

Creative Solutions to Dam Safety Issues

Joseph J. Orlins¹, Katharyn Gallagher², Clint Oman³, Lisa Petronis⁴, and Sarah Ross⁵

¹ Department of Civil Engineering, Rowan University, 201 Mullica Hill Road, Glassboro, NJ 08028 Phone (856) 256-5328; FAX (856) 256-5242; email: orlins@rowan.edu

² Department of Civil Engineering, Rowan University, gall0808@students.rowan.edu

³ Department of Civil Engineering, Rowan University, oman9897@students.rowan.edu

⁴ Department of Mechanical Engineering, Rowan University, petr9387@students.rowan.edu

⁵ Department of Civil Engineering, Rowan University, ross6754@students.rowan.edu

Abstract

To help overcome the financial burden of the engineering analyses associated with rehabilitation of privately owned dams, a unique partnership has been developed between dam owners, Rowan University, and the local engineering community. Undergraduate engineering students have been working with a faculty member to conduct hydraulic and hydrologic analyses and flood inundation mapping, as part of the Engineering Clinic program at Rowan. The results of this project are being evaluated by a team of external practicing engineers, and then submitted to the New Jersey Bureau of Dam Safety and Flood Control for regulator review.

Involving students in all aspects of the dam evaluation introduces many concepts not included in traditional classroom instruction, such as the ecological benefits (and detriments) of small dams. In addition, students are exposed to the socio-economic and political realities that engineers must contend with in professional practice. Thus, having students work on a real-world analysis and design project provides an all-around win-win situation: Students work on a unique educational opportunity; the dam owner receives valuable services; State regulators are satisfied; and public safety is upheld.

Introduction

There are many small and medium-sized dams in southern New Jersey that are in need of rehabilitation. The NJDEP Dam Safety Section has indicated that within Gloucester County alone, there are 5 dams classified as “High Hazard” (meaning a potential loss of life would result if the dam failed) in need of rehabilitation, and 28 others in the eight southern counties of New Jersey. Another 140 in the region are classified as “Medium Hazard” (meaning substantial property damage would result if the dam failed). Most of these dams were originally built for local mills, but are now used solely for impounding water for scenic and recreational use. Figure 1 shows the locations and types of ownership for all of the dams in the state. The State of New Jersey requires that these dams be maintained or removed, to promote public safety. Publicly owned dams are subject to the same provisions as private dams.

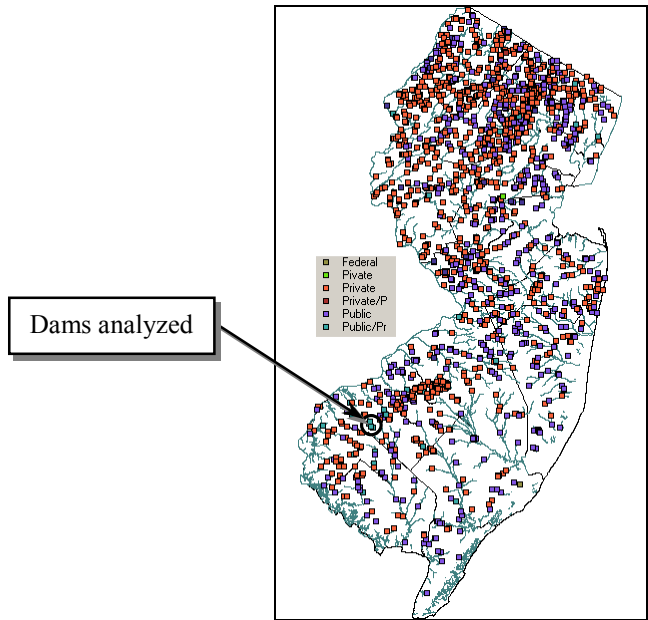


Figure 1: Dams and dam ownership in New Jersey.

A problem arises when a dam owner cannot afford to either repair or retire (remove) the structure. In such cases, funds are sometimes available from the State of New Jersey in the form of grants (for publicly owned dams) or loans (for privately owned dams) to facilitate dam safety investigations and rehabilitation. However, these funds have not been available for several years. Private dam owners are thus faced with large expenses for engineering services (either for dam rehabilitation or removal) and construction activities. Alternatively, private dam owners can defer maintenance or rehabilitation, at the risk of lawsuits brought by the State seeking compliance of existing dam safety regulations. In either situation, the private dam owner is faced with bleak prospects.

The problem is compounded when land use upstream of the dam has changed from the time when the dam was originally constructed. When land use changes from agricultural to suburban or urban development, runoff from the catchment is increased so that peak flows are higher and occur sooner after the start of a rainfall event. Increased peak discharge for a given storm event results in flows greater than what dam spillways were originally designed to accommodate. Thus, dam owners must also conduct hydrologic analyses of the watersheds upstream of their dams, determine current design flows (typically the Probable Maximum Flood (PMF), based on the Probable Maximum Precipitation (PMP) (NRC, 1985)), and then assess the capacity of the existing spillway. If the existing spillway is not large enough to handle the new design flow, modifications must be made to the dam. The end result is that a private dam owner becomes responsible for changes in hydrologic conditions over which he or she had no control.

Dams in Upper Mantua Creek Watershed

Virtually all of the dams in southern New Jersey were created for industrial or agricultural uses, or as roadway embankments over streams. Most of these dams were constructed decades ago, and many have fallen into disrepair. Three privately owned dams in the upper Mantua Creek watershed (Figure 1) are typical of many in the region. Historically, the major land use in the watershed was agricultural. Today, agriculture usage accounts for less than 25% of the land area, with suburban housing developments replacing peach orchards.

Wadsworth Dam is on the main stem of Mantua Creek. The dam is 15 feet high, and is located upstream of a state highway and an electrical power substation. The original timber crib dam was built in the mid-1800s, to provide waterpower for a sawmill. A flood destroyed the timber crib dam in 1925. The current structure was built in 1926, with a 350-foot long earthen embankment dam and concrete semicircular arch spillway.

Because of the size of the dam and downstream structures, the Wadsworth Dam is classified as a Class I (“High Hazard”) structure, meaning that if the dam were to fail, there is a high probability for loss of life and/or extensive property damage. The Safe Dam Act of 1981 requires dams in this hazard category to be inspected every 2 years, and they must have Emergency Action Plans and Operation and Maintenance manuals. The New Jersey Department of Environmental Protection (NJDEP) Bureau of Dam Safety and Flood Control regulates all dams in the state. When dams are not in compliance with the Dam Safety Act, then dam owners may be subject to litigation from the state Attorney General’s Office.

Sterling Lake Dam is a short distance upstream from Wadsworth Dam, on the Duffield Run tributary to Mantua Creek. This structure is also an earthen embankment structure with a concrete semi-circular overflow spillway. A county road runs over the embankment portion of the dam, with a concrete arch culvert immediately downstream of the spillway. Lake Sterling Dam is also a Class I structure.

Kandle Lake Dam is about 1.5 miles upstream from Sterling Lake Dam on Duffield Run. This earthen embankment structure is a Class II (“Significant Hazard”) dam, meaning that if the dam were to fail, there is less likelihood of loss of life, but still the potential for property damage and flooding. A dirt roadway crosses along the crest of the embankment. The roadway is an access road to a swimming club and campground, and does not have regular traffic. There are two concrete drop-box outlets that regulate water level in the lake and act as overflow spillways.

Heavy rains in September 1940 caused all three of these dams to fail due to overtopping. The dams were rebuilt again soon thereafter. Due to the hazard classification of these structures, the NJDEP has been pressing the dam owners to conduct dam breach analyses, flood inundation mapping, and develop emergency

action plans. Since the three structures are in such close proximity in the same watershed, it makes sense to analyze them together.

Educational Partnership for Assessing Dams

A unique partnership has been developed between the owners of the three private dams, Rowan University, and the local engineering community. Third- and fourth-year Engineering students have been working with a faculty member to conduct hydraulic and hydrologic analyses and flood inundation mapping, as part of the *Engineering Clinic* program at Rowan. The results of this project are being evaluated by external practicing engineers, and then submitted to the NJ Department of Environmental Protection's Bureau of Dam Safety and Flood Control.

Engineering Clinics

The engineering curriculum at Rowan University contains a core of *Engineering Clinic* classes, which span disciplinary boundaries and span the entire four-year undergraduate experience (Schmalzel, *et al.*, 1998). The four engineering programs at Rowan (Chemical, Civil and Environmental, Electrical and Computer, and Mechanical) have a common curriculum for the freshman year. Clinics for first-year students focus on basic, introductory skills. In the second year, engineering students are introduced to multidisciplinary interaction as well as written and oral communication through a number of projects. In the third and fourth years, students participate in team projects that feature open-ended problem solving and design. The upper level Clinics are ideally suited for undergraduate students wishing to conduct basic research and develop engineering solutions to real-world problems.

Students met with owners, state regulators, and practicing professionals to obtain background information on the project. Using existing data sources and new field surveys, student teams have developed hydrologic models of the watersheds for analyzing spillway capacities and the effects of possible dam breach scenarios.

The computer program HEC-1 was used to analyze inflow and outflow hydrographs, as well as dam breach scenarios for each of the three dams. Students found that the existing spillways at all three dams are undersized for current design flows, and that peak outflows nearly doubled in cases of dam failure (Figure 2).

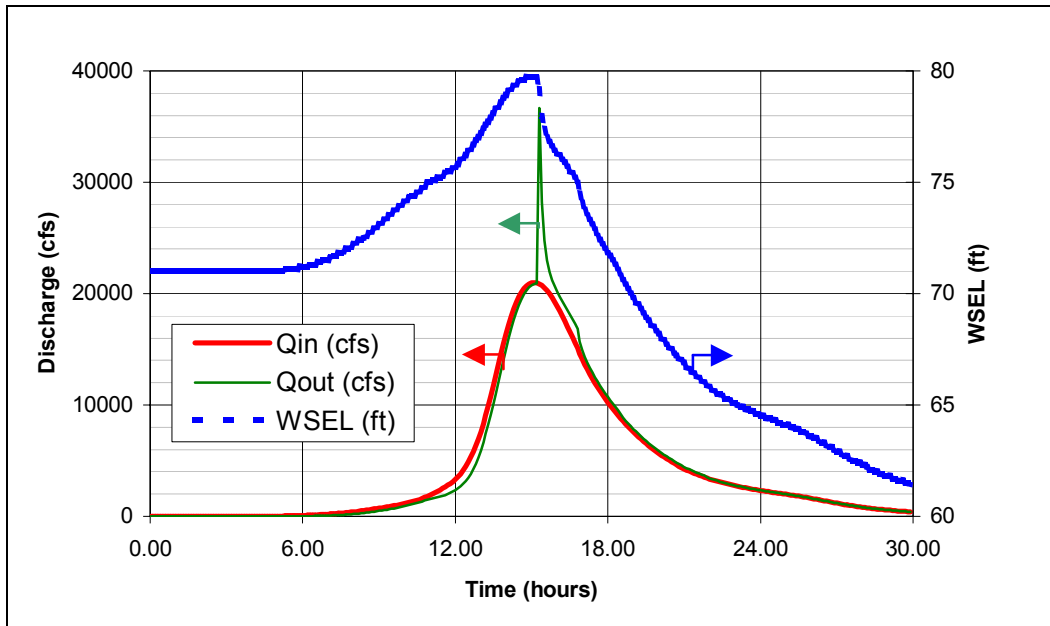


Figure 2: Inflow and outflow hydrographs with dam failure.

Student teams conducted the hydrologic analysis of all three dams over a period of three semesters, and are currently assessing the impacts of dam failures (including multiple dam failures) on lands downstream of the structures. In addition to analyzing current conditions, students developed conceptual alternatives for dam repair and rehabilitation.

Conclusions

To date, students at Rowan University have conducted hydrologic and hydraulic analyses for three privately owned dams in southern New Jersey. Wadsworth, Sterling, and Kandle Lake Dams in the upper Mantua Creek watershed were analyzed to assess the impact of dam failure on lands downstream of the structures. Physical parameters such as watershed areas, land use, and precipitation intensity were used to estimate stream flow for a number of storm events. Each storm event was run with and with out dam failure conditions, in order to determine downstream inundation effects. The results indicate the spillways are undersized for current peak design flows. Students have developed conceptual alternatives for dam rehabilitation.

Involving students in all aspects of the dam evaluation introduces many concepts not included in traditional classroom instruction, such as the ecological benefits (and detriments) of small dams. In addition, students are exposed to the socio-economic and political realities that engineers must contend with in professional practice. Thus, having students work on a real-world analysis and design project provides an all-around win-win situation: Students work on a unique educational opportunity; the dam owner receives valuable services; State regulators are satisfied; and public safety is upheld.

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