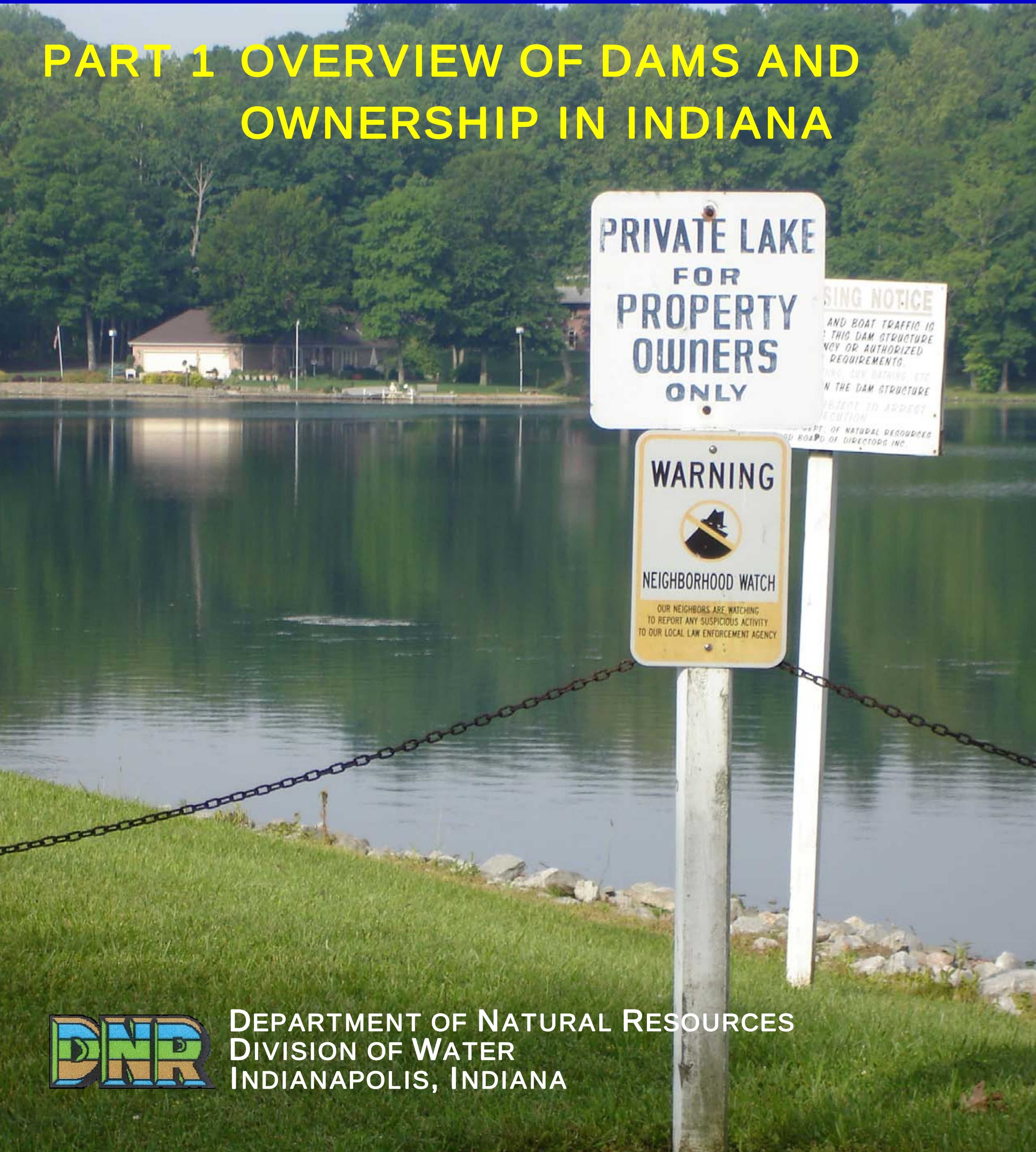
INDIANA DAM SAFETY INSPECTION MANUAL

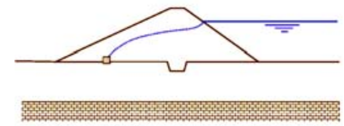
UPDATED 2007



PART 1 OVERVIEW OF DAMS AND OWNERSHIP IN INDIANA

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER
INDIANAPOLIS, INDIANA

INDIANA DAM SAFETY INSPECTION MANUAL



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Preface – Part 1

The Indiana Dam Safety Inspection Manual is based on accepted practice and consists of information developed from existing documentation on dam safety inspections obtained from state and federal agencies. Dam safety is a complex and multi-disciplinary practice that continues to evolve as professionals gain a better understanding of how the various dam components behave under different loading conditions and how society's level of risk tolerance changes with time. This manual is a "living document" that will change to reflect evolving national practice. As this manual improves with time, it will provide a stable reference for good dam safety inspection practice as administrators, program priorities, and statutes change. The manual consists of five separate parts:

Part 1, this part, describes ownership responsibilities and roles, risks and hazards of dam failure, and provides a detailed overview of dams in Indiana.

Part 2 presents guidelines for operating and maintaining a dam, including specific instructions on how to prepare a management and maintenance plan and how to respond to emergencies.

Part 3 provides guidance on evaluating dam safety and performing dam inspections. It covers who should perform the inspections and how, and provides guidance on identifying and reporting dam deficiencies and problems.

Part 4 describes guidelines for preparing Emergency Action Plans (EAP) to guide the dam owner during emergency situations. It also covers Emergency Response planning.

Part 5 is a compilation of Dam Safety Fact Sheets that present information on a variety of dam operational issues, such as seepage, slope protection, embankment stability, and spillway design, to name a few.

This manual should not be used in lieu of appropriate dam safety technical courses or training by a dam safety professional in the area of dam inspection. However, it should be used by experienced dam safety professionals as a reference and reminder of the aspects required to make a thorough dam safety inspection and evaluation. It should be stressed, however, that inspections alone do not make a dam safe; timely repairs and maintenance are essential to the safe management and operation of every dam.

The dam owner is responsible for maintaining the dam in a safe condition, and should do whatever is necessary to avoid injuring persons or property. As once stated by a highly respected legal scholar, "It is clear that compliance with a generally accepted industry or professional standard of care, or with government regulations, establishes only the minimal standard of care. Courts may assess a higher standard of care, utilizing the "reasonable person" standard and foreseeability of risk as the criteria. It is fair to say that persons who rely blindly upon a governmental or professional standard of care, pose great danger to others, and present a legal risk to themselves, when they know or reasonably should know that reasonable prudence requires higher care."

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INDIANA DEPARTMENT OF NATURAL RESOURCES · DIVISION OF WATER ·

Acknowledgements and Disclaimer

This Manual was developed by Christopher B. Burke Engineering, Ltd. (CBBEL) for the Indiana Department of Natural Resources (IDNR), Division of Water. Principal editors, authors, and support staff within CBBEL included: Siavash E. Beik, P.E. (Project Manager & Technical Editor), Ken Bosar, P.E. (Principal Author), and Jon Stolz, P.E. (Technical Consultant). Principal reviewers and project coordinators at the Division of Water included Kenneth E. Smith, P.E. (Assistant Director) and George Crosby, P.G. (Manager, Dam and Levee Safety Section).

A four-member peer review team provided technical review and advice during the preparation of the manual. The team members included Charles Rucker P.G., Robert Biel, P.E., Thomas Hugenberg, P.E., and John Pfeifer, P.E., all former Army Corps of Engineers dam safety professionals.

Much of the material presented in the manual was adapted from various publications developed by Federal and State agencies for dam inspection, operation, and maintenance. In many cases, pertinent text and illustrations were directly utilized within the manual with permission. A complete list of these publications is provided in the Appendices under References. The photographs were primarily obtained from IDNR and CBBEL files for Indiana dams; some photographs were obtained from public sources. The following is a list of agencies whose publications were extensively used in the preparation of this handbook:

Indiana Department of Natural Resources
Association of State Dam Safety Officials
U.S. Army Corps of Engineers
U.S. Department of Agriculture Natural Resources Conservation Service
U.S. Department of the Interior, Bureau of Reclamation
Wisconsin Department of Natural Resources
Ohio Department of Natural Resources
Colorado Division of Water Resources
Pennsylvania Department of Environmental Protection

Special recognition is given to the Federal Emergency Management Agency (FEMA) who provided funding to the IDNR for the development of this manual. Special recognition is also given to the Association of State Dam Safety Officials (ASDSO) for their leadership in developing effective dam safety programs and policies for the furtherance of dam safety. Their diligence in assisting the U.S. dam safety community was an important factor in the issuance of the FEMA grant.

Use of trade names, brand names, or drawings designating specific products is for reference purposes only and does not constitute an endorsement of products or services by CBBEL, review team members, the State of Indiana, or any of the cooperative agencies/organizations. Information describing possible solutions to problems and concerns, repairs, and emergency actions are intended for guidance only. The dam owner should seek qualified professional help for construction of new dams and extensive remedial measures for existing dams. Site-specific plans, emergency actions, and repair procedures should be developed on a case-by-case basis; CBBEL, review team members, the State of Indiana, any of the cooperative agencies/organizations and references cited assume no responsibility for the manner in which the contents of the Manual are used or interpreted, or the results derived therefrom. Current IDNR regulations pertaining to dams should take precedence to information contained within this Manual.

Indiana Dam Safety Inspection Manual Revisions		
Revision No.	**Date**	**Revisions Made**
0	Aug 28, 2003	First Edition published and placed on IDNR web site.
1	Aug 28, 2007	General grammatical revisions throughout; updated for new dam regulations and policy; added new Part 4, Emergency Preparedness; the original Part 4, Dam Safety Fact Sheets, has been renumbered as Part 5; revised Fact Sheets 1, 9, 11, 14, 17; revised front covers and prefaces; revised Table of Contents.

PART 1 OVERVIEW OF DAMS AND OWNERSHIP IN INDIANA

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CHAPTER 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 OVERVIEW

This manual was written to assist dam owners, inspectors, and qualified dam safety professionals in inspecting dams and maintaining them in a safe and stable condition. Dams are complex structures and usually require a multi-discipline approach to adequately address inspection, maintenance, and other safety issues. Therefore, dam owners should always obtain proper professional help when inspecting and maintaining dams and their appurtenant works.

The primary focus of any dam safety effort is the protection of lives and property in the area downstream from the impoundment. Every owner should be aware of the potential hazard that his\her dam poses to the inhabitants and property and of the need to properly maintain the dam in such a way as to reduce this hazard as much as possible. The liability for damages resulting from a dam failure rests with the owner of the dam.

Figure 1-1 Dams are commonly used to provide recreational resources and can enhance property values, but they must be properly maintained to realize their potential.

A good safety inspection and maintenance program is also important to the owner's bottom line. The typical dam represents a considerable cash investment. Replacement or major repair costs could be high. Loss of the dam could result in the loss of a water source, recreational facility, flood protection, or other assets.

It is important for the dam owner to recognize that dam safety inspections alone do not make dams safe. Dams require an on-going inspection and maintenance program to insure their continued safety and useful life. This fact is not always fully appreciated. Often there is a tendency to neglect dams once construction is completed.

This manual presents a logical approach that should be followed to evaluate the safety of dams in Indiana. Its intent is to inform the dam owner, operator, or others of general aspects of dam safety inspections, operation, and maintenance so that they can recognize certain unsafe conditions that may be associated with their structures. If unsafe conditions are recognized, professional services may be required to assess the problem and to take appropriate remedial action. This manual provides general guidance on some of the more common problems, but it is not intended to cover every type of condition, situation, or emergency that could possibly cause a dam to become unsafe or fail.

This manual may also be used as a reference to qualified dam safety professionals with expertise in dam design, construction, and inspections. Some of the information presented in the manual may be basic knowledge to these individuals, but the inspection procedures, documentation, and reporting should be followed by all.

The design of a dam is the task of an experienced professional engineer. The implementation of major remedial measures for a dam generally requires the help of an experienced professional engineer or a qualified dam safety professional. The application of trial-and-error "home remedies" to dam problems is not recommended and such an approach may prove to be far more costly than obtaining and acting on professional guidance. The text and illustrations of this manual are not intended to serve as a design guide either for the construction of new dams or for extensive remedial measures for existing dams. Rather, they are intended to serve as a source of information which the owner can use in his/her regular maintenance and inspection activities and as a general guide as to when professional services are needed to insure the safety of a dam.

1.2 DAM SAFETY LAWS

The Indiana General Assembly has established dam safety laws to protect the citizens of Indiana. Generally, the laws are intended to insure that the dam owner maintains his/her dam in a safe manner. The laws also define inspection requirements, violation conditions, and actions that the Indiana Department of Natural Resources (IDNR) will take if the dam owner violates the law. IDNR currently regulates all dams that meet any one of the following criteria:

(1) the drainage area above the dam is greater than 1 square mile
(2) the dam embankment is greater than 20 feet high
(3) the dam impounds more than 100 acre-feet

All dams that meet any one of these criteria will be regulated by IDNR under Indiana Code (IC) 14-27-7.5, “Regulation of Dams.” IC 14-27-7.5 presents the legal requirements for operating, maintaining, and inspecting regulatory dams in Indiana. A new administrative code under 312 IAC 10.5, “Regulation of Dams”, also presents definitions and creates procedures related to hazard classifications. A copy of the current Indiana Code for the regulation of dams is contained in Appendix A of Part 1. The most recent version of the statutes can be found on the website of the Indiana General Assembly. All dam owners should read and maintain a copy of the current Indiana Code for the regulation of dams in their dam safety file.

The primary focus of the dam safety laws is that dam owners are responsible for keeping their dam safe and for operating it in a manner that minimizes potential safety risks to downstream lives and property. Dam owners can be held accountable for any damage that results from the failure of their dams, so they should do whatever is necessary to avoid injuring persons or property. As stated by Professor Denis Binder in Legal Liability for Dam Failures, "It is clear that compliance with a generally accepted industry or professional standard of care, or with government regulations, establishes only the minimal standard of care. Courts may assess a higher standard of care, utilizing the "reasonable person" standard and foreseeability of risk as the criteria. It is fair to say that persons who rely blindly upon a governmental or professional standard of care, pose great danger to others, and present a legal risk to themselves, when they know or reasonably should know that reasonable prudence requires higher care."

IDNR has established a hazard classification system for Indiana dams in IC 14-27-7.5. The hazard classification is used to determine dam design and permitting criteria and safety inspection procedures. It is important that dam owners fully understand the hazard classification of their dam and their responsibilities associated with the classification. Downstream owners or residents may petition the IDNR to classify or reclassify a dam as high hazard and thus place the dam under IDNR jurisdiction (if not previously under IDNR jurisdiction) if they believe that the dam is a high hazard structure. (See Subchapter 1.6 and Appendix A, Part 1 for additional information on the hazard classification of dams.)

Even if a dam does not fall under IDNR jurisdiction, it would be prudent for all dam owners to develop a dam safety program that includes safety inspections, and an operation and maintenance plan.

If a dam does fall under IDNR jurisdiction, a permit will be required to construct or modify the dam or its appurtenant structures. During the permit application process, IDNR will review the information provided by the dam owner for adequacy. The owner's designer is responsible for the safe design of all components of the dam and appurtenant works. IDNR has specific guidelines (see Subchapter 1.7, Part 1) that assist in the design and construction of the dam.

1.3 IMPORTANCE OF DAM SAFETY

The storage of water is a potentially hazardous activity; it creates increased risk to lives and property situated downstream of the dam. The owner of a dam is responsible for operating and maintaining the dam in a safe manner to prevent harm to others and their property. An uncontrolled dam breach can cause serious property damage and injury or the loss of life downstream, depending on the size of the reservoir and the type and location of buildings or other structures. It is therefore very important for dam owners to establish and maintain an effective safety program that includes safety inspections, operation, maintenance, and upgrades (as required) of the dam and reservoir.

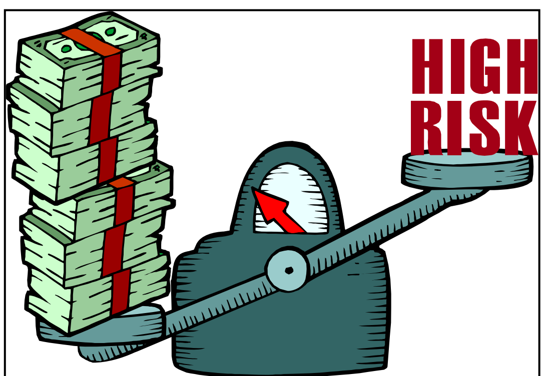

Figure 1-2 Dam ownership can become a high risk if an effective dam safety program is not implemented.

Although not the focus of this manual, it should be pointed out that the dam owner is also responsible for unsafe conditions within and around the reservoir that could result in injury or loss of life to people who use or visit the reservoir. Steep slopes, sinkholes, depressions, or excessive vegetation could lead to accidents that cause serious personal injury.

All dams, including dams that fall under IDNR jurisdiction, should be operated and maintained in a safe manner. Under Indiana law, IC 14-27-7.5-7, “Maintenance, repair; and sale; duties of owner,” the owner of a structure shall maintain and keep the structure in the state of repair and operating condition required by the following:

(1) the exercise of prudence
(2) due regard for life and property
(3) the application of sound and accepted technical principles

The dam owner may be held liable for property damage and personal injury and for failing to prevent such mishaps.

1.4 RESPONSIBILITIES OF DAM OWNERSHIP

1.4.1 Overview

Dam ownership imposes significant legal responsibilities and potential liabilities on the dam owner. The dam owner should be aware of the potential liabilities and learn how to deal with these liabilities.

Figure 1-3 The dam owner is responsible for repairing this damage downstream of the dam.

This subchapter presents general legal and insurance matters to help dam owners minimize their exposure to liability due to dam ownership or operation. It is intended only as a general introduction to the many issues regarding dam owner liability. This manual does not present answers to specific legal issues. Dam owners and operators should obtain competent legal counsel when dealing with specific issues. Dam owners should always act as if they are liable if there is any doubt.

1.4.2 Potential Liability Issues

The responsibility for maintaining a safe dam rests with the owner. A dam failure resulting in an uncontrolled release of the reservoir can have a devastating effect on persons and property downstream. Safely maintaining a dam is a key element in preventing a failure and limiting the liability that an owner could face. The general rule is that a dam owner is responsible for its safety. Dam owners should consult with their own experienced attorneys for specific legal advice concerning liability and financial responsibility to those who may be affected by dam safety issues.

The failure of a dam has the potential for catastrophic impact on communities, private property, and public works downstream. Experience reveals that the failure of even small dams can result in serious injuries, fatalities, and extensive property damage. The dam owner loses a valuable asset, and faces reconstruction costs and possible liability for downstream damages. Local communities may be directly impacted due to building damage, injuries, fatalities, lost water supply, damaged transportation and infrastructure, and lost recreational assets.

The extent of an owner's liability will vary, depending on the statutes and case law precedents. The concept of strict liability imposes liability on a dam owner for damages that occur regardless of the cause of failure. The alternative theory of negligence considers the degree of care employed by the owner in constructing, operating, and maintaining a dam. Historically, courts have sought to compensate those injured by a dam failure.

When assessing liability, the standard of care exercised by an owner will be closely examined. The standard of care should be in proportion to the downstream hazards involved. Where the risk is great, owners must be especially cautious.

Compliance with government or professional standards does not absolve an owner from liability, but it does establish a minimum standard of care to be used by owners. The extent of liability in any situation depends on the facts of the case and how those facts are interpreted by a judge or jury. Consequently, actions that result in owner liability in one case may not result in liability in different cases. In general, a dam owner is required to use "reasonable care" in the operation and maintenance of a dam and reservoir.

Figure 1-4 Erosive discharge from an uncontrolled dam breach severely impacted the downstream areas.

In today's litigious society, it is safe to assume that in the case of a catastrophic dam failure, extensive litigation will ensue. Any competent lawyer, representing the victims will sue all possible wrongdoers in seeking redress, including the owners and operators of the facility, and possibly the architects, engineers, contractors, sub-contractors, and consultants involved in the original construction, any subsequent modifications, and dam safety inspections.

An essential and logical part of an organization's management program is the control of potential losses that may arise. To manage risks, an owner can utilize a combination of standard operation procedures, employee training, regular maintenance, emergency preparedness, and liability insurance. A dam owner can take several actions to help protect against financial loss.

To help minimize dam owner liability, every dam should have:

- a state dam safety permit (if applicable)
- a management and maintenance plan, and an emergency action plan (if lives and property are at risk); see Part 4
- documented periodic inspections
- warning signs and controlled access.

1.4.3 Environmental Concerns

A dam owner needs to be generally aware of potential environmental issues before a dam is constructed or purchased, or its method of operation is altered (some of these areas of concern are discussed below). The dam owner should carefully consider the possible impacts of dam operation and how it affects the environment. He/she should seek professional help for a full evaluation of potential environmental problems.

Within the reservoir, it is likely that sediments have accumulated over the years. Release of these sediments downstream by operation of the dam, changing the reservoir level, or removing the dam could result in significant damage and liability to the dam owner. In addition, release of sediments downstream could adversely impact plant and wildlife for significant time periods. It is also common that the sediments contain pollutants.

Large discharges that can result from an uncontrolled dam breach can cause serious environmental damage downstream. These flows can cause severe erosion and can carry the sediment into receiving streams and other water bodies. Large discharges can destroy fish spawning beds, bird nesting areas, plant life, and other aquatic habitat. Man-made structures can also be damaged or destroyed by such discharges.

The dam owner should contact the appropriate government agency for potential environmental issues.

1.4.4 Insurance

The primary purpose of dam insurance is to share the risk and protect the assets and financial well being of the dam owner. Insurance cannot make a dam safe, or make an inherently faulty construction or renovation project into a good one. Inadequate coverage or insufficient limits on that coverage, coupled with a major loss, can mean the financial ruin of a dam owner. In order to obtain insurance and get a reasonable rate, the dam owner may have to show that the dam meets acceptable standards with regard to design, construction, and operation.

1.5 DAM SAFETY INSPECTION REQUIREMENTS

A dam safety inspection program should include four types of dam safety inspections:

(1) formal technical inspections,
(2) maintenance inspections
(3) informal inspections
(4) special inspections


Figure 1-5 Embankment dam with a concrete riser is a common type of dam requiring inspection in Indiana.

A formal technical inspection is the most comprehensive form of inspection and usually includes a review and analysis of available data and plans, a field examination, and preparation of a report. A key component of a formal technical inspection is the compilation or review of all available information for the dam and the surrounding area. Formal technical inspections should be performed by a team of one or more professional engineers, geologists, or qualified technicians, accompanied by the dam owner or his representative. Composition of the group is determined by the type of dam and its appurtenant works, the condition of the dam, and any statutory requirement.

A maintenance inspection is a preventive measure designed to identify problems and to develop solutions to prevent further degradation. Maintenance inspections generally involve reviewing previous inspection reports, performing a field examination, and completing a report form or inspection brief. Maintenance inspections are usually performed by the dam tender, maintenance staff, or the dam owner.

In the case of an informal inspection, the evaluation process typically consists of a field examination and completion of a report form or inspection brief. An informal inspection can be conducted at any time, and may include only portions of the dam or its appurtenant structures. Informal inspections are usually conducted by project personnel or dam owners as they operate the dam to monitor known problem areas, or to provide an update on site conditions between maintenance and technical inspections.

A special inspection may need to be performed to resolve specific concerns or conditions at the site on an unscheduled basis. Special inspections may be conducted following severe storm events, earthquakes, or other incidents which could affect the integrity of the dam. These inspections may also be part of a response to an emergency situation, such as rising reservoir levels during a storm, or excessive seepage resulting in piping. These inspections are usually performed by the dam owners, maintenance personnel, or qualified dam safety professionals.

Dam inspections are typically referred to as safety inspections since they are intended to help protect the safety of people and property downstream by providing a means of evaluating and maintaining the dam's integrity. Part 3 of the Indiana Dam Safety Inspection Manual presents procedures and information on conducting dam safety inspections.

1.6 DAM HAZARD CLASSIFICATION SYSTEM

As defined by Indiana Law, "hazard classification" means a rating assigned to a structure by the Department (IDNR) based on the potential consequences resulting from the uncontrolled release of its contents due to a failure or wrongful operation of the structure.

Indiana currently places all dams into one of three hazard classifications:

(1) High hazard: A structure the failure of which may cause the loss of life and serious damage to homes, industrial and commercial buildings, public utilities, major highways, or railroads.
(2) Significant hazard: A structure the failure of which may damage isolated homes and highways, or cause the temporary interruption of public utility services.
(3) Low hazard: A structure the failure of which may damage farm buildings, agricultural land, or local roads.

The hazard classification of a dam is determined by evaluating the area that would be affected by inundation in the event the dam fails. A correlation between the amount of inundation and the hazard classification is summarized on the table in Part 1, Appendix B. In many cases, the hazard classification of a dam can be determined by a review of current topographic maps and a visual inspection of the downstream floodplain for a distance commensurate with the size of the reservoir. If a breach analysis is required to determine the area of inundation, methodology accepted by IDNR should be used.

A property owner, the owner's representative, or an individual who resides downstream from a dam may request in writing that IDNR declare the dam to be a high hazard structure if they believe that the dam failure would cause a loss of life or damage to their home, building, utility, major highway, or railroad. If IDNR receives such a request, they will investigate the dam and area downstream, notify the dam owner of the investigation, and make a determination as to whether or not the dam is a high hazard structure. If IDNR determines that the dam is a high hazard structure, all corresponding regulatory requirements will apply. The dam will also be placed under IDNR jurisdiction even if it was not before the determination.

The dam spillway design is based on the hazard classification. IDNR has specific spillway design guidelines which must be followed to obtain a permit for a new dam, or to obtain a satisfactory rating for an existing dam. In general, a high hazard dam must be designed to safely pass 100% of the probable maximum precipitation (PMP) storm event, and a significant or low hazard dam should safely pass 50% of the PMP storm event. A PMP storm is a very large event, typically resulting in accumulated rainfall of 25 inches or more in small watersheds in Indiana.

Over time, development may occur in the area downstream of a dam. In fact, a manmade lake sometimes encourages downstream development. If a new dam is being planned, it may be prudent to design the dam spillway for a higher hazard classification. This can help the owner avoid major dam and spillway modifications at a later date in the event that downstream development occurs, the hazard classification increases or land availability may be restricted.

1.7 GENERAL GUIDELINES FOR NEW DAMS & IMPROVEMENTS TO EXISTING DAMS IN INDIANA

Table 1-1 Table of Contents
General Guidelines for New Dams & Improvements to Existing Dams in Indiana (2001 Edition)

The Indiana Department of Natural Resources, Division of Water prepared the *General Guidelines For New Dams & Improvements To Existing Dams In Indiana* for project engineers, technical professionals, and owners involved in the design and construction of dams or the modification of existing dam's that are under the jurisdiction of the IDNR. The intent of these guidelines is to provide direction to experienced dam design professionals so that the final product, the dam, is safe and the owner's investment in professional engineering is maximized.

The majority of information given in the guidelines document is general and provides many of the dam safety technical principles used throughout the country. The Project Engineer in charge of the design of a dam must be a registered professional engineer and have the training and experience to properly apply these guidelines to the specifics of the site and the needs of the owner. If the owner's Project Engineer follows these guidelines and an appropriate engineering design package is submitted to IDNR's Division of Water, the time to obtain approval on the proposed work will be significantly reduced. A committee of 17 professionals from the private engineering community and IDNR contributed significant time to the development of the guidelines.

The guidelines are useful for the design of small to medium sized dams with the following typical characteristics:

- An earth embankment with appurtenant works constructed to remain stable under a variety of loading conditions for the design life of the structure.
- A properly sized principal spillway that will convey the runoff from normal rainfall events.
- An emergency spillway channel placed an adequate distance from the earth embankment that will operate infrequently and safely pass runoff from the design storm without overtopping the dam.

Because each project requires site specific considerations, the guidelines should not be viewed as a "cookbook" for the design, construction, modification, or repair of a dam. The intent of the document is to outline the general technical data, plans, and engineering computations that need to be submitted with the permit application for the proposed work. If the guidelines are followed, the time necessary for the technical review and approval should be reduced. Guidance on analyses and design issues for innovative, untested, or high-risk dam designs is not covered in the guidelines. The extent of engineering tests, analyses, studies, evaluations, and assessments that are needed to justify an atypical design is beyond the scope of this manual. Further, the time to conduct the additional and extensive engineering analysis and review can be significant when compared to the typical dam described above.

Dams are complex structures that typically require a multidisciplinary analysis and design approach. Over the years, there have been many incomplete engineering submittals to the IDNR that lacked adequate detail in a particular technical area (hydrologic/hydraulic, geotechnical, geological, surveying or structural). The analysis and design of a dam must be supervised by a Project Engineer who is a registered professional engineer. A complete engineering submittal requires adequate technical input and support from hydrologic, hydraulic, geotechnical, geological, structural, and mechanical engineers, as well as licensed land surveyors. It is important for the Project Engineer to consider archaeological and environmental issues in the design or modification of a dam. An understanding of the roles of the various stakeholders is necessary for the design, construction, and operation of a safe dam.

Questions concerning the guidelines should be addressed to the Division of Water at the Indiana Department of Natural Resources, 402 W. Washington Street, Indianapolis, Indiana, 46204. The guidelines are available on IDNR's website for public use at http://www.in.gov/dnr/water/dam_levee/index.html.

CHAPTER 2.0

AN OVERVIEW OF DAMS

2.0 AN OVERVIEW OF DAMS

2.1 DAMS IN INDIANA


Figure 2-1 Earth embankment dam in Indiana.

A dam is a man-made barrier constructed for the purpose of storing or diverting water. The barrier is usually constructed across a watercourse such as a stream or river, and usually consists of earthen materials or concrete. There are more than 1,200 dams in Indiana, including approximately 250 high hazard dams. Most dams in Indiana are earth embankment dams less than 50 feet high, and typically are used for recreation, flood control, and water supply. Some dams store water to harness its force to generate electricity. Many of the existing dams in Indiana are relatively old (30 years or more), making dam safety inspections and maintenance an important part of their operation plan.

Every dam should accomplish the following objectives under all anticipated loading conditions:

(1) hold back or store water safely
(2) contain the water and resist leakage
(3) maintain its shape and configuration
(4) resist movement in any direction
(5) safely pass maximum design flood events

The water stored behind the dam imposes significant forces on the embankment and foundation materials. The pressures exerted on the dam and its foundation increase as the depth of stored water behind the dam increases, thus requiring greater resistance to leakage and movement. The pressure of the stored water loads the dam such as to tend to push the dam downstream, creating the potential for stability problems. Therefore, greater water depths require wider, stronger dams. Resistance to leakage is important since the purpose of the dam is to store water. Once leakage starts, it can get progressively worse with time and can create a safety hazard and eventually cause dam failure. The function of maintaining the shape is more related to dams constructed of earth material or rock than those made of concrete. The shape refers to the outline of the dam or the profile along the centerline. The final shape of the dam is usually dictated by the type and amount of material necessary to resist leakage and movement. If the shape of the dam changes, it may no longer be able to perform its required functions and may become a safety hazard. External forces, such as earthquakes and extreme weather events can also affect and change the ability of a dam to perform its functions. Therefore, dams must be properly designed and maintained to withstand all conceivable forces that may be encountered. Indiana dam embankment design should follow the guidelines contained in, "Earth Dams and Reservoirs," published by the U.S. Department of Agriculture Soil Conservation Service, Engineering Division.

Figure 2-2 is a section through an earth embankment dam illustrating many of the principal components of a typical dam. The dam in the sketch is called a zoned dam since the cross section consists of zones of different materials, including an impervious core and a pervious outer shell. Understanding the purpose of these components is essential to any evaluation of a dam's condition. The following discussion describes the principal components and their purpose.

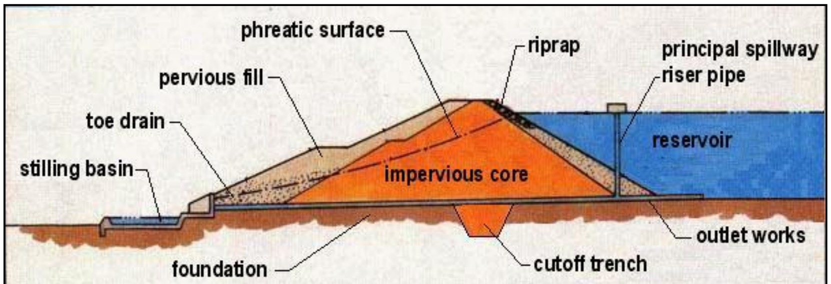

Figure 2-2 Section through a typical embankment dam with a riser pipe used as the principal spillway.

The part of the dam site which must support the dam is the foundation. Although other factors are involved, the first task of the foundation is to provide firm support for the entire dam. A soft foundation, for example, would not support the weight of the dam. Because the main purpose of the dam is storage of water, the foundation must also resist the flow of water under the structure. A clay material or unfractured hard rock, for example, would resist the flow of water under the structure much more effectively than sand or gravel. An impervious cutoff trench may be required if the foundation consists of porous materials.


Figure 2-3 Upstream slope, downstream slope, crest, and reservoir of an earth embankment dam.

The reservoir is the body of water impounded by the dam. The basin behind the dam or the area covered by the reservoir is just as important as the dam itself. Its size and shape determine the volume of the reservoir. Like the dam, the foundation, and the abutments, the basin must contain the water.

The embankment is the main part of the dam, and is usually referred to as the dam. In Indiana, the embankment usually consists of local soil materials which may vary in quality. Some dams consist of an impervious soil core in the center of the embankment with rock covering (pervious fill) the upstream and downstream slopes to protect the core and to provide strength to the embankment (see Figure 2-2). In the case of a concrete dam, a concrete structure is used instead of an embankment.

The upstream embankment slope is the inclined surface of the dam that is in contact with the reservoir. This slope must be protected from erosion due to waves. Erosion protection may include grass, or the placement of riprap or some other durable material. The crest is the top surface of the dam. Often a roadway is established across the crest for traffic or to facilitate dam operation, inspection, and maintenance. The shoulders are the upstream and downstream edges of the crest. The downstream slope is the inclined surface of the dam away from the reservoir. This slope also requires protection from erosive effects of rain. Grass is often used for erosion protection on the downstream slope. The toe (or downstream toe) is the junction of the downstream slope (or face in the case of a concrete dam) of the dam with the ground surface. Riprap is a layer of stones, broken rock, or precast blocks placed in random fashion on the upstream slope of an embankment dam, on reservoir shores, or on the sides of channels to protect against wave erosion and ice action. Large riprap is referred to as armoring.

The cutoff trench is an excavation in the foundation of a dam for the purpose of construction of a vertical barrier (such as a core or diaphragm) to seepage. Often the core is extended into the foundation by digging a trench along the length of the dam and filling it with the flow-resistant material. Extending the barrier into the foundation to control the flow of water under the dam is important, especially if a porous material such as sand, gravel, or weathered/fractured bedrock lies directly beneath the embankment. If the foundation has low resistance to the flow of water, for instance, through fractured rock or a sand layer, the most effective means of reducing the flow of water through the foundation is a cutoff.

The abutment is that part of the valley side against which the dam is constructed. The contact between the abutment and the embankment slope is called the slope-abutment-interface or groin. The abutments and groins are designated as left or right when facing downstream while standing on the crest of the dam. The abutments must offer support to the structure in the length-wise, upstream-downstream, and vertical directions.

Figure 2-4 Photograph of abutment (right), embankment (left), riprap-lined groin, and spillway outlet.

The spillway is a structure over or through which storm or flood flows are discharged from the reservoir. If the rate of flow is controlled by mechanical means, such as gates, the structure is considered a controlled spillway. Otherwise, the spillway is considered as uncontrolled. The principal spillway is the initial spillway designed to carry the storm or flood discharge. It may be either a drop inlet (riser) or an overflow structure. Usually, the principal spillway is designed to maintain the water in the reservoir at a constant level known as the normal pool. The emergency spillway is designed to safely pass the discharge of large storms or flood flows in conjunction with the principal spillway, thereby preventing the dam from being overtopped and possibly breached. Spillways must be designed and constructed to prevent overtopping of the dam embankment for the anticipated maximum loading conditions. A spillway can be located on either abutment or constructed as part of the dam. Sometimes a natural drainage channel adjoining the reservoir is used to carry floodwater safely around the dam. The location is selected based on the topography, size of expected storm, and economics. The adequacy of an existing spillway requires evaluation by a qualified dam safety professional. Uncontrolled spillways should not be constructed over embankment fill materials.

Figure 2-5 Riprap-lined stilling basin at spillway outlet.

Figure 2-6 Toe drain pipe outlet (right) located near principal spillway outlet.

The outlet works are structures (pipes) which are used to drawdown or drain the reservoir. The primary purpose of the outlet works is to provide for controlled release of the water from the reservoir behind the dam. Upon demand, the outlet can be used to release water downstream for irrigation or other uses. The system is also used to lower the reservoir in an emergency or for maintenance and repair of the dam and appurtenant structures. The size of the outlet system is determined by the rate of the demand for use of the water. A valve must be included to regulate the drawdown rate.

The stilling basin or plunge basin is a basin or pool area at the toe of the dam into which the spillway and outlet works discharge. This area is designed to dissipate the energy of the flow so as to prevent downstream scour or erosion (see Figure 2-5).

Figure 2-7 Trash racks on riser spillway structure.

The toe drain is a method of controlling the seepage of water through a dam. Water entering the drain should flow freely through the drain and exit safely beyond the dam without wetting the material in the downstream slope. A pipe is often installed in the toe drain to carry the internal seepage water away from the dam to prevent erosion of the soil from the embankment. The collector pipe is usually surrounded by a filter material and placed in the toe of the dam or laid in a trench beneath the toe. Other types of drains may be used to collect seepage water.

Appurtenant structures refer to ancillary features of a dam such as outlet works, spillways, powerhouse, tunnels, trash racks, etc. The trash rack is a screening device located at an intake structure to prevent the entry of debris.

2.2 TYPES OF DAMS

Most dams in Indiana are earthfill embankment dams. However, there are a few rockfill and concrete dams. This subchapter briefly describes the characteristics of each of these dam types.

Earthfill Dams

Earthfill embankment dams are by far the most common type of dams. An earthfill dam is defined as an embankment dam in which more than 50% of the total volume is formed of compacted fine-grained soil obtained from a borrow area. Fine-grained soil is a soil material with more than 50% passing the #200 mesh sieve, typically clays. A homogeneous earthfill dam is an embankment dam constructed of similar earth material throughout, except for possible inclusion of internal drains or drainage blankets. Excessive water seeping from the downstream slope of a dam is an unsafe condition that requires remedial measures to correct the situation. Therefore, every effort is made in design of an earth dam to minimize the chance for uncontrolled water to exit on the downstream face.

Many of Indiana’s soils are well suited for embankment dam construction. Fine-grained, cohesive soils (typically clays) that are resistant to water seepage are common. This is the main reason that earth embankment dams are prevalent.

An embankment dam which is composed of zones of selected materials having different degrees of porosity, permeability, and density is called a zoned embankment dam. The zoned dam provides control of the flow of water with a core having a very high resistance to flow. In the case of the zoned dam with a drain, a coarse-grained material is installed to adequately control internal seepage.

Depending on the dam foundation conditions, seepage control under the dam may also be required. Core trenches are often installed under the embankment to control seepage through permeable materials that may be present (e.g. sand, gravel, fractured bedrock). The core trench is typically excavated to a relatively impermeable soil barrier layer and filled with compacted soil that can retard or stop the seepage. Gout curtains, slurry walls, or other types of cutoff walls may also be used to control foundation seepage.

Rockfill Dams

A rockfill dam is an embankment dam in which more than 50% of the total volume comprises compacted or dumped pervious natural or crushed rock. Most rockfill dams are similar in shape to earth dams. The difference is that rock fragments make up the primary material used for construction. The choice of constructing a rockfill dam versus constructing an earth dam is usually based on availability of materials. Because rock fragments alone would leave large openings for seepage flow, a central core, like that in the zoned earth dam, is required. Also, note that the core usually extends into the foundation to help control the flow of water under the dam. A transition zone is usually necessary to protect the core from internal erosion. The transition zone is designed to keep the fine-grained core materials from being washed into or through the rockfill. Gout curtains, slurry walls, or other types of cutoff walls may also be used to control foundation seepage.

Concrete Dams

Concrete dams are the least common in Indiana. Concrete is probably the most durable material for building dams and has a very high resistance to seepage. A concrete dam is unique in that it directly transfers the pressures created by the stored water to the foundation and abutments. A concrete dam, therefore, is dependent upon the ability of the foundation and abutments to hold the dam in place. Like earth or rockfill dams, a concrete dam must have special provisions for controlling seepage under the dam. The most common method is pressure grouting a line of holes into the foundation and abutments before the dam is constructed. The cement grout will fill most voids or fractures in the rock.

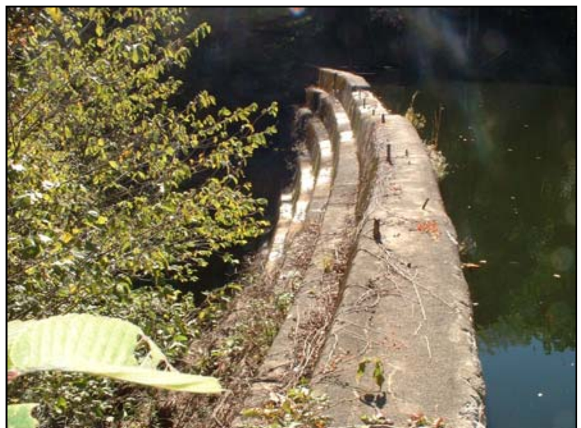

Figure 2-8 A concrete arch-shaped gravity dam in Indiana.

There are three basic designs for concrete dams: gravity, arch, and buttress types. Combinations of these types are also possible. For instance, a gravity dam may be constructed in an arch-like shape, and buttresses may be used to help support it. Roller compacted concrete construction techniques are becoming an economic alternative to traditional concrete construction methods.

Figure 2-9 Typical earth embankment dam with riprap shore protection.

2.3 CONSTRUCTION MATERIALS

Figure 2-10 Grass-lined emergency spillway.

Most dams in Indiana are embankment dams constructed with soil fill material. The fill should be a cohesive soil (clay) with adequate strength characteristics to withstand the long term forces to which it will be subjected.

The types of materials that are used or found on embankments are often dictated by the dam design or anticipated usage of the embankment, including access and roadway requirements. Gravel, rock (riprap), concrete, asphalt, articulated concrete blocks, and grass are often used to help stabilize the embankment surfaces. Most materials normally require a subbase treatment before placement. For example, rock placed on an embankment for wave action will require a proper filter material beneath it to prevent subsurface soil erosion. Concrete and asphalt should also have a proper subbase for drainage and bearing support, usually consisting of a coarse aggregate (gravel). Except for soil, most of these materials are used for embankment slope protection, roadways, etc.

Figure 2-11 Riprap slope protection on an embankment dam.

The embankment surfacing must be capable of withstanding the worst-expected conditions (rainfall, wave action, high winds, vehicular and foot traffic) to prevent damage to the underlying dam structure. If the dam contains an impervious core, adequate protective material should be provided on the surface to protect the core from damage by frost heave and from the formation of desiccation cracks at the top of the impervious core. In all cases, it is preferable that the material used to cover the embankment is a material that will not shrink or crack when dried out. This will prevent the formation of drying cracks in the embankment and the possible infiltration of reservoir water or surface runoff into the dam's cross section through the surface cracking. If the embankment is a homogeneous earth fill dam constructed of cohesive soil material (common in Indiana), a layer of topsoil is usually placed over the fill to cover the cohesive soil and promote grass growth.

Embankment soil fill is usually covered with grasses or riprap to prevent erosion. If the dam is a rockfilled structure, or a zoned embankment dam, the slopes and crest will usually be rock. Benches are often used on either the upstream or downstream slopes to reduce overall slope angles, or grades, and to help control stormwater runoff.

Figure 2-12 Public road on dam crest.

When access across the dam is needed only for maintenance operations that can be scheduled during favorable weather conditions, no special crest surfacing is required. In these cases, the crest surfacing is usually composed of soil materials placed during original embankment construction. If access across the dam is required under all weather conditions for the safe and routine operation of the dam, or for public travel, the crest should be surfaced with gravel or pavement. If the dam is a rockfilled structure, the crest may also be rock. Again, if access is required, the top of the rockfill is often smoothly finished or gravel is placed on the crest to provide a smooth roadway. Any modifications to retrofit a dam with an access road may require a proper engineered design and approval from state and local agencies.

2.4 GEOLOGICAL SETTING

The geological setting is a very important factor when designing dams, or when trying to troubleshoot problems or safety deficiencies. It is crucial that the inspector fully understand the geological features and conditions of the site to better assess problems and deficiencies. For example a dam located in a glacial outwash area is likely to be sitting on permeable granular materials, which would tend to transmit water (seepage) in the foundation and abutment areas.

Site-specific information obtained from a geotechnical exploration program will better define and qualify the subsurface conditions in a given geological setting. For example, a dam located in a karstic geological setting will require subsurface exploration data to better define the physical parameters and extent of typical solution features (voids and joint openings) in the foundation, abutment, and spillway areas of the structure.

All dams should be assessed in light of both the local site and regional geological conditions. In addition to knowing the construction history of the dam and appurtenant structures, the inspector or the inspection team should have knowledge of the potential geologic factors that may influence the performance and safety of an existing dam. For example, successful filling and sustainability of the impoundment are directly linked to the geological setting. Part 5 contains a fact sheet to help dam owners gain a better understanding of their geological conditions.

Indiana dams typically consist of embankments made of earth materials over soil or rock foundations with auxiliary channel spillways through natural ground. As such, dams in specific regions tend to have similar characteristic or potential problems, some of which were not considered in the original design but later emerged as geologic hazards.

Many existing dams were constructed without appropriate methods and/or components to adequately address the existing geologic materials or the geologic conditions. Some of the dam safety deficiencies, as listed below, are a result of the dam builder not recognizing the physical characteristics and technical problems of certain geologic materials/conditions and implementing an appropriate design to mitigate the problems.

- Settlement, instability and/or cracking of the dam may reflect weak foundation conditions or unsuitable soil materials in the embankment.
- Seepage and/or leakage at the downstream toe or abutment/groin areas are frequently associated with the permeability characteristics of the underlying bedrock or soil.
- Natural hazards such as landslides, subsidence, and seismic events may quickly cause a component of the dam to fail leading to an uncontrolled breach.

2.5 THE WATERSHED

The watershed is the area that is located upstream of the dam that contributes water to the reservoir. The size of the watershed, shape of the watershed, soil and surface conditions, topographic features, land use, the amount and intensity of rainfall, and vegetative conditions are the principal factors that will determine how much water will drain into the reservoir and the time it will take for the water to reach the reservoir. The water that flows across the land surface and ends up in the reservoir is commonly known as runoff. Generally, the larger the watershed is, the greater the amount of runoff will be. It is also easy to see that the smoother the land surface is, the greater the runoff will be. For this reason, urban development in the watershed will typically increase the amount of runoff that will enter the reservoir. Urban development usually consists of construction of buildings, roads, parking lots, sidewalks, piping, ditches, etc. All of these features make the land surface smoother and more impermeable, resulting in more runoff. Installing stormwater collection and conveyance ditches and piping will make the runoff travel quicker and reach the reservoir sooner. This will also tend to increase the peak rate of runoff entering the reservoir. Therefore, more urban development in the watershed will

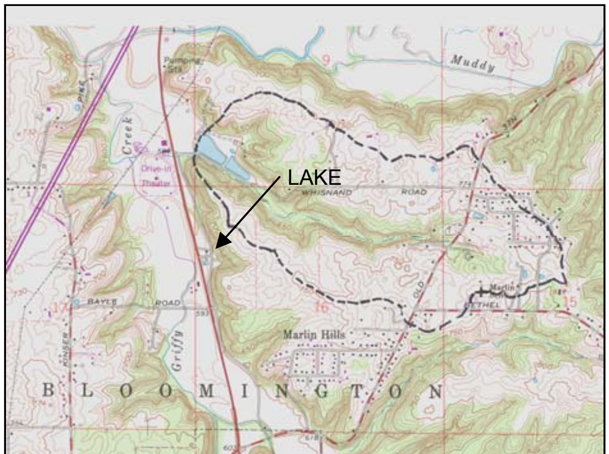

Figure 2-13 USGS quadrangle map depicting approximate watershed and divide for a small reservoir.

result in more water entering the reservoir.

The limits of the watershed are defined by the watershed divide; a line that divides the area whose runoff flows toward the reservoir from land whose runoff flows away from the reservoir. The watershed divide is determined by the topographic characteristics, and generally, it follows topographically high points. Hydrologists typically draw the location of the watershed divide on a topographic map, such as a detailed site survey or a USGS quadrangle map. Defining the divide is usually the first step in analyzing the watershed characteristics.

Dam owners must monitor urban development in the watershed and fully understand how the development can affect the reservoir and dam. If a dam and its spillways were constructed before the urban development occurs, and if they were not designed to account for the development, the dam may not be able to safely pass the increased amount of runoff that will result. The ability of the dam and its spillways to accommodate flood events diminishes as the amount of urban development increases. If significant new development occurs, new hydrologic and hydraulic analyses should be performed to determine the impact the new development has on the dam. Larger spillway structures may have to be installed to maintain the safety of the dam and downstream property. The best way to monitor watershed development is through a combination of visual inspection and review of recent aerial photography. Many counties and the Indiana State Land Office periodically obtain aerial photography that is available to the public. Examples of upstream development projects that commonly affect the dam are the construction of another dam, a water conveyance system, or the construction of a new housing subdivision.

Generally, the more water that enters the reservoir from the watershed, the higher the water level will rise behind the dam. And in turn, the higher the reservoir rises in the dam, the higher the discharge will be through the spillway(s). Through a combination of reservoir storage and spillway discharge, a dam must be able to handle the watershed runoff that enters the reservoir from the design storm event without overtopping the dam or adversely affecting the spillway or it outlet structures.

2.6 DOWNSTREAM DEVELOPMENT ISSUES

In Indiana, the hazard classification of dams is based on the potential for loss of life and property in the area downstream of the dam. High hazard dams are those that do pose a threat if the dam were to fail, regardless of how safe the dam and its appurtenant works are at the present time. A dam’s hazard classification can change at anytime due to potential development in the downstream area. Therefore, just because a dam is not classified as a high hazard dam when it is designed and built does not mean it may not someday become a high hazard dam. The implications of a high hazard classification are increased monitoring and reporting obligations, larger spillway system, as well as increased risk and liability for the dam owner.

The dam owner must continually monitor downstream development throughout the life of the dam and reservoir. And unless the dam owner has ownership of the land downstream, he/she has no control over building and development in the potential inundation zone. Government entities usually do not have the means or authority to limit development below dams in all of the dam-failure inundation areas.

Figure 2-14 This house, located along the receiving stream downstream of a dam, represents poor planning, development, and technical judgment.

The dam owner must have a good idea of the dam-failure inundation zone below the dam to be able to monitor development within that zone. This is usually accomplished by obtaining professional help to perform a dam breach analysis. The breach analysis provides an estimate of the elevations to which flood waters would rise and the distance downstream that would be impacted in the event of a catastrophic dam failure. The inundation area is plotted on a map of the downstream area, typically a USGS 7 ½ minute quadrangle map, along with the location of any development within the zone. The list of downstream residents with their telephone numbers is often plotted on the map for easy reference in the case of emergencies. Sometimes it is obvious that development has occurred in the inundation zone without performing a breach analysis, especially when the development is close to the dam in the low-lying areas.

The best way to monitor downstream development is through a combination of visual inspection and review of recent aerial photography. It is the dam owner's responsibility to protect downstream landowners from harm no matter when the development occurs. Therefore, the dam owner should make downstream inspections part of the normal dam operating plan.

2.7 STORAGE AND RELEASE OF WATER

A dam is constructed for the purpose of storing water; the storage of water poses a risk to downstream areas and a liability to the dam owner. Therefore the ability of the dam to retain the water is of prime importance.

Uncontrolled release of water, such as seeps, piping, or embankment overtopping, is usually undesirable and must be monitored and controlled to prevent a dam breach failure. Some concrete dams are designed to be overtopped; in these cases the spillway is over the top of the dam. Overtopping of an earth dam is usually a disastrous event and should be prevented at all costs. Water seeping through or under the dam is undesirable, but usually occurs at most dams since the soil used to construct dams and their foundations is permeable. Therefore, plans and controls are usually implemented to control the seeping water and discharge it safely without endangering the dam. The dam owner is responsible and liable for any damage that might occur because of an uncontrolled (or controlled) release of stored water.

The spillways and outlets works are designed for controlled release of the reservoir water, during sunny day operation and flood events. Spillways are the normal, day-to-day release mode; outlets are designed to drawdown the reservoir below the spillway elevation. Outlet works, also called drawdown works or drains, are used for various reasons:

- quickly lower water level if dam failure is an issue
- lower water level for dam repairs or maintenance
- regulate downstream flow
- provide irrigation water
- drive hydro-machinery

Whatever the release mechanism, dam owners must design spillways, outlet works, of seepage discharge facilities to avoid impacts to downstream receiving waters, land adjacent to the receiving water, or the dam itself. The release structure must be designed to avoid excessive flows and flow velocities that could inundate or erode buildings, roads, or other structures in the downstream areas. Typically, spillways should be designed so that the discharge during flood events is no greater than the flows before the dam was built. On the other hand, outlet facilities may need to be operated on a continual basis to provide irrigation water or to maintain minimum stream flows for downstream users. Dam owners must be aware of riparian rights of downstream landowners and water users so that they don't diminish the availability of water to those entities.

Figure 2-15 Valve for drawdown works located in bottom of riser structure; the valve stem should be extended to the top of the riser.

CHAPTER 3.0

DAM OWNER'S ROLE

3.0 DAM OWNER'S ROLE

3.1 SAFETY PROGRAM

The dam owner is responsible for maintaining the safety of the dam. Owners should develop their own safety program which includes dam safety inspections, monitoring plans, maintenance of the structures, emergency action plans when necessary, and dam operation. A well planned safety program is directly related to the dam structure and its immediate environment and depends on the owner's knowledge of the dam and how it works. The elements of the safety program are combined to form the Dam Management and Maintenance Plan which is described in more detail in Part 2 of the Indiana Dam Safety Inspection Manual.

Developing an effective dam safety program is the single most important measure a dam owner can take to reduce the possibility or consequences of dam failure. Potential losses resulting from dam failure will continue to increase and may intensify as population growth and land development continue. Determination of liability is the legal means developed by society to recover damages due to a "wrong" (in this case, lack of dam safety) and is another aspect of the dam safety problem. A thorough understanding of this legal process can help the dam owner decide the steps to be taken to reduce liability.

Dam owners should also be financially prepared to perform necessary dam inspections, maintenance, and repairs. A reserve monetary fund that will cover the required expenses throughout the life of the dam should be established and maintained. The owner will have to make an estimate of the required annual expenditures to set up an appropriate financial mechanism.

3.2 COMPLIANCE WITH CURRENT STATE REQUIREMENTS

The dam owner is responsible for complying with all current state requirements concerning dam ownership and operation. This responsibility applies to constructing and operating new dams, existing dams, modification of existing dams and their appurtenant works, safety inspection procedures, and dam maintenance. Failure to comply with the laws can result in state-imposed fines and penalties, as well as state mandates to drawdown or remove the dam and reservoir completely. When in doubt, the dam owner should contact IDNR or obtain assistance from a qualified dam safety professional to determine the applicability of current dam safety laws (see Part 1, Chapter 1).

Ignorance of the laws is no excuse for noncompliance, and failure to follow Indiana laws will generally cost the dam owner more money than had he/she properly complied in the first place. Noncompliance may also increase the owner's potential liability costs associated with downstream damages in the event of a dam failure, especially if the noncompliance can be proven to be intentional negligence.

Although a dam can be designed and constructed to be a safe structure, lack of routine maintenance and repair, or changing conditions, can eventually cause the dam to become unsafe. If a dam is not in compliance with State law, the owner will be required to improve the dam to bring it into compliance.

3.3 REPORTING REQUIREMENTS

Under current law, the dam owner must have a professional engineer inspect high hazard dams at regular intervals and submit an inspection report to IDNR on an approved form (see Part 3). The report must include an evaluation of the dam's condition, spillway capacity, operational adequacy, and structural integrity. The report must also include a determination of whether deficiencies exist that could lead to the failure of the dam, along with recommendations for maintenance, repairs, or alterations to the structure to eliminate the deficiencies.

IDNR is currently responsible for the inspection of significant and low hazard dams at regular intervals. IDNR completes an inspection report for these dams and maintains a copy of each report in their files. IDNR presently charges the dam owner a fee for these inspections: significant hazard dam - $200; low hazard dam - $100. However, such routine inspection by the IDNR does not absolve the dam owner of the liability and responsibility to operate and maintain a safe dam. Dam owners are encouraged to conduct independent inspections no matter what hazard classification the dam has.

The dam owner should also file a verbal or written report for any of the following incidents to their engineer as well as the IDNR as soon as they occur or as they begin to occur:

- significant changes in the dam's condition that affect dam safety, such as slides, deep sink holes, significant seepage, or piping
- unintentional releases of reservoir water resulting from a dam component failure
- an uncontrolled breach failure
- change in hazard classification due to downstream development
- intent to make major dam repairs

The dam owner must notify IDNR in writing of the sale or other transfer of ownership of the dam. The notice must include the name and address of the new owner.

3.4 FINANCIAL OBLIGATIONS

Anyone who builds a new dam or owns or acquires an existing dam must be prepared to bear certain financial obligations, including:

- ongoing dam inspection and repair
- routine dam maintenance

- potential upgrades if upstream/downstream conditions or dam structure degradation so warrant
- liability insurance

Depending on the hazard classification, the current condition, and the size and type of the dam or structure, these financial obligations can be substantial expenditures. Therefore, it is very important for a prospective dam owner to fully evaluate the requirements before building or purchasing a dam. Routine dam maintenance costs may be relatively modest, but large scale repairs, or dam upgrades can cost the dam owner large amounts of money.

Insurance can provide liability and asset protection, so it is very important to dam owners, especially high hazard dam owners. The level of insurance is based on the value of the facilities at risk, potential downstream impacts, condition and age of the dam, likelihood of an incident occurring, government requirements, and the cost of available insurance. Insurance may cover liability and damage, the cost of business interruption, lost income, and worker's compensation.

3.5 SELECTION OF A QUALIFIED DAM SAFETY PROFESSIONAL

A property owner planning to construct or acquire a dam should retain the services of a registered professional engineer experienced in the design and construction of dams and spillways. It is common practice for the owner and the engineer to discuss the owner's needs, the intended purpose of the dam, and the project budget before any design work is performed. During the design process, the owner should remain in close contact with the engineer to periodically review the design and the desired project goals. Design plans that are submitted to IDNR or other agencies for permitting usually require the seal and signature of a professional engineer licensed in the state of Indiana.

The inspection of a dam requires the services of a dam safety professional with a broad range of specialized expertise. Dam safety inspections require an understanding of hydrology, hydraulics, soils, and the behavior of the materials used to construct and support the dam. The inspection should be supervised by a project engineer, who is a registered professional engineer. The project engineer will likely need specialized technical input and support from hydraulic, geotechnical, geological, structural, and mechanical engineers as well as licensed land surveyors.

Finding and hiring a registered professional engineer to design or inspect a dam can be a difficult task from the point of view of the owner. The dam owner should get feedback on the engineer's qualifications, responsiveness, experience, and ability to obtain a permit. Compared to the number of engineers in Indiana, very few have experience designing dams, performing construction inspections, and inspecting existing dams. During the period 1977-1981, 607 Corps of Engineers Phase I Reports were prepared for non-federal dams in Indiana, and the vast majority of these reports were prepared by professional engineers in private practice.

The proper way to select an engineer or inspector is by assessing their qualifications, ability to perform the work in a timely manner, and willingness to work with the owner. Selecting a professional firm by comparing cost proposals or by competitive bidding can result in selecting someone who asks the lowest fee and provides the least service; therefore, the owner should be aware of the pitfalls of competitive bidding for professional services. While fee based competition may result in lower initial design costs, lower costs are often associated with inexperienced engineers and frequently limit the engineer's ability to conduct detailed evaluations that are necessary to develop a cost effective and innovative design. Furthermore, a low design cost often results in a significant increase in the cost of construction as well as long term costs associated with operation and maintenance of the dam.

The generally accepted procedure for selecting a qualified dam safety professional includes the following:

- define the scope of work for the project
- identify potential professional firms
- send several firms the scope of work, and request
- evaluate the proposals and conduct selected interviews
- determine which firm best meets the owners needs
- negotiate the terms of the agreement and the price

Proposals are normally requested from three or four firms and usually contain the following information:

- firm’s background and understanding of the project
- related project experience
- a work plan for the project
- qualifications of the key personnel that will be involved.

The fee for professional services should always be reasonable from the point of view of the owner and the professional firm. This is especially true because many dams are owned by people with fixed incomes and limited resources. The fee proposal that an owner will receive from a professional firm normally relates only to direct labor and administrative costs. With regard to permits, the condition of an existing dam is usually the most important factor in determining the cost of preparing a permit application. When numerous modifications are required to bring an existing dam into compliance with the law, the fees will ordinarily be higher.

A written contract should be insisted upon by the professional firm. In today's society, a handshake by the owner and the professional and reliance upon good faith simply will not do. Litigation seems to be a popular course of action and it is extremely important for understandings and agreements between the dam owner and the professional to be in writing. At a minimum, the contract should cover the following items:

- a description of services to be provided by the engineer

- a description of any services to be provided by the owner
- the fee to be paid to the firm, including payment procedure and terms
- procedures for changing the scope of services
- provisions for termination of the contract

During dam construction or repair, the owner should work closely with both the engineer and the contractor. Unforeseen site conditions are frequently uncovered that require the owner to approve design changes. The contractor's primary role is to construct or repair the dam and the appurtenant works in accordance with the plans and specifications. It is the contractor's responsibility to notify the engineer of any changes in the site conditions exposed during construction that vary from those shown on the drawings, in the specifications, or in any documents on site investigations. The contractor is responsible for making sure that the construction is conducted in a safe manner, that all state, federal and local regulations are adhered to during construction, and that the construction site is secure.

The Division of Water should be contacted before significant field changes are made to the approved plans. Once the dam has been constructed and the reservoir has filled, the engineer should certify that the dam was constructed in accordance with the design plans and submit as-built drawings to IDNR, Division of Water.

After construction, an owner assumes the role as the primary caretaker of the project. Routine inspection and maintenance allows early detection of many problems that could occur with a dam. The owner should inspect the dam often, keep records of observations and measurements and learn as much as possible about the operation and maintenance of the dam. The owner may have to, or may want to, hire a qualified dam safety professional to conduct routine safety inspections, particularly on high-hazard dams.

3.6 PERMITS

If a dam does fall under IDNR jurisdiction, a permit will be required to construct or modify the dam or its appurtenant structures. During the permit application process, IDNR will review the information provided by the dam owner for adequacy. The owner’s designer is responsible for the safe design of all components of the dam and appurtenant works. IDNR has specific guidelines (see Subchapter 1.7, Part 1) that should be followed for the design and construction of the dam, and these guidelines should be adhered to by the dam owner to obtain and maintain a permit. Part of the permitting process involves public notification of the construction activities before construction begins.

Most new dams and significant dam repair work will also require erosion control plan approval before construction may begin. The Indiana Department of Environmental Management (IDEM) and the Natural Resource Conservation Service are involved with review and approval of the design and construction plans. Public notification is also required for this permitting process.

IDEM and the US Army Corps of Engineers (USACE) may also be involved with dam construction projects, and may issue permits for construction in State or Federal waters, stream impacts, wetland impacts, or wetland mitigation, depending on the site specific conditions.

Local permits may be required from county or city drainage boards, and from sanitary authorities, as applicable. Drainage board approval is usually required for the embankment grading plans and the modification to the county drainage patterns and stormwater discharge. Approval may also be required from county or city sanitary authorities if residences are located adjacent to the reservoir and they are on well water or septic systems. In these cases, the dam plans and calculations must demonstrate that the reservoir flood stage levels will not impact the water wells or septic systems. Local requirements may vary from one municipality to another.

The dam owner should enlist the help of a qualified dam safety professional to determine the full range of permitting requirements for the construction, repair, or upgrade of the dam. The type of permitting issues also affect the type of engineering plans and calculations that must be performed, the information that must be submitted to the agencies, and the length of time it will take before actual construction work may begin.

3.7 RECORD KEEPING

Dam project files should be compiled in a systematic format. A standardized, orderly, predetermined arrangement will facilitate the use of the files and accommodate future additions more readily. Generally, the project files will grow with time as new and additional information is added.

Dam owners should file all pertinent information in the project file, including background information, geological data, mapping, design information and plans, construction records, inspection records, monitoring data, photographs, maintenance and repair records, project correspondence, and other operational information. Table 3-1 contains a summary of the broad range of information that may be included in the project file.

The data sources for a specific dam may be in several locations, depending upon the developmental history of the project, previous file maintenance techniques, and any ownership changes.

Records for dams constructed with the Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) or IDNR assistance may be found in the active files and archives of those agencies. If design or other engineering services were provided by other Federal agencies such as the Bureau of Reclamation (now the Water and Power Resources Service) or the U.S. Army Corps of Engineers (USACE), records may be located in the archives of those agencies. Engineering firms that have been involved with the dam should have project files concerning the work they performed.

Table 3-1
Recommended Information Database for Project Files

(1) Background Information

- Dam owner & responsible parties
- Dam location
- Site topographic mapping
- Surface & subsurface geology
- Exploration techniques employed
- Regional & site seismicity
- Soil surveys and land use
- Photographs
- Emergency Action Plan (if available)

Sources

- Regional & site geologic & seismic reports
- Logs of drill holes & test pits
- Geophysical exploration reports
- Project files & maps
- Materials testing reports
- USGS Quadrangle maps
- County soil maps

(2) Design Information

- Material engineering properties
- Embankment design & materials
- Stability analysis & assumptions
- Structural design criteria
- Drainage area characteristics
- Rainfall & stormwater runoff analysis
- Design flood
- Reservoir flood routing analysis
- Spillway and outlet hydraulic analysis & design
- Mechanical & electrical components
- Hazard potential classification

Sources

- Design reports & calculations
- Technical record of design
- IDNR project files
- Field & laboratory test reports
- Flood hydrology reports
- Hydraulic model reports
- Precipitation and runoff calculations
- Contract plans & specifications
- Dam breach flood routing analysis
- Geotechnical reports

(3) Construction Records

- Construction procedures, methods & control
- Quality control test procedures & results
- Foundation surface characteristics & treatment
- Abutment surface & treatment
- Subsurface treatment & drainage control
- Design-related changes
- Final configuration of dam & foundation
- Extraordinary events during construction

Sources

- Construction specifications
- Daily construction inspection reports
- Construction progress record
- Quality control testing reports
- Foundation acceptance reports
- Project correspondence
- As-constructed drawings & photographs
- Instrumentation installation reports

(4) Operational Performance Records

- Inspection Reports
- Post-construction record floods & seismic activity
- Hydraulic performance of spillway & outlet
- Structural behavior of embankment & foundation
- Water retention behavior of embankment & foundation
- Chronological reservoir stages
- Noteworthy spillway & outlet discharges
- Repairs, alterations or modifications & reasons
- Materials deterioration descriptions
- Layout & performance of surveillance instrumentation
- Original instrumentation design assumptions
- Access route to the dam, spillway & outlet
- Maintenance records
- Operating procedures & records

Sources

- Previous operation & maintenance reports
- Previous inspection reports
- Special inspection reports
- Instrumentation records
- Design operating criteria
- Standard operating procedures & manuals
- Materials testing reports
- Regional & site maps showing access routes
- IDNR project files
- Dam owner's project files

CHAPTER 4.0

DAM INSPECTOR RESPONSIBILITIES

4.0 DAM INSPECTOR RESPONSIBILITIES

4.1 EXPERIENCE AND TRAINING

The required expertise of the inspector or inspection team depends on the type of inspection being performed, the type of dam, and the site conditions. The inspection personnel should be familiar with dam design and construction, the causes of dam failures, and the visual signs which identify problems or potential concerns. It is recommended that inspectors have formal training on dam inspection techniques. Table 4-1 lists some guidelines for the qualifications of the inspector or inspection team.

Table 4-1
Recommended Inspection Team

Formal Technical Inspection
- Lead Inspector - registered professional engineer with dam experience
- Assistant Inspector(s) - other dam safety professionals as needed based on type of dam and appurtenant works
- Dam Owner or representative

Maintenance Inspection
- Dam Maintenance Personnel - may be accompanied by a qualified dam safety professional

Informal Inspection
- Dam Owner or Maintenance Personnel

Special Inspection
- Dam Owner or Maintenance Personnel - should be accompanied by engineer or other professional

Note: Assistant Inspectors should be professional engineers or geologists with expertise in the materials or area of investigation; e.g. a geologist would be required for complex geological foundation conditions.

Inspection teams for a formal technical inspection should include a registered professional engineer, experienced in dams, as the lead inspector. The lead inspector should have knowledge with soil and soil construction, hydrology, hydraulics, dam design and construction, and dam safety inspection methods. The inspection team size and member expertise will vary depending upon the type of dam, and the condition of the dam or types of problems that may be present. A formal technical inspection of a dam and its appurtenances requires study, investigation, and analyses of many diverse, individual subjects and conditions, together with evaluations of their interrelationships. Accordingly, this kind of inspection requires skilled specialists with expertise that is pertinent to the dam conditions, and individuals with the broadest possible experience in all phases of dam design and construction engineering for overall review. Inspecting personnel may include individuals who are civil engineers, geotechnical or mining engineers, hydrologists, geologists, structural engineers, engineering technicians, dam operators or tenders, and other specialists, depending on the components of the dam to be inspected. The lead inspector may perform the visual inspection alone if he/she has a broad-based, educational and technical experience with dams and if the dam does not have complex features or severe problems. On larger, complex dams it is likely that no one individual will have all the necessary expertise that is required, and an inspection team will be needed. Larger organizations may be fortunate enough to have staff that includes mechanical engineers, hydrologists, electrical engineers, geotechnical engineers, and other specialists available to evaluate specific features of a dam.

Inspecting personnel, regardless of their field of expertise, need to have knowledge in the design, analysis, construction, and operation of dams. The dam owner or his representative should always be present during a formal technical inspection to learn as much as possible about the dam and potential problems.

A maintenance inspection is typically performed by the person(s) assigned responsibility for the operation or maintenance of the dam and its appurtenant works. This person is often referred to as the dam operator or dam tender. The person assigned this responsibility should be familiar with the dam and should possess sufficient knowledge to make accurate assessment of the dam's condition. An engineer or other qualified dam safety professional may accompany the dam operator or tender during a maintenance inspection, but generally does not.

The dam owner, dam operator, or dam tender typically performs informal inspections and special inspections. Again, an engineer or other qualified dam safety professional may be required to assist in a special inspection depending on the specific situation.


Figure 4-1The inspector evaluating this dam must be familiar with concrete, modes of deterioration, and repair methods.

There may be times when specialists must apply scientific and engineering knowledge and experience to a wide range of tasks during a dam inspection. These tasks may include interpretation of the geologic structure of dam sites, appraising the engineering properties of the foundation and embankment, predicting and analyzing seepage, calculating and analyzing stresses and stability of embankments and appurtenant structures, evaluating the runoff from watersheds, estimating the capacity and flow in spillways and outfalls, evaluating the mechanical and electrical equipment if present, and analyzing instrumentation and other monitoring data. The proper performance of these tasks usually requires qualified individuals such as civil engineers, soils or geotechnical engineers, engineering geologists, structural engineers, hydraulic engineers, and hydrologists. Occasionally there may be a need for the services of a mechanical engineer, an electrical engineer, or a seismologist. The assistance of engineering and geological technicians, surveyors, and laboratory technicians may also be required.

Highly specialized services may also be required for some dams. These services may include underwater visual inspections, televised conduit inspections, or geophysical investigations. These services are readily available through specialized firms and will usually require advance notification and contractual arrangements. Televised conduit inspection may be required when conduit diameters are small or when direct access is not possible or feasible. Drilling or other geophysical services may be required if additional subsurface information is needed. If drilling is required, more often than not soils laboratory services will be required to determine the engineering parameters of the soil samples obtained during drilling. Only firms with experience pertaining to the specific materials at the site should be selected.

Finally, the prepared inspector or inspection team needs to have a thorough knowledge of the dam's history so that they can put what they see into perspective. A review of applicable project records improves the inspector's ability to evaluate observed conditions while on the site. The review of the project documents will alert the inspector to conditions and features of special concern and should identify information the owner or operator should have available at the inspection. With prior notification, the owner or operator can have this information available and be prepared to answer pertinent questions.

4.2 INSPECTOR LIABILITIES

Dam inspectors are responsible for helping the dam owner protect the safety of life and property, so they must possess the expertise and knowledge needed to fully evaluate the dam in question. Failure to discover potential dam safety problems due to a poor inspection could have disastrous results and the inspector could be held liable for such an oversight, especially if the problem should have been detected by an experienced dam safety professional. The dam owner hires a professional inspector to perform a service that will help protect him (the dam owner) from potential financial and legal liabilities resulting from dam failures. Therefore, the dam owner has a reasonable right to expect an accurate and comprehensive report on the condition of the dam, along with recommendations for needed repairs, monitoring, or other follow-up work. An individual should not perform the inspection if he/she is not knowledgeable with the conditions or materials that are present at the dam. It is important that the dam owner use only qualified inspectors, and it is even more important that inspectors do not perform inspections that are beyond their expertise or capabilities.

Inspectors should approach every inspection as though they could be held accountable for any damage that would result from a potential safety problem that they did not discover. On the other hand, it is reasonable to expect that the inspector can not be held accountable for safety problems that could not be observed during the field examination. These problems could include such things as foundation piping that exited in some obscure spot downstream of the dam, embankment problems that occur under water where normal inspections could not detect the problem, or a problem on an embankment that is heavily vegetated and not accessible for inspection. Likewise, an inspector can not be held liable for safety problems that develop after the visual inspection is completed.

It is recommended that inspectors, or their firms, carry professional liability insurance to cover errors of omission, such as problem oversight, or negligence due to incomplete inspection coverage. It is further recommended that the dam owner only hire professionals or firms that carry liability insurance.

CHAPTER 5.0

RISKS AND HAZARDS OF DAM FAILURE

5.0 RISKS AND HAZARDS OF DAM FAILURE

5.1 RISKS OF DAM FAILURE

Risk can be defined as the probability that a dam may fail; no matter how well a dam is built or maintained, the risk of failure cannot be reduced to zero. Hazard describes the probable consequences of dam failure, such as, loss of life and property damage. A dam may have a small risk of failure, but may present a high hazard should failure occur, particularly if a large number of people live within the inundation zone of the dam. Since all dams pose some risk, no matter how small, all dams present a hazard to the public or property. Dam failures are severe threats to life and property and are now being recorded and documented much more thoroughly than in the past. Recorded losses have been high. Life and property loss statistics fully justify the need for dam owners to better understand the risks of failure and the hazards to the public posed by dams, the types of conditions or factors that promote these risks, and, generally, the reasons why dams fail. Improving a dam owner's understanding of risk factors and possible reasons for failure is an essential first step in any overall effort to improve dam safety and preserve the benefits of dam ownership.

The risk factors that can cause dam failure are translated into high risks when people or property are threatened. These risk factors can be classified into one of four categories: 1) structural factors, 2) natural factors, 3) human factors, and 4) operating factors.

Structural Factors

The dam structure itself can be a source of risk due to possible design or construction flaws, the size of the dam and the storage area of the reservoir, the complexity of the dam and its appurtenant works, the age and condition of the dam, general foundation and abutment conditions, seepage potential, construction material characteristics, and weaknesses which develop because of aging. Poor embankment design or construction can lead to cracking or sliding of the soils which may result in the uncontrolled discharge of water. Poorly installed embankment materials or spillway structures can lead to serious soil piping or seepage, both of which can lead to uncontrolled loss of water. The site immediately surrounding the structure may also increase structural risk if the dam is not positioned or anchored properly or if excessive reservoir seepage erodes the foundation or abutments. The abutments and foundation may have inherent weaknesses in the form of faulting and rock condition, such as fractures, shear zones, relief jointing and solubility. Some embankment, foundation, or abutment materials have a potential for liquefaction to occur during seismic events. High dams will impose more pressure on the embankment and foundation of the dam which can increase the risk of seepage and slope failure. Reservoirs with inadequate storage capacity can lose their ability to contain flood events by losing storage from sedimentation. Construction material characteristics such as permeability, erodibility, and strength also may present a risk to dam failure if they are inadequate for the dam loading conditions. As dams age, they tend to lose their strength through material deterioration, making them more susceptible to dam failure. All of these conditions pose risks to the dam safety by potentially affecting the structural integrity of the dam, the foundation, or the abutments.

Natural Factors

Natural risks such as floods from high precipitation, floods from dam failures, earthquakes, landslides, and sedimentation are also important contributors to risk. Floods from high precipitation are the most significant natural events that can impact dams and pose a hazard to people and property. Failure to account for these events has been costly both to dam owners and the public in general.

Flash floods can happen anywhere, even in small watersheds. Floods are the most frequent and costly natural events that lead to disaster in the U.S. Therefore, flood potential must be included in risk analyses for dam failure. Indiana has design flood criteria that are based on a percentage of the probable maximum precipitation (PMP) based on the dam's hazard potential. A PMP is the precipitation that may be expected from the most severe combination of critical meteorologic conditions that are reasonably possible in the region. This assumed event becomes the basis for the design of structural and hydraulic elements of the dam.

When a dam fails as a result of a flood, more people and property are generally placed in jeopardy than during natural floods. The Rapid City, South Dakota flood of 1970, which killed 242 people, caused a dam failure which added significantly to the loss of life. When a natural flood occurs near a dam, the probability of failure and loss of life almost always increases. The sudden surge of water generated by a dam failure usually exceeds the maximum flood expected naturally, therefore, residences and businesses that would escape natural flooding can be at extreme risk from dam failure flooding. When one dam fails, the sudden surge of water may well be powerful enough to destroy another downstream dam, compounding the disaster.

Earthquakes are also significant threats to dam safety. Both earthen and concrete dams can be damaged by ground motions caused by seismic activity. Cracks or seepage can develop, leading to immediate or delayed failure. Recent detailed seismic analyses have indicated that the seismic risk is essentially nationwide. Dam owners should be aware of the history of seismic activity in their locality and should develop their dam safety emergency procedures accordingly.

Indiana has several faults, but, unlike California's famous San Andreas Fault, nearly all of Indiana's faults are buried and can't be seen at the surface. Most of the faults that have been mapped in Indiana are located in the southwestern corner of the state. These faults extend into Illinois and are collectively known as the Wabash Valley Fault System. These mapped faults are believed to be unlikely candidates for future movement. The earthquakes that have occurred in Indiana during the last 200 years are believed to be the result of movement along faults at great depth below the surface. This depth and the nature of the rock layers at that depth have limited the ability of seismologists to successfully map earthquake-generating faults using reflection seismic profiling. Much more research is needed before we will know the full extent of faulting beneath Indiana and the potential for movement along those faults.

During the last two centuries, earthquakes with epicenters in Indiana have been relatively minor events. However, this has not always been the case. Indiana University archaeologists Pat Munson and Cheryl Munson, and U.S. Geological Survey geologist Steve Obermeier have found evidence of at least 6 major earthquakes with epicenters in Indiana during the last 12,000 years. The largest of these quakes appears to have had an epicenter near Vincennes and has been estimated to have been many times more powerful than the quake that struck the Los Angeles area in January 1994.

The New Madrid fault in what is now southeastern Missouri experienced movement on December 15, 1811, that produced shock waves that rippled through the earth with such force that buildings collapsed, trees toppled, and the Mississippi River changed course. The result was one of the most powerful earthquakes ever recorded in North America. During the next two months, the area was rocked by three more quakes as powerful as the first (one just six hours after the first) and hundreds of smaller ones. The larger quakes shook the earth with enough force to cause church bells to ring in Washington, D.C. They were felt in Indiana and were even felt a thousand miles away in New Hampshire.

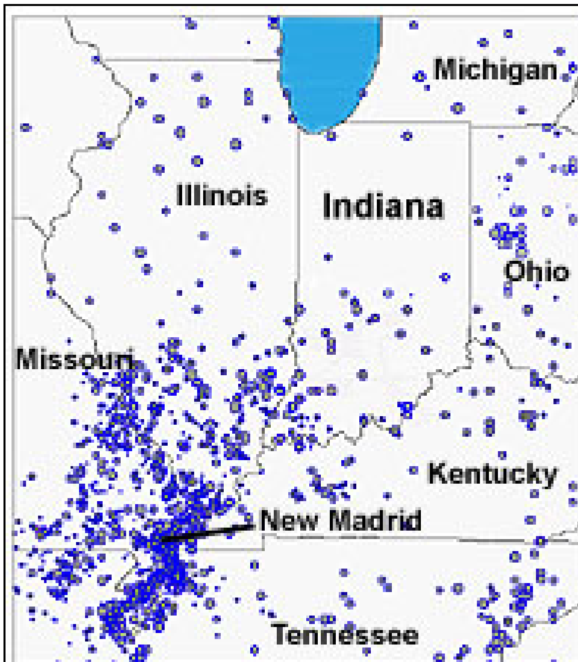

Figure 5-1 Earthquake epicenters in Indiana and neighboring states from 1800 to 1995 (source: Indiana Geological Survey).

Since the New Madrid quakes, Indiana has felt the effects of many earthquakes (see figure 5-1). The strongest of these was the 1895 Charleston, Missouri quake, which damaged buildings in Evansville and other parts of southwestern Indiana. According to the U.S. Geological Survey, the strongest quake centered in Indiana during historic times struck the Wabash River valley on September 27, 1909. This quake knocked down chimneys, broke windows, and cracked plaster in the lower Wabash Valley and was reportedly felt in Arkansas, Illinois, Iowa, Kentucky, Missouri, Ohio, and Tennessee. More recently, Indiana was shaken in 1987 by a quake centered near Olney, Illinois, just west of Vincennes.

Rock slides and landslides may impact dams directly by blocking a spillway or by eroding and weakening abutments. Indirectly, a large landslide into a reservoir behind a dam could cause an overflow wave which may exceed the capacity of the spillway and lead to failure. A land (or mud) slide can form a natural dam across a stream which can then be overtopped and fail. In turn, failure of such a natural dam could then cause the overtopping of a downstream dam or by itself cause damage equivalent to the failure of a human-made dam. In addition, large increases in sediment caused by slides (or runoff) events can materially reduce storage capacity in reservoirs and thus increase a downstream dam's vulnerability to flooding. Sedimentation can also damage low-level gates and water outlets; damaged gates and outlets can lead to failure.

Human Factors

Human behavior is another element of dam failure risk; simple mistakes, operational mismanagement, unnecessary oversights, or destructive intent can interact with other hazards to compound the possibility of failure.

All sorts of other human behavior should be included in risk analyses. Vandalism for example cannot be excluded and is, in fact, a problem faced by many dam owners. Vegetated surfaces of a dam embankment, mechanical equipment, manhole covers, and rock riprap are particularly susceptible to damage by people. Every precaution should be taken to limit access to a dam by unauthorized persons and vehicles. Dirt bikes (motorcycles) and four-wheel drive vehicles, in particular, can severely degrade the vegetation on embankments. Worn areas lead to erosion and more serious problems. Mechanical equipment and associated control mechanisms should be protected from purposeful or inadvertent tampering. Buildings housing mechanical equipment should be sturdy, have protected windows, heavy duty doors, and should be secured with deadbolt locks or padlocks. Detachable controls, such as handles and wheels, should be removed when not in use and stored inside the padlocked building. Other controls should be secured with locks and heavy chains where possible. Manhole covers are often removed and sometimes thrown into reservoirs or spillways by vandals. Rock used as riprap around dams is sometimes thrown into the reservoirs, spillways, stilling basins, pipe spillway risers, and elsewhere. Riprap is often displaced by fishermen to form benches. The best way to prevent this abuse is to use rock too large and heavy to move easily or to slush grout the riprap. Otherwise, the rock must be regularly replenished and other damages repaired. Regular visual inspection can easily detect such human impacts.

Two extremes of human purpose can both result in public risks: 1) the will to destroy through war or terrorism, and 2) the urge to develop and to construct. Dams have proven to be attractive wartime targets, and they may be tempting to terrorists. On the other hand, a terrorist's advantage from holding the public at risk may well be illusory; the deliberate destruction of a dam is not at all easy to bring about. Yet the possibility exists that such an act could take place, and it should not be discounted by the dam owner. Another more common activity that poses a risk is the tendency for people to settle below dams. The construction of residences, buildings, and other structures in the potential flood inundation zone creates new risks, and will probably create increased risks in the future.

Operating Factors

Operating factors that could pose a risk to dam failure, and thus, create a safety hazard to people and property include the remoteness and accessibility to the site, lack of operator training or experience, poor dam maintenance procedures, lack of an inspection program, reliability of power for electrical equipment, and the complexity of the equipment and operating procedures at the dam.

Thus, a broad range of natural and human hazards exist that, taken separately or in combination, increase the probability of dam failure and injury to people and property.

5.2 TYPES AND CAUSES OF DAM FAILURE

Dam failures are usually the result of improper design or construction, or poor maintenance. Dam failures are categorized into two types in this manual: **Type 1**, component failure of a structure that does not result in a significant reservoir release; and, **Type 2**, uncontrolled breach failure of a structure that results in a significant reservoir release.

Figure 5-1 Type 1 component failure.

Type 1 failures include localized seepage and structural failures of dam components that do not breach the dam into the reservoir. Type 1 failures are generally local failures of a dam feature, such as an embankment slide that does not breach the crest, a spillway structural failure, a piping condition in its early stage of formation, a trash rack failure, or settlement on an earth dam embankment that does not extend to the water level. Type 1 failures are critical, require immediate attention, and may lead to a Type 2 failure. Type 1 failures may also require emergency response, reservoir drawdown, or remedial correction.

Type 2 failures are failures that do result in a significant release of the reservoir and may eventually result in a dam breach with total release of the reservoir. There are three general categories of Type 2 failures: (1) hydraulic failures, (2) seepage failures, and (3) structural failures. Type 2 failures often result from Type 1 failures that were improperly corrected or were ignored.

Figure 5-2 Type 2 uncontrolled breach failure. This started as a seepage failure and progressed to a structural failure of the dam.

There are many complex reasons for dam failure, including both structural and nonstructural. Many sources of failure can be traced to decisions made during the design and construction process and to inadequate maintenance or operational mismanagement. Failures have also resulted from the natural hazards already mentioned, such as large scale flooding and earthquake movement.

The United States Bureau of Reclamation Research has shown that approximately one-third of all uncontrolled breach failures are a result of overtopping due to inadequate spillway capacity. Another one-third of dam failures are caused by uncontrolled seepage through the embankment or foundation. The remaining one-third of dam failures is caused by foundation failures and other miscellaneous causes. This summary is highly simplified, and in reality, most dam failures result from a combination of events.

Overtopping may develop from many sources, but often evolves from inadequate spillway design. Alternatively, even an adequate spillway may become clogged with debris. In either situation, water flows over other sensitive parts of the dam, such as abutments or the dam crest, and erosion and failure follow. Concrete dams are more susceptible to foundation failure than overtopping, whereas earthfill dams suffer more from seepage and piping.

The major reason for failure of fill or embankment dams is piping or seepage. All earthen dams exhibit some seepage; however, this seepage can and must be controlled in velocity and amount. Seepage occurs through the structure and, if uncontrolled, can erode material from the downstream slope or foundation backward toward the upstream slope. This "piping" phenomenon can lead to a complete failure of the structure. Piping action can be recognized by an increased seepage flow rate, the discharge of muddy or discolored water below the dam, sinkholes on or near the embankment, and a whirlpool in the reservoir.

Earth dams are particularly susceptible to hydrologic failure since most soils erode at relatively low water flow velocities. Hydrologic failures result from the uncontrolled flow of water over the dam, around the dam, adjacent to the dam, and

Table 1-1
Types of Dam Failures

Type 1 - Component Failure

- Localized, does not breach dam
- Insignificant release of reservoir water
- Types
  1. Seepage failure
     - Pervious reservoir rim or bottom
     - Pervious foundation
     - Pervious dam
     - Leaking conduits
     - Cracks in dam
     - Seepage erosion
     - Inappropriate vegetation
  2. Structural failure
     - Dam or foundation slides and sloughs
     - Dam settlement
     - Spillway cracks or failure
     - Severe erosion

Type 2 - Uncontrolled Breach Failure

- Results in dam breach
- Significant or total release of reservoir water
- Types
  1. Hydraulic failure
     - Dam overtopping
     - Wave erosion
     - Dam toe erosion
     - Severe erosion
  2. Seepage failure
     - Pervious reservoir rim or bottom
     - Pervious foundation
     - Pervious dam
     - Leaking conduits
     - Cracks in dam
     - Piping through dam or along conduits
     - Inappropriate vegetation
     - Windblown trees
     - Animal burrows
  3. Structural failure
     - Dam and foundation slides
     - Dam failure
     - Dam settlement
     - Spillway cracks or failure

the erosive action of water on the dam's foundation. Once erosion has begun during overtopping, it is almost impossible to stop. In a very special case, a well-vegetated earth embankment may withstand limited overtopping if water flows over the top and down the face as an evenly distributed sheet and does not become concentrated in a single channel.

Failure of concrete dams is primarily associated with foundation problems. Overtopping is also a significant cause, primarily because of spillways with inadequate capacity. Earthquakes and poor concrete design or construction may also result in failure of concrete dams.

5.3 NOTABLE DAM FAILURES

Earthen Dam Failures

South Fork Dam, Pennsylvania

South Fork Dam was an embankment dam built across the Conemaugh River, about 9 miles above Johnstown, Pennsylvania, between 1838 and 1853. The purpose of the dam was to supply water to a navigable canal from Johnstown to Pittsburg. The dam was 70 feet high and impounded 12,400 acre-feet. The dam was modified by closing off the outlet pipes, building a bridge over the spillway, installing a road on the embankment crest, and lowering the embankment by 3 feet. A fish screen was also installed in front of the spillway to keep the fish from passing over the spillway. A very heavy rainstorm occurred on May 30 and 31, 1889. The reservoir filled and the spillway went into operation. A large amount of debris was washed into the reservoir and moved toward the spillway where it became lodged against the fish screen. The reservoir continued to rise as the spillway was largely blocked. Attempts to clear the spillway were unsuccessful, and eventually the dam was overtopped. The dam subsequently failed by erosion releasing a flood wave estimated to be 30 to 40 feet high. The flood moved down the narrow valley of the Conemaugh River toward Johnstown and other smaller communities, which were already experiencing flooding from the rainfall. The flood wave swept through Johnstown in about 10 minutes. The devastation was tremendous. Altogether, the death toll was estimated at 2,209, making this one of the worst disasters in terms of loss of life in United States history. It was later calculated that if a spillway had been built according to specifications and if the original outlet pipes had been available for full capacity discharge, there would have been no overtopping.

Teton Dam, Idaho

Teton Dam was a 305-ft high central core, zoned, earth and gravel fill embankment designed by the Bureau of Reclamation and completed in November 1975. The dam was located on the Teton River in eastern Idaho. The Teton Dam failed on June 4, 1976, when reservoir filling was nearly complete. The failure was attributed to (1) internal erosion (piping) of the core of the dam deep in the right abutment foundation key trench, with the eroded soil particles finding exits through channels in and along the interface of the dam with the highly pervious abutment rock and talus to points at the right groin of the dam; (2) destruction of the exit avenues and their removal by the out-rush of reservoir water, (3) the existence of openings through inadequately sealed rock joints which may have developed through cracks in the core zone in the abutment key trench; (4) the development of piping through the main body of the dam that quickly led to complete failure; and (5) the design of the dam did not adequately take into account the foundation conditions and the characteristics of the soil used for filling the abutment key trench. Flooding downstream inundated the communities of Rexburg and Sugar City, Idaho, among others, and 11 people were killed. Property damage was in excess of half a billion dollars.

Fontenelle Dam, Wyoming

Fontenelle Dam is a zoned earthfill embankment located on the Green River in Western Wyoming. The dam was completed in 1964, and is 128 feet high and over 1 mile long. A cutoff trench extends to bedrock and a grout cap and line of grout holes was drilled along the centerline of the trench. During construction, several open joints and cracks were encountered in the area of the spillway intake. These cracks angled into the abutment in a downstream direction. A line of grout holes was added around the spillway intake to restrict seepage through the foundation in this area. Also, an impervious blanket was extended upstream along the lower part of the abutment. No foundation surface preparation was done to seal the foundation in contact with the embankment. Embankment material was placed directly over the open joints and cracks in the foundation rock. As the reservoir began to fill, a seep occurred about 2,000 feet downstream of the dam. Seepage continued to increase as the reservoir level rose. On September 3, 1965, when the reservoir was nearly full, a seep appeared on the downstream slope of the dam. Within one day, the seep worsened and removed 10,000 cubic yards of soil from the embankment. A 30 feet deep sinkhole developed on the crest the following day. Repair operations, consisting of rebuilding the damaged embankment section, and extensive grouting, and a concrete diaphragm cutoff wall eventually solved the seepage problem and averted an uncontrolled breach failure. The seepage had come through the rock joints in the abutment and exited on the downstream slope, causing the near disastrous failure.

Baldwin Hills Dam, California

The Baldwin Hills Dam was constructed between 1947 and 1951 in the city of Los Angeles. Located on a ravine, the reservoir was formed by a continuous homogeneous compacted embankment, with the maximum section being 232 feet high. The Baldwin Hills Dam failed on December 14, 1963 following displacement of its foundation. The displacement created a 3-ft wide crack in the embankment, causing seepage and eventual breaching. The reservoir was completely drained in 2 hours. At least 2 theories for the failure have been proposed. It has been speculated that pressurization of the nearby oil field caused movement along one of the faults passing beneath the reservoir. Others believe that differential settlement occurred along one of the faults due to the fractured and loosened nature of the fault zone material. Five people were killed by the flood waters and nearly 1,000 homes were damaged. Total property damage was over $11 million.

Lawn Lake Dam

The Lawn Lake Dam was a 24-ft high earthfill dam built in 1903 in the Rocky Mountains of Colorado at an elevation of almost 11,000 feet. The dam was owned and operated by a private irrigation company. Early on the morning of July 15, 1982, the dam failed releasing 700 acre-feet of water at a peak discharge of 18,000 ft^3/s. The flood waters raced down the steep Roaring River channel scouring it to a depth of as much as 35 feet and into the broad flat valley of the Fall River. There the flood waters were briefly impounded by Cascade Dam, a 17-ft-high concrete gravity dam. Eventually, Cascade Dam was overtopped by more than 4 feet and also failed. The damages from the failure totaled $31 million and three people were killed. The probable cause of the failure was believed to be the deterioration of the lead caulking used to seal the connection between the upstream outlet-works pipe and the valve housing. As a result, water under reservoir head was able to enter the fill and rapid progressive internal erosion, or piping, led to a breaching of the dam.

Kelly Barnes Dam

The Kelly Barnes Dam on Toccoa Creek near Toccoa, Georgia, was about 400 feet long, 20 feet wide at the crest, and 42 feet high at the maximum section. The dam was concave upstream. The lake had a normal impoundment of about 18 million cubic feet (410 acre-feet) and a surface area of about 42 acres. The lake level rose by approximately 4.5 feet before the dam failed, and the water volume increased to about 27 million cubic feet. The Kelly Barnes Dam failed at approximately 1:30 a.m., November 6, 1977, after a period of intensive rain. Thirty-nine people were killed and damages were estimated at $2.8 million.

The dam went through various stages of development: first as a rock crib dam, and then with subsequent stages as an earth dam. The rock crib dam was completed about 1899 to back up water which would be used to power a small hydroelectric plant located near the foot of the falls. About 1937, the Toccoa Falls Bible Institute was interested in developing a more dependable power source and decided to build an earth dam over the rock crib dam. This construction was performed with equipment provided by a local manufacturer. After World War II, the earth fill was raised to a point where an earth spillway on the left side of the valley could be utilized, and a low point on the rim on the right side away from the dam would serve as a secondary spillway in case high flows occurred. The final height of the dam was approximately 42 feet above the rock foundation. This installation served as a power source until 1957 for the Toccoa Falls Bible Institute, which later became the Toccoa Falls College. At this time, the development of power was stopped but the dam continued to be used as a recreation lake.

The Federal Investigative Board could not determine a sole cause of the November 6, failure. It did conclude that a combination of factors caused the failure. The most probable causes were a local slide on the steep downstream slope, probably associated with piping, an attendant localized breach in the crest followed by progressive erosion, saturation of the downstream embankment, and subsequently a total collapse of the structure.

Buffalo Creek Dam

On February 26, 1972, the Buffalo Creek (tailings) Dam in West Virginia failed, causing a flood wave that killed 125 people and left another 4,000 homeless. The embankment, which consisted of a pile of coal mine waste, impounded the reservoir but lacked the features of an engineered dam. It was part of a system of spoil embankments and sediment basins on a tributary of Buffalo Creek. Waste had been accumulating for about 25 years before the failure. The piles consisted of shale, sandstone, low-grade coal, and various kinds of timber and metal scrap. By 1960, the first embankment had been extended to a length of approximately 1200 feet, a width of roughly 500 feet, and a height of approximately 150 feet. This embankment had evidently burned for many years. In about 1960, the mining company, to reduce stream pollution, began to run waste water from its plant into the impoundment behind the embankment. The material from this source was naturally finer than the embankment material and tended to seal the embankment. The seepage slowed, and the reservoir level rose. Federal inspectors visited the complex in 1966 and reportedly called attention to the precarious condition of the embankment. In 1967, a new embankment was constructed 600 feet upstream from the first barrier. Then, in 1970, a third fill was placed 600 feet upstream from the second. The result was a staircase of poorly built embankments, with the upper two founded on the soft sediment in the settling basins. By 1972, the newest of the three embankments was roughly 500 feet in length and had risen about 44 feet above the sediment in the middle pool. Its broad crest was nearly as wide as it was long. A 24-inch steel overflow pipe was reportedly installed in July 1971, which extended diagonally through the fill from one side toward the center. Aside from this, the reservoir had neither spillway nor outlet. The pipe evidently did not have an inlet structure or any cutoff collars.

Occasional slips and breaks had occurred during the lifetime of the embankments. In 1971, a mining company worker said that he had seen black water issuing from the floor of the middle pool, indicating leakage through or under the uppermost dam. In the three days preceding the failure, about 3.7 inches of rain fell in the area. Storm runoff caused the reservoir behind the third dam to rise. The water level reportedly was within 1 foot of the crest 4 hours before the collapse. Between 6 and 8 a.m. on that day, the water rose onto the graded crest and washed through dumped waste that stood as high as 7 feet above the crest. A mining company employee reportedly was dispatched at 6:30 a.m. to find bulldozers for excavation of an emergency spillway, but the equipment never reached the site. Longitudinal cracks appeared in the soggy fill. Slumping of the downstream face dropped the crest and accelerated the overflow. The dam broke at about 8 a.m. The upper pool had contained approximately 40O acre-feet of sludge and water, which was completely discharged within a quarter of an hour. During the next 3 hours, a flood wave estimated as high as 20 feet moved down the 15 miles of the Buffalo Creek valley at about 5 miles per hour. The village of Saunders at the upper end of this reach was washed out, and extensive damage was done to several other settlements downstream.

Canyon Lake Dam

One of the most intense floods in American history struck South Dakota's Black Hills on

June 9, 1972, and destroyed much of Rapid City, a community of 43,000 people. Canyon Lake was a 40-acre reservoir west of Rapid City. Canyon Lake Dam was an earthen embankment approximately 20 feet high and 500 feet long, constructed by the Works Progress Administration in 1938. The cause of the disaster was a violent rain-storm which developed suddenly. Beginning early in the evening and continuing into the night, as much as 10 inches of rain fell on a watershed where the normal annual precipitation was only about 14 inches. Runoff accumulated rapidly on the steep rock slopes and gained velocity in the narrow canyons on its way to the populated areas to the east. Rapid Creek was discharging an estimated 30,000 cubic feet per second into Canyon Lake. Floodwaters were rising fast against the 20-foot high earth dam. At approximately 8:30 p.m., spillway releases were made in an attempt to control the lake level. Beginning at about 9 p.m., a cloudburst brought as much as 6 inches of rain in 2 hours. Rapid Creek broke out of its banks. The mayor and the city engineer of Rapid City inspected the Canyon Lake Dam just before 10 p.m. Men from the police and fire departments were dispatched to warn people downstream from the reservoir. Many residents underestimated the danger at first and remained in their homes. Water was surging down the streets.

Near 10:30 p.m., the Canyon Lake Dam spillway was obstructed by debris and the embankment was on the verge of overtopping. The storm water began to overtop the dam and began to scour the embankment. The muddy torrent pouring from the reservoir overwhelmed the winding channel of Rapid Creek all the way through the city. At about 10:45 p.m., the dam washed out. The water and debris disgorged through the breach. When the Canyon Lake Dam collapsed, the surge of debris-laden water struck Rapid City with full force. Buildings near the creek were shattered. Many of the occupants were unable to escape. Mobile homes and trailers were washed away. Powerlines were knocked down and propane tanks were ruptured. There were many fires and explosions. Natural gas escaped from broken pipelines and burst into flames from the sparks of the downed powerlines. The final toll was 237 fatalities, 5 persons missing, and 5,000 homeless in the path of the flood. More than half of Rapid City was said to be devastated. Twelve hundred houses were demolished, and 2,500 others were extensively damaged. About 100 commercial and industrial buildings had been ruined. Approximately 5,000 wrecked automobiles were scattered throughout the city. Seven of the nine bridges which had spanned Rapid Creek, 80 blocks of street, and 5.5 miles of railroad trackage were reported to have been destroyed. Total property damage was estimated at $60 million.

Concrete Dam Failures

Austin, Pennsylvania

An example of a foundation problem can be found in the failure of the Austin, Pennsylvania Dam in September, 1911. The concrete gravity dam was constructed in 1910 and was designed to contain 600 acre-ft of water. Shortly after reservoir filling began, the dam dropped about 6 inches at the toe and slid out about 18 inches at the spillway. Reservoir filling continued. On September 30, 1911 the dam suffered failure as portions of the dam slid along the base and/or fell on their downstream face.

Eventual failure occurred because of weakness in the foundation or in the bond between the foundation and the concrete. The death toll was estimated at 87.

Walnut Grove, Arizona
In 1890 the Walnut Grove dam on the Hassayompa River failed due to overtopping, killing about 150 people. The failure was blamed on inadequate capacity of the spillway and poor construction and workmanship. A spillway 6 X 26 feet had been blasted out of rock on one abutment, but with a drainage area above the dam site of about 500 square miles, the spillway could not provide nearly enough discharge capacity.

St. Frances Dam, California
The St. Francis Dam was a 205-ft high concrete gravity arch dam built in 1926. The dam impounded a reservoir of 38,000 acre-feet. The design of St. Francis Dam was suspect. The dam was raised twice during construction by a total of 20 feet or 11 percent of its design height without widening the base. The failure of the St. Francis Dam (part of the water supply system for Los Angeles) was also attributed to a variety of problems related to foundation pressures, seepage around the foundation and operation. St. Francis Dam failed suddenly just before midnight on March 12, 1928. The reservoir was nearly full at the time and emptied in about 70 minutes. The failure not only removed most of the dam, but large sections of the foundation as well. The flood wave traveled 9 miles down San Fancisquito Creek and then another 40 miles down the Santa Clara River to the Pacific Ocean. Between the dam and the ocean, 450 people in towns and construction camps were killed. A recent analysis of the failure concluded that the failure initiated with downslope movement of the left abutment leading to tension cracks in the upstream face of the dam causing destabilizing uplift pressures within the dam and subsequent collapse. Seepage through the abutments prior to the failure had been reportedly muddy, suggesting that foundation material was being removed, but the cloudy water had been dismissed by the dam's designer as originating from a nearby construction site.

Vaiont Dam
The Vaiont Dam in Northern Italy is a thin-arch concrete dam built in the late 1950's and filled in 1959; the dam is 850 feet high. In 1960, a relatively small slide of some 1.3 million yd^3 occurred on the left abutment near the dam. At this time, it was discovered that creep was occurring over a much larger area on the left abutment. In 1960-1961, a bypass tunnel was driven through the right abutment for a distance of 1¼ miles. This was done to assure that water could reach the outlet works in case of future slides. Also, as a precaution, after the 1960 slide the reservoir was limited to a maximum elevation of 2,230 feet. This reservoir elevation was about 145 feet below the top of the dam. Gravitational creep on the left reservoir slope continued during the 1960-1963 period. Movements of up to 10 to 12 inches per week were observed on occasion. In early October 1963, following weeks of heavy rains, engineers realized that all the observation stations on the left abutment were moving together as a "uniform unstable mass." On October 8, the engineers began to lower the reservoir, however, because of the heavy inflow from rainfall and the movement of the huge slide mass into the reservoir, the level of the reservoir actually rose. On the evening of October 9, 1963, a

massive rock slide occurred on the left abutment immediately upstream from the dam. Over 300 million yd^3 slid into the reservoir, filling the reservoir for 1¼ miles upstream from the dam to depths of over 1,000 feet. This all occurred within a period of 15 to 30 seconds. The dam was overtopped by a 330-foot wave which headed down the narrow canyon toward the city of Longarone, about a mile downstream from the dam. The flood wave was over 230 feet high at the mouth of Vaiont Canyon and hit Longarone head on. Everything in its path was destroyed. Over 2,600 people were killed by the flood. The slide created strong earth tremors which were recorded in Brussels, over 500 miles away. Remarkably, the dam sustained no damage to the main shell or abutments. However, the dam can no longer be used because the cost of removing slide material is too great. The slide was caused by a combination of factors including:

1. adverse geologic features in the reservoir area
2. man-made conditions imposed by impounding water with bank storage, affecting the otherwise delicately balanced stability of a steep rock slope
3. progressive weakening of the rock mass with time, accelerated by excessive groundwater recharge (2 weeks of rain)

APPENDICES

APPENDIX A

INDIANA CODE FOR REGULATION OF DAMS

INDIANA CODE (IC) 14-27-7.5 Chapter 7.5 Regulation of Dams

(Note: Consult the Indiana General Assembly web page for the most recent version of this Code.)

IC 14-27-7.5-1
Applicability

Sec. 1. This chapter does not apply to the following:
- (1) A structure that meets the following conditions:
  - (A) Is built for the sole purpose of erosion control, watering livestock, recreation, or providing a haven or refuge for fish or wildlife.
  - (B) Has a drainage area above the dam of not more than one (1) square mile.
  - (C) Does not exceed twenty (20) feet in height.
  - (D) Does not impound a volume of more than one hundred (100) acre-feet of water.
- (2) A structure that is regulated under the federal Mine Safety and Health Act of 1977, unless the structure is proposed to be retained as a permanent structure after bond release.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-2
"Hazard classification"

Sec. 2. As used in this chapter, "hazard classification" means a rating assigned to a structure by the department based on the potential consequences resulting from the uncontrolled release of its contents due to a failure or misoperation of the structure.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-3
"Height"

Sec. 3. As used in this chapter, "height" means the vertical dimension of a structure as measured from the lowest point in the natural streambed or watercourse under the centerline of the structure to the top of the structure.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-4
"Owner"

Sec. 4. As used in this chapter, "owner" means an individual, a firm, a partnership, a copartnership, a lessee, an association, a corporation, an executor, an administrator, a trustee, the state, an agency of the state, a municipal corporation, a political subdivision of the state, a legal entity, a drainage district, a levee district, a conservancy district, any other district established by law, or any other person who has a right, a title, or an interest in or to the property upon which the structure is located.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-5
"Structure"

Sec. 5. As used in this chapter, "structure" means a dam and its appurtenant works.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-6
"Volume"

Sec. 6. As used in this chapter, "volume" means the amount of water that is impounded by a structure:

(1) at or below the elevation of the top of the structure; or
(2) at or below the maximum design flood pool elevation;

whichever is lower.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-7
Maintenance, repair, and sale; duties of owner

Sec. 7. (a) The owner of a structure shall maintain and keep the structure in the state of repair and operating condition required by the following:

(1) The exercise of prudence.
(2) Due regard for life and property.
(3) The application of sound and accepted technical principles.

(b) The owner of a structure shall notify the department in writng of the sale or other transfer of ownership of the structure. The notice must include the name and address of the new owner of the structure.

As added by P.L.148-2002, SEC.15. Amended by P.L. 71-2004, SEC. 13.

IC 14-27-7.5-8
Powers and duties of department; hazard classifications

Sec. 8. (a) The department:

(1) has, on behalf of the state, jurisdiction and supervision over the maintenance and repair of structures in, on, or along the rivers, streams, and lakes of Indiana;

(2) shall exercise care to see that the structures are maintained in a good and sufficient state of repair and operating condition to fully perform the intended purpose;
(3) shall grant permits for the construction and operation of structures in, on, or along the rivers, streams, and lakes of Indiana;
(4) may adopt rules under IC 4-22-2 for permitting, maintenance, and operation that are necessary for the purposes of this chapter; and
(5) may vary the standards for permits, maintenance, and operation, giving due consideration to the following:
(A) The type and location of the structure.
(B) The hazards to which the structure is or may be exposed.
(C) The peril to life or property if the structure fails to perform the structure's function.

(b) The department shall establish by rule the criteria for assigning a hazard classification to a structure that is based on the potential consequences resulting from the uncontrolled release of the structure's contents due to a failure of the structure. The hazard classification system must include the following classes of structures:
(1) High hazard: A structure the failure of which may cause the loss of life and serious damage to homes, industrial and commercial buildings, public utilities, major highways, or railroads.
(2) Significant hazard: A structure the failure of which may damage isolated homes and highways, or cause the temporary interruption of public utility services.
(3) Low hazard: A structure the failure of which may damage farm buildings, agricultural land, or local roads.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-9
High hazard structures; inspections; report; duty to make repairs or alterations; notice of violation

Sec. 9. (a) The owner of a high hazard structure shall:
(1) have a professional engineer licensed under IC 25-31 make a technical inspection of the high hazard structure and prepare or revise the emergency action plan for the structure at least one (1) time every two (2) years;
(2) submit a report of the inspection in a form approved by the department to the department. The report must include at least the following information:
(A) An evaluation of the structure's condition, spillway capacity, operational adequacy, and structural integrity.
(B) A determination of whether deficiencies exist that could lead to the failure of the structure, and recommendations for maintenance, repairs, and alterations to the structure to eliminate deficiencies,

including a recommended schedule for necessary upgrades to the structure.

(b) If after an inspection under subsection (a) the licensed professional engineer who conducted the inspection determines that maintenance, repairs, or alterations to a high hazard structure are necessary to remedy deficiencies in the structure, the owner shall perform the recommended maintenance, repairs, or alterations.

(c) The department shall issue a notice of violation under section 11 of this chapter to the owner of a high hazard structure who fails to:
(1) have the structure inspected under subsection (a);
(2) perform recommended maintenance, repairs, or alterations to the structure under subsection (b); or
(3) biennially submit the inspection report prepared under subsection (a).

(d) The department may make a technical inspection of a high hazard structure to ensure compliance with this chapter.

As added by P.L.148-2002, SEC.15. Amended by P.L. 1-2003, SEC 60; P.L. 186-2003, SEC. 72.

IC 14-27-7.5-10
Significant and low hazard structures; inspections; reports; fees

Sec. 10. (a) The department shall make a technical inspection of:
(1) a significant hazard structure at least one (1) time every three (3) years; and
(2) a low hazard structure at least one (1) time every five (5) years;
or at more frequent intervals if the exigencies of the case require.

(b) The department shall place in the files of the department a report of each inspection conducted under subsection (a).
(c) The department shall charge the following for engineering inspections:
(1) For a significant hazard structure under subsection (a)(1), a fee of two hundred dollars ($200).
(2) For a low hazard structure under subsection (a)(2), a fee of one hundred dollars ($100).

As added by P.L.148-2002, SEC.15. Amended by P.L. 186-2003, SEC. 73.

IC 14-27-7.5-11
Notice of violation

Sec. 11. (a) If the department finds that a structure is:
(1) not sufficiently strong;
(2) not maintained in a good and sufficient state of repair or operating

condition;
(3) not designed to remain safe during infrequent loading events; or
(4) unsafe and dangerous to life and property;
the department may issue a notice of violation under IC 14-25.5-2..

As added by P.L.148-2002, SEC.15. Amended by P.L. 71-2004, SEC 14.

IC 14-27-7.5-12
Emergency measures to protect life and property

Sec. 12. (a) If at any time the condition of a structure becomes so dangerous to the safety of life and property that, in the opinion of the department, there is not sufficient time for the issuance and enforcement of an order for the maintenance, alteration, repair, reconstruction, change in construction or location, or removal of the structure in the manner provided in this chapter, the department may immediately take the measures that are essential to provide emergency protection to life and property, including the lowering of the water level by releasing water or by a controlled breach of the structure.

(b) The department may recover the cost of the emergency measures from the owner by appropriate legal action.

As added by P.L.148-2002, SEC.15.

IC 14-27-7.5-13
Violations

Sec. 13. An owner who knowingly fails to effect the maintenance, alteration, repair, reconstruction, change in construction or location, or removal within the time limit set forth in the notice of violation of the department under:
(1) section 11 of this chapter; or
(2) IC 13-2-20-4 (before its repeal);
commits a Class B infraction. Every day of failure constitutes a separate infraction.

As added by P.L.148-2002, SEC.15. Amended by P.L. 71-2004, SEC. 15.

IC 14-27-7.5-14
Right of entry upon premises

Sec. 14. The department and the department's agents, engineers, geologists, and other employees may, for purposes of determining the department's jurisdiction and performing the engineering inspections provided in sections 9 and 10 of this chapter, enter upon any land or water in Indiana without liability for trespass. The owner of a structure shall do the following:
(1) Cooperate with the department and the department's agents, engineers, geologists, and other employees in the conduct of the inspections.

(2) Facilitate access to the structure.
(3) Furnish upon request the plans, specifications, operating and maintenance data, or other information that is pertinent to the structure.

As added by P.L.148-2002, SEC.15. Amended by P.L. 186-2003, SEC 74.

IC 14-27-7.5-15
Exemption of department from liability

Sec. 15. This chapter does not create a liability for damages against the department or the department's officers, agents, and employees caused by or arising out of any of the following:
(1) The construction, maintenance, operation, or failure of a structure.
(2) The issuance and enforcement of a notice of violation or a rule issued by the department to carry out the department's duties.

As added by P.L.148-2002, SEC.15.

IC14-27-7.5-16
Request to have structure declared high hazard; notice

Sec. 16. (a) A property owner, the owner's representative, or an individual who resides downstream from a structure:
(1) over which the department does not have jurisdiction under this chapter; and
(2) that the property owner, the owner's representative, or the individual believes would cause a loss of life or damage to the person's home, industrial or commercial building, public utility, major highway, or railroad if the structure fails;
may request in writing that the department declare the structure a high hazard structure

(b) If the department receives a request under subsection (a), the department shall:
(1) investigate the structure and the area downstream from the structure;
(2) notify the owner of the structure that the structure is being investigated;
(3) review written statements and technical documentation from any interested party; and
(4 after considering the available information, determine whether or not the structure is a high hazard structure.

(c) The department shall issue a written notice of the department's determination under subsection (b) to:
(1) the individual who requested the determination; and
(2) the owner of the structure that is the subject of the request.

(d) Either:
(1) the individual who requested a determination;

(2) the owner of the structure that is the subject of the request;

may request an administrative review under IC 4-21.5-3-6 within thirty (30) days after receipt of the written determination.

(e) If the department determines that a structure is a high hazard structure under subsection (b), the provisions of this chapter concerning high hazard structures apply to the structure.

As added by P.L.71-2004, SEC.16

APPENDIX B

HAZARD CLASSIFICATION OF DAMS

HAZARD CLASSIFICATION FOR DAMS

DAMAGE TO:	AREA AFFECTED BY DAM BREACH		
	LOW	**SIGNIFICANT**	**HIGH**
LOCATION	***Rural or Agricultural*** Damage would be minimal and would mostly occur on dam owner's property. No building, road, railroad, utility, or individual significantly affected. Damage is limited to farm buildings, agricultural land, and local roads.	***Predominantly Rural or Agricultural*** but roads, buildings, utilities or railroads may be damaged.	***Developing or Urban*** Where individuals could be seriously injured or killed. Buildings, roads, railroads or utilities seriously damaged.
POTENTIAL LOSS OF LIFE Flood depths greater than 1 foot in occupied quarters. Potential of loss of human life may occur.	***No***	***No***	***Yes***
ROADS County roads, state two-lane highways. or U.S. highways Serving as the only access to a community. Multilane divided state or US highway, including an interstate highway.	***No Damage***	***May Damage*** Interruption of service for not more than 1 day.	***Serious Damage*** Interruption of service for more than 1 day.
RAILROADS Operating Railroads	***No Damage***	***May Damage*** Interruption of service for not more than 1 day.	***Serious Damage*** Interruption of service for more than 1 day.
OCCUPIED QUARTERS Homes-Single family residences, apartments, nursing homes, motels and hospitals	***No Damage***	***May Damage*** Damage that would not render the structure unusable	***Serious Damage*** Damage where the flow velocity at the building compromises the integrity of the structure for human occupation.
UTILITIES	***No Damage***	***May Damage*** Damage may occur to important utilities where service would not be interrupted for more than 1 day but either of the following may occur: 1) buried lines can be exposed by erosion, or 2) towers, poles and above ground lines can be damaged by undermining or debris loading.	***Serious Damage*** Interruption of service to interstate and intrastate utility, power or communication lines serving towns, communities or significant military and commercial facilities in which disruption of power and communication would adversely affect the economy, safety, and general well-being of the area for more than 1 day.

APPENDIX C

REFERENCES

REFERENCES
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