http://ccrm.berkeley.edu/

[e] CCRM National Science Foundation sponsored RESIN project background available at http://ccrm.berkeley.edu/resin/

[f] Detailed descriptions of System Risk Assessment and Management processes, approaches, and analytical formulations available at https://drive.google.com/open?id=0Bz1I1mIutSEnUEJtbmluSVVCa0U and https://drive.google.com/open?id=0Bz1I1mIutSEnTFVkaDUxLTNYZ2M

[g] Products (documents, reports, videos) developed by the RESIN project are available at
https://drive.google.com/open?id=0Bz1I1mIutSEnOEV1TkFxS2JsZFU
https://drive.google.com/open?id=0B0_jjqbhy5meOENOSzRGbTVJNFU
https://drive.google.com/open?id=0Bz1I1mIutSEnclRwVGNHanVfb1U
https://drive.google.com/open?id=0Bz1I1mIutSEnanczemd2MDBySXc
https://drive.google.com/open?id=0Bz1I1mIutSEneklySnZnOHJkWWM
https://drive.google.com/open?id=0Bz1I1mIutSEnX3gyN2FpWjE3NGc

[h] Current list of CCRM ODAG members available at https://drive.google.com/open?id=0Bz1I1mIutSEnWUpfZWkxU0NmOTQ

Since early February, we have received significant inputs from many retired former California Department of Water Resources (DWR) Division of Engineering engineers, Operations and Maintenance engineers, and former DWR operators and managers. These individuals were and still are highly respected, and experienced in design, construction, operations, and maintenance (O&M) of the California State Water Project (SWP) facilities, and in developing preparations for and responding to SWP emergencies assisted by the California Governor's Office of Emergency Services (Cal OES). These individuals received Director level recognition and awards from the cited State organizations. At this time, with one exception[i], these people have requested their names not be made public to help preserve their privacy. These people willingly volunteered their knowledge, experience, documentation, and advice as very important resources that have been integrated into this report.

These people have demonstrated consistently their desire to contribute in positive ways to realization of two primary Objectives: 1) attempting to help improve the management, engineering, and operations of DWR, and 2) encourage the State help DWR secure other essential resources needed to develop, maintain, and improve DWR and SWP operations and the results from those operations.

The ultimate Goal of these two Objectives has been to help re-establish and advance DWR and the Division Of Safety of Dams (DSOD) and the associated responsible State and Federal agencies groups (e.g. State Water Contractors) capabilities to provide for the reliable delivery of a vital resource – water, and to contribute to provision of associated Infrastructure Systems,[j] such as those for Flood Protection, that are able to provide essential public infrastructure services having desirable Safety,[k,2] As Low As Reasonably Practicable (ALARP) Risks[l], and Quality[m] performance characteristics for the citizens of the State of California.

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[i] updated Don Colson report on Emergency Spillway use disastrous decisions available at https://drive.google.com/open?id=0Bz1I1mIutSEnZGFlNzhoS2tvMkU

[j] **Systems** - Interconnected, interactive, interdependent Human, Organization, Hardware, Structure, Environment, Guidelines, Standards, Procedures and Processes and Interfaces between the foregoing Components.

[k] **Safety** – Freedom from undue exposure to injury and harm including capabilities to deliver ALARP Risks. For more background: https://drive.google.com/open?id=0Bz1I1mIutSEnbUgwUXZ6WXlYMmc https://drive.google.com/open?id=0Bz1I1mIutSEnUkpQcXRGQklDbHM

[l] **ALARP Risks** – Combinations of the Likelihoods and Consequences of major infrastructure System failures – Risks - that are As Low As Reasonably Practicable (ALARP) based on Historic, Current Standards of Practice, and Monetary short-term and long-term present-valued Costs (direct, indirect, current, future) – Benefit (failures prevented and mitigated, decreases in Likelihoods and Costs) analyses and assessments.

[m] **Quality** – combination of public infrastructure system Serviceability (provide important resources and services), Safety, ALARP Risks, Durability (freedom from undesirable, undetected, and un-remediated degradation in System Quality performance characteristics) and Compatibility (freedom significant negative impacts on the environment, public, commerce and industry, and government).

Of particular importance to this phase of our investigation is the report written by two members of the CCRM ODAG that summarizes ***The "Watering Down" of the Department of Water Resources Division of Safety of Dams.***[n] This report summarizes DWR and DOSD multi-decade progressive 'Losses of Core Competencies' and contains recommendations for DWR – DSOD re-organization, management, operations, maintenance, and engineering resources and oversight.

In addition, we have received important inputs, guidance, and other resources to help develop our understanding of the circumstances and factors that were operative during development of the Oroville Dam Spillway failures from two organizations and groups of concerned citizens who established, operated, maintained, and continue to develop internet Group Communication web sites: 1) Metabunk.org[o] and 2) FreeRepublic.com[p]. These two groups continue to develop important information and insights we have attempted to properly interpret and integrate into this report.

We have compiled a series of discussions previously posted on FreeRepublic.com that have particular importance in this phase of our investigation. This compilation is provided in this report as a single down-loadable reference.[q] The major issues addressed in this series are:

1) DWR's decision to Split the Spillway design in 1960's - Politics of Engineering Judgment: How Failure is introduced - #2596
2) Cracked Anchor Tendons & Failures, FERC, DWR engineering data conflicts & changing definitions, unknowns of tendons - #3334
3) DSOD Inspector "unloads" in report - DWR's indifference to maintenance - DWR using seepage flow as "crude" replacement for lost Piezometers - #3675
4) Headworks design flaw - Shear cracking in Pier Columns - Risk to FCO gate structures - differential settlement of bridge lift footing - #3703
5) Large Concrete Block formation by DWR in "deep void" filling - erosion forming voids - drain pipe dropping & clogging by concrete/grout entering drain lines -tree roots - #3704
6) DSOD Inspector report notes that known defective areas in spillway repairs will be performed only after damage from heavy flows - #3707
7) FERC issues a long list of corrections to DWR on Quality Control Inspection Program (QCIP). Demonstrates lack of engineering experience by DWR on QCIP - #3778
8) Radial Gate Side Seal Assembly issues - design flaws? - excessive leakage of side seals deemed "normal" by DSOD - susceptible to debris jamming? - divers removing wedged debris to open gates - #3846/3847

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[n] The "Watering Down" of the Department of Water Resources Division of Safety of Dams available at https://drive.google.com/open?id=0Bz1I1mIutSEnUks4T3ljdjlLcWs

[o] **Metabunk.Org** ,accessible at: https://www.metabunk.org/forums/OrovilleDam/

[p] **Free Republic.Com**, accessible at:
http://www.freerepublic.com/focus/search?q=quick&m=all&o=time&s=Oroville+Dam&find=Find and http://www.freerepublic.com/focus/news/3524221/posts?q=1&;page=1#1

[q] Compiled Free Republic Oroville Dam spillway failures discussions available at https: https://drive.google.com/open?id=0Bz1I1mIutSEnZ1BDXzAwZS12cDA

9) Water Vortex in front of Emergency Spillway noted & photographed by DSOD - withheld this information in public reports - discrepancy Found in FERC Performance Review document - why keep from public? - #3862
10) DWR Organizational Ethics - Engineering Incompetence or Engineering Deception - Flawed information - Press Releases, Town Halls, Press interviews, Legislative Testimony - #3903
11) New Oroville Spillway 1:50 Model testing - Scalability issues - Forensic Team "stalling"? Politics? - Suggested Forensic Team HOF issues to investigate - #3924
12) Former DSOD Chief admits "Maybe we did miss it" (signs to spillway failure) - points to Forensic Team to give an answer - "maybe" verses "Known or Unknown" - #3931
13) DWR twisting BOC's comments? Turning them into "conclusions"? Highly Misleading? -Preemptive strike to mute intentional use of "fill material" in building of spillway? - #4012

Of particular importance to this phase of our investigation is a series of ten (10) reports authored by the second author of this report. These reports address four categories of 'breakdowns' associated with the Oroville Dam 'System':[r]

1) Persistent existing 'Leaks' and 'Wet Spots' on and around the dam (Reports 1 – 4),
2) Persistent existing 'Cracks' in the Gated Spillway Headworks reinforced concrete supporting structure and broken and cracked gate anchor 'tendons' (Reports 6, 7, 10),
3) Progressive failures of the Gated Spillway and historic 'patchwork' repairs (Reports 5, 8), and
4) DWR – DSOD mis-management 'liabilities' (Report 9).

Summary of Conclusions

The flaws and defects incorporated into the Oroville Dam Gated Spillway represent accumulated results from the Gated Spillway's Life-Cycle Phases (1965 to February 2017). The Life-Cycle defects include those developed during Design, Construction, Operations and Maintenance (O&M) Phases. Of particular importance in this Root Causes investigation[s] were the Standards, Guidelines, procedures and processes used by the California Department of Water Resources (DWR) and the associated Division of Safety of Dams (DSOD) during the life-cycle phases of the Gated Spillway.

The California Code of Regulations and The California Water Code **charge DWR and DSOD with primary responsibilities and accountabilities for specified State Water Supply dams and reservoirs during their lives: *"...as to the Safety of design, construction, maintenance, and operation of any dam or reservoir."*** [t]

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[r] Compiled reports 1 – 10 authored by Tony Johnson available at https://drive.google.com/open?id=0Bz1I1mIutSEnR3U4QVY2TFRWLWc

[s] See Appendix A pages 1-4 for background on performance of Root Causes Analyses.

[t] A compiled summary of DWR – DOSD responsibilities, accountabilities and practices is available at https://drive.google.com/open?id=0Bz1I1mIutSEnWTJsM2Q4V0F3MTA

In the April 17^{th} Preliminary Root Causes Analysis report[u] and the May 11^{th} Legislative Oversight Testimony report[v], specific defects and flaws in the Gated Spillway were cited and described that could be identified and corroborated based on the photographic evidence and documentation referenced in those reports' references. A summary of the analyses of the physical causes of the initial failure in the Gated Spillway was provided.

Our Root Causes Analyses investigations have concluded the physical effects of the life-cycle flaws and defects incorporated into the Gated Spillway were **highly interactive and cumulative. The interactions resulted in progressive deterioration of the performance abilities of the Gated Spillway and resulted in reduction of its Safety and increases in its Risk of failure. This process continued until the Gated Spillway failed during the early February 2017 Oroville Dam reservoir discharges.**

Our Root Causes Analyses investigations have concluded **that 'inappropriate'[w] standards and guidelines, procedures and processes were used by the Department of Water Resources (DWR) and the associated Division of Safety of Dams (DSOD) to evaluate and manage the Risk[x] of failure characteristics of the Gated Spillway.** These standards and guidelines, procedures and processes failed to adequately and properly address **Aging, Technological Obsolescence**, and **Increased Risk of failure** characteristics of the Orville Dam Gated Spillway.

Due to the multi-decade 'Loss of Core Competencies', the management of DWR and DSOD failed to provide adequate Management (planning, organizing, leading, controlling), Engineering, Operations, and Maintenance personnel 'skills, knowledge and performance capabilities' and other important 'resources' required to effectively prevent and mitigate the failures of the Gated Spillway.[m] **The Gated Spillway was 'managed to failure' by DWR and DSOD.**

In addition, the available evidence indicates validation and approval of the long-term continued **use of these 'inappropriate' standards, guidelines, procedures and processes** was provided by the Federal Energy Regulatory Commission (FERC). **The Gated Spillway was 'regulated to failure' by FERC.**

We have received 'redacted' reports released by the DWR Board of Consultants (BOC)[y] and the DWR Forensic Engineering Team (FET),[z] and by the U.S. Army Corps of Engineers (USACE)

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[u] Report available at https://drive.google.com/open?id=0Bz1I1mIutSEnSUY5WjluQmhPXzg

[v] Report available at https://drive.google.com/open?id=0Bz1I1mIutSEnWHozRUsyNFl1Y2c

[w] 'Inappropriate' – intentional deviations from mandated acceptable practice Standards and Guidelines.

[x] **Risk** – Likelihood and Consequences associated with major failures of an Engineered System.

[y] Reports available at https://drive.google.com/open?id=0Bz1I1mIutSEnOXdGMU1Ob0JGcFE
https://drive.google.com/open?id=0Bz1I1mIutSEnWXB4NVNRVUhsR1U
https://drive.google.com/open?id=0Bz1I1mIutSEnT3ZDcll6NDZkRnM

[z] Report available at https://drive.google.com/open?id=0B0_jiqbhy5meVEpjR1RlZExBR1E

Institute for Water Resources Risk Management Center.[aa] Also, we have received a report written by Bernard Goguel that provides a summary of his analyses of the initial failure in the Gated Spillway.[bb]

Our reviews of the physical causes related to design, construction, operation and maintenance of the Gated Spillway identified in these reports leads us to conclude these findings substantially corroborate those identified in the April 17th Preliminary Root Causes investigation report, summarized in the May 11th Summary and Recommendations report and in this report. These additional reports have provided important additional details and background on the life-cycle Physical Root Causes of the Gated Spillway failures.

Summary of Gated Spillway Defects, Flaws, Development of Initial Failure, and Root Causes

The following sections summarize the Gated Spillway's physical defects and flaws, initial failure, and Root Causes of this failure identified during this investigation. The evidence (documentation and photographic) to support these identifications are cited in each of the following sub-sections and the References Section of this report:

Design[1,3]

1. Spillway base slabs of insufficient thickness for the design hydraulic conditions: 4 to 6 inches thick at minimum points;
2. Spillway base slabs not joined with 'continuous' steel reinforcement to prevent lateral and vertical separations;
3. Spillway base slabs designed without effective water stop barriers embedded in both sides of joints to prevent water intrusion under the base slabs;
4. Spillway base slabs not designed with two layers of continuous steel reinforcement (top and bottom) to provide sufficient flexural strength required for operating conditions; and
5. Spillway base slabs designed with ineffective 'ground' anchors to prevent significant lateral and vertical movements.

Construction[1,4]

1. Failure to excavate the native soils and incompetent rock overlying the competent rock foundation assumed as a basic condition during the spillway design phase, and fill the voids with concrete, and
2. Failure to prevent spreading gravel used as part of the under-slab drainage systems and 'native' soils to form extensive 'graded blankets' of permeable materials in which water could collect and erode.

[aa] Report available at https://drive.google.com/open?id=0Bz1l1mlutSEnN2V2VnJ2cVhJWVE

[bb] Report available at https://drive.google.com/open?id=0Bz1l1mlutSEncnVEUktrQkNjRms

Operations & Maintenance[1,5]

3. Repeated ineffective repairs made to cracks and joint displacements to prevent water stagnation and cavitation pressure induced water intrusion under the base slabs with subsequent erosion of the spillway subgrade, and in some cases, to effectively 'plug' and severely decrease water flow through the spillway drains; and
4. Allowing large trees and other vigorous vegetation to grow adjacent to the spillway walls whose roots could intrude below the base slabs and into the subgrade drainage pipes resulting in reduced flow and plugging of the drainage pipes.

Development of Initial Failure

Appendix B summarizes a chronological progression of Root Causes analyses to the final genesis of the Initiating Blowout Failure, including the specific Root Causes 'pre-failure conditions.' A collection of critical evidential photographs, document clips, and images, from the combing through of thousands of pages of source information and a combined effort of thousands of hours of research and analyses, provides translation of the foregoing summaries to failure - into a 'walk through' of the cause and effect chronological progression ending in the final blowout of the spillway on February 7, 2017. The 'walk through' chronology also provides insight into the Human and Organizational Factors involved in how conditions continued to progress despite the many signs of distress in the spillway.

By the time of the February 2017 spillway releases from the Oroville reservoir, the Gated Spillway had become heavily undermined and the foundation subgrade eroded by previous flood releases. The spillway releases completed the undermining of the spillway slabs, allowing water cavitation to further damage the slabs and open joints and cracks, and develop stagnation pressures and foundation subgrade seepage pressures to further erode the supporting soils and degraded rock and lift the 'weak' slabs ('hydraulic jacking') breaking them into pieces.

After the almost catastrophic water release over the un-surfaced Emergency Spillway, the subsequent water releases down the gated spillway propagated the initial spillway breach until the spillway releases ceased.

Organizational Root Causes

Our investigations have concluded the Root Causes of the Gated Spillway failures are founded primarily in Organizational Malfunctions (see Appendix A and Appendix B) due to human and organizational decision making, task performance, knowledge development and utilization as developed and propagated by DWR and DSOD during the Gated Spillway Design, Construction, and Operations & Maintenance activities.[6, 7]

The report titled ***The "Watering Down" of the Division of Safety of Dams"*** concludes:[cc]

> *"The most significant examples of organizational influence are the recently exposed existence of DSOD inspection reports dating back to 1989. For reasons yet to be fully determined, identified deficiencies were either ignored, treated as low priority, not acted upon or a combination thereof.* ***However, complacency, lack of industry standard level maintenance, and possibly pressure from internal DWR management and external State Water Contractors' representatives to hold down maintenance costs were key contributors. The lack of concern and focus in the timely addressing of the Dam Headworks concrete spalling and cracking, missing welds, gate trunion cable cracks, and dam abutment "wet spots", all noted deficiencies listed in reports generated by DSOD, private engineering consultant(s), the Board of Consultants (which reports to the Director), US Army Corps of Engineers, and FRCIT, serve as prime examples of the DWR culture and failures."***

In 2009, the American Society of Civil Engineers issued a report titled **"Guiding Principles for the Nation's Critical Infrastructure."** [11] This identified four guiding principles that form the foundation for **Risk Management** of the Nation's Critical Infrastructure:

1. Quantify, communicate, and manage Risk,
2. Employ an integrated Systems approach,
3. Exercise sound Leadership, Management, and Stewardship in decision-making processes, and
4. Adapt critical infrastructure in response to dynamic conditions and practice.

This report states: ***"these guiding principles are fully interrelated. No one principle is more important than the others and all are required to protect the public's safety, health, and welfare."***

A fundamental premise integrated into these four guiding principles is **Risk Management**. ASCE recommended four things needed to effectively integrate risk assessment, risk management, and risk communication strategies into our nation's critical infrastructure programs:

1. Produce a best-practices guide and develop and publish codes, standards, and manuals for assessing and communicating risk.
2. Develop a public-policy framework that establishes tolerable risk guidelines and allocates costs for managing risks and consequences.
3. Provide professional education and training to members of the design and construction industries on identifying, analyzing, and mitigating risk.
4. Screen all existing critical infrastructure projects to determine if updated risk analyses are warranted. **Require that Risk Analyses be performed for all proposed critical infrastructure projects.**

[cc] The "Watering Down" of the Department of Water Resources Division of Safety of Dams available at https://drive.google.com/open?id=0Bz1I1mIutSEnUks4T3ljdjJLcWs

In 2016, the Federal Energy Regulatory Commission (FERC) issued **Risk-Informed Decision Making (RDIM) Risk Guidelines for Dams.** [16] These risk-based guidelines were issued 40 years after President Carter's 1977 Memorandum on the Safety of Dams that explicitly addressed "risk based analysis,"[dd] and 7 years after the American Society of Civil Engineers issued the Guiding Principles for the Nation's Critical Infrastructure that also explicitly addressed "**manage risk.**" **There is no evidence that FERC or DWR - DOSD utilized this background during the Operations and Maintenance inspections of the Gated Spillway.**[1,5]

The Orovile Dam Gated Spillway failure – self-destruction was preventable. Over decades, there were many opportunities for DWR, DSOD, and FERC to recognize and investigate serious issues that could have led to effective remedial measures. Evidence[ee] documented in this Root Causes Analysis Investigation (Appendix B) reveals the significant extent in decades of missed opportunities for DWR, DSOD, and FERC to detect and investigate severe anomalies.[8]

The lack of recognition of the significance of the severe issues revealed in Appendix B, from the beginning of the construction of the spillway to present, reveals the long-term systematic failures of DWR, DSOD, and FERC to identify and rectify critical components of the Oroville Dam Gated Spillway to the required level of the **Operating Standard of Care:** ***thus, "Negligent."***[9] These egregious long-term repeated failures violated the **First Principle of Civil Law**: "***imposing Risks on people if and only if it is reasonable to assume they have consented to accept those Risks.*" Risk control is a central goal of Civil Law**[10]

We have concluded DWR and DSOD should have taken the steps to update the design, construction, O&M standards and upgrade the Oroville Dam facilities so as to satisfy its documented Statutory, Regulatory, and Management responsibilities for the Safety and Risk Management of these facilities.[f] A superficial **'Patch and Pray'** approach is not an acceptable Safety and Risk Management Process for important public infrastructure Systems.

Previous experiences from formal Root Causes investigations of failures of both U.S. public and private industry infrastructure Systems (e.g. New Orleans hurricane flood protection system during Hurricanes Katrina and Rita[ff], BP Deepwater Horizon Macondo well blowout[gg], and the PG&E San Bruno pipeline explosion[hh]) lead to the conclusion **the wrong standards and**

[dd] 1977 Memorandum available at https://drive.google.com/open?id=0Bz1I1mIutSEnTGlSRzBMNTBsTDA

[ee] A summary of the written evidence contained in DWR – DOSD and FERC inspection reports is provided in - https://drive.google.com/open?id=0Bz1I1mIutSEnNG1Vem9lYlFFcjA

[ff] Katrina Investigation - https://drive.google.com/open?id=0Bz1I1mIutSEnSlBkVWktZi1uX28
https://drive.google.com/open?id=0Bz1I1mIutSEnNnEwbGRSV3ZxRHM

[gg] BP Deepwater Horizon Investigation -
https://drive.google.com/open?id=0Bz1I1mIutSEnVVdwbnF6czJGTmM
https://drive.google.com/open?id=0Bz1I1mIutSEnM2NrcnpPOEhzY00
https://drive.google.com/open?id=0Bz1I1mIutSEnRjFsUms2TVJRalk
https://drive.google.com/open?id=0Bz1I1mIutSEnbGRRdjlMc3FsSTg

[hh] PG&E San Bruno Investigation - https://drive.google.com/open?id=0B0_jiqbhy5meWGV5aEtVeFE5OUU
https://drive.google.com/open?id=0Bz1I1mIutSEnTTEwcEpLRjFPWHM

guidelines were being used (applied) to re-qualify these other critical infrastructure systems for continued service. Like the Oroville Dam Gated Spillway, these critical infrastructure systems had embedded defects and flaws introduced during Design, Construction, and Operating & Maintenance that were combined with Aging, Technological Obsolescence, and increased Risk effects.

Similarly, these infrastructure systems purportedly were designed, constructed, operated, and maintained according to the "Standards and Guidelines of the time." **In all cases, the evidence indicates there were multiple intentional deviations from these Standards and Guidelines during their entire life-cycles.** All of these infrastructure Systems were regulated by Local, State, and Federal agencies. These major failures also represented 'Regulated Failures.'

Further, our previous experiences from formal Root Causes investigations indicate the majority of Standards and Guidelines currently being used were originally intended for design, not re-qualification or re-assessment of existing aged infrastructure Systems that have experienced Aging, Technological Obsolescence, and increased Risk effects. Our reviews indicate in many cases 'inappropriate' standards and guidelines were being used to re-qualify these infrastructure systems for continued service. **The currently available information indicates this continued long-term use of 'out-of-date' and 'inappropriate'[ii] Standards, Guidelines, processes and procedures is one of the primary Root Causes of the failures of the Orville Dam Gated Spillway.**

Other Developments

Gated Spillway Headworks

We have reviewed documentation and written testimony that provides plentiful evidence (e.g., DWR – DOSD - FERC annual inspection reports 2008-16) there are important existing defects and damage in critically important parts of this Gated Spillway subsystem. The reported defects and damage include failed (2) and cracked (28) spillway gate anchor tendons (Figure 1), cracked reinforced concrete gate supporting structures (Figure 2), and severe gate binding.

We have not found evidence these important Gated Spillway subsystem components have been included in the current or future DWR – DOSD – FERC Gated Spillway repair and rehabilitation planning. If the structural support and anchorages are inadequate to support the gate loadings, catastrophic failure of the gates could occur with catastrophic effects. Given the extreme importance of the Spillway Headworks, DWR – DOSD and FERC should be required to take effective actions to properly remediate these important structural components. Advanced Quality Assurance and Quality Control (QA/QC) equipment and methods should be used to assure that the desired initial and long-term Safety and Reliability characteristics of this important structure are achieved and maintained.

[ii] 'Inappropriate' - intentional deviations from mandated 'acceptable practice' standards and guidelines.

Figure 1: Broken (2) and cracked (28) spillway gate control anchor tendons.

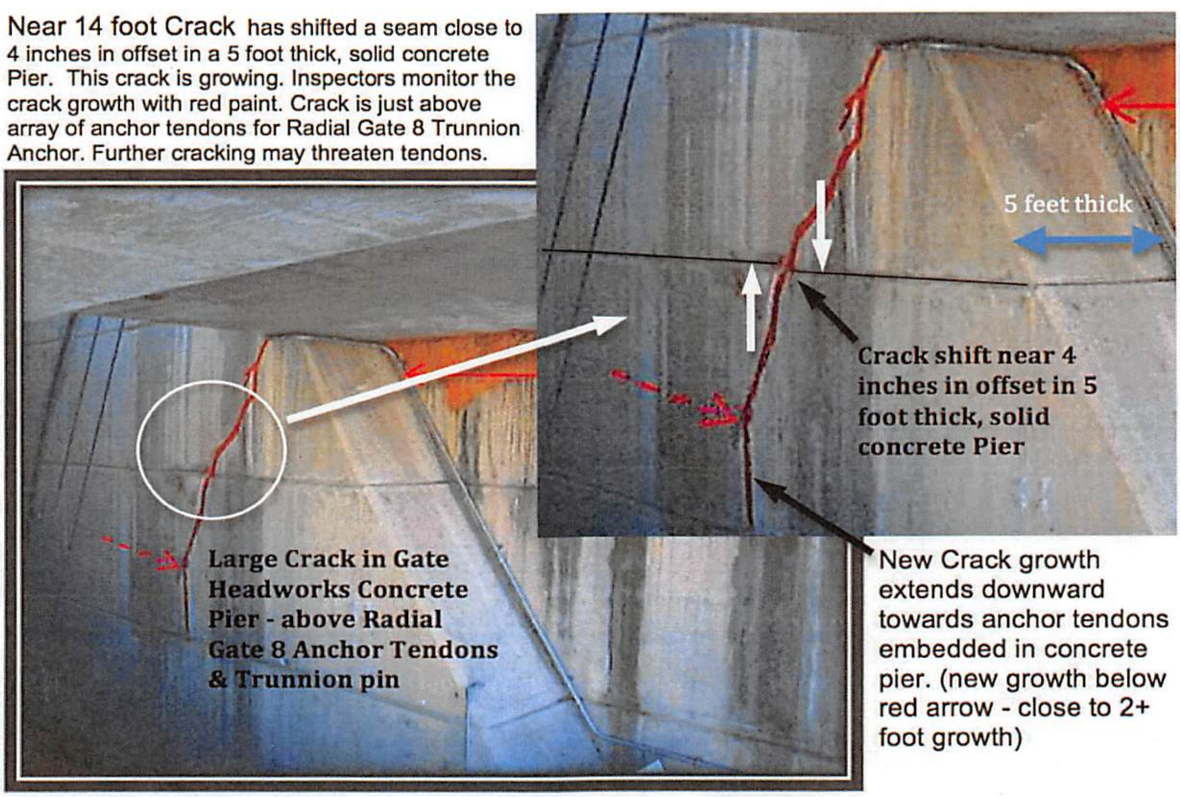

Figure 2: Gate Headworks cracked reinforced concrete pier support structure.

Three reports written by the second author of this report review and analyze the available documentation on these concerns. These reports are summarized below and identified as Reports 6, 7, and 10:[q]

Report 6: Large 14 Foot Crack in Headworks? Cracking Radial Gate Steel Tendons? Threat to Spillway yet no Repairs in 2017? A threatening 14 foot long crack growing in a massive 5 foot thick concrete pier at Radial Trunnion Gate 8 in Oroville's Spillway Headworks? DWR Board investigating how many of the internal cracking of the 50 year old aging "end of life" 384 steel anchor tendons may fail before they deem the Headworks operationally unsafe? Two steel tendons have already failed, test data reveals 28 more with crack indicators in the steel, some near the "critical failure size". Yet DWR doesn't know with certainty how many more are at risk of failure? Are there any plans to fix these major spillway Gate Headworks issues with emergency repairs for 2017? Why hasn't DWR revealed this information to the public?

Report 7: Headworks Cracking Risking 3 Highest Level FERC Category 1 Probable Failure Modes? New Design Flaws Discovered? The Federal Energy Regulatory Commission (FERC) requires Potential Failure Mode (PFM) assessments at dams in a process to proactively identify modes of "potential" failure as a method to ensure appropriate safe operating performance margins. PFM's are an integral part of the FERC Dam Safety and Surveillance Monitoring Reporting process (DSSM's). High Reliability Systems, such as a dam and a spillway structure, require a constant assessment of conditions where FERC and the dam owners cooperate in this proactive DSSM's based exercise. Thus any findings requiring actions, whether further assessment or structural remedies, provide safeguarding the level of failure probabilities to "As Low As Reasonably Practicable" (ALARP). Civil law is based on this principle when entering into "controlling risk as effectively as possible"

Report 10: Will Oroville Spillway Gates Fail in Heavy Flows? Design Flaws & Fixes Risk Gate Binding? In 2007, during an official Federal Energy Regulatory Commission (FERC) Inspection, Radial Gate 4 jammed after only lifting 6 feet of its 33 foot travel. From the perspective that all components of the Spillway Radial Gates are considered a High-Reliability System, what ensued in the subsequent Engineering Failure Analysis Report findings could only be read as an engineering nightmare. Quoting the Report: "During Federal Energy Regulatory Commission required operational testing Spillway Gate No. 4 would only open to approximately 7 feet at which time the motor would trip offline from overload." "Initial inspection found heavy galling marks on the right side wall plates as well as protruding bolts on the seal assembly directly adjacent to the wall plates. A bronze plate was also found between the wall and seal. This plate was later determined to be from a retrofit done in 1974." "The seal assemblies were removed and disassembled. A large amount of mud and debris was found behind the seal. The seal inflation piping was completely filled with mud and debris also. One bronze guide shoe was damaged beyond repair." "Two main items were attributed to the gate binding: 1. Lack of maintenance caused the system to degrade and become clogged with mud and debris. 2. Due to irregularities in the seal assemblies - it appears they were not properly adjusted for the proper clearance over the entire length of the seal."

Oroville Dam Persistent 'Wet Spots'

We have reviewed DWR – DOSD – FERC Oroville Dam inspection reports covering the period 2008 – 2016. These reports contain a series of photographs that show the continued development of 'Leaks' and 'Wet Spots near the dam abutments (Figures 3, 4, 5).

DWR - DSOD, and FERC should be required to focus high quality field investigations and detailed analyses of the results from these investigations to determine and confirm if important seepage is taking place in and around the Oroville Dam. If such threats are confirmed, then proven effective remediation measures should be implemented and validated to assure that the dam is 'Safe' and 'Reliable' for current and future use.

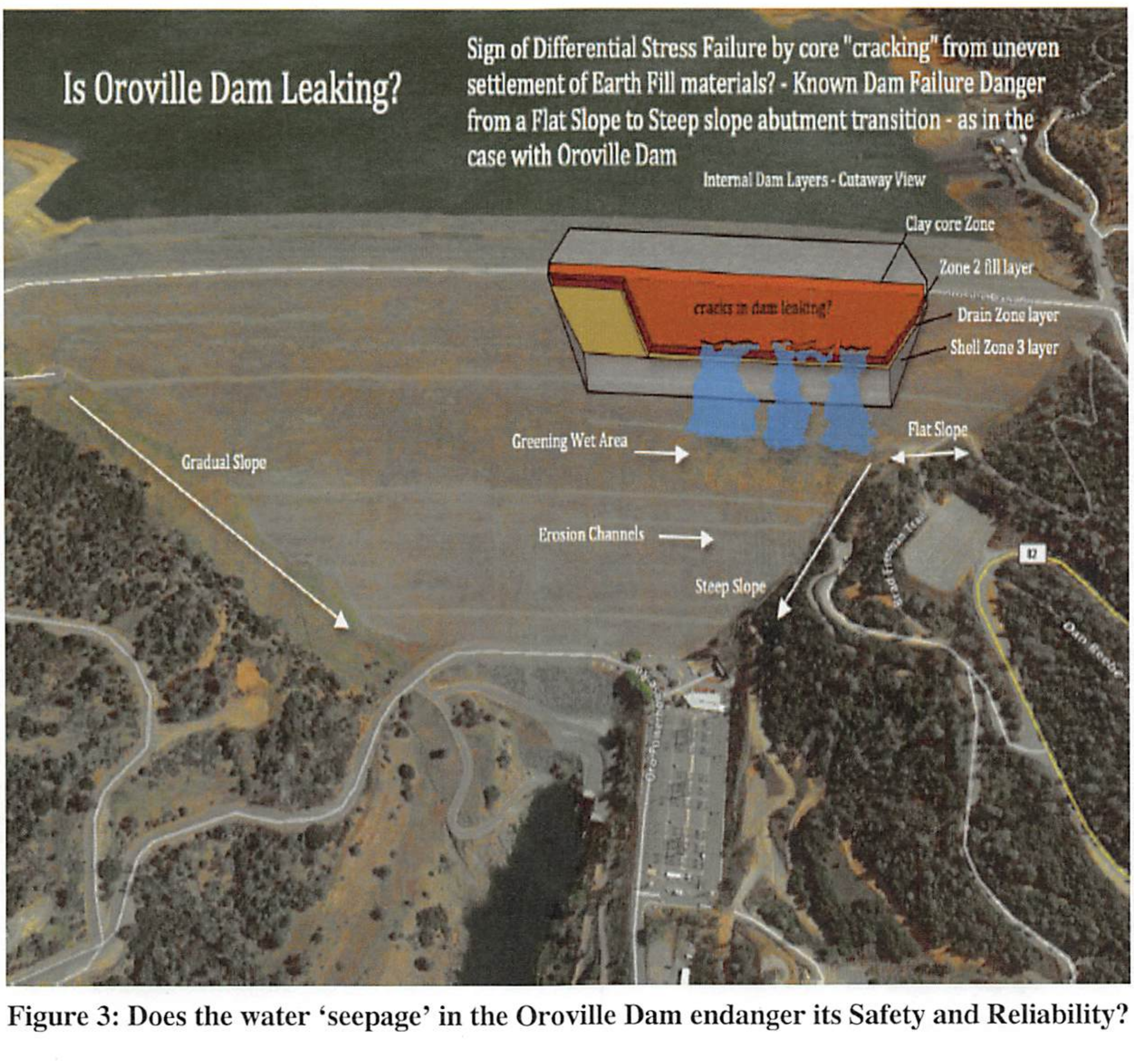

Figure 3: Does the water 'seepage' in the Oroville Dam endanger its Safety and Reliability?

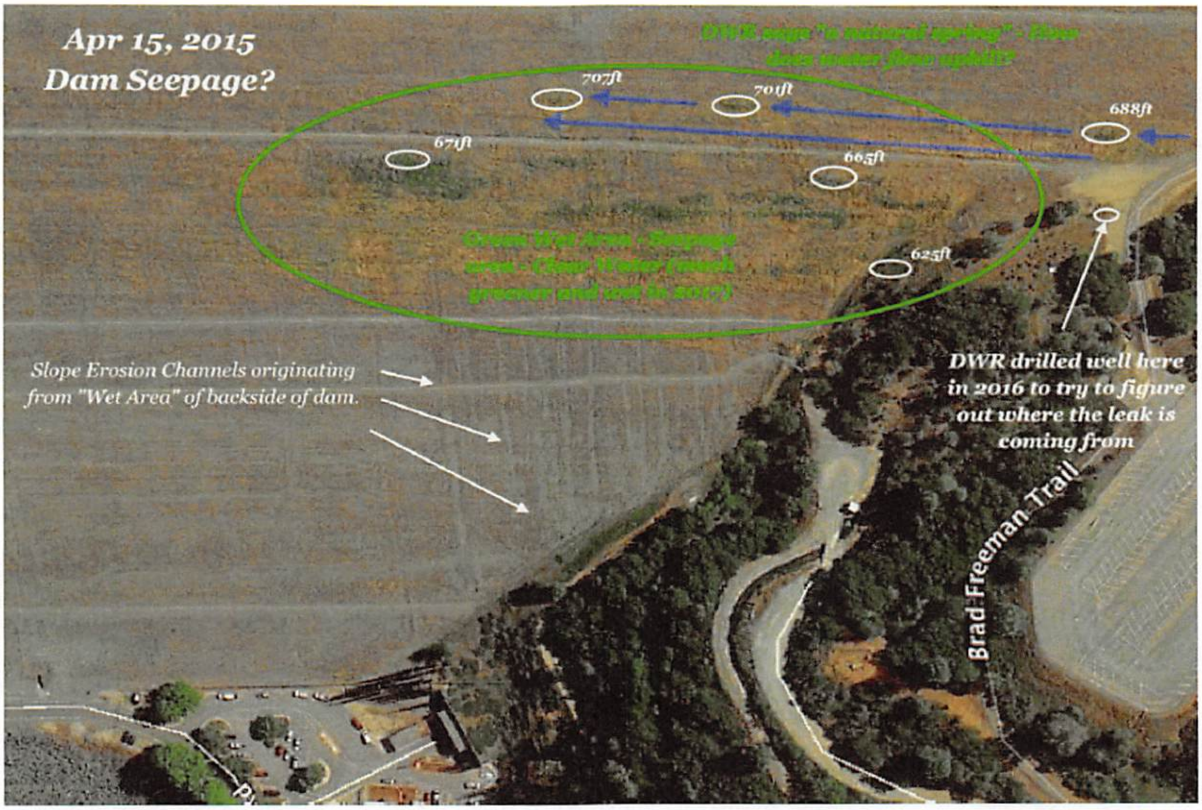

Figure 4: 2015 image of vegetation following an upward elevation slope away from the left abutment. Erosion channels, greenage locations, non-greenage above and below and up the embankment, uphill water flow, contradicts against a left abutment spring. Image courtesy of Google Earth.

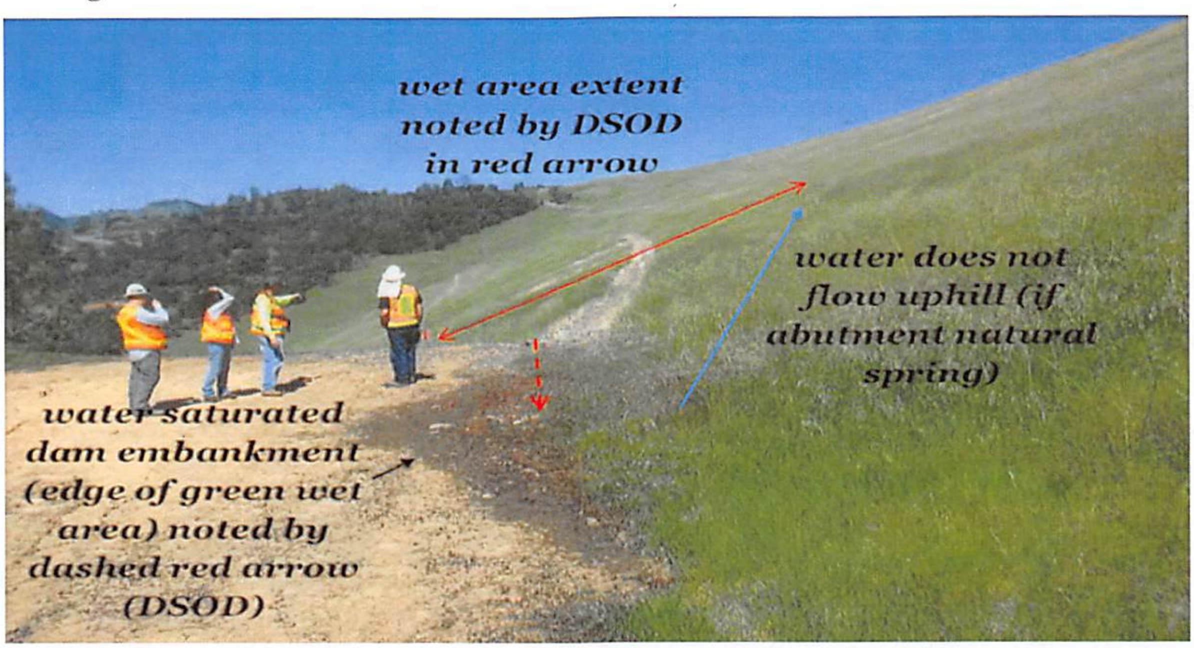

Figure 5: Water does not flow uphill if the dam abutment 'wet spot' is a "natural spring."

Four reports written by the second author of this report review and analyze the available documentation on these concerns. These reports are summarized below and identified as Reports 1, 2, 3, and 4:

Report 1: Oroville Dam Leaking? 50yr Proof of "through the dam" leakage? Will the dam breach? Oroville Dam may be facing a breach danger from a serious and a dangerous form of a slow motion failure mode of the left abutment of the dam. Recently, authorities to the dam have responded to the public stating "its a natural spring", or "the green spot is from rain". Yet, outside of a public forum, DWR asked the Federal Energy Regulatory Commission (FERC) to move a test drill well near the leakage to try to get answers in 2016. If it's known to be a harmless "natural spring" or from "rain" why drill? Why hasn't DWR publicly announced that they have a "test well" near the leakage area, which they noted to FERC, quote "data collected may be beneficial in understanding seepage"? However, DWR's recent town hall meeting's answers, by DWR engineers and representatives, do not stand up to honest engineering scrutiny. The public deserves an honest technical risk assessment of this known dam failure mode threat.

Report 2: Oroville Dam Breach? DWR Investigating Leaking - Hasn't Revealed This to the Public - Oroville Dam may be exhibiting a dangerous failure mode from an effect known as "Differential Settlement". This phenomenon occurs by sections of the dam "compacting" at a different rate. Thus, internal forces are applied to the center of the dam that has known to cause loss of the integrity of the core, cracking of the core, clogging of the internal drainage system, and longitudinal cracking along the interface between embankment zone fill materials. Historic failures of "Differential Settlement" at dams has found a critical component that risks the danger from the dam having an abutment with a "sharp abutment" slope change. A first sign of this alarming problem would be unexplained seepage, wet spots, or greening areas on the back side of the dam (to which Oroville Dam is exhibiting).

Report 3: Oroville Dam History Images, Reveals Clues to Dam Leakage? What Should be Done? Mysteries to the clues of Oroville Dam's leakage revealed in historical dam images? Does DWR/DSOD already know that there is a leak through the dam from inspection reports, yet they are keeping this from the public? Why push the narrative of "rain falls...then grass grows" when the public should be made fully aware of a potentially serious precursory dam failure mode? What should be done to guarantee that this leak is not at an accelerated threshold risk threat if there is greater "unseen" leakage?

Report 4: Oroville Dam Leak? With All Internal Dam Water Sensors Broken? No Breach Warning? An earthquake induced leak or if an internal erosion defect develops, deep within the earthen fill zones at Oroville dam, DWR would have no warning, nor the ability to do an immediate slope stability assessment, as the numerous dam's internal Piezometers are non-functional or dead. FERC has been asking DWR to fix this issue for years, as it's a major Dam Safety Issue. Why hasn't DWR responded? Why does the tallest earthen dam in the U.S.A. have zero working Piezometers to detect any threat to a potential internal instability to warn citizens of a pending breach?

Remediation of Organizational Root Causes

Recommendation #1

DWR – DOSD have demonstrated important needs for significant additional resources – primarily human and organizational resources – to help them get the proposed spillway repairs and rehabilitation efforts completed so those parts of the Oroville Dam system can meet current applicable **System Risk Assessment and Management based standards and guidelines** for development of **High-Reliability Organizations**[jj] having **High-Reliability Management** able to deliver **High-Reliability Systems** with **As Low As Reasonably Practicable Risks.**[11]

This development would go above and beyond the current standards and guidelines currently cited by DWR, DSOD, and the DWR Board of Consultants. The Oroville Dam is an extremely important part of the State Water Project and of California's public infrastructure systems. **Going forward, the Best Available and Safest Technology (BAST) should be required and properly used.**[12]

In addition to the results from this Root Causes Investigation, this recommendation is based on experiences and results from a six-year duration research and development project sponsored by the NSF and conducted by the Center for Catastrophic Risk Management (CCRM) at the University of California Berkeley. This project was identified by NSF as the RESIN systems project.[kk]

This project had two fundamental goals: 1) further develop and validate advanced analytical processes and procedures that could provide realistic quantitative evaluations of Risks associated with operations of complex engineered infrastructure systems—SRAM processes, and 2) apply these advanced validated SRAM analytical processes and procedures to the infrastructure systems in the California Sacramento – San Joaquin Delta.[9]

The advanced SRAM analytical procedures and processes were developed and validated with applications to past infrastructure failures.[9] Then, these validated SRAM analytical procedures and processes were applied to several specific infrastructure systems that had particular importance to continued operations in the California Delta.[9] These specific structure locations were identified with a Geographic Infrastructure System (GIS) developed specifically for the RESIN project in accordance with the guidelines provided by the Department of Homeland Security and the Federal Emergency Management Agency (FEMA).

The locations were identified as choke points – locations where failures would trigger failures of the other infrastructure systems that were in the same locations; these multiple infrastructure systems were interconnected, interdependent, and highly interactive. Two environmental conditions were specified: 1) potential flooding events during 2010, and 2) potential flooding events during 2100 (including potential effects from global climate changes, and continued use

[jj] See Appendix A pages 13 – 17 for background on characteristics High Reliability Organizations.

[kk] University of California CCRM NSF RESIN research and development project - http://ccrm.berkeley.edu/resin/

of the 2100 inspection, maintenance, and repair Operations and Maintenance processes and procedures).

The two locations chosen for the application of the advanced analytical formulations and processes were: 1) Sherman Island and 2) Natomis Basin. Representatives from local, state, and federal government agencies that had responsibilities for the infrastructure systems were involved in these developments (e.g., DWR, California Emergency Management Agency, U.S. Army Corps of Engineers, Sherman Island Reclamation Board, U.S. Coast Guard, University of California Davis, University of Colorado, Mills College). During this project, the RESIN research project team involved 35 faculty members, 73 undergraduate and graduate students in courses and research projects developed for this project, six post-doctoral researchers, and many other vital support personnel.

Results from the applications were documented extensively in public reports and reports to NSF, and published in reports, presentations, graduate and undergraduate courses, and refereed conference and journal publications. During 2009 – 2010, results from these applications were presented to public and government representatives concerned with the infrastructure systems located at Sherman Island and the Natomis Basin.

These applications of the advanced SRAM processes and procedures to the infrastructure systems at the two locations had one consistent result:[13] **The risk of major infrastructure systems failures were not "tolerable" or "As Low As Reasonably Practicable" (ALARP) based on U.S. and international Risk Tolerability guidelines.**

The recent experiences with other U.S. infrastructure systems have served to corroborate results from these NSF RESIN Infrastructure SRAM studies (New Orleans hurricane flood protection system during Hurricanes Katrina and Rita, BP Deepwater Horizon Macondo well blowout, and the PG&E San Bruno pipeline explosion). **The infrastructure System Risk Assessment and Management challenges at the Oroville dam involve much more than the Oroville Dam infrastructure system challenge. These infrastructure SRAM challenges also are State[14] and U.S. National challenges.[11,15]**

Recommendation #2

DWR's Management, Division of Engineering, and Division of Operations and Maintenance (O&M) standards, guidelines, procedures, and processes should be founded on the **proven best available SRAM** technology. This technology includes, **but "goes beyond"**, that currently documented in the U.S. Army Corps of Engineer's ***Dam Safety*** guidelines,[16, ll]in the Federal Energy Regulatory Commission (FERC) ***Risk Guidelines for Dam Safety***,[17] in the Federal

[ll] More background provided at http://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/About-the-Program/Policy-and-Guidance/
and http://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/About-the-Program/Policy-and-Guidance/Federal-Flood-Risk-Management-Standard/

Emergency Management Agency (FEMA) ***Federal Guidelines for Dam Safety***,[18] and in the Bureau of Land Management (BLM) ***Dam Safety Public Protection Guidelines***.[19,mm]

The most important "**goes beyond**" **elements concern those associated with Human and Organizational Factor Uncertainties (Appendix A).**[2, 6, 10] Multi-decade International use of System Risk Assessment and Management processes has clearly shown these elements must be included in valid and validated procedures and processes required to develop "realistic" assessments of the likelihoods and consequences (Risks) of major failures and for development and implementation of effective risk management barriers – standards, guidelines, procedures, and processes – used during the life-cycle of important public and private infrastructure systems.

Analyses of these "Human and Organizational Factor" Uncertainties (Extrinsic, Types 3 and 4 Uncertainties) are combined with those included in many traditional engineering analyses: natural (Aleatory) variability and analytical model (Epistemic) uncertainties (Intrinsic, Types 1 and 2 Uncertainties). Detailed investigation of a wide variety of failures associated with engineered infrastructure Systems has demonstrated that the majority of the Root Causes of these failures are associated with Human and Organizational Factors – Extrinsic Uncertainties. All four categories of Uncertainties must be included to develop realistic full-scope Risk Analyses, **thus avoiding the "E3" error of "working the wrong problems precisely."**[2, 13]

Other countries have continued, and are continuing, to implement advanced System Risk Assessment and Management standards and guidelines to help manage, engineer, construct, operate and maintain their important infrastructure systems. Examples include those developed and implemented by the U.K. Health and Safety Executive in their Safety Case Regime developments, and by the governments of Australia and New Zealand in their Risk Management Guidelines.[20,21] The International Standards Organization (ISO) have developed and published a large number of very useful standards based on System Risk Assessment and Management that have been incorporated into those of the U.K. Health and Safety Executive, and those of Australia and New Zealand.[22] In addition, similar standards and guidelines have been developed and implemented in Norway and the Netherlands.[23] **These Standards and Guidelines – 'Safety Case Regimes' – address both Intrinsic (Types 1 and 2) and Extrinsic (Types 3 and 4) Uncertainties**.

In the U.S., the commercial Nuclear Power Generation and Transmission organizations and owner-operators (e.g., the PG&E Diablo Canyon nuclear power plant) and the U.S. Nuclear Regulatory Commission (NRC) for many years have applied this proven advanced technology.[nn] Similarly, the commercial public air transportation organizations (e.g. United Airlines, Boeing Aircraft Company) and the U.S. Federal Aviation Administration (FAA) have applied this technology in development of their standards, guidelines, procedures and processes. These organizations have developed an admirable record for safety and reliability. The U.S. Chemical

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[mm] For additional references consult National Dam Safety Program at http://damsafety.org/resourcecenter/national-dam-safety-program-guidelines-flyers-and-other-tools

[nn] Nuclear Regulatory Commission SRAM Probabilistic Risk Analyses (PRAs) – http://www.nrc.gov/about-nrc/regulatory/risk-informed/pra.html

Safety Board (CSB) and Center for Chemical Process Safety have advanced a similar set of standards and guidelines for implementation of safety case regimes for high hazard chemical processing facilities.[oo]

Experience during the past several decades has shown that System Risk Assessment and Management technology, if properly implemented, can be very useful to help develop and maintain ***Safe*** (risks are ALARP) and ***Reliable*** (high likelihoods of delivering acceptable performance) systems. **This experience has also shown that if not properly implemented, System Risk Assessment and Management technology can be very counterproductive.** Some of this experience has shown that improper implementation can help cause major infrastructure system failures.[2, 8] **The single most important resource required for proper implementation are people who have formal training and experience in Risk Management – System Risk Assessment and Management processes and procedures.**

Experience and results from analyses of 10-year duration formal efforts by seven organizations to effectively apply SRAM technology has shown that **"Five Cs"** are required to be able to develop and maintain safe and reliable systems.[24] **All Five Cs are required all of the time to be able to realize success with implementation of this technology.**

The **Five Cs** are:

1) **Cognizance** – the involved organizations must develop an acute awareness of the hazards and threats that confront their systems. Worry and concern is constant. Awareness is crucial. Diligence to maintain systems with ALARP Risks that are 'Safe' is even more critical.
2) **Commitment** – the management and operating personnel must develop a sustained 'top down and bottom up' commitment from those involved that the necessary resources (human, organizational, monetary, knowledge, experience, physical, environmental) will be provided to enable effective application of ALARP risk management 'barriers' (integrated proactive, reactive, and interactive processes) to enable development and maintenance of systems that have ALARP risks. The commitment must be to develop high reliability organizations with high reliability management that will consistently deliver systems having ALARP risks.
3) **Culture** – The beliefs, values, feelings, and resource allocation and utilization processes of the organization must be one devoted to "Getting it right, doing it right and knowing what is right," consistently delivering Systems that have ALARP risks, and understanding that these efforts require constant vigilance, diligence and continuous improvements.
4) **Capabilities** – The human, organizational, and other parts of the systems (combinations of human operators, responsible organizations, hardware, structures, environments, standards and guidelines, and the interfaces between these interconnected, interactive, interdependent **components**) must be highly developed and "excellent" so the proven

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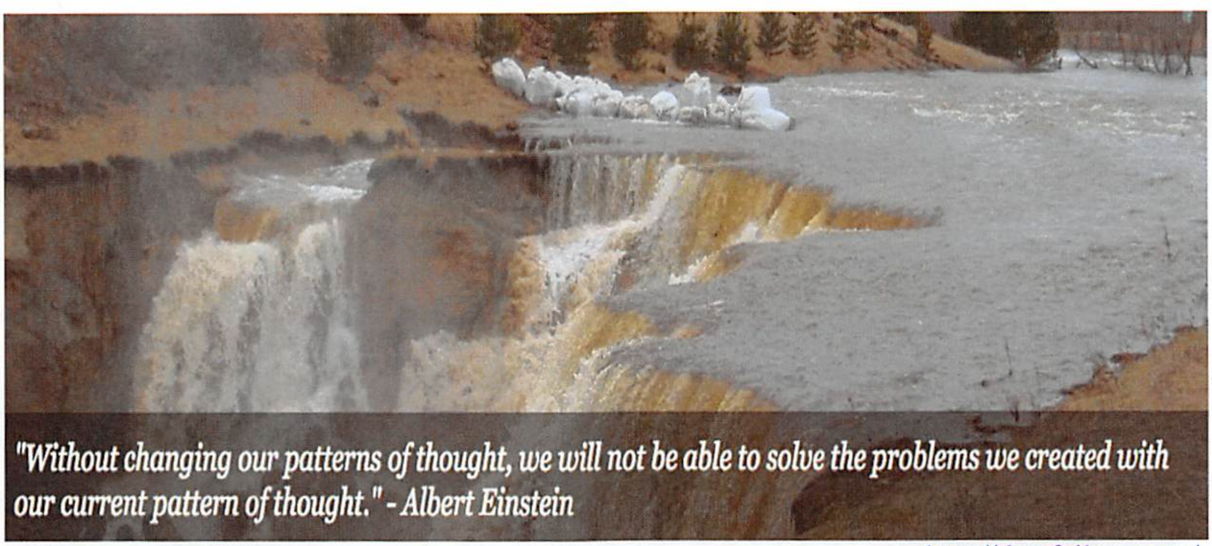
[oo] https://www.aiche.org/ccps/topics/elements-process-safety/commitment-process-safety/process-safety-culture

principles of SRAM technology can be properly and effectively developed and implemented. These efforts are focused on continuous improvements to enable realization of the different kinds of benefits from application of SRAM technology.

5) **Counting** – This is a very important 'C.' Counting means development of valid and validated *quantified metrics* (with numbers) that can be used by managers, engineers, and operations and maintenance personnel to help them determine system risks (likelihoods and consequences) throughout the life-cycle of a system. These valid and validated metrics serve the same purposes as an automobile speedometer; to give the diver/s dependable ways to determine the safe speed, given the road, traffic, weather, and surrounding community conditions; the safe speed (ALARP risk) depends on the local conditions. Risks that are ALARP are based on quantitative monetary cost-benefit evaluations that include proper recognition of both short-term and long-term monetary costs (direct, indirect, onsite, offsite, property, productivity, quality of human life, and environmental impacts), standards-of-practice evaluations, historic precedents, and national and international standards and guidelines for determination of ALARP risks.[25] What is effectively measured can be more effectively managed.

Summary

Results from this investigation of the Root Causes of the failures of the Gated Spillway, Emergency Spillway, and Other Developments (Spillway Headworks, Dam Abutments 'Wet Spots') have been consistent with those from a large number of previous forensic investigations of failures and disasters associated with engineered infrastructure systems: **it is the *Human and Organizational Factors* that are the primary challenge to being able to develop Safe and Reliable engineered infrastructure systems.**[26] This is the reason for emphasizing in this report **the need to develop high-reliability organizations with high-reliability management that can and will deliver High Reliability Systems that have As Low As Reasonably Practicable Risks and are Safe, Durable, Serviceable, and Compatible (Appendix A).**



http://damfailures.org/

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EXHIBIT 3

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Center for Catastrophic Risk Management

Providing Solutions
for catastrophic risks to societal infrastructures

Analyses of the Oroville Dam 'Wet Spots' Developments

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September 5, 2017

[a] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEnd05fWUNlVXcyWFk
Additional background available at - http://www.mensjournal.com/magazine/bob-bea-the-master-of-disaster-20130225 and http://discovermagazine.com/2013/june/14-master-of-disaster

[b] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEneTN6YlNKRVdZcGs

Introduction

We have performed a review and critique of the report issued by the California Department of Water Resources (DWR) on August 30, 2017 titled: "***Assessment of the Vegetation Area on the Face of the Oroville Dam.***" [c, 1] This is the fourth in the series of public reports that have addressed the multiple failures that developed at the Oroville Dam before, during, and after February, 2017.[2] As before, this work has been performed as unfunded (approximately 3,600 pro-bono hours) volunteers of the University of California at Berkeley (UCB) Center for Catastrophic Risk Management (CCRM) Oroville Dam Advisory Group (ODAG). We initiated this work on January 27, 2017.

The results contained in this report have been developed based on the currently available public document and information sources cited at the end of this report, and cited and included in our three previous reports.[2] When possible, we have provided Google Document links to all of these referenced documents so readers of these reports can access, review, and corroborate our analyses and documentation of the information.

Unfortunately, access to the majority of the documents referenced in the DWR August 30th report have not been provided by DWR and are not generally available to the public. In addition, most of the recent relevant documents we have been able to obtain from DWR sources have been extensively 'redacted.' Consequently, these documents are not useable because majority of the information essential to verify and corroborate what has been included in the DWR August 30th report currently is not available to the public.

Our evaluations of these extensively redacted documents combined with the guidelines we have obtained and previously used that address the Federal Energy Regulatory Commission's Critical Infrastructure Information (FERC CEII) indicate these CEII guidelines are not being properly applied by DWR.[3] In several cases, we have been able to obtain both original and redacted documents. Comparisons of the redacted and un-redacted documents indicates in many cases information is being 'selectively redacted' that is unfavorable or contrary to the information being provided by DWR for public access and does not have energy generation and distribution CEII Security implications. Until this unnecessary 'information access blockade and selective filtering' is stopped, we are forced to base our evaluations, analyses, validations, and assessments on the currently available documentation DWR, FERC, and other sources have provided for our review.

The opinions expressed in this Report are ours alone. The opinions expressed herein are a fair and accurate summary of our opinions, based upon our experience, education, training, and expertise.

Robert Bea and Tony Johnson

[c] References cited are included in the References Section at the end of this report together with Google Document links to archived copies of the available cited documents.

Conclusions

In our July 20th report,[2] we addressed "Other Developments," including the "Oroville Dam Persistent Wet Spots." This report further developed the analyses of available background information and the recommendations included in the May 11th report. In the July 20th report, we recommended what should be done to properly address the importance of the 'historic wet spots':

> **"DWR - DSOD, and FERC should be required to focus high quality field investigations and detailed analyses of the results from these investigations to determine and confirm if important seepage is taking place in and around the Oroville Dam. If such threats are confirmed, then proven effective remediation measures should be implemented and validated to assure that the dam is 'Safe' and 'Reliable' for current and future use."**

Appendix A of this report summarizes results from our previous and current detailed analyses of the available data and information on the Oroville Dam's Persistent 'Wet Spots.' Our current analyses of the available information and data have reinforced and corroborated the conclusions and findings contained in our July 20th report.

Appendix B of this report summarizes results from our current analyses of DWR's August 30th report.[1] Appendix B also references the only detailed information on the dam seepage we have been able to review. This information is included in a report (Bulletin No. 203) issued by DWR in April 1977 titled "Performance of the Oroville Dam and Related Facilities During the August 1, 1975 Earthquake."

As documented in Appendix B, our current analyses indicate there are many distortions, errors, and omissions included in DWR's August 30th report. For example, the authors and reviewers of the DWR report are not cited; most of the references cited in the DWR report are not available for review; and the details of previous purported engineering analyses whose results are cited in this report are not documented in the report or cited references.

We conclude that DWR's August 30th report is a superficial summary 'public relations' report that is not consistent with the importance of the seepage related hazards and uncertainties relative to the Safety (having As Low As Reasonably Practicable Risks of Major Failures) of this important part of California's vital water infrastructure system. This report does not document analyses that would meet the required Civil Law Standard of Care for the Oroville Dam infrastructure system.[4]

The August 30 DWR report is not responsive to the recommendations in either our May 11th or July 20th reports.[2] Our reviews indicate this report is another in the series of DWR documents that 'analyzes' the historically available information and previous analyses of that information and arrives at its previous conclusion that the 'Wet Spots' ('Vegetation Area', page 24, Section 4.3) do not pose any important Safety challenges to the Oroville Dam, e.g. **"This vegetation area does not cause a dam safety concern."**

Our reviews of the August 30th DWR report indicate this report contains the same type of DWR 'Organizational Thinking' that led to mis-diagnosis and mis-management of the Risks associated with the 2017 failures of the Gated Spillway and the Emergency Spillway at the Oroville Dam. It was this same type of 'Organizational Thinking' that led to the failure of the Teton Dam in 1976. This report documents another example of DWR's previous and continuing **"Normalization of Deviance"** (reference book titled "*The Challenger Launch Decision*" by Diane Vaughan) that leads to **"Predictable Surprises"** (reference book with this title by Max Bazerman and Michael Watkins) founded on **"Lethal Arrogance"** (reference book with this title by Lloyd Dumas) that defeats **"Managing the Unexpected"** (reference book with this title by Karl Weick and Kathleen Sutcliffe). This DWR report again fails to utilize the advanced Dam Safety Risk Management guidelines issued earlier by FERC, and the other Federal Government Agencies cited (with download links) and discussed in our July 20th report.

Based on the information provided in the August 30th DWR report and the information summarized in Appendix A, **we are not able to determine whether or not the current Oroville Dam seepage related potential failure modes pose Dam Safety Risks that are or are not As Low As Reasonable Practicable (ALARP)** as prescribed by current FERC and other Federal Government Dam Safety Risk Management Guidelines. These advanced Dam Safety Risk Management Guidelines require continuing formal data gathering and analyses that allow future hazard developments to be properly detected, analyzed, and corrected - mitigated when necessary ('Real-Time', Interactive Risk Management).

Because of the potential importance of these seepage related failure modes, we conclude that DWR must be required to do the additional field data gathering, analysis of this new data and re-analysis of the existing data, determine, validate and document quantitative assessments of the uncertainties associated with and likelihoods of occurrence of the seepage related failure modes as expressed in the likelihoods and consequences of Risks, and determine if these Risks are ALARP as prescribed by current FERC and other Federal Government Dam Safety Risk Based Management Guidelines.

Summary: Appendix A

REPEAT OF ST FRANCIS DAM AND TETON DAM FAILURES?

Appendix A reveals that DWR faces crucial uncertainties, conflicts in analyses, and an extensive lack of consideration of critical relevant factors, in the current seepage report (presented as "rainfall only") regarding an accurate determination to the source to the Dam Green Wet Area. Appendix A details the history, the extent, and relevance of these numerous critical issues that should have been fully analyzed and thoroughly investigated regarding the Green Wet Spot Seepage Anomaly. This compilation includes DWR's consideration, but then dismissal, of an Oroville Dam Failure condition leading to a potential major Dam seepage related failure (item 31).

The described Oroville Dam failure sequence is near identical to the abutment seepage and the subsequent swift and catastrophic breach failure of Idaho's Teton Dam in 1976. Yet, between DSOD and DWR there have described and noted four different versions of the "source" of the seepage, each of which conflicts in evidence between the versions with respect to each other. With "versions" ranging from DWR noting to FERC in a 2014 Part 12D detailed analysis that the "seepage source" is from a "plurality of an existence of natural springs", to a singular "a natural spring" in an April 2017 town hall meeting, then to DWR changing to a narrative of "rainfall only" in their newly released report. Conspicuously missing in the new DWR report are DSOD inspection reports detailing strong evidence of a "through the dam leakage" path, in defining the "reservoir" as the seepage source (2014 and 2015 inspections). Most notably, the DSOD July 2015 inspection report found wet seepage on the face of the dam even in a severe heat and an on-going drought which included photographs of brown grass. Thus any narrative of a "nothing to worry about" emphasis in placing the seepage source as "rainfall only", with so many unanswered questions, may result in a dangerous complacency.

The Left Abutment has proven to have numerous cracks, in the metavolcanic rock, that surprised DWR in its stability behavior by the large 100,000 cubic yard rockslide during construction; even after the rock excavation was "thought to be" completed. DWR blamed the destabilization from heavy water penetration into "cracks" in the rock that triggered the massive landslide. This same nature of a geological surprise, in unexpected geological abutment conditions, was a primary root cause to the failure of St Francis Dam in 1928. Yet, with no working piezometers in the dam, DWR is heavily placing the measured safety of the dam using simple peripheral seepage points as "indicators" from the toe drain, gallery tunnels, and core block seepage. Thus, any "lost" or "unseen" water penetration, that escapes these "indicators", could go unnoticed until the potential event of a sudden breach failure occurs.

Indeed, a DSOD inspection report notes a volume of water penetration, increasing every year, through deep rock cracks in the Left Dam Abutment into the Hyatt Power plant. This clearly demonstrates the ability for water to migrate deep into the Left Abutment rock through cracks. This level of high "transmissivity" in the Left Abutment Rock has the ability to divert internal "unseen leakages" away from the toe drain seepage weir. With DWR critically depending only on these "indicators", without any internal piezometers or sensors providing "definitive proof", DWR is making a High Risk choice that has a "catastrophic High Risk potential" that was well described in their Part 12D Dam Failure exercise in 2014. This was dismissed by DWR as their version was from a different core leakage mechanism (DWR had not considered Left Abutment slope induced failure mode of "Differential Settlement" in the Part 12D analysis exercise). Until DWR answers all of the crucial relevant factors, with a thorough investigation and using "in the dam" piezometer instrumentation giving solid "proof" data, Oroville Dam could end up in the history archives as the greatest natural disaster in California History - if not in the entire United States - if it is later found to be from a destabilizing internal leakage that led to a sudden breach of the Dam.

Appendix A is an in-depth compiled a series of engineering analysis, engineering discussion, DSOD inspection report findings, and questions with answers, all found to have particular importance to the Green Wet Area Anomaly. Sources include writings from both authors, the second author, and postings on FreeRepublic.com that reveal a wide scope of engineering analysis on the Anomaly. This compilation is provided in this report as a single down-loadable reference. The major issues addressed in this series are:

1) California Code Regulations, two noted sections, regarding law on "General Safety Requirement - shall not or would not constitute a danger to life or property", and Section 6081 where "the department shall take into consideration the possibility that the dam or reservoir might be endangered by seepage" - Appendix A, page 1.

2) DWR's new "narrative" on the Green Spot - Back to "Rain" again - natural spring seems to be "out" - #4132 - Appendix A, page 2.

3) #2 How Good - or Bad - is using a Toe Drain to detect Dam Anomalies? (When you don't have any working piezometers in the dam) - #4131 - Appendix A, page 7.

4) How Good - or Bad - is using a Toe Drain to detect Dam Anomalies? (When you don't have any working piezometers in the dam) - #4125 - Appendix A, page 10.

5) DWR Report on Green Spot is out - Going "all in" on rainfall theory - Will they lose public trust? - Worse, is DWR risking thousands of lives with a flawed report? - #4216 - Appendix A, page 13.

6) Critical Evidence/Flaw #2 - DWR report conclusion to Sections 4.2 and Section 4.1 - Dam Wet in the midst of "on-going drought" - #4218 - Appendix A, page 16.

7) Critical Evidence/Flaw #3 - Erosion channels in DWR report do not match existing Erosion channels - Do not match losses of sands/gravels in 2011 to 2015 (11% growth) - #4219 - Appendix A, page 20.

8) Critical Evidence/Issue #4 - DWR's Green Spot Report fails to mention that Piezometers & Crossarm sensors are 1,300+ feet away from the Left Embankment - Huge engineering oversight in analysis - #4220 - Appendix A, page 24.

9) Critical Evidence/Issue #5 - Major - DWR's plots in early 70's proves differential settlement is occurring - Yet DWR report claims concrete core prevents this - Defies known Dam Design Failures & Physics - #4223 - Appendix A, page 26.

10) Further Engineering Analysis regarding the Oroville Dam Green Wet Area Anomaly, Q&A on seepage, phreatic level, and affects on Dam Safety - Appendix A, page 32.

11) Compilation of DSOD, DWR, and Article references specific to Green Wet Area - Appendix A, page 37.

12) Compilation of DSOD Inspection report (1998 to 2016) notes specific to Green Wet Area – Appendix A, page 39.

13) Oroville Dam Leakage History. Original leakage behavior of the first "settlement" phases of the dam, twin large green areas distinct from current Green Wet Area - Appendix A, page 44.

14) Oroville Dam History Images - Reveals Heavy soil migration from internal leakage erosion - Differential settlement Twin Columns - Potent Green Leakage area today – Appendix A, page 45.

15) Spectral Photograph revealing the extent of historic vegetative growth intensity - Appendix A, page 47.

16) Clean Surface of dam with no erosion channels vs Dense Erosion channels - Linked? - Appendix A, page 48.

17) Early dam operation - Did the early dam "saturate itself"? Or "dirt itself"? - Appendix A, page 49.

18) Early dam operation - The Aftermath of the "Saturation", the "Dirt" - Appendix A, page 50.

19) Subsurface saturation? - Combined with Rain? - Causing "fines" erosion? - Wide area saturation? - Appendix A, page 54.

20) How the dam was intended to work - Where does the water go? - Appendix A, page 57.

21) Why Engineers are stumped - Seasonal Rains - Consolidation - Multi-year sectional layers - Differential Settlement => Green wet area? - Appendix A, page 59.

22) What is Differential Settlement? Can it crack the core? - Appendix A, page 60.

23) DWR/DSOD recognizes dense Erosion channels in "determining what...needs to be done ...re: slope stability - Appendix A, page 63.

24) Erosion Channels, where did the "fines" go? Unseen wide area "flow" below the Green Wet Area - Appendix A, page 66.

25) How does Green Wet Area become Brown Grass damp Area? - Appendix A, page 71.

26) Guided Waterflow "Steps" from layered sections? - Appendix A, page 75.

27) Porting of Zone 3 soils to Green Wet Area, Clogging of Drain Zone, Suffusion, Grass Browning from Summer Temps yet continued subsurface seepage flow evidence - Appendix A, page 77.

28) References: DSOD report notes, Articles, DWR/FERC communications, - Appendix A , pages 79 to 92.

29) Failure of Oroville Dam - Part 12D FERC 2014 report - "Natural Springs" stated as a primary mechanism - Missing from new DWR report - Why? - Includes 4 different conflicting "narrative" versions of explanations of the dam water seepage "source" – Appendix A, page 91.

30) DSOD inspectors stating Green Area Seepage from Reservoir, Saturated embankment DSOD photo, "water does not flow uphill" - Appendix A, page 95.

31) 100,000 Cubic Yard Rockslide - Caused by cracks in rock - DWR notes cracks and seepage as potential Failure Mode of Dam - DWR excavated a "flat bench", deviated from original Dam Embankment Plan HYD-502, sharpened the slope to "differential settlement" - "flat bench" impeding internal drainage - Leak Path? - Appendix A, page 98.

References

[1] California Department of Water Resources (2017): *Assessment of the Vegetation Area on the Face of the Oroville Dam,* August 30, available at https://drive.google.com/open?id=0Bz1I1mIutSEnWThySU1nTWF3dWM

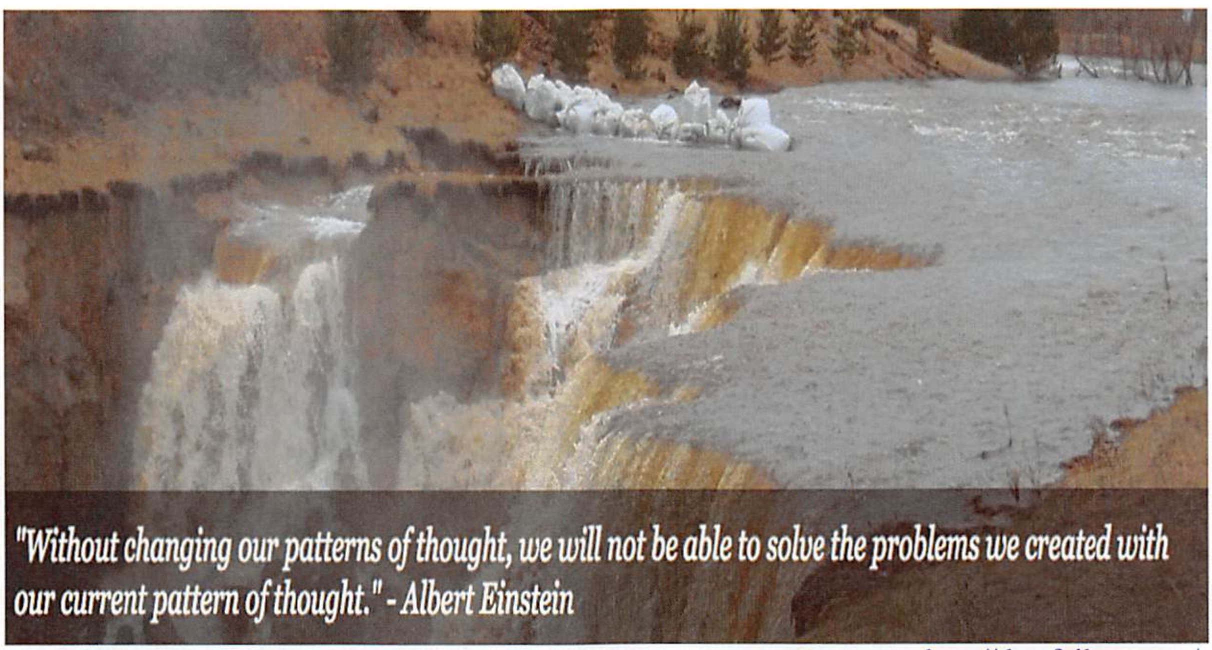
[2] Bea, R. G. (2017a): *Preliminary Root Causes Analysis of the Failures of the Oroville Dam Gated Spillway*, Center for Catastrophic Risk Management, University of California Berkeley, April 17, available at https://drive.google.com/open?id=0Bz1I1mIutSEnSUY5WjluQmhPXzg

Bea, R.G. (2017b): *Legislative Oversight Testimony Report*, Center for Catastrophic Risk Management, University of California Berkeley, April 17, available at https://drive.google.com/open?id=0Bz1I1mIutSEnWHozRUsyNFl1Y2c

Bea, R.G. and Johnson, T. (2017): *Root Causes Analyses of the Oroville Dam Gated Spillway Failures and Other Developments,* Center for Catastrophic Risk Management, University of California Berkeley, July 20, available at https://drive.google.com/open?id=0Bz1I1mIutSEnbFJuVUJZWWNNVlU

[3] United States of America Federal Energy Regulatory Commission (2016): *Regulations Implementing FAST Act Section 61003 – Critical Electric Infrastructure Security and Amending Critical Energy Infrastructure Information; Availability of Certain North American Electric Reliability Corporation Databases to the Commission*, 18 CFR Parts 375 and 388, November 2016 available at https://drive.google.com/open?id=0Bz1I1mIutSEnMl90UkdYSnBVTm8

[4] Bea, R.G. (2017): *Risk and Civil Law*, The Standard of Care, Center for Catastrophic Risk Management, University of California at Berkeley, available at https://drive.google.com/open?id=0Bz1I1mIutSEnMlpGV05Wb190M0k



http://damfailures.org/

EXHIBIT 4

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Summary of the Root Causes Analyses of the Oroville Dam Gated Spillway Failures

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January 9, 2018

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[a] Summary background available at https://drive.google.com/open?id=0Bz1I1mIutSEnd05fWUNIVXcyWFk
Additional background available at - http://www.mensjournal.com/magazine/bob-bea-the-master-of-disaster-20130225 and http://discovermagazine.com/2013/june/14-master-of-disaster

Introduction

This report summarizes results from forensic Root Causes Analyses of the Oroville Dam Gated Spillway failures performed by volunteers of the University of California at Berkeley (UCB) Center for Catastrophic Risk Management (CCRM) Oroville Dam Advisory Group (ODAG). This work was initiated on January 27, 2017.

The results contained in this summary report are based on the information included in the Preliminary Root Causes Analysis of the Failures of the Oroville Dam Gated Spillway report (April 17, 2017), in the Legislative Oversight Report: Oroville Dam report (May 11, 2017), and the Root Causes Analyses of the Oroville Dam Gated Spillway Failures and Other Developments (July 20, 2017). [b, 1]

Robert Bea

Summary of Conclusions

The flaws and defects incorporated into the Oroville Dam Gated Spillway represent accumulated results from the Gated Spillway's Life-Cycle Phases (1965 to February 2017). The Life-Cycle defects include those developed during Design, Construction, Operations and Maintenance (O&M) Phases. Of particular importance in this Root Causes investigation[c] were the Standards, Guidelines, procedures and processes used by the California Department of Water Resources (DWR) and the associated Division of Safety of Dams (DSOD) during the life-cycle phases of the Gated Spillway.

The California Code of Regulations and The California Water Code **charge DWR and DSOD with primary responsibilities and accountabilities for specified State Water Supply dams and reservoirs during their lives: *"...as to the Safety of design, construction, maintenance, and operation of any dam or reservoir."*** [d]

In the April 17[th] Preliminary Root Causes Analysis report[e] and the May 11[th] Legislative Oversight Testimony report[f], specific defects and flaws in the Gated Spillway were cited and

[b] References cited are included in the References Section at the end of this report together with Google Document links to archived copies of the available cited documents.

[c] See Appendix A pages 1-4 for background on performance of Root Causes Analyses.

[d] A compiled summary of DWR – DOSD responsibilities, accountabilities and practices is available at https://drive.google.com/open?id=0Bz1I1mIutSEnWTJsM2Q4V0F3MTA

[e] Report available at https://drive.google.com/open?id=0Bz1I1mIutSEnSUY5WjluQmhPXzg

described that could be identified and corroborated based on the photographic evidence and documentation referenced in those reports' references. A summary of the analyses of the physical causes of the initial failure in the Gated Spillway was provided.

These Root Causes Analyses investigations have concluded the physical effects of the life-cycle flaws and defects incorporated into the Gated Spillway were **highly interactive and cumulative. The interactions resulted in progressive deterioration of the performance abilities of the Gated Spillway and resulted in reduction of its Safety and increases in its Risk of failure. This process continued until the Gated Spillway failed during the early February 2017 Oroville Dam reservoir discharges.**

These Root Causes Analyses investigations have concluded **that 'inappropriate'[g] standards and guidelines, procedures and processes were used by the Department of Water Resources (DWR) and the associated Division of Safety of Dams (DSOD) to evaluate and manage the Risk[h] of failure characteristics of the Gated Spillway.** These standards and guidelines, procedures and processes failed to adequately and properly address **Aging, Technological Obsolescence**, and **Increased Risk of failure** characteristics of the Orville Dam Gated Spillway.

Due to the multi-decade 'Loss of Core Competencies', the management of DWR and DSOD failed to provide adequate Management (planning, organizing, leading, controlling), Engineering, Operations, and Maintenance personnel 'skills, knowledge and performance capabilities' and other important 'resources' required to effectively prevent and mitigate the failures of the Gated Spillway.[m] **The Gated Spillway was 'managed to failure' by DWR and DSOD.**

In addition, the available evidence indicates validation and approval of the long-term continued **use of these 'inappropriate' standards, guidelines, procedures and processes** was provided by the Federal Energy Regulatory Commission (FERC). **The Gated Spillway was 'regulated to failure' by FERC.**

I have received reports released by the DWR Board of Consultants (BOC)[i], the DWR Independent Forensic Team (IFT),[j] and by the U.S. Army Corps of Engineers (USACE) Institute for Water Resources Risk Management Center.[k] [l] Also, I have received a report written by

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[f] Report available at https://drive.google.com/open?id=0Bz1l1mIutSEnWHozRUsyNFl1Y2c

[g] 'Inappropriate' – intentional deviations from mandated acceptable practice Standards and Guidelines.

[h] **Risk** – Likelihood and Consequences associated with major failures of an Engineered System.

[i] Reports available at https://drive.google.com/open?id=0Bz1I1mIutSEnOXdGMU1Ob0JGcFE
https://drive.google.com/open?id=0Bz1I1mIutSEnWXB4NVNRVUhsR1U
https://drive.google.com/open?id=0Bz1I1mIutSEnT3ZDcll6NDZkRnM

[j] Report available at https://drive.google.com/open?id=0B0_jjqbhy5meVEpjR1RlZExBR1E

[k] Report available at https://drive.google.com/open?id=0Bz1l1mIutSEnN2V2VnJ2cVhJWVE

[l] Report available at https://drive.google.com/file/d/1vhHDDjFfdrBrVMLecBX9ICLyHwgIdW8A/view

Bernard Goguel that provides a summary of his analyses of the initial failure in the Gated Spillway.[m]

My reviews of the physical causes related to design, construction, operation and maintenance of the Gated Spillway identified in these reports leads me to conclude these findings substantially corroborate those identified in my April 17th Preliminary Root Causes investigation report, summarized in my May 11th Summary and Recommendations report, and in our July 20th Root Causes Analyses report. These additional reports have provided important additional details and background on the life-cycle Physical and Human – Organizational Root Causes of the Gated Spillway failures.

Summary of Gated Spillway Defects, Flaws, Development of Initial Failure, and Root Causes

The following sections summarize the Gated Spillway's physical defects and flaws, initial failure, and Root Causes of this failure identified during this investigation. The evidence (documentation and photographic) to support these identifications are cited in each of the following sub-sections and the References Section of this report:

Design[1,2]

1. Spillway base slabs of insufficient thickness for the design hydraulic conditions: 4 to 6 inches thick at minimum points;
2. Spillway base slabs not joined with 'continuous' steel reinforcement to prevent lateral and vertical separations;
3. Spillway base slabs designed without effective water stop barriers embedded in both sides of joints to prevent water intrusion under the base slabs;
4. Spillway base slabs not designed with two layers of continuous steel reinforcement (top and bottom) to provide sufficient flexural strength required for operating conditions; and
5. Spillway base slabs designed with ineffective 'ground' anchors to prevent significant lateral and vertical movements.

Construction[1,3]

1. Failure to excavate the native soils and incompetent rock overlying the competent rock foundation assumed as a basic condition during the spillway design phase, and fill the voids with concrete, and
2. Failure to prevent spreading gravel used as part of the under-slab drainage systems and 'native' soils to form extensive 'graded blankets' of permeable materials in which water could collect and erode.

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[m] Report available at https://drive.google.com/open?id=0Bz1I1mIutSEncnVEUktrQkNjRms

Operations & Maintenance[1,4]

3. Repeated ineffective repairs made to cracks and joint displacements to prevent water stagnation and cavitation pressure induced water intrusion under the base slabs with subsequent erosion of the spillway subgrade, and in some cases, to effectively 'plug' and severely decrease water flow through the spillway drains; and
4. Allowing large trees and other vigorous vegetation to grow adjacent to the spillway walls whose roots could intrude below the base slabs and into the subgrade drainage pipes resulting in reduced flow and plugging of the drainage pipes.

Development of Initial Failure

Appendix A summarizes a chronological progression of Root Causes analyses to the final genesis of the Initiating Blowout Failure, including the specific Root Causes 'pre-failure conditions.' A collection of critical evidential photographs, document clips, and images, from the combing through of thousands of pages of source information and a combined effort of thousands of hours of research and analyses, provides translation of the foregoing summaries to failure - into a 'walk through' of the cause and effect chronological progression ending in the final blowout of the spillway on February 7, 2017. The 'walk through' chronology also provides insight into the Human and Organizational Factors involved in how conditions continued to progress despite the many signs of distress in the spillway.

By the time of the February 2017 spillway releases from the Oroville reservoir, the Gated Spillway had become heavily undermined and the foundation subgrade eroded by previous flood releases. The spillway releases completed the undermining of the spillway slabs, allowing water cavitation to further damage the slabs and open joints and cracks, and develop stagnation pressures and foundation subgrade seepage pressures to further erode the supporting soils and degraded rock and lift the 'weak' slabs ('hydraulic jacking') breaking them into pieces.

After the almost catastrophic water release over the un-surfaced Emergency Spillway, the subsequent water releases down the gated spillway propagated the initial spillway breach until the spillway releases ceased.

Organizational Root Causes

My investigations have concluded the Root Causes of the Gated Spillway failures are founded primarily in Organizational Malfunctions due to human and organizational decision making, task performance, knowledge development and utilization as developed and propagated by DWR and DSOD during the Gated Spillway Design, Construction, and Operations & Maintenance activities.[5, 6]

The report titled ***The "Watering Down" of the Division of Safety of Dams"*** concludes:[n]

"The most significant examples of organizational influence are the recently exposed

[n] The "Watering Down" of the Department of Water Resources Division of Safety of Dams available at https://drive.google.com/open?id=0Bz1l1mlutSEnUks4T3ljdjJLcWs

existence of DSOD inspection reports dating back to 1989. For reasons yet to be fully determined, identified deficiencies were either ignored, treated as low priority, not acted upon or a combination thereof. ***However, complacency, lack of industry standard level maintenance, and possibly pressure from internal DWR management and external State Water Contractors' representatives to hold down maintenance costs were key contributors. The lack of concern and focus in the timely addressing of the Dam Headworks concrete spalling and cracking, missing welds, gate trunion cable cracks, and dam abutment "wet spots", all noted deficiencies listed in reports generated by DSOD, private engineering consultant(s), the Board of Consultants (which reports to the Director), US Army Corps of Engineers, and FRCIT, serve as prime examples of the DWR culture and failures."***

In 2009, the American Society of Civil Engineers issued a report titled **"Guiding Principles for the Nation's Critical Infrastructure."** [11] This identified four guiding principles that form the foundation for **Risk Management** of the Nation's Critical Infrastructure:

1. **Quantify**, communicate, and manage Risk,
2. Employ an integrated **Systems** approach,
3. Exercise sound **Leadership, Management, and Stewardship** in decision-making processes, and
4. **Adapt critical infrastructure in response to dynamic conditions and practice**.

This report states: ***"these guiding principles are fully interrelated. No one principle is more important than the others and all are required to protect the public's safety, health, and welfare."***

A fundamental premise integrated into these four guiding principles is **Risk Management**. ASCE recommended four things needed to effectively integrate risk assessment, risk management, and risk communication strategies into our nation's critical infrastructure programs:

1. Produce a best-practices guide and develop and publish codes, standards, and manuals for assessing and communicating risk.
2. Develop a public-policy framework that establishes tolerable risk guidelines and allocates costs for managing risks and consequences.
3. Provide professional education and training to members of the design and construction industries on identifying, analyzing, and mitigating risk.
4. Screen all existing critical infrastructure projects to determine if updated risk analyses are warranted. **Require that Risk Analyses be performed for all proposed critical infrastructure projects.**

In 2016, the Federal Energy Regulatory Commission (FERC) issued **Risk-Informed Decision Making (RDIM) Risk Guidelines for Dams.** [16] These risk-based guidelines were issued 40 years after President Carter's 1977 Memorandum on the Safety of Dams that explicitly addressed "risk based analysis,"[o] and 7 years after the American Society of Civil Engineers issued the

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[o] 1977 Memorandum available at https://drive.google.com/open?id=0Bz1I1mIutSEnTGISRzBMNTBsTDA

Guiding Principles for the Nation's Critical Infrastructure that also explicitly addressed "**manage risk.**" **There is no evidence that FERC or DWR - DOSD utilized this background during the Operations and Maintenance inspections of the Gated Spillway.**[1,5]

The Orovile Dam Gated Spillway failure – self-destruction was preventable. Over decades, there were many opportunities for DWR, DSOD, and FERC to recognize and investigate serious issues that could have led to effective remedial measures. Evidence[p] documented in the July 20th Root Causes Analysis Investigation report reveals the significant extent in decades of missed opportunities for DWR, DSOD, and FERC to detect and investigate severe anomalies.[7]

The lack of recognition of the significance of the severe issues revealed from the beginning of the construction of the spillway to present, reveals the long-term systematic failures of DWR, DSOD, and FERC to identify and rectify critical components of the Oroville Dam Gated Spillway to the required level of the **Operating Standard of Care:** ***thus, "Negligent."***[8] These egregious long-term repeated failures violated the **First Principle of Civil Law**: "***imposing Risks on people if and only if it is reasonable to assume they have consented to accept those Risks.***" **Risk control is a central goal of Civil Law**[9]

I have concluded DWR and DSOD should have taken the steps to update the design, construction, O&M standards and upgrade the Oroville Dam facilities so as to satisfy its documented Statutory, Regulatory, and Management responsibilities for the Safety and Risk Management of these facilities.[r] A superficial **'Patch and Pray'** approach is not an acceptable Safety and Risk Management Process for important public infrastructure Systems.

Previous experiences from formal Root Causes investigations of failures of both U.S. public and private industry infrastructure Systems (e.g. New Orleans hurricane flood protection system during Hurricanes Katrina and Rita[q], BP Deepwater Horizon Macondo well blowout[r], and the PG&E San Bruno pipeline explosion[s]) lead to the conclusion **the wrong standards and guidelines were being used (applied) to re-qualify these other critical infrastructure systems for continued service.** Like the Oroville Dam Gated Spillway, these critical infrastructure systems had embedded defects and flaws introduced during Design, Construction, and Operating & Maintenance that were combined with Aging, Technological Obsolescence, and increased Risk effects.

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[p] A summary of the written evidence contained in DWR – DOSD and FERC inspection reports is provided in - https://drive.google.com/open?id=0Bz1I1mlutSEnNG1Vem9lYlFFcjA

[q] Katrina Investigation - https://drive.google.com/open?id=0Bz1I1mlutSEnSlBkVWktZi1uX28
https://drive.google.com/open?id=0Bz1I1mlutSEnNnEwbGRSV3ZxRHM

[r] BP Deepwater Horizon Investigation -
https://drive.google.com/open?id=0Bz1I1mlutSEnVVdwbnF6czJGTmM
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[s] PG&E San Bruno Investigation - https://drive.google.com/open?id=0B0_jjqbhy5meWGV5aEtVeFE5OUU
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Similarly, these infrastructure systems purportedly were designed, constructed, operated, and maintained according to the "Standards and Guidelines of the time." **In all cases, the evidence indicates there were multiple intentional deviations from these Standards and Guidelines during their entire life-cycles.** All of these infrastructure Systems were regulated by Local, State, and Federal agencies. These major failures also represented 'Regulated Failures.'

Further, my previous experiences from formal Root Causes investigations indicate the majority of Standards and Guidelines currently being used were originally intended for design, not re-qualification or re-assessment of existing aged infrastructure Systems that have experienced Aging, Technological Obsolescence, and increased Risk effects. Our reviews indicate in many cases 'inappropriate' standards and guidelines were being used to re-qualify these infrastructure systems for continued service. **The currently available information indicates this continued long-term use of 'out-of-date' and 'inappropriate'[t] Standards, Guidelines, processes and procedures is one of the primary Root Causes of the failures of the Orville Dam Gated Spillway.**

Results from this investigation of the Root Causes of the failures of the Gated Spillway, Emergency Spillway have been consistent with those from a large number of previous forensic investigations of failures and disasters associated with engineered infrastructure systems: **it is the *Human and Organizational Factors* that are the primary challenge to being able to develop Safe and Reliable engineered infrastructure systems.**[10] This is the reason for emphasizing in this report **the need to develop high-reliability organizations with high-reliability management that can and will deliver High Reliability Systems that have As Low As Reasonably Practicable Risks and are Safe, Durable, Serviceable, and Compatible.**

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[t] 'Inappropriate' - intentional deviations from mandated 'acceptable practice' standards and guidelines.

[2] **Design documents**

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