Dams are a critical component to sustaining and improving our lives and living conditions. The basic goal of dam design and construction remains unchanged: to safely store water at an elevated level. Research and technology development have steadily changed and continue to alter the path by which we evaluate, design, construct, and monitor dams.

Catastrophic floods from dam failures are represented throughout the history of the United States. The 1889 Johnstown Flood in Pennsylvania, caused by failure of the South Fork Dam, killed more than 2,000 people. The 1976 Teton Dam in Idaho failure occurred during first filling, killing 11 people and 13,000 head of cattle, and causing about $2 billion in downstream damages. The Kelly Barnes Dam in North Georgia was first built in 1899, and was raised several times over the next 60 years. The flood wave caused by the collapse of this dam killed 39 people and caused extensive property damage.

If we ask what aspects of current technology could have altered the history of these and other dam failures, we need to first recognize that technology merely implies tools available to do a job. We cannot make conclusive statements of the specific benefits of technology on catastrophic dam failures. However, evaluating, understanding, and successfully using advanced tools provide additional pathways to reduce the potential for dam incidents and failures. By expanding understanding; improving tools used to validate assumptions, analysis approaches, and decisions; and rigorously applying quality review processes, we better understand and respect the risks and consequences that dams present.

Technology does not replace the education, focus, dedication, and experience of a seasoned professional team. Technology is simply an aid to augment understanding of forces and complex material behaviors controlling our natural world. Only with diligent use and review by experienced professionals can technology advance understanding.

Examples of relatively recent advances in design and analysis technology include:

- **Development of spillways with increased efficiency.** Safely storing and releasing water is one of the more critical considerations in dam design. Development of new spillway types, modifications to existing spillways, and improved understanding of spillway hydraulics have delivered enormous benefits to dam owners and to those living or working downstream of dams. Labyrinth weirs, which form a zig-zag pattern in plan view, were first introduced in the 1970s. They have evolved significantly over the past 40 years. Labyrinths have much greater discharge capacity than linear spillways having the same plan width.

- **Finite element and difference computer programs for evaluating structural, geotechnical, and hydraulic issues.** These programs are capable of modeling complex mechanics of materials problems for a wide range of fluids and solids, and they allow a designer to more efficiently evaluate potential designs and make changes to improve safety and/or reduce construction and long-term maintenance costs.

While certainly not comprehensive, the technologies above provide insight into the on-going evolution occurring in dam design processes. There have also been notable improvements in dam construction, including new and improved equipment capabilities and advances in efficiency.

Monitoring technology is another area where progress has positively impacted dam safety. From devices such as vibrating wire piezometers, to comprehensive monitoring systems connected to automated web and call networks, technology has improved the frequency of data collection and, more importantly, the clarity and quality of data evaluation. Better and more timely recognition of evolving site conditions allows for a more efficient and focused response to both operational and emergency conditions.

Advances in evaluation, design, construction, and monitoring may have prevented the cited dam failures, but we will never know. Technology, when properly applied and implemented, will improve dam safety. In addition, the technologies of today will be improved upon and replaced by the technologies of tomorrow. As engineers, we need to stay current with available technologies, maintain a firm understanding of applied engineering principles, and remain cautious in the use of both.
The National Performance of Dams Program (NPDP) was founded in 1994 at Stanford University. It is devoted to the collection of information on the current and historical performance of dams for the purpose of supporting dam engineering and safety. (http://npdp.stanford.edu)

THE NUMBERS: DAM FAILURES AND CONSEQUENCES

There have been more than 1,400 dam failures in the U.S. since 1850. Dam failures are a critical reminder of the need to learn from and improve dam performance.

Figure 1 shows the cumulative number of failures from 1848 to 2005. The dashed line is the total without the more than 200 failures that occurred in Georgia in 1994.

Looking Ahead

Today, the NPDP is evolving in a number of ways; revising and expanding online resources, adding specialized data resources (e.g., penstocks, geomembrane solutions, labyrinth spillways and post-tensioned anchor systems (coming)), partnering with industry leaders (Carpi, Schnabel Engineering), and sponsoring an annual risk symposium. Visit http://npdp.stanford.edu/CEESymposium.

Lower San Fernando Dam

February 9, 1971

The Lower San Fernando Dam, owned by the Los Angeles Department of Water and Power, was perched above the San Fernando Valley. Had the dam breached and released the reservoir, tens of thousands of residents in the San Fernando Valley would have had a flood to deal with, in addition to the after effects of the earthquake. The embankment failed due to liquefaction; however, the dam did not breach (no uncontrolled release of the reservoir).

The embankment failed due to liquefaction; however, the dam did not breach (no uncontrolled release of the reservoir).

For the dam to hold as it did, a number of things had to simultaneously occur:

- Crest displacements did not exceed the available freeboard
- One of the two outlet towers had to survive
- The reservoir level had to be low at the time of the earthquake
- The Upper San Fernando Dam did not fail
- The outlet works were operational after the earthquake
- Timely response by the LA Department of Water and Power.

Many lessons were learned from this event and, more importantly, lessons are still being identified and learned. Click here to understand more.
EMERGENCY ACTION PLAN WORKSHOP, Cumming, GA
February 25, 2015 / 8:30 am - 3:30 pm

Schnabel Engineering will be providing an instructional workshop in Cumming, GA, for dam owners on the preparation of Emergency Action Plans (EAP). The workshop will enable dam owners to better understand the importance of an EAP and the steps required to develop and implement an effective EAP for dams. The Georgia Safe Dams Program (GSDP) currently requires dam owners who do not currently have an Operations Permit from GSDP to submit an EAP for their dam. In the near future, GSDP will require all Category I dam owners to submit an EAP. Even without GSDP regulations, it is in the dam owner’s best interest to have a functional EAP to reduce exposure and liability in the case of a dam incident.

REGISTRATION INFORMATION
Registration prior to February 15 is $65. After February 15, the registration fee is $80. Space limitations require that only two representatives from each dam may register for the course. Click here to register now! Questions? Call Randy Bass at (770) 781-8008 or email dams@schnabel-eng.com.

VIRGINIA DAM OWNER TRAINING WORKSHOP, Richmond, VA
March 7, 2015 / 9:00 am - 4:30 pm

Schnabel Engineering and the Virginia Department of Conservation and Recreation (DCR) Dam Safety Program invite you to attend the annual Dam Owner Training Workshop. This one-day training workshop includes sessions on a variety of topics geared toward updating and keeping you abreast of dam related regulations.

REGISTRATION INFORMATION
Deadline for registration is March 2. Click here to register now! Questions? Call Jonathan Pittman at (336) 274-9456 or email dams@schnabel-eng.com.

RCC 2015 - INTERNATIONAL RCC DAM SEMINAR AND DUCK RIVER RESERVOIR PROJECT STUDY TOUR, Nashville, TN / May 4 - 6, 2015

Schnabel Engineering and ASI Constructors, Inc. are proud to announce that registration has started for the RCC 2015 – International RCC Dam Seminar and Duck River Reservoir Project Study Tour. Join us May 4 - 6, 2015, in Nashville, TN! This event is an ongoing gathering of engineering and construction industry professionals involved in heavy-civil design and construction worldwide. The intent of the conference is to promote and continue the technical evolution of Roller-Compacted Concrete (RCC) in the dam and water resources markets.

REGISTRATION INFORMATION
Registration prior to April 11 is $495. After April 11, the registration fee is $595. Space is limited. Click here to register now! Questions? Call Randy Bass at (770) 781-8008 or email dams@schnabel-eng.com.