

A Community-Based Hydrologic Design Project

Joseph Orlins, Ph.D., P.E.

Civil and Environmental Engineering, Rowan University, Glassboro, NJ

Kim Groff, Ph.D.

Earth Solve, Inc., Acton, MA

Paul Greger, P.E., P.P.

Greger Consultants, LLC, Glassboro, NJ

R. Wayne Groff

Pitman, NJ

Abstract

There are numerous small dams in southern New Jersey in need of rehabilitation. Many of these dams were built in the early part of the 20th century either as roadways across streams or to provide power for local mills, but are currently used only for recreational purposes. When the dams were originally built, they generally had adequate protection regarding flood conditions. However, development in the region has changed the hydrologic conditions upstream of many of these dams significantly. The existing spillways at virtually all of these dams were designed for pre-development flows; with the excess flow brought by development, spillway modifications must be made to increase capacity and maintain dam safety.

The State of New Jersey requires that deficient dams be improved and maintained or removed, to promote public safety. Public entities such as counties and municipalities are generally eligible for State grants to pay for dam safety evaluations and repairs. However, privately owned dams are not eligible for grants. For dams owned by an individual, the costs associated with engineering investigations and dam rehabilitation are often prohibitively expensive. As a result, repairs are often deferred. When repairs are not made in a timely manner, the NJ Department of Environmental Protection Dam Safety Section must take legal action against the dam owner to ensure that public safety is upheld.

To help overcome the financial burden of the engineering analyses associated with dam rehabilitation, a unique partnership has been developed between the owner of a private dam, Rowan University, and the local engineering community. Third-year Civil and Environmental 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 NJ State Dam Safety Section.

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. This paper will discuss the process, successes, and failures of the initial partnership effort.

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.

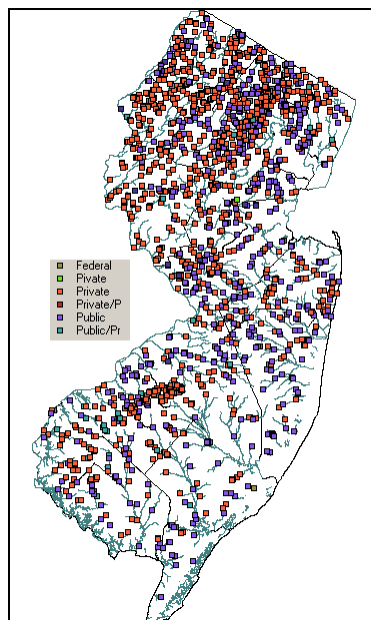


Figure 1: Dams and dam ownership in New Jersey

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.

Issues and Concerns

It is important to recognize that there are essentially no naturally occurring lakes in southern New Jersey. Virtually all of the lakes in the region were made by the construction of dams over a period of more than 300 years. The most recently constructed dams were built in the 1930's and 1940's for agricultural uses; most of the dams were constructed for long-gone industrial needs. Many of these dams were built in association with the grist and saw mills scattered throughout the area. Today these dams and lakes provide other community and regional needs, including:

- Flood control & protection
- Stormwater management
- Removal of sediment, nitrates, phosphates and other pollution
- Aeration of creeks to increase dissolved oxygen levels from flow over spillways
- Water for fire protection (many areas near lakes are not served by public water supplies)
- Habitat for both seasonal and residential animals and birds
- Public recreation
- Community aesthetics & history

There are clearly benefits associated with maintaining existing dams in the region. If a dam is removed to reduce the downstream hazard potential in the case of dam failure, then there are other issues that are of concern, including:

- Higher peak stream flows due to increased runoff from developed areas, which could cause:
 - Risk of downstream property damage
 - Erosion or damage to downstream stream banks, requiring ongoing repair until banks are reestablished based upon new conditions
- Downstream lakes would lose some recreational values because of additional sediment deposition
- Fire protection may be reduced for communities that rely on lakes for fire water supply
- A reduction in market value for properties adjacent to the lakes, resulting in a reduction in property tax revenues

Thus, there are more aspects to dams than pure engineering analysis and design. Social, economic, and political attributes must also be considered. However, the financial burden is still on the dam owner to undertake any studies, designs, restoration, or removal.

Wadsworth Dam

Wadsworth Dam on Mantua Creek is but one example of the many dams in the State subject to these provisions. The dam is located on Mantua Creek, in Gloucester County (Figure 2). Historically, the major land use in the watershed was agricultural. Today, agriculture usage accounts for less than 25% of the land area, as shown in the aerial photograph in Figure 3.

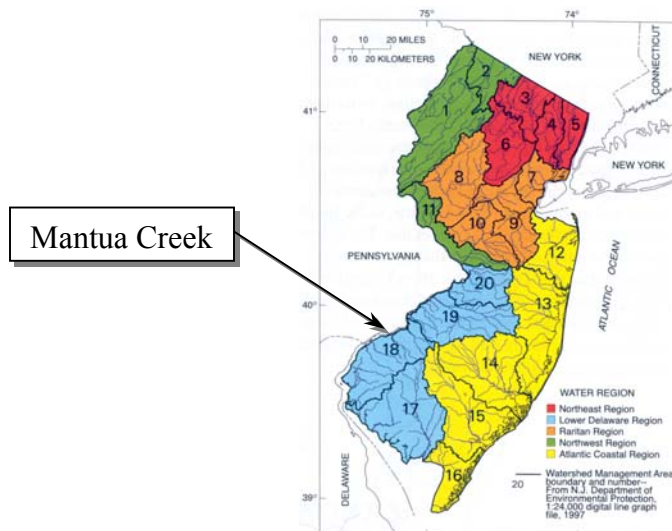


Figure 2: Location of Mantua Creek (from Watt, 2000)

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, shown in Figure 4. Heavy rains in September 1940 caused the new dam to fail due to overtopping; approximately 75 feet of the earthen embankment was washed away. The dam was rebuilt again soon thereafter.

Because of the size of the dam and downstream structures, the Wadsworth Dam is classified as a “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 Dam Safety Section of the New Jersey Department of Environmental Protection (NJDEP-DSS) 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.

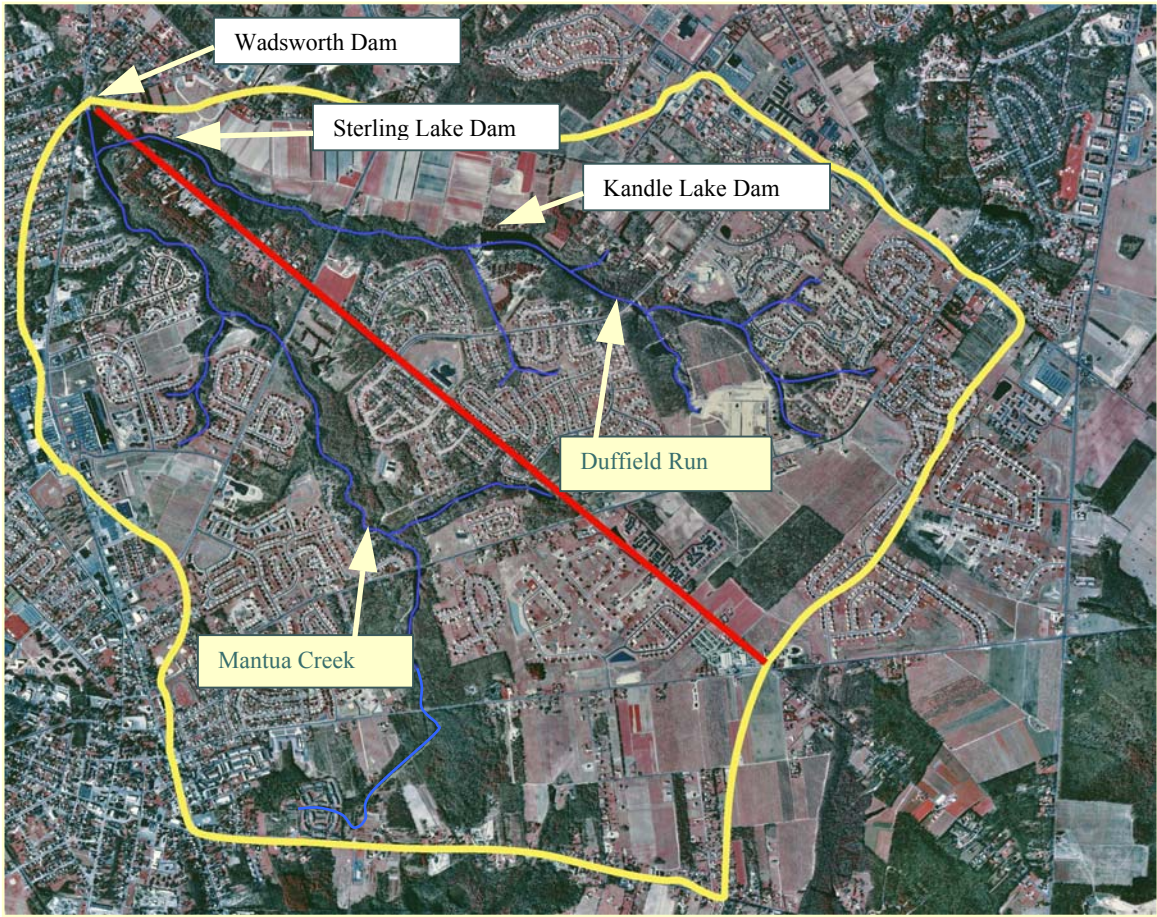


Figure 3: Upper Mantua Creek Watershed, showing location of Wadsworth Dam.

The current owner purchased Wadsworth Dam and adjacent property in 1979, about the time Federal and State legislation regarding dam safety was enacted. As part of this legislation, the U.S. Army Corps of Engineers conducted Phase I investigations of all of the dams in the state. The Phase I investigation of Wadsworth Dam indicated that there were a number of deficiencies with the structure that needed to be repaired. Over the next few years, the owner completed all of the general maintenance and repair work suggested by in the Corps report, and had the dam inspected at regular intervals. However, no inspection had been done recently, and maintenance had been deferred on the structure.

Heavy rainstorms in September 1999 and August 2000 caused the failure of seven dams in New Jersey, and notable damage to another 47. In response to those events, the NJDEP Dam Safety Section issued orders to 800 dam owners to perform an inspection of their dams as required by the New Jersey Dam Safety Standards (NJDEP, 2000). This included Wadsworth Dam on Mantua Creek.



Figure 4: The spillway at Wadsworth Dam, looking upstream.

Currently, the dam is not in compliance with provisions of the New Jersey Safe Dam Act. One of the key elements required to keep the dam in operation is an updated hydrologic analysis of the basin upstream of the dam, and assessment of flood inundation areas downstream of the dam in the event of dam failure. These studies are used as the basis for developing an Emergency Action Plan.

Historically, the dam owner had less-than-cordial relations with the Dam Safety Section of NJDEP. While the owner had no opposition to the concept of dam safety, he had limited financial resources to use for repair, maintenance, and engineering analyses. If a private consulting firm were hired to conduct the engineering analysis, the investigation and reports could cost upwards of \$10,000 - \$15,000. The cost of repairing and upgrading the dam to meet current standards is estimated to be \$750,000, and the cost of removal would be on the order of half a million dollars.

Faced with letters from the State threatening litigation if the studies were not conducted and the dam repaired, the dam owner lowered the level of the lake as an interim measure to reduce the risk of dam failure. When the water level was lowered in the lake, adjacent property owners complained at their loss of waterfront access and the non-aesthetic qualities of the resulting mudflats. These neighbors threatened lawsuits, if the lake were not restored. Clearly, the dam owner was caught in the middle.

Partnerships

To help overcome the engineering and financial burdens associated with dam rehabilitation, creative community-based projects have been developed. To address the technical issues, a unique partnership was created between the dam owner, local engineers, academia, and government regulators. To address the economic issues, a partnership between the dam owner, state, county, and local governments, and others is currently under development.

Initial Discussions: The project started when the lead author contacted the dam owner, inquiring about the possibility of using the dam and associated lake as a learning laboratory for Civil and Environmental Engineering students at Rowan University. Since the dam is located close to the university campus, it was reasoned that the dam could be used to provide unique experiences for students to learn about hydraulic structures, flow measurements, water quality, limnology, and aquatic ecosystems.

The dam owner was happy to allow access to the dam for educational opportunities. In addition, he indicated that there was a need for particular engineering analyses and repairs, to satisfy the New Jersey Dam Safety Standards. The owner had contracted a local private engineering firm to conduct some of the required studies, but did not have the financial resources to complete the analysis, much less the funds to either repair or remove the structure.

Initial student projects started in the Spring Semester of 2001. This involved two students, who learned about the history of the dam, the changes in hydrologic conditions upstream of the dam, and how to conduct stream discharge measurements. These activities were intended to establish the types of educational labs that could be conducted at the site, for future use in the lead author's regular courses in Water Resources Engineering.

A Plea For Help: The Dam Safety Section of the NJDEP was not satisfied with the progress being made regarding current inspections of the dam and development of the Emergency Action Plan and Operation and Maintenance Manual for the dam. The State Attorney General's office was contacted to initiate litigation against the owner.

The dam owner contacted the elected official representing his district in the New Jersey State Senate. A meeting was held at the Senator's office, where the dam owner, a local engineer, and neighboring lakefront property owners voiced their concerns, and sought relief from the State. Representatives from the Dam Safety Section outlined the current State laws regarding dam safety, and the Deputy Attorney General described the litigation process. The Senator acknowledged the issues and problems faced by the owner and community at large, and indicated that legislation had been proposed to provide some financial relief for dam owners. The Senator offered to facilitate future meetings between the owner, local and county governments, the State regulators, and the Attorney General's office. The owner agreed to seek completion of the engineering analyses by the private consulting firm, for submission state regulators.

The hired engineering consultant submitted the requested flood inundation mapping to the state regulators in the summer of 2001. Upon reviewing the study, the State had many questions, comments, and concerns, and requested that the study be expanded and a formal report prepared.

The Academic Partnership: A technical meeting was held between the owner, the Dam Safety Section, the Deputy Attorney General, a local engineer, and the lead author. The engineer who conducted the inundation study was invited, but did not attend. The State outlined their concerns regarding the study, and required them to be addressed, with a new report submitted.

It was suggested that the original firm be asked to make the revisions. In parallel, engineering students under the supervision of the lead author could redo the analysis, as an academic exercise. If the original firm was not willing to address the comments, then the university team could submit their analysis and report to the regulators. Since no additional funds from the owner were forthcoming, the private consulting firm declined to participate further. This left the burden of the engineering analysis on the faculty and students at Rowan University.

The goals of the Rowan analysis are threefold:

- To provide a practical, “real-world” learning experience for upper-level engineering students;
- To provide a service to the community; and
- To foster the concept of academic/public/private partnerships for developing solutions to local and state engineering issues.

These goals are similar to those used in other community-based projects for undergraduate civil engineering students (Padmanabhan and Katti, 2002).

A Student-Centered Project: Student involvement in the new hydrologic analysis began in Fall Semester of 2001 as part of the upper level *Engineering Clinic*. The engineering curriculum at Rowan University contains a core of Engineering Clinic classes (Clinics), which cross over disciplinary boundaries and span the entire four-year undergraduate education. The origins of the Clinic program at Rowan have been described previously [Schmalzel, *et al.*, 1998]. The content and nature of the Clinics vary over the four-year curriculum, as shown in Table 1.

Table 1: Overview of Engineering Clinic Content

| Year | Engineering Clinic Theme (Fall) | Engineering Clinic Theme (Spring) |
|-----------|---|-----------------------------------|
| Freshman | Engineering Measurements | Competitive Assessment |
| Sophomore | Interdisciplinary Design | Discipline Specific Design |
| Junior | Open-ended problem solving in small teams | |
| Senior | Open-ended problem solving in small teams | |

Clinics for first-year students focus on basic, introductory skills. In the second year, engineering students are introduced to multidisciplinary action through a number of projects. In the third and fourth years, students participate in team projects that feature open-ended problem solving and design.

Due to the scope and complexity of the project, an upper-level clinic project was deemed appropriate. A team of four students from Civil and Environmental Engineering were selected to work on the project. All of the students are in their 3rd year of studies, and had completed coursework in mathematics, physics, statics, and solid mechanics. They were concurrently enrolled in their first Fluid Mechanics course (which was also taught by the primary author). The students were divided into two teams of two students each, to facilitate completion of the Hydrologic and Hydraulic Analysis in a timely manner, and to focus learning activities on specific engineering tasks. One team of students has focused on the hydrology upstream of Wadsworth Dam, while the second team has worked to evaluate downstream impacts.

A general outline of project activities was presented to the student project team at the start of the semester, along with a detailed list of tasks to be achieved. This outline is shown below in Figure 5.

Wadsworth Dam Analyses
Junior / Senior Clinic
Fall 2001
Faculty Advisor: Dr. Joseph Orlins
orlins@rowan.edu

Objectives: The goal of this project is to conduct hydrologic and hydraulic analyses for Wadsworth Lake Dam on Mantua Creek, and assess the impact of dam failure on lands downstream of the structure. The dam is located approximately two miles north of Rowan University, near the intersection of Delsea Drive and Pitman-Downer Road. The dam is privately owned; the dam owners have limited resources to conduct engineering studies of dam safety and perform corrective actions.

Deliverables: The primary deliverable for this clinic project will be a written report (due at end of semester), describing in detail the hydrologic analysis and inundation mapping. The report should follow a format similar to that accepted by the NJDEP Dam Safety Office for hydrologic analyses of dams. Secondary deliverables include a poster and web site (due at mid-semester), explaining the nature of the project, planned work activities, and work completed to date.

In addition, weekly project summaries are required via email. These summaries can be brief, stating what goals were set for the week and what progress was made, along with the amount of time spent on the project by each team member that week.

Grading: The level of effort expected for this clinic project is between 10 and 12 hours per week, including time during the regularly scheduled clinic periods. You will be evaluated based upon:

- Weekly status reports
- Successful completion of tasks
- Successful completion of written deliverables (web page, poster, final report)
- Honest assessment of you & your teammates' performance

Your group will be assigned an overall grade. Your individual grade will be based upon the group grade, with adjustments (up or down) based upon peer evaluations.

Figure 5: Student Project Handout

Students worked closely with the faculty sponsor throughout the semester, learning all aspects related to the project. This included site visits, literature reviews, reviews of good and bad examples of engineering reports (provided by the NJDEP), the hydrologic analysis, and reporting.

At the end of the semester, the students made a presentation to the state regulators, the dam owners, a local engineer, and faculty. Preparation of the final hydrologic analysis report is in progress. In spring semester, the student team will continue, working on the downstream flood inundation study, a feasibility study of technical alternatives for dam rehabilitation, and additional analyses of two other dams in the watershed.

The Political / Financial Partnership: The State Senator facilitated another meeting among the dam owner of Wadsworth Dam, the owners of two other private dams upstream of Wadsworth Dam, State regulators and attorneys, county and local governments, and other stakeholders. Since there are many organizations, people and communities that are directly and indirectly affected by the removal or repair of dams, it was felt that all potentially affected parties should be represented.

All the above groups have a shared interest in protecting their property and/or the properties within their communities. The main purpose of the political/financial partnership is to develop an understanding of the need to repair and upgrade the private and publicly owned dams in the watershed. Ideally, the partnership would share expenditures associated with permitting, repairing and restoring the dams.

While not all of the stakeholders may be interested enough to contribute financial resources to the project, it was deemed important to be inclusive rather than exclusive. Each stakeholder at the meeting was asked to discuss the concerns and problems regarding the dams with their representing committees or organizations.

Successes

There have been a number of successes associated with this partnership approach to local dam safety problems. First and foremost, public safety concerns are being addressed. Stakeholders are actively seeking solutions to dam hazard issues, instead of ignoring or minimizing the problems. After many years of lax enforcement and deferred maintenance, progress is being made on engineering analyses for repair and rehabilitation of the dams. An adversarial relationship between dam owners and state regulators has been transformed into a working relationship, where neither side is interested in pursuing litigation. In addition, state regulators are accepting work by students done under the supervision of a faculty member with a Professional Engineering license.

Student involvement in the project has been successful, in that students gain valuable experience not only with the engineering aspects of the project, but also with the non-technical issues, as well. Students working on the project have seen first-hand the interaction between regulators,

legislators, attorneys, and property owners, and have a better understanding of the economic and social impacts of engineering projects. One of the students has applied for a scholarship sponsored by the Association of State Dam Safety Officials, and the NJDEP will be hiring another one of the students to work as summer interns.

Failures

To date, no financial solution has been developed to cover the costs of repair or removal of Wadsworth Dam. Pending legislation that would provide grants to private dam owners was vetoed by the State Governor, and current fiscal shortfalls in the State of New Jersey make such funding a remote possibility for the time being. Even though the initial steps have been made to form a financial partnership between the dam owners, local, county, and state governments, and other interested parties, no formal arrangements have been established. The county and local municipalities are reluctant to sign on as financial stakeholders (as none claim any ownership interest in the dam), and none are interested in acquiring the dam to be used as a public amenity, even if that allowed State funds to be used for the repairs.

While these failures may seem daunting, work is continuing to educate the stakeholders about the importance of dams for water quality and as a community resource. In addition, other creative solutions are being sought for financing rehabilitation of the structures.

Conclusions

Dam safety is an issue of public safety, and poses particular problems for private dam owners. Partnerships created between dam owners, academia, practicing professionals, and regulators can be an innovative and effective way to address issues of dam safety. 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.

Acknowledgements

The authors would like to thank John Moyle and Joseph Ruggeri from the Dam Safety Section of the New Jersey Department of Environmental Protection and Robert Baranowski from the NJ Attorney General's office for their willingness to work as part of the partnership process. New Jersey State Senator John Matheussen has helped cultivate the partnership efforts, bringing numerous stakeholders to the table to discuss common interests and goals. Finally, thanks are due to the undergraduate students who have worked on the project: Jeff Delessio, Jessica Fusaro, Greg McGrath, Laura Miller, Clint Oman, and Jeffrey Puterbaugh.

References

- National Research Council (NRC) [1985] *Safety of Dams: Flood and Earthquake Criteria*. National Academy Press, Washington, D.C.
- New Jersey Department of Environmental Protection, Dam Safety Section (NJDEP) [2000]. <http://www.state.nj.us/dep/nhr/engineering/damsafety/>
- Padmanabhan, G., and Katti, D. [2002] "Using Community-Based Projects in Civil Engineering Capstone Courses," *Journal of Professional Issues in Engineering Practice and Education*, ASCE, 128:1, 12-18.
- Schmalzel, J.L., Marchese, A.J., Mariappan, J., and Mandayam, S. [1998] "The Engineering Clinic: A Four-year Design Sequence." *2nd Annual Conference of National Collegiate Invention and Innovation Alliance*, Washington, DC.
- Watt, M.K. [2000] *A Hydrologic Primer for New Jersey Watershed Management*. U.S. Geological Water-Resources Investigation Report 00-4140, West Trenton, NJ.

About the Authors

JOSEPH J. ORLINS, Ph.D., P.E.

Dr. Orlins is an Assistant Professor of Civil and Environmental Engineering in the College of Engineering at Rowan University. Dr. Orlins is a registered Professional Civil Engineer in several states and is actively involved in water resources engineering education and research. He received his B.S.C.E degree from the University of Washington in 1993, and his M.S. and Ph.D. in Civil Engineering at the University of Minnesota in 1996 and 1999, respectively.

KIMBERLY GROFF, Ph.D.

Dr. Groff is a consulting engineer with EarthSolve, Inc. in Acton, MA. She received her B.A. in Biology from University of Delaware in 1980, M.S. in Environmental Science from Drexel University in 1982, and Ph.D. in Environmental Engineering from Georgia Tech in 1987.

PAUL GREGER, P.E., P.P.

Mr. Greger is an independent practicing professional engineer and planner with almost 30 years experience in the southern New Jersey region. He is active in all aspects of watershed management and protection. He received his B.S. in Civil Engineering from Rutgers University in 1973.

R. WAYNE GROFF

Mr. Groff is the owner of Wadsworth Dam. He operated a nursery on the shores of Wadsworth Lake for almost two decades. He has since retired, and spends his time relaxing by the lake and touring the countryside on his motorcycle.