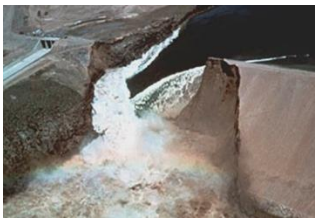

Dam Failure Investigation Guideline

Association of State Dam Safety Officials

This guide shares lessons from previous dam failure experiences and is designed to assist State dam safety agencies and dam owners in making good decisions during the chaotic and high stress period during and following a dam failure.

With modification, this Guideline could also be used to investigate major dam incidents and partial failures that did not proceed to full dam failure.

Completed By: The ASDSO Dam Failure & Incidents Committee

Updated: September 13, 2011

Association of State Dam Safety Officials
Dam Failure Investigation Committee
Interim Dam Failure Investigation Guideline

Contents

I. BACKGROUND AND PURPOSE

This document was created by the Association of State Dam Safety Officials (ASDSO) Dam Failure Investigation Committee (DFIC) (see the committee roster in Appendix A). The committee includes members with direct experience in most of the major dam failures of the past 10 years including Silver Lake Dam (Michigan), Big Bay Dam (Mississippi), Taum Sauk Dam (Missouri), Hadlock Pond Dam (New York), Lake Delhi Dam (Iowa) and Hope Mills Dam (North Carolina). The committee also gathered information on the KaLoko Dam failure (Hawaii) and the levee failures in New Orleans. These failures caused the loss of seven lives and hundreds of millions of dollars in losses (exclusive of the New Orleans levee failures).

There has been variability in how these dam failures were investigated.

The committee charter is to provide guidance to State Dam Safety Officials (SDSOs) when preparing for and conducting a dam failure investigation. The charter tasked the committee with the development of two products:

1. An Interim Guideline (this document)
2. A final report due in 2012 (with investigation report template)

By sharing lessons from previous dam failure experiences, the Committee wishes to assist SDSOs in making good decisions during the chaotic and high stress period during and following a dam failure.

With modification, this Guideline could also be used to investigate major dam incidents and partial failures that did not proceed to full dam failure.

II. AUTHORITY

This document was created under the authority of the Association of State Dam Safety Officials (ASDSO). The DFIC charter includes development of this Interim Guideline document.

This guideline is not law or policy and, therefore, is not binding on the States. Individual States may use the guideline to adopt a policy with a requirement to conduct investigations of dam failures involving loss of life, significant economic damages, and/or other major impacts.

III. INTRODUCTION

Dam failures are usually tragic events. Competent and independent investigations serve the following purposes:

- To determine the cause(s) of failure
- To understand contributing factors including organizational and cultural factors.
- To learn what went right and recognize efforts/successes
- To better support communication with the public and the press
- To identify lessons learned
- To recognize deficiencies and advance design/construction practices
- To improve understanding of warning signs of dam distress
- To improve dam safety regulation and dam engineering
- To prevent future failures
- To increase awareness of dam safety and civil infrastructure

The SDSO should consider consequences of the failure and other factors in determining whether an investigation is needed, though the Committee recommends that failures that result in loss of life or high economic losses should be investigated. The scale of the investigation is usually in direct proportion to the magnitude of the loss of life and other losses impacts.

Major dam incidents (without full dam failure) and failure of low hazard potential dams should also be considered for investigation**.**

There is a clear need to establish and maintain independence of the investigation team members. In the past, investigations have been seriously derailed due to public concerns that the investigation members (or their home organizations) had a stake in the outcome of the investigation.

Table 1 below provides information on many of the major dam failures and their investigations in the past 40 years.

See *Dam Failure Investigation Approaches*, Baker/Graham, 2008 and individual dam failure investigation reports for more information.

Table 1

Summary of Selected Dam Failures and Investigations

Year	Dam Name, State	Dam Height (ft)	Water Released (ac-ft)	Owner/ Regulator	Loss of Life	Damages	Brief Summary of Investigation Process
1972	Buffalo Creek, WV	44	982	Private Coal Company/ None?	131	$19 million (1972 dollars)	Governor appointed an "ad hoc" commission. There were public concerns about perceived lack of independence of commission members. Here is the final commission report: http://www.wvculture.org/history/disasters/buffcreekgovreport.html U.S. Department of the Interior established a Federal commission. The U.S. Senate requested the USACE to investigate other coal waste dams in the region.
1976	Teton, ID	305	251,000	Bur Rec/Bur Rec	11	$300 million (1976 dollars) 3000 homes were destroyed.	3 days post failure, the US Department of the Interior established the Interior Teton Dam Failure Review Group (IRG). They had three different subgroups: geology, grouting, and embankment construction. The State of Idaho also established the "Independent Panel to Review Cause of the Teton Dam Failure." Here is the Independent Panel Report: http://www.archive.org/stream/reporttousdepart00inde/reporttousdepart00inde_djvu.txt The General Accounting Office also reviewed the dam design/construction practices of Reclamation and the USACE.

2003	Silver Lake Fuse Plug Spillway, MI	33*	25,000	Electric Utility/ FERC	0	$100 million. Damaged homes, roads/ bridges, and flooded a large coal powerplant.	Staff engineers were immediately dispatched to site. The FERC formed an investigative team. A separate "Independent Review Board" was also established. The utility also hired a consultant to review the failure. http://www.ferc.gov/industries/hydropower/safety/projects/silver-lake.asp
2004	Big Bay, MS	51	14,200	Private land owner/ State of Mississippi	0	$8.5 million. More than 100 homes were destroyed.	The dam owned employed a consulting engineer to investigate the cause of failure.
2005	New Orleans Levees, LA	Approx. 15	250,000	Various/ USACE	App. 1200	$20 - $28 billion. 100,000 homes damaged or destroyed.	The USACE formed the Interagency Performance Evaluation Task Force (IPET) consisting of 23 members from Federal, water districts, a consultant and academia. Their work was peer reviewed by the National Research Council. Here is the final IPET report: http://www.usace.army.mil/CECW/Pages/ipetrep_final.aspx An independent investigation was also performed by a team led by the University of California at Berkley and sponsored by the National Science Foundation - here is their report: http://www.ce.berkeley.edu/projects/neworleans/

2005	Taum Sauk Upper Reservoir, MO	84	4350	Private utility/ FERC	0 deaths 4 injuries	Fines totaled $195 million. The dam replacement was very expensive.	Within 2 days, the FERC published an Action Plan. There were two investigative teams: one team of FERC dam safety engineers and an independent panel. Final report: http://ferc.gov/industries/hydropower/safety/projects/taum-sauk.asp
2006	KaLoko, HI	50	1140	Private owner/ State of Hawaii	7	Several homes and roads were destroyed. Damages totaled about $9 million	The State attorney general began an investigation. A citizen's group calling itself "Dam Mad" launched a petition drive for an independent investigation believing that the attorney general had a conflict of interest. The State legislature established a "Hawaii Special Deputy Attorney General" (also an engineer) to investigate. A criminal case was filed against the dam owner and has taken many years to resolve. Investigation report: http://pinetreewatchdog.org/wp-content/uploads/2011/08/Kaloko-Report.pdf
2010	Lake Delhi	38	9920	Recreation association / State of Iowa	0	16 residences destroyed/70 damaged. 180,000 cubic yards of sediment released downstream.	The Iowa governor sent a letter to FEMA requesting an investigation team. FEMA worked with the National Dam Safety Review Board to form a team. The USACE, Bur Rec, and FERC provided members gratis. The team did not arrive on site until six weeks following the failure. Investigation report: http://www.iowalifechanging.com/lakedelhi/

* Height includes the combined height of the fuse plug embankment and the fuse plug foundation material eroded in the breach event.

IV. PLANNING FOR POTENTIAL DAM FAILURES

The SDSO should brief their field staff on procedures for responding to incidents that could lead to dam failures, collecting information during the failure, and carrying out a successful investigation. They should also brief senior staff on likely actions needed during and following a dam failure (including the likely need for an investigation).

The technical paper *Dam Failure Investigation Approaches* (Baker and Graham, 2008) provides an overall understanding of dam failure investigations, including examples from recent failures. This and other documents will be posted on the ASDSO DFIC website.

The SDSO should plan in advance for potential failures by:

- Reviewing relevant case studies of past failures and the response to such failures to extract applicable lessons learned
- Training/communicating with field staff about dam safety incident response and failure investigation procedures (such as video, safety, documentation, timeline, etc.)
- Thoroughly documenting any known problems with the dam and keeping good records
- Incorporating this guidance into State program emergency action plans/policies/procedures

V. DURING THE DAM FAILURE EVENT

What should State dam safety officials (SDSO) do upon hearing about a developing dam failure?

1. Confirm the event is actually taking place – is it really an incident or failure?
2. Follow established procedures for emergency events, such as notifying law enforcement, emergency management, senior State staff and dam safety staff.
3. Learn whether the dam is State-regulated or regulated by others (e.g. Federal Energy Regulatory Commission, US Bureau of Reclamation, or other Federal agency). The State's responsibilities are greater for a State-owned or State-regulated dam. If the dam is regulated by others, coordinate with this entity and modify the recommendations provided below as applicable.
4. Collect information about the dam from State dam safety files and the Internet. Of prime importance are the Emergency Action Plan (EAP), the inundation map, warning/evacuation plans, construction documents and drawings, and any design reports, past inspection reports, and past investigations.
5. Promptly send State dam safety staff to the site with gear (see Appendix B for a recommended list of equipment). Make sure that they know their role and the activities they should perform in the field (e.g. supporting efforts to save the dam, keeping a log of events describing actions and observations, taking video/pictures with date/time stamps). It is

helpful to take several photos from the same position during the event. Record reservoir elevations, gate positions, flow readings and other instrumentation readings with time/date. Emphasize that dam failure sites can be inherently dangerous (e.g. sinkholes open up, slopes fail, or flows cause rapid erosion) and that they are not to put themselves at risk.

Although not part of the failure investigation, the following steps should also be performed:

- Support the dam owner in the use of the Emergency Action Plan and State Emergency Management Agency in the warning and evacuation of people downstream. Verify areas that would be inundated by reviewing the inundation map (if available) and/or Internet (e.g. Google Earth/MapQuest/Bing/DSAT).
- Support efforts in the field to intervene with technical expertise, equipment, and materials to prevent failure, if possible.

What should be done immediately following the failure?

1. Make the site safe. Areas of interest to the investigators and areas (such as scarps) that present a hazard to the public should also preferably be fenced off.
2. Secure the site and physically protect areas important to the investigation against tampering and/or degradation. Coordinate with appropriate authorities.
3. Create a log to document your activities and other events related to the emergency.
4. Hold coordination conference calls with follow-up emails to document decisions made in the calls.
5. Develop a communication plan to ensure communication with the public and others throughout the dam failure and investigation process. Have local staff take names and contact information from those that witnessed the event. Interview these people about the failure including their estimated time at which events occurred. Perform such interviews as soon as possible, while memories are fresher and more reliable.
6. Develop an initial press release stating the main points that the public needs to know and work with public affairs staff to post on Internet and distribute to the public and news entities. Media interest can be intense.
7. Alert appropriate State officials that a failure investigation will likely be needed (when appropriate).
8. Perform photo and video documentation of the site. Document inundated areas downstream. Disaster response agencies may perform aerial photographic survey mapping to determine the extent of the damages.
9. Send a formal communication to the dam owner that an investigation will likely be conducted and that they must not make physical changes to the site (except as necessary to make the site safe).

How should a Communication Plan be prepared?

1. Work with your public affairs office to determine a media point of contact.
2. Determine the main information points to communicate to the public:
    a. This dam failure is a serious issue that needs to be addressed.
    b. The State's dam safety office is the appropriate entity to address this problem because our mission is to ensure that an independent investigation is performed.
    c. The State dam safety office has a reasonable/responsible approach to handle this issue.
    d. The State dam safety office is listening, cares, and will address issues as they arise.
3. Prepare to provide background on dam safety and the State's dam safety program:
    a. Find the number of dams in your state, their hazard class, and ownership.
    b. Collect general information on the state of similar dams.
    c. Get program component background – authority, inspections, and design criteria.
4. Prepare for questions, such as:
    a. When was this dam last inspected?
    b. Who owns or is responsible for the dam?
    c. What caused the dam to fail?
    d. Will there be an investigation?
    e. What is the State doing for the victims?
    f. Where can people go for help?

VI. SETTING UP THE INVESTIGATION

When should an SDSO set up an investigation?

The following should be considered in determining whether an investigation is necessary:

1. Did the failure cause loss of life or injuries?
2. Did the failure cause significant economic, cultural, or environmental impact beyond that of the dam owner? Are there likely to be lawsuits to recover damages?
3. Is the dam regulated by the State?

Note that the State may choose to perform an investigation of a failed dam regulated by others.

How quickly should the investigation be established?

In general, the sooner the investigation is established, the better. Evidence can change or degrade. People's memories fade or become inaccurate. If the investigation cannot be quickly established (within a few days), consideration should be made to having State dam safety staff collect information in the field and provide the information to the team once it is formed.

How much will the investigation cost?

A simple low hazard dam failure with limited consequences may be able to be investigated by a single competent engineer for less than $10,000. The 3-member Lake Delhi investigation team costs roughly $110,000. The investigation following the New Orleans levee failures cost many millions of dollars. The cost will depend on the number of members, complexity, and scope of the review.

Is there a conflict of interest if the State sets up an investigation but may not have adequately inspected or regulated the failed dam?

The State should be aware of this potential conflict of interest and take steps to ensure the independence of the investigation team. The scope of the investigation must include the State's performance in regulating and inspecting the failed dam. The investigation team should have this instruction in writing. Failure to include the State's activities in the investigation could threaten the independence and credibility of the investigation.

How can I assure the independence of the investigation team and its members?

The members should be assigned from organizations that have no actual or perceived interest in the outcome of the investigation. Team members can be asked to sign a "no conflict of interest statement." The perceived independence can be affected by who sets up the investigation, who selects team members, who pays, etc.

How does an SDSO set up an investigation?

Specific procedures for how to set up and fund an investigation have not been established at the time of the writing of this interim guide.

The 2010 Lake Delhi Dam failure serves as the most recent example of how to set up a dam failure investigation. Based on Lake Delhi and other failures, the following are recommended steps to set up an investigation:

1. Brief senior State officials (e.g., the natural resources director and attorney general) on the failure and next steps. Cite previous dam failure experience of other states (good and bad) and the benefits of conducting a thorough and independent technical investigation.
2. Coordinate with the ASDSO Dam Failure Investigation Committee, the National Dam Safety Program, and the dam owner about the possibility of an investigation. Discuss the following:

- Scope of the investigation: should it review only the failure at the dam site or should it also include a review of the emergency response?
- Scale of the event and consequences of failure.
- Likely failure mode(s) involved and disciplines needed on the team.
- Which organizations could supply team members (most team members should come from different organizations)?
- Discussion of the education, experience, and expertise of potential team members. Team member must be recognized experts in their discipline. In general, experts in failure investigation will have a strong command of relevant engineering theory and corresponding ability to develop sophisticated analytical models, firsthand experience in investigating past failures, and broad exposure to dam failures derived from reviewing a large number of failure case studies (since very few individuals have personally participated in a large number of dam failure investigations).
- Which member will lead the investigation?
- Technical Advisors can be assigned on a part time basis to the team to cover specific technical disciplines.
- Any potential conflict of interest that these organizations or potential members may have.
- Timing.
- Funding (funding may be available from private/Federal entities providing team members or from the Federal Emergency Management Agency).
- Note that large/complex failures may need task groups (e.g., for modeling) to support the investigation team. Large/complex failures may also warrant the creation of a separate peer review team to review the work of the investigation team.

The Federal Energy Regulatory Commission (FERC) set up two investigation teams for the failures of Taum Sauk and Silver Lake Dam:

1. Data collection team: This FERC team got to the site quickly, collected data, performed analysis, and shared their results.

2. Independent investigation team: This team oversaw the work of the data collection team and arrived at their own independent conclusions about the failure.

3. Develop a formal memorandum or letter and establish the investigation emphasizing the independence and other key aspects of the investigation. Send this memorandum/letter to the team and other interested parties (e.g., the media).

How should the project be managed?

There can be a great many logistics, coordination, and management tasks involved in conducting an investigation. For larger investigations, it may be desirable to identify a project manager for the team. This project manager will free the technical investigation members to focus on the technical aspects of the investigation.

Will there be other investigations?

There may be other investigations. The following examples of entities may proceed with their own investigations:

- The dam owner
- The dam designer or construction firm
- Judicial (civil or criminal)
- Insurance company
- State Legislature
- Office of State Inspector General
- Congress (usually for failures of Federally-regulated dams)
- General Accounting Office (usually for failures of Federally-regulated dams)
- Federal agencies (usually for failures of Federally-regulated dams)

These other investigations should be coordinated; the Federal Energy Regulatory Commission (FERC) addressed this issue following the Silver Lake Failure (see **[PDF]** FERC Initial Report of Findings, **Silver Lake**, July 24, 2003,File Format: PDF/Adobe Acrobat - Quick View).

Any site investigations by multiple investigation teams must be coordinated. Multiple, uncoordinated site investigations will likely lead to confusion and loss of evidence. Coordination should be initiated as soon as possible by a conference call or meeting with all investigative parties. Consider the need for only one on-site field program that collects the needed information for all parties. Periodic coordination meetings/updates should be held.

How is the potential liability of team members addressed?

The report should contain a signature page with a narrative of professional statement and limitations (there may be several standard disclaimer examples available). If the investigation team members are State and Federal employees, their liability is limited because the State and

Federal government will represent them if they were acting within the scope of the job. Contractor employees should address potential liability with their firms.

Once team members are identified, what are the next steps?

1. Provide a letter of authority to the investigation team leader to conduct the investigation.
2. Ensure that the investigation team has appropriate authority to access the site – in some cases provide a letter to the dam owner authorizing the investigation team.
3. Identify a State person and a dam owner representative to liaison with the team.
4. Review the communication plan for ways to announce the investigation, its independence, membership, and objectives. Emphasize transparency and welcome input from the public.

How long will the investigation take?

A relatively straightforward investigation can be completed in 2 to 3 months. It is more typical for an investigation to take about 6 months. Investigation of a major dam failure (such as Teton or the New Orleans Levees) may take years.

VII. CONDUCTING THE INVESTIGATION

What, in general, are the steps in conducting an investigation?

1. The team collects and reviews dam and event information, records, and files.
2. The team visits the site and collects site information, conducts interviews, and reviews local records.
3. The team performs additional site forensic investigations and analyses.
4. The investigation report is developed, reviewed, signed, and transmitted.

How should the investigation get underway?

The team should have a kickoff meeting (conference call) to plan and begin the investigation. Some of the topics discussed should include:

- Development of a project plan
- Discussion of the authority documents
- Data sharing and communication methods (FTP, SharePoint, email groups, etc.)
- Reviewing data collected and asking what additional data is needed
- Consider what geotechnical (or other) field data collection program is needed

- Consider the need for a conference call with local staff
- Hydrologic and seismic data of the event and the record of reservoir elevations (as appropriate)
- Plan for the site visit (when, equipment needed, agenda, objectives)

What philosophy and approach should the team have?

Each failure investigation should be conducted to address the specific circumstances of each particular failure. However, the following are some general considerations which will apply to most failure investigations:

- The investigation is not just about the discovery of the actual physical processes which led to failure. Beyond the physical dimension, the investigation should also address the human contributors to failure such as poor design, poor construction, lack of inspection, poor maintenance, inadequate training, incorrect operations, lack of staff, ineffective organizational culture, misadjusted instruments, poor regulation, etc. These human factors can generally be divided into three categories: (a) lack of information (e.g., due to limited materials sampling and testing), (b) lack of understanding (e.g., due to inaccurate analytical models), and (c) errors, heuristics, and biases in human reasoning, judgment, and decision making at both individual and group/organizational levels, as described in the social psychology literature during the past few decades.
- Each team member should have an open mind and not prematurely lock in on favored hypotheses regarding causes and failure modes until all data is available, analyzed, and reviewed. However, it may be helpful to develop multiple *candidate* hypotheses early in the investigation though dialogue among team members, with hypotheses then being modified, rejected, and added as the investigation progresses, and with the ultimate goal being to identify a single leading hypothesis at the conclusion of the investigation. While the investigation is under way, these tentative working hypotheses generally should not be shared with the public, since doing so can create a bias to resist changing the hypotheses.
- Scientific hypotheses can usually be extensively tested, with the hypotheses considered to be increasingly corroborated as they pass more tests over time. In contrast, dam failures involve a single event which has already occurred, and thus cannot be replicated even once for testing, much less multiple times. As a result, the plausibility of failure hypotheses should be judged based on how well each hypothesis fits the available evidence, both in absolute terms and relative to competing hypotheses.
- Consider all possible failure modes and their causal interactions in space and time:
    - Instead of there being a single primary/root cause, there may be multiple causes of comparable importance.
    - Causes may act in parallel such that they counter each other, add to each other, and/or amplify each other (e.g., interaction of seepage and erosion involved in piping).
    - Causes may follow each sequentially, so that if A causes B, B in turn causes C, with B thus serving as both cause and effect.

- Flow charts or branching failure mode event trees may aid in graphically displaying processes.
- One cause can contribute to different effects in varying degrees, and a given effect may have several causes which contribute in varying degrees. In other words, a "cause/effect matrix" may be involved, as developed by one of the Committee members (Alvi) for investigation of partial failure of Prettyboy Dam.
- In short, failure can be due to an elaborate set of events, and so a goal of failure investigation is to develop a narrative "story" which explains the failure. This is analogous to the approach taken in historical sciences such as cosmology, geology, evolutionary biology, and archeology (and perhaps history itself).

What information should be provided to the team?

Provide contact information from State staff, dam owner, dam operators, eye witnesses, and law enforcement.

Provide dam information, including dam design drawings/specifications, dam modification design drawings/specifications, construction reports/photos, performance/monitoring information, inspection reports, EAP, inundation map, and important correspondence.

Also provide event information including: press releases, eyewitness accounts, log of operations, event timeline, photographs, video, surveys, news reports, emails, and websites.

The team may have to request/search for information not provided by State and owner. Sources may include museums, libraries, etc. The team may request information directly from the public.

How should information be provided to the team?

Because team members will likely be located in different areas of the country, electronic sharing of information is preferred. However, some file sizes can be very large. The State should consider setting up a password-protected File Transfer Protocol site. Another method could be to send pre-loaded thumb drives or CDs to each reviewer via trackable express mail. Whatever method is used, it is helpful to group information by type or date/time.

What will the team do during the site visit?

1. The team will normally attend an entrance meeting with State representatives at an office near the dam site.
2. The team should review additional local and State office records.
3. The team will go to the dam site. Often, they will take measurements, perform limited surveys, collect material samples, and take photos. They will plan further site investigation.

4. The team should interview the following: eyewitnesses, dam operation staff, maintenance staff, bystanders, inspectors, dam designer, contractors, and others. It is important to document what people were thinking or doing and what they saw or heard. Tie people's recollections to the time line of events.
5. In accordance with the communication plan, the State should consider setting up a public meeting so people can meet with the team, learn about the investigation, and provide information.
6. Develop a timeline of events.
7. Conduct multiple site visits if necessary.

What types of forensic studies may be performed?

The types of forensic studies and related data collection efforts depend on the dam type, the failure modes, and the extent of the data available. For example, if the failure involved the foundation and there is little information about the foundation, it may be necessary to conduct a drilling/sampling exploration program.

Studies could include:

- Geophysical
- Geotechnical
- Hydraulic modeling
- Test pits or exploratory excavations
- Detailed surveys

What types of analyses may need to be performed?

The types and depth of analyses depend on the failure modes and complexity involved. For example, if an embankment dam had overtopped and failed in a flood, it may be necessary to study hydrology, dam hydraulics, and slope stability.

What other work might the team perform?

- Conducting briefings
- Separating fact from fiction
- Developing graphics to visualize processes and the failure sequence
- Coordinating with any other ongoing investigations
- Serving as fact witnesses for subsequent court proceedings

VIII. INVESTIGATION REPORT

Who is the intended audience for the report?

The report will be read by the State, the dam owner, relatives of those who have died or been injured (if any), people or entities who have experienced losses, the press (and therefore the larger public), the justice system (plaintiffs, defendants, attorneys, judges), and engineers wishing to improve the practice of designing, constructing/operating dams. The communication plan should address how the report will be drafted and organized.

It is important to be in control of the message that goes out. The report should be organized and written to allow for understanding by all of the above (this could be accomplished by including an executive summary). This may mean explaining the failure cause(s) in layman's terms for the public, as well as in highly technical terms for the engineering audience. Actual photos or created visualizations of the failure sequences can serve both of these audiences.

What should the report contain?

The report should contain all material relevant to the investigation. To avoid making the report too large, use appendixes.

How should the report be organized?

[Note: The Committee will post a sample report format on the ASDSO DFIC website.]
Here is a sample table of contents:

Title page
Executive Summary
Authority and Purpose
Team Membership
Methodology (how the team performed its work)
About the Dam
- Dam description
- Design (as applicable to the failure modes)
- Construction (as applicable to the failure modes)
- Operations and Maintenance (as applicable to the failure modes)
- Instrumentation and Monitoring (as applicable to the failure modes)

About the Failure Event
- General description
- Timeline of events
- Photos
- Witness descriptions

Field data
Analyses
Failure modes
    Failure modes considered
    Failure modes judged to be plausible
    Need for field data and analyses
Other investigations
Likely contributing causes, failure modes, and sequence of events
    Note: Contributing causes include organizational and human factors, as well as poor maintenance, operational errors, instrumentation problems, poor design/construction, lack of monitoring, and anything else that created the situation which put the dam at risk.
Lessons for the Future
Acknowledgements
Appendixes

Who should review the draft report?

Develop a plan for review of the report; normally the report is not sent to the public in draft. The report may need to be reviewed by the following:

1. Team members
2. Entities who authorized the investigation
3. Technical peer reviewer (depending on the scope/scale of the investigation)

How is the report finalized and who should receive the final report?

Develop a plan for reviewing, signing, finalizing, and distributing the final report. The signed report should be sent under letter of the investigation team to the entity that established the team. Copies of the letter (with report attached) should be sent to other interested parties.

The State can issue a press release indicating that the investigation is complete and including a link to the report itself. Public meetings can be held to share the results with the public. The report should be posted on the Web site.

IX. SHARING LESSONS FOR THE FUTURE

Lessons for the future can be in the areas of dam design, operations, monitoring, inspection, construction, maintenance, standards, guidelines, risk, research, regulation, or ownership.

The investigation team should develop and deliver papers/presentations to dam safety conferences. An engineering case study should be developed so that engineers can learn from the failure in a facilitated session. Consider disseminating lessons learned through ASDSO.

Lessons learned about emergency management should be shared with emergency management entities for the dam.

Lessons about particular failure modes should be shared with organizations that represent engineers in that area. For example, if the failure mode involved a specific type of gate, the report should be sent to entities that design, construct, or operate dams with that particular type of gate.

X. ACKNOWLEDGEMENTS

The Dam Failure Investigation Committee would like to thank the many attendees at the 2009 ASDSO National Dam Safety Conference Soapbox on Dam Failure Investigations. Their contributions to the soapbox were documented and served as the basis for forming the committee.

The Committee would also like to thank organizations from dam safety and other industries who contributed their knowledge and experience to the Committee.

APPENDIX A

Association of State Dam Safety Officials
Dam Failure Investigation Committee Roster
Updated 9/6//11

CHAIR

Mark E. Baker, P.E., PMP
Dam Safety Officer
National Park Service
WASO-PFMD
12795 W. Alameda Parkway
Lakewood, CO 80228
Mark_E_Baker@nps.gov
Work: 303-969-2921, Cell:
720-443-9015
Fax: 303-987-6784
Related dam failure: Teton and Lawn Lk

EXECUTIVE SPONSOR

Alon Dominitz
New York
axdomini@gw.dec.state.ny.us
NY Department of Environ. Protection
625 Broadway, 4th Floor
Albany, NY 12233-3504
518-402-8130
Related dam failure: Hadlock Pond

MEMBERS

Irfan Alvi, P.E.
President & Chief Engineer
Alvi Associates, Inc.
110 West Road, Suite 410
Towson, MD 21204
Work: 410-321-8877 x12
ialvi@alviassociates.com
Related dam failure: Prettyboy Dam

Jason Boyle, P.E.
State Dam Safety Engineer
Minnesota DNR
500 Lafayette Road
St. Paul, MN 55155
Phone: 651-259-5715, Cell: 651-917-1715
Email: jason.boyle@state.mn.us

Robert (Bob) Clay, P.E.
Missouri, Department of Natural Resources
Dam Safety Program
PO Box 250
Rolla, MO 65401
Work: 573-368-2175, Cell: 573-368-6191
Bob.clay@dnr.mo.gov
Related dam failure: Taum Sulk

Warren Harris IV
New York
Senior Associate
CHA, Inc.
III Winners Circle
PO Box 5269
Albany, NY 12205
Work: 518-453-2851,
Cell: 518-248-2809
WHarrisIV@chacompanies.com
Related dam failure: Hadlock Pond

Tami Idol
North Carolina
Assistant State Dam Safety Engineer
Department of Environmental & NR
1612 Mail Service Center
Raleigh, NC 27699
919-733-2876
Tami.idol@ncmail.net

Wayne King
Federal Energy Regulatory Commission (FERC)
Work: (678) 245-3075, Cell: 404-661-1270
Wayne.king@ferc.gov
Related dam failure: Lake Delhi, Taum Sauk

Lori McDaniel
Iowa
Work: 515-281-8094, Cell: 515-210-8294
Lori.mcdaniel@dnr.iowa.gov
Related dam failure: Lake Delhi

Dusty Myers, P.E.
Mississippi
Work: 601-961-5207, Cell: 601-624-1427
Dusty_myers@deq.state.ms.us
Related dam failure: Big Bay

Mark Ogden, P.E.
ASDSO Representative
Cell: 859-333-3650
3594 Rochfort Bridge Dr
Columbus, OH 43221
mogden@asdso.org

Jim Pawloski, P.E.
Michigan
Work: 989-705-3443, Cell: 231-499-5608
Pawloskij@michigan.gov
Related dam failure: Silver Lake

Neil Schwanz, P.E.
USACE
Work: 651-290-5653, Cell: 651-769-3509
Neil.t.schwanz@usace.army.mil
Related dam failures: Lake Delhi, Katrina
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APPENDIX B

List of Equipment for Responding in the Field to a Dam Incident or Failure

Maps showing alternative access and locations for outgoing communication on satellite phones, cell phones, or field radios	Bolt cutters (for locks when people forget their keys)
Clear jars for taking seepage samples and determining if piping is occurring	Proper identification
Flags and stakes for marking seepage areas	Hard hat, high-visibility vest
Tape measure	Rope, safety equipment/clothing
Five-gallon bucket and stopwatch	Tools: hammer, screwdrivers, pliers, vice grip
Digital camera, batteries, and USB cable	Staff rod, probe pole
Duct tape and knife	Life vest
Power inverter and battery cables	Whistle
Laptop for Web access (email, sharing photos, monitoring weather)	Chest waders
Good rain clothing (Tyveck suits work well), umbrella, waterproof boots	Foldable ladder
Cell/satellite phone	Amber rotating beacon for vehicle
Extra batteries/chargers for camera, phone, etc.	Leather gloves (two pair)
Paper (including waterproof paper), pencil, all weather writing pen, black Sharpie, lumber crayon, highlighter	Flashlight (with batteries)
Ruler, clipboard, sticky notes, clips	Mini-marker flags
Bubble level (for measuring wall tipping)	Orange surveyor's flagging
Calculator	Orange spray paint
	Personal first aid kit
	Traffic flares (three each)
	Orange traffic flag
	Folding pocket knife

Many of the above items are from a paper presented at the Association of State Dam Safety Officials (ASDSO) conference by Jerry Oden at Montgomery County Maryland.

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