

BUREAU OF RECLAMATION'S DAM SAFETY PROGRAM

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ABSTRACT

Reclamation is the owner of 362 high and significant hazard dams in the 17 western states. More than 50 percent of the inventory is more than 50 years old. The structures are critical components of an extensive and valuable water resource infrastructure in the west. As structures age, continued safe performance becomes a greater concern. The challenges for Reclamation cannot be met without a multifaceted approach to address the agencies' responsibilities. Reclamation's approach includes utilizing existing organizational structures, implementing dam safety decisionmaking policy, utilizing recurring and issue driven activities supported by risk analysis tools, and carrying out activities which invest in the expertise of staff. An aggressive program of risk reduction corrective actions is a critical component of the dam safety activities. Reclamation also has special activities which enhance and ensure organizational communication and which involve independent consultant review.

Reclamation places great reliance on recurring and issue driven operation and maintenance and dam safety activities to detect, intervene, and effectively respond to dam safety issues. Reclamation is now implementing regular use of risk analysis approaches to identify, evaluate, and manage issues involving the safety of the public. Risk analysis provides a systematic approach to the prediction of the likelihood of how the structure will perform, not just an assessment of how they were designed to perform. The implementation of risk analysis approaches has identified many areas where additional information or research is needed to improve our understanding of probable loads, likelihood of response, and the identification of potential consequences. Reclamation is actively pursuing many of these issues to improve our risk management. Risk analysis has already provided benefits to Reclamation in the justification of risk reduction actions to the Office of Management and Budget (OMB) and to the public.

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THE DAM SAFETY CHALLENGE

The United States Department of the Interior, Bureau of Reclamation, (Reclamation) is a Federal water resource development and management agency which is authorized to operate in the 17 western states through the Reclamation Act of 1902 and subsequent legislation. In carrying out its' mission Reclamation has developed water resource projects where dams play a major role in the viability of the developed resource. Reclamation serves as the fifth largest electric utility in the 17 western states and the nation's second largest wholesale water supplier. Reclamation operates 58 hydroelectric powerplants averaging 42 billion kilowatt-hours annually and delivers 10 trillion gallons of water to more than 31 million people each year. Reclamation also provides 1 out of 5 western farmers (140,000) with irrigation water for 10 million farmland acres that produce 60 percent of the nation's vegetables and 25 percent of the nation's fruits and nuts. Developing and sustaining this valuable resource carries an inherent public trust by our stakeholders that the Federal expenditures provide benefits and that these benefits are not outweighed by the public risks.

Reclamation has reservoirs impounded by 457 dams and dikes. Of these dams and dikes, 362 would place the public at risk if they were to fail. These 362 structures, located at 250 different project facilities, form the focus of Reclamation's dam safety program activities. Most of these structures were Reclamation designed and constructed under Reclamation management as part of an authorized Federal water project. However, Reclamation owns some dams which were designed and constructed by non-Federal entities and became part of a Reclamation project through authorizing legislation. The program also includes seven privately-owned dams that have become part of Reclamation projects through various legislation.

Approximately one-third of the Reclamation owned dams are operated and maintained by Reclamation employees while the remaining two-thirds of the dams are operated and maintained by the beneficiary water districts through contracts with Reclamation.

The public trust held by our stakeholders includes different and sometimes conflicting objectives. However, the stakeholders would all generally agree that the lives and property of those individuals residing, traveling, or recreating downstream of Reclamation dams needs to be a top priority. In 1998 in Congressional appropriation hearings the Assistant Secretary for Water and Science, and the Commissioner noted in their opening statements that the continued safe performance of Reclamation dams was a top priority. Reclamation dams are usually key features of Congressionally authorized projects which provide authorized benefits to organized water and power users and authorized public purposes such as flood control. However, since construction, the dams have provided additional benefits not included in the original project authorization such as recreation and fish and wildlife. Water and power users and project beneficiaries are not only concerned about the preservation of the resource but are also concerned about

the costs which authorized users may be responsible for bearing, either through operation costs or through their participation in modification costs. The interests of the Federal tax payers also need to be represented as much of the examination, monitoring, and investigation costs are considered to be Federal costs as well as a significant portion of the modification costs.

Reclamation is not regulated by an independent agency. Therefore, Reclamation is challenged to fulfill the public trust by self regulating its dams through its own programs and actions. However, Reclamation is not without meaningful input into how the public trust is satisfied. The *Federal Guidelines for Dam Safety* were implemented by presidential memorandum dated October 4, 1979, for dams owned or regulated by the Federal government. In addition, the Reclamation Safety of Dams Act was passed in 1978 to provide additional authority and guidance to Reclamation.

The Reclamation Safety of Dams Act of 1978 and the subsequent 1984 amendments provide authority to carry out dam safety activities and perform modifications considered reasonably necessary to reduce public risk. This allows Reclamation to sustain the water resources while reducing the public risks; however, it has also challenged Reclamation to better define the risks and benefits of the dams. For modifications needed for new hydro logic or seismic criteria, or changes in the state of the art, the cost of the total modification project would be 15 percent reimbursable by the authorized water users such as irrigation, municipal and industrial water, and power. In other words, 85 percent of the cost of risk reduction would be a Federal cost. The Acts also require that a formal modification report be submitted to Congress expressing the need for structural modifications, the corrective action deemed to be required, alternative solutions to structural modification that were considered, the estimated cost, and environmental impacts of the recommended modification. Risk reduction actions are compared in accordance the *Economic and Environmental Principles and Guidelines for Water and Related Resources Implementation Studies*. The modification reports are required for all Safety of Dams modifications with actual construction greater than \$750,000 and the modification reports must receive clearance from the Office of Management and Budget prior to transmittal to Congress.

The challenges are to credibly describe the public safety issues and associated risks to stakeholders, to reliably evaluate the performance and expected performance of our dams, and to make good decisions about prudent program practices, prioritization, and modifications in order to responsibly protect the public below Reclamation dams in a financially accountable manner.

MEETING THE DAM SAFETY CHALLENGE

The challenges for Reclamation cannot be met without a multifaceted approach to address the agencies responsibilities. The objective of Reclamation's dam safety program is to

ensure that structures do not create unacceptable risks to public safety and welfare, property, the environment, and cultural resources. Reclamation's approach includes utilizing existing organizational structures, implementing dam safety decisionmaking policy, utilizing recurring and issue driven activities supported by risk analysis tools, and carrying out activities which invest in the expertise of staff. An aggressive program of risk reduction corrective actions is a critical component of the dam safety activities. Reclamation also has special activities which enhance and ensure organizational communication and which involve independent consultant review.

Reclamation's Organization

Between 1990 and 1994 the organization of Reclamation underwent significant change. The changes were principally driven by Reclamation's desire to structure an organization which would provide good service to our constituents and stakeholders and also empower decisionmaking and program accountability at appropriate levels in the organization. Today Reclamation has about 5,600 employees. Reclamation is lead by the Commissioner who is supported by the staff of the Commissioner's Office which has Reclamation-wide program responsibilities. The Commissioner's Office includes organizations lead by the Director of Operations, the Chief of Staff, and the Director of the Office of Policy. Within the organization of the Director of Operations is the Dam Safety Office which carries out Reclamation-wide dam safety program activities and within the Office of Policy is the Dam Safety Officer who carries out Reclamation-wide dam safety review and advisory activities. Reclamation has 5 Regional Offices under the leadership of Regional Directors who have responsibility to ensure the continued day to day operation of Reclamation facilities. The Regional Directors utilize Area Offices under the leadership of Area Managers to carry out project specific water management functions. The Regional Directors, Chief of the Dam Safety Office, and Dam Safety Officer all are advisory to the Commissioner and have direct reporting on dam safety issues. Reclamation is blessed with knowledgeable technical individuals throughout the organizations. However, Reclamation's Technical Service Center, located in Denver, provides technical assistance throughout Reclamation and continues to be the center of expertise for dam design, analysis, and construction.

Reclamation Dam Safety Decisionmaking

The Commissioner of Reclamation is assigned the responsibility to ensure that Reclamation projects sustain the valuable public resources and also protect the public. The safety of the public is very important. Therefore, Reclamation has developed and is implementing a decisionmaking policy in which the Regional Director, Area Manager, and the Chief of the Dam Safety Office must collaborate on dam safety related decisions. The decisionmaking group helps ensure that public safety, technical, operational, and other important issues are appropriately considered in decisionmaking. A variety of Reclamation's recurring and issue driven dam safety program activities identify potential issues and develop information for the decisionmakers. Reclamation's decisionmaking policy also requires that the delegation of decisionmaking is documented which helps

establish individual roles and responsibilities among the varied organizational structures at Reclamation's Regional and Area Offices. As a reality, the delegation of certain decisionmaking to staff is necessary to ensure that an organization with an inventory and programs the size of Reclamation's can respond appropriately to potential issues and manage recurring activities. However, important risk reduction decisions involving restricting the resource or significant structural modification receive the personal attention of the Regional Directors, the Area Managers, and the Chief of the Dam Safety Office. Actual responsibilities for dam safety program activities may fall under the direction of the Regional Director, the Area Manager, or the Chief, Dam Safety Office. Risk analysis is used as a basic tool in the development of the information for decisionmaking for activities under the direction of the Chief, Dam Safety Office. Reclamation has also produced *Guidelines for Achieving Public Protection in Dam Safety Decision Making*, April 1997, to provide guidance on the interpretation of risk analysis results in decisionmaking. Emergency action planning has also been developed at all Reclamation dams to ensure that appropriate actions can be taken by the agency during an emergency to protect the public, our employees, our contractors, and the Federal facilities.

Operation & Maintenance and Dam Safety Program Activities

Reclamation is responsible for an aging infrastructure. Approximately 50 percent of Reclamation's dams were built between the years of 1900 and 1950 and the average age of the structures is 54 years. Reclamation considers that approximately 90 percent of the dams were built before current state-of-the-art design and construction practices. This does not mean that the dams represent risks to the public. It does however, represent that the dams generally do not have the design redundancies which are included in state-of-the-art facilities. Reclamation places a great reliance on recurring and ongoing operation, maintenance, and dam safety activities to detect, intervene, and effectively respond to dam safety incidents. These activities include structural performance monitoring, emergency action planning and exercising, operator training, and an aggressive examination program to help ensure that Reclamation and our water district partners can respond to issues or incidents if they should arise. The effectiveness of these activities has been evaluated and Reclamation has implemented many process improvements over the last five years. A blanket-level of risk management, or risk reduction, is provided across the inventory of dams by the recurring and ongoing dam safety activities such as these.

Significant energy has been put into Reclamation's emergency management activities over the last 3 years. An aggressive program to upgrade and exercise emergency action plans at each dam was initiated to improve the effectiveness of the plans as well as the potential preparedness of the downstream communities. The emergency action plans have been enhanced with the development of response levels tied to potential dam performance, operations, and incidents. These plans are exercised with downstream officials through orientation, table top, and functional exercising. Not only have the

exercises improved the responsiveness of Reclamation, our district operators, and the downstream emergency response officials, but the downstream officials now better understand the potential operation of the dams. Therefore, downstream community officials are better informed about potential dam operations and can consider that information as they carry out their community planning responsibilities. Emergency action plans are being updated annually and will be exercised on a three year interval.

As noted in the challenges, Reclamation is not regulated by an independent agency. However, recognizing the value of independence in operation, maintenance, and dam safety evaluations, Reclamation utilizes reviewers from a variety of independent internal organizations to ensure that day to day issues do not influence the evaluations and to bring fresh sets of eyes to the structure. Annual facility reviews are conducted and documented by Reclamation staff on all Reclamation owned dams to ensure an annual Federal presence on district operated facilities, develop a record of performance, and to communicate with operators. Periodic facility reviews are conducted at each dam on a 6-year cycle by individuals organized under the direction of Reclamation's Regional Directors yet organizationally independent from the day to day operational responsibility. Comprehensive facility reviews are conducted under the combined direction of the Regional Directors and the Chief of the Dam Safety Office utilizing senior technical staff from the Technical Service Center. The comprehensive facility reviews are conducted every 6-years on an alternating 3-year cycle with the periodic reviews. The inspection cycles may be accelerated based on site specific conditions.

The comprehensive facility review is an activity which has undergone significant development over the past 6 years. The review is actually broken up into five activities. The first activity is the development or updating of performance parameters where potential failure modes are developed, monitoring is reviewed for appropriateness and performance expectations are established. The performance parameters help establish flags for the very important instrumentation and observational monitoring which take place at the facility by Reclamation or water district operators who are our eyes and ears between facility reviews. The performance parameters also help establish flags for a second level of ongoing monitoring data review in Reclamation's Technical Service Center by monitoring specialists. The second activity of the comprehensive facility review is the physical examination of the dam condition and review of ongoing activities by a team led by the Technical Service Center (representing the Chief of the Dam Safety Office) and regional and area office staff (representing the Regional Director and the Area Manager). The physical examination may take several separate steps as mechanical equipment inspection and underwater inspection may need to be performed separately from the main dam inspection. The examination also provides the opportunity for the examiners to communicate with operators about their observed performance and the analysts expected performance. The third activity is the development of the report of findings for the facility. The Senior Engineer from the Technical Service Center is responsible for developing a comprehensive report of findings which presents issues and

potential issues in a risk context. The fourth step in the process is the presentation of the report of findings to the Dam Safety Advisory Team which provides internal critical review of the findings and also provides advisory input to the decision makers on appropriate agency actions to continue to operate the facility, to further assess the potential risks, or to take risk reduction actions. The Dam Safety Advisory Team is made up of senior level engineers and other technical specialties from the Technical Service Center. The benefits of the Dam Safety Advisory Team review include the enhancement of communication and the broadening of the experience of the Dam Safety Advisory Team members across the full inventory of dams. The final step in this process is for Reclamation to take appropriate actions in regard to the findings and recommendations. The presentation of issues and potential issues in a risk context provides the decisionmakers with important information to determine the appropriate action and priority for scheduling follow on actions.

The analysis of technical dam safety issues is under the combined direction of the Regional Directors and the Chief of the Dam Safety Office and relies on a major role played by the Technical Service Center. The Technical Service Center not only provides an appropriate level of organizational independence but also represents a significant technical resource and center of dam design, analysis, and construction expertise. Once potential issues are identified in a risk context, data collection and analyses are typically required to investigate and evaluate the issue. If continued safe dam operations appear compromised, corrective action alternatives are evaluated and a preferred alternative selected. Risk analysis is used throughout the process to assist in the identification of the value of potential data collection in reducing uncertainty in the estimation of risks and in the significance of dam modifications to achieve risk reduction.

As dams age, a performance history for the dam is developed. However, continued safe performance becomes a greater concern and challenge due to the effects of age, lack of state-of-the-art features, and the many uncertainties associated with many existing dams. Customizing the ongoing, recurring, and issue driven risk management activities to more effectively manage risk at each dam helps to meet this challenge. What specifically should be monitored at each dam and how should it be monitored? Risk analysis practices facilitate the assessment of complicated risk factors and the influence introduced by associated uncertainties. Extensive use of engineering judgement is typically required to answer the dam safety questions. Decisions based on engineering judgements have always been fundamental to dam safety evaluations due to an inherent abundance of uncertainties. Existing dams are typically plagued with uncertainties because they often lack many state-of-the-art design and construction features, predicted structural responses may be non-linear, and project documentation is often incomplete. Risk analysis approaches provide a mechanism to better define, organize, and understand these uncertainties and their significance. The options and importance to reduce uncertainties can then be considered from a more informed position. In addition, all factors that contribute to risk are more readily identified and considered in a risk analysis framework

which can lead to a better understanding of risk and consequently more effective, comprehensive, and balanced risk management.

Research and Development

The *Federal Guidelines for Dam Safety* indicated that risk-based analytical techniques and methodologies were a relatively recent addition to the tools available for assessing dam safety at that time. The guidelines also noted that with further refinement and improvement, risk-based analysis will probably gain wider acceptance in the engineering profession and realize potential as a major aid to decision making in the interest of public safety. The guidelines encouraged agencies to conduct research to refine and improve the techniques and to develop the methodologies and base of expertise necessary to apply risk-based analysis to dam safety evaluations.

Reclamation has historically concentrated its dam safety research and development on issues where significant future program funding was anticipated either to analyze or to modify structures. Under this approach, many design tools were developed including means to design embankment overtopping protection, fuse plugs for spillways, and much work has also been done to assess the erosion potential due to overtopping of concrete dams. Anticipating the need for structural modifications, Reclamation was driven to evaluate more cost effective solutions acknowledging that these solutions did not provide the confidence of traditional yet expensive spillway modifications. To date the overtopping protection and the fuse plug design tools have been used on Department of Interior dams.

Presently, Reclamation is considering risk analyses and decisions when prioritizing and evaluating our dam safety research funding. Our research and development may improve our risk analysis process. The general objective of our research is to develop and research tools that will enhance our present risk-based decisions and analysis techniques. This new look at dam safety research has revealed the need to increase work to address the risk issues related to seepage and piping as well as a need to develop somewhat of a balance of development between the other areas. The other areas include hydro logic loading probabilities, seismic loading probabilities, concrete dam analysis for seismic loading (nonlinear), liquefaction assessment, nondestructive dam evaluation and assessment, overtopping, and structural performance. Generally, Reclamation has tried to collaborate with other interested parties in the described research. In this way the funding available to Reclamation is leveraged to provide a broader benefit.

Technical development workshops have also been hosted and attended by Reclamation personnel to obtain the input from others on our processes and future development plans for risk analysis input and tools.

In 1998 Reclamation established a group referred to as the "Risk Cadre" to facilitate and accelerate Reclamation's use and confidence in the use of risk analysis as a tool in

structuring dam safety investigations and communicating results. The Cadre has developed methodologies to standardize analysis and are also developing tool boxes to assist in the quantification of risk. The Cadre is made up of senior level dam designers with extensive background in dam safety investigation, analysis and corrective action construction. Therefore, the tool boxes are focused at information needed by those responsible for carrying out and communicating dam safety issues.

Structural Modifications to Reduce Risks

Reclamation has maintained an aggressive program of implementing risk reduction actions at our high and significant hazard dams. The 1978 Safety of Dams Act authorized \$100 million to provide for the safety of existing Reclamation dams and related facilities and the 1984 amendments authorizing an additional \$650 million, indexed for inflation, for dam safety purposes. Reclamation has spent \$703,728,000 through September of 1998 on correcting structural deficiencies at 44 dams modified under the Safety of Dams Act authority. An addition 6 dams are currently under modification. These dam safety risk reduction actions have been critical components in Reclamation's water management mission.

Programmatic Review and Oversight

In order to better manage Reclamation's dam safety issues and to provide public accountability, Reclamation undertook an extensive programmatic review by an Association of State Dam Safety Officials (ASDSO) Peer Review Team in 1996. The Federal Guidelines for Dam Safety were used to measure the effectiveness of Reclamation's dam safety activities. The 1997 ASDSO Peer Review Team Report to the Commissioner reported that Reclamation has a good dam safety program and made recommendations for program improvements based upon findings of the team. Reclamation has been addressing the findings of the Peer Review Team and will have all the findings addressed by the end of 1999. Several significant recommendations were made by the Peer Review Team. The first led to the development of the Dam Safety Officer position in the Office of Policy in 1997. The Dam Safety Officer serves in a review and advisory capacity to the Commissioner on the dam safety related activities under the direction of the Chief of the Dam Safety Office, the Regional Directors, and the Area Managers. In addition, the Dam Safety Officer also administers a recently developed Reclamation Dam Safety Program Independent Standing Review Board. The Standing Review Board consists of 3 independent consultants representing different programmatic and technical specialties which will serve to provide Reclamation with independent review of Reclamation's dam safety program activities. The development of the Independent Standing Review Board also addresses recommendations of the Peer Review Team. Reclamation has also implemented an Annual Reporting Process which addresses many of the findings in the 1997 Peer Review Team Report.

The implementation of Reclamation's Dam Safety Program Annual Reporting process in 1997 has provided many benefits in the areas of communication of dam specific issues,

program activities, and in developing accountability for dam safety related program activities throughout Reclamation. The process consists of three activities. The first is the preparation of an Annual Area Office Dam Safety Report which includes and documents issues, activities, and accomplishments related to the Reclamation facilities. The second major activity of the Annual Reporting process is the Annual Area Office Dam Safety Assessment Meeting which takes the form of the Area Manager to the Regional Director reporting on dam safety and related operations issues. Required attendees for the annual assessment meeting is the Regional Director, Area Manager, Chief of the Dam Safety Office, and the Reclamation Dam Safety Officer. Responsible staff of the Area, Regional, and Dam Safety Offices regularly participate in the meetings. The meetings generally occur from December thru February to allow for reporting of items completed through the end of the fiscal year and also to ensure that critical issues can be communicated prior to winter and spring runoff/flood seasons. As was noted earlier in the paper, Reclamation has undergone significant organizational change which has flattened the organization structure. The annual assessment meeting ensures that scheduled communication occurs and that dam safety issues can be considered as Area Managers carry out their day to day operational responsibilities. The third activity of the annual reporting process is reporting by the Chief of the Dam Safety Office and the Reclamation Dam Safety Officer to the Commissioner. The Chief of the Dam Safety Office is responsible for reporting on overall accomplishments, including implementation activities that have successfully addressed previous annual assessment recommendations, activities related to policy development, program analysis, and accomplishments which pertain to Government Performance and Results Act performance measures. The Dam Safety Officer's report provides an assessment of the overall effectiveness of dam safety, adequacy of administrative and technical practice, the organization's degree of compliance to applicable laws, policies, and directives, and identifies opportunities for improvement and recommends actions to strengthen dam safety.

Dam safety issues at Reclamation dams can be technically challenging and the results of the technical evaluations have far reaching impacts on the national resources or on public safety. Therefore, Reclamation utilizes independent review boards to provide technical advice on significant projects. Generally, those which are moving toward modifications to reduce public risks have an independent review board developed early in the decisionmaking so that their input can be considered in the technical development of alternatives and in the actions which Reclamation implements

Achterberg, Hennig, and Redlinger, *Implementation of Risk Analysis Principles into the Bureau of Reclamation's Dam Safety Program Actions*, 18th Annual USCOLD Lecture Series, 1998