Connecting Practice with Education through Civil Engineering Capstone Design Experience:
Puddingstone Reservoir Operational Level Study

Project Abstract

The Civil Engineering Department requires all undergraduates to complete a senior design team project over the course of six months. The facilitators include practicing registered engineers from different disciplines related to the project. The project requires integration and synthesis of acquired knowledge as well as the consideration of alternative solutions, methods, and constraints such as economic, environmental, health and safety, social, political, sustainability, constructability, and ethical. The team performs a complete analysis and design including the application of constraints. They then prepare a final design report including: memoranda, computations, drawings, specifications, and cost estimates. The written and oral reports are presented to a panel of faculty and representatives from the industry. All students are required to participate in the presentation. The panel includes a number of registered engineers that ask follow-up questions and provide the students with feedback on the technical merits of the report as well as the professionalism of the presentation.

For the past couple of years the University has had the opportunity to partner with local agencies to afford the senior design team an opportunity to work on real world projects. The facilitators coordinate with representatives of the agency, who are also practicing registered engineers, on the scope of work and timelines for deliverables. The agency reviews the draft submissions and provides comments. The students then address these comments and submit revised reports.

Water supply is a major concern throughout Southern California and requires innovative solutions to meet increasing demands due to dwindling supplies. The 2009 project was a partnership with the County Department of Public Works, and the County Department of Recreation. Puddingstone Lake is a 253-acre reservoir located at the Frank G. Bonelli Regional Park. The scope of this project was to evaluate several operational water surface elevations at the reservoir to determine the impacts to existing recreational and operational facilities, and to downstream structures and spreading grounds. Changes in the operation of the dam were contemplated in order to allow conservation of more water for recharge into local aquifers. The project also required the design of new recreational facilities at the lake, including boat ramps, a boathouse, and other structures. A cost benefit analysis and evaluation of various constraints were conducted for each of the operational levels. The project was divided into five major tasks, and Technical Memoranda were written for each task.

Over the six-month duration of the design class, students with the mentorship of practicing engineers developed and implemented the project plan. The facilitators also gave technical lectures and assignments in their areas of expertise as well as practical lectures on project organization, cost estimation, report writing, legal issues, and presentation skills. Through these many avenues students gained insight as to the value of experience and professional registration. The students benefitted greatly from the integration of professional practice and education inherent to the senior design project which prepared them for handling real world projects.

Connecting Professional Practice with Education through Civil Engineering Capstone Design Experience:

Puddingstone Reservoir Operations Level Study

Section I: Project description

INTRODUCTION

The Civil Engineering Department requires all undergraduates to complete a senior design project over the course of two quarters. Two full time and four part time faculty, all registered professional engineers, facilitated the course. Students work as a team to first coordinate the project, and then divide into groups assigning tasks to individual members. The project begins with the initial phases of planning and designing of a typical civil engineering project as encountered in practice. The project requires integration and synthesis of acquired knowledge as well as the consideration of alternative solutions, methods, and constraints such as economic, environmental, health and safety, social, political, sustainability, constructability, and ethical. The students prepare an initial study to determine the environmental documents needed for the project to meet the California Environmental Quality Act. A preliminary report and oral presentation is required at the end of the first quarter. During the second quarter the team performs a complete analysis and design including the application of constraints. By the end of the second quarter, a final design report including memoranda, computations, drawings, cost estimates, etc is prepared. The final design report and an oral presentation are given to a panel of faculty and representatives from the industry. All students are required to participate in the presentation. The panel has the opportunity to ask follow-up questions and provide feedback.

For the past couple of years the Civil Engineering Department has had the opportunity to partner with local agencies to afford the senior design team an opportunity to work on real world projects. The facilitators coordinate with representatives of the local agency, who are also practicing registered engineers, on project specifications and timelines for deliverables. The agency reviews the draft submissions and provides comments. The students then address these comments and submit revised reports.

The 2009 project entailed evaluating several operational water surface elevations at Puddingstone Reservoir to determine impacts to existing park facilities. The purpose of this project was to evaluate costs and benefits associated with operating the reservoir at different levels to allow the conservation of more storm water for recharge into local aquifers.

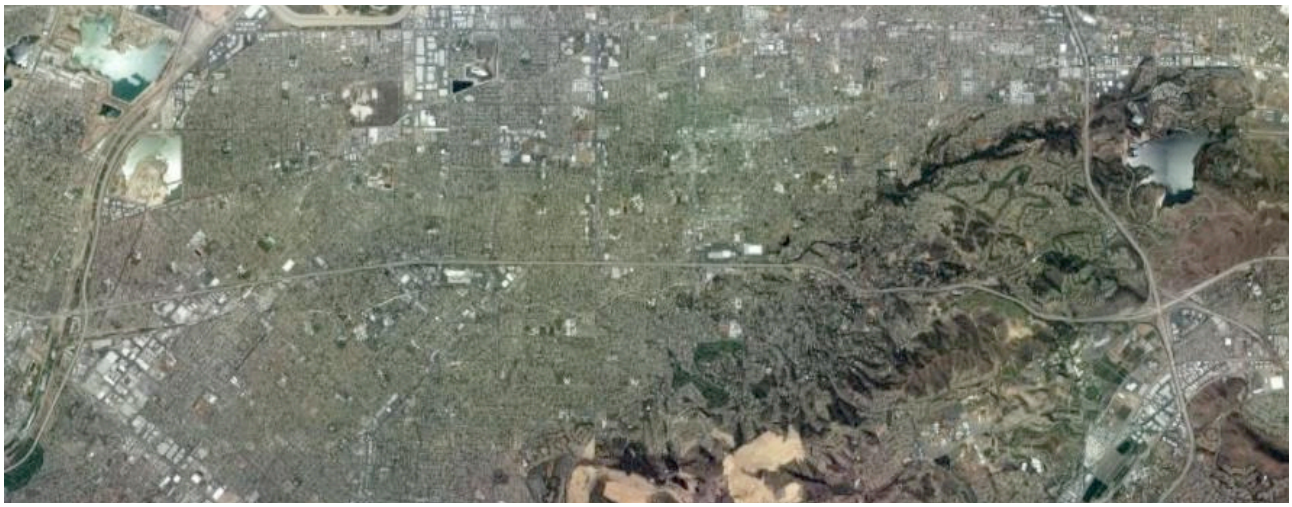
BACKGROUND

Puddingstone Reservoir is located in Frank G. Bonelli Regional Park near the cities of Pomona, La Verne, and San Dimas. The reservoir is owned and operated for water conservation and flood control benefits by the Los Angeles County Flood Control District (LACFCD) through the County of Los Angeles Department of Public Works (DPW). The park is maintained by the County of Los Angeles Department of Parks and Recreation (DPR).

Frank G. Bonelli Regional Park features the 250-acre Puddingstone Reservoir supporting populations of perch and crappie and stocked with trout, bluegill, catfish, and largemouth bass. In addition, the lake is ideal for swimming, waterskiing, wind surfing, and sailing. There are boat rentals, hot tubs, an equestrian center and even a wedding chapel to rent. Other recreational

amenities include RV campsites, trails for hiking, biking and horseback riding, play equipment, gazebos, and group rental picnic areas. Food and beverage concessionaires are provided. Puddingstone Reservoir discharges into Walnut Creek which stretches approximately 10 miles across Los Angeles County (Figure 1). The creek is part of the Los Angeles County Flood Control System and is maintained by DPW. Portions of Walnut Creek are concrete channel, while other sections are still natural. Within the project boundaries there are 26 bridges crossing Walnut Creek. In the past, high releases from Puddingstone Dam have combined with local inflow to cause erosion and flooding along the creek. There have also been accounts of flooding on private property and at the airport near Puddingstone Reservoir.

Figure 1: Overview of Walnut Creek



SOUTHERN CALIFORNIA WATER SUPPLY ISSUES

Back-to-back dry years and low reservoir levels have put California in a statewide drought. The state's major reservoirs were at about one-third of capacity in late 2008 at a time when they would typically have been at about two-thirds. State water officials estimate that it will take more than one extremely wet winter for storage levels to recover. On June 4, 2008, California Governor declared an official drought.

To cope, local water agencies around the state are drawing down their reserves and taking aggressive action to reduce water use. The Department of Water Resources has established a Drought Water Bank to facilitate water transfers in a potential third dry year.

With California officially in a drought, local water agencies are dealing with multiple challenges. A survey conducted by the Association of California Water agencies (ACWA) shows that drought and court-ordered restrictions on water deliveries are having an array of impacts on local water agencies. These impacts include increased groundwater pumping, less water for groundwater recharge, increased water costs, impacts to the agricultural businesses, increased algae blooms, loss of jobs, and an uncertain water supply picture in the coming years.

LAKE PUDDINGSTONE PERMITTING RESTRICTIONS

The reservoir has a Department of Safety of Dams (DSOD) seismic restriction for water levels at 945 feet above mean sea level (AMSL). This limit can be temporarily exceeded during major

flood events, but must be drawn down as soon as practicable after storm events. An agreement between the LACFCD and the DPR allows use of the reservoir for recreational activities such as those previously described. The agreement restricts operational levels for the water surface of the reservoir to 940 feet AMSL at the beginning of the summer. Over the summer, water is lost to evaporation and percolation. The restriction currently prevents exposure of chlorination lines owned by the DPR towards the end of the summer. Other facilities impacted by changes of operational levels include docks for boats, beaches, walking distances to restroom facilities, etc.

Operation of the reservoir at lower levels would allow DPW to make more space available in the reservoir by the beginning of storm season to capture storm runoff. Current pre-storm drawdown limits do not allow the reservoir to be drawn down below 937 feet AMSL when large storms are expected to affect the area for extended periods of time.

The results of this study will provide information that will be used by the DPW to reach an agreement with DPR on the operational level at Puddingstone Dam that provides the most benefit for residents of the County of Los Angles.

SCOPE OF WORK

The scope of work for this project as provided by DPW was to evaluate several operational water surface elevations at Puddingstone Reservoir to determine the impacts to existing park facilities. The purpose of the project was to evaluate costs and benefits associated with operating the dam to allow conservation of more storm water for recharge into local aquifers.

This scope of work identified tasks to be completed by the senior design team. The tasks provided information that was used to make a recommendation to DPR on the operational level at Puddingstone Reservoir that provides the most benefit for residents of the county. For each task, a technical memorandum (tech memo) was submitted to DPW for review. Table 1 lists the tasks and the number of hours allotted for each. The tasks are explained in detail below Table 1.

Table 1. Tasks and Allotted Hours

Task	Hours
1. Develop a HEC-HMS/ResSim Model for Puddingstone Reservoir	300
2. Develop a HEC-RAS Model of Walnut Creek	350
3. Evaluate Reservoir Operation Levels and Impacts to Facilities	300
4. Evaluate Modifications to DPR Infrastructure	200
5. Cost/Benefit Analysis of Each Operation Level	300
6. Final Project Report and Recommendations	200
7. Total Hours	1650

Task 1 – Develop a HEC-HMS/ResSim Model for Puddingstone Reservoir

A hydrologic model of the reservoir was needed to determine reservoir water surface elevations in response to inflows and outflows. Once the model was created and working properly it was used to evaluate reservoir operation alternatives. The model was built using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) and the Hydrologic Engineering Center Reservoir System Simulation (HEC-ResSim) programs. Historic inflow and outflow at the dam, water surface elevations (WSEs), evaporation data, and downstream spreading

capacities were considered. At the end of Task 1, *Tech Memo 1 – HEC-HMS/ResSim Development and Evaluation* was submitted to DPW for review.

Task 2 – Develop a HEC-RAS Model of Walnut Creek

A hydraulic model was needed in evaluating flow depths and scour potential in Walnut Creek during operation of the reservoir facility to be used for evaluating impacts related to flow rates generated by historic events and design floods. This model was developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) program. Recent LIDAR survey data and aerial photography for the channel, data sheets from the US Army Corps of Engineers on channel sizes for lined sections of the creek, and field investigation of channel roughness conditions were all necessary for completing the model. At the end of Task 2, *Tech Memo 2 – Hydraulic Model Development Report* was submitted to DPW for review.

Task 3 – Evaluate Reservoir Operation Levels and Impacts to Facilities

With the completion of the reservoir and channel models, evaluation of alternative elevations was considered. The alternative operational elevations were 940, 937, 935, and 930 feet AMSL. Evaluation of these alternatives required:

- Evaluating evaporation and infiltration losses
- Determining the volume of water that can be conserved by having operational limits that allow more storage availability in the reservoir during storm season
- Determining peak outflows from the dam at each level for design storms and major historic events
- Determining reservoir drawdown times assuming flow rates of 50, 250, 500, and 700 cubic feet per second (cfs)
- Analyzing HEC-RAS results for the outflows in the previous step and determining flooding and scour impacts to downstream areas

At the end of Task 3, *Tech Memo 3 – Evaluation of Alternative Reservoir Levels* was submitted to DPW for review.

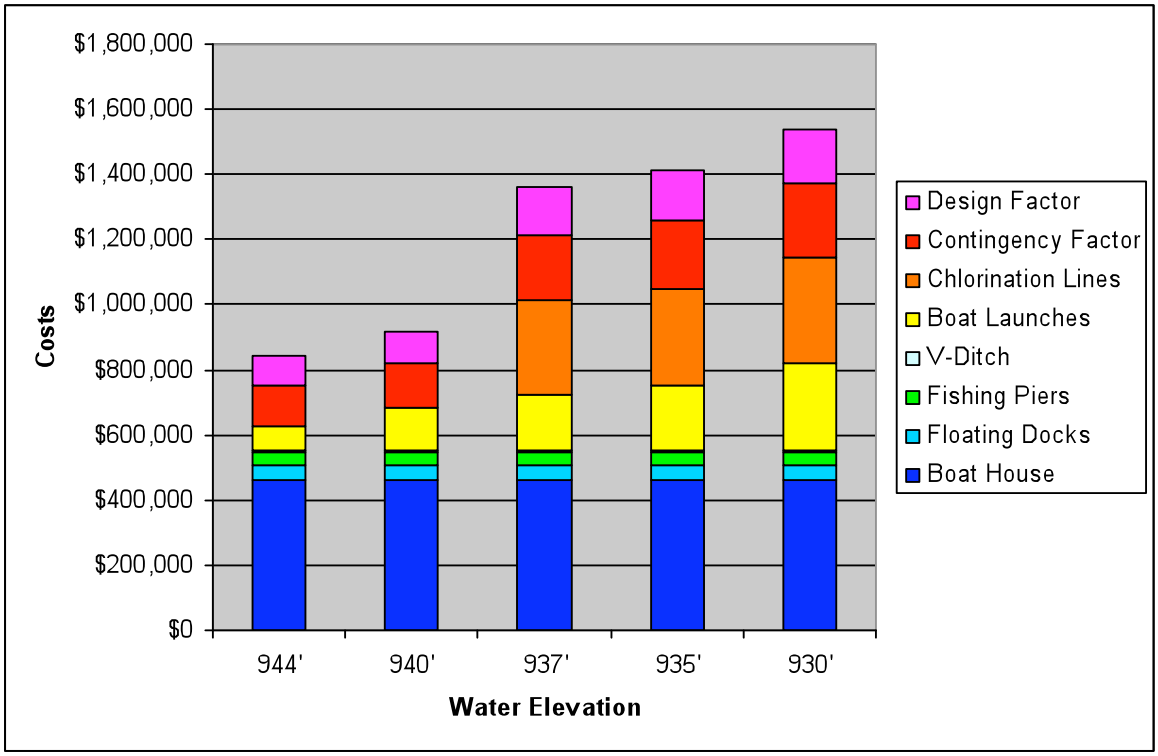
Task 4 – Evaluate Modifications to DPR Infrastructure

This phase of the project required evaluating the DPR facilities at Frank G. Bonelli Regional Park. Conceptual plans and specifications for modification of existing facilities were completed for each of the levels of operation. Cost estimates for proposed facility modifications were also prepared. Following Task 4, *Tech Memo 4 – Evaluation of DPR Facilities and Infrastructure Modifications* was submitted to DPW for review.

Task 5 – Cost/Benefit Analysis of Each Operation Level

This task required comparing the costs to modify the recreational area facilities to the benefits of flood protection and water conservation. Recent water purchase cost information was considered in determining the benefits. A detailed construction cost estimate for materials and labor was prepared. A 20% contingency factor and a 12% design factor were added to the cost estimates shown in Figure 2. Loss of revenue from recreational use fees was also considered. The team then submitted *Tech Memo 5 – Cost/Benefit Analysis for Alternative Reservoir Levels* to DPW for review.

Figure 2: Costs of Structural Modifications at Alternative Water Elevations



Task 6 – Final Project Report and Recommendations

The team prepared the final report encompassing the five previous tasks. The report summarized the findings of the individual tasks and referenced the technical memorandums for further details. Along with the report, a final oral presentation was made.

CONCLUSION

After reviewing the results of the models and looking at the cost benefit analysis, various constraints, and all the needed construction modifications, the senior design team recommended that the operations of the Puddingstone Reservoir change to reaching a WSE of 930 ft. MSL on October 15th of each year. This will maximize the storage in the lake providing the greatest benefit for residents of the County of Los Angeles.

Section II: Collaboration of faculty, students, and professional engineers

Over the six month duration of the design class, engineering faculty and four practicing registered engineers from four different disciplines worked in collaboration with the students to develop and implement a project plan. The team included two hydraulics and hydrology engineers responsible for the analysis of the hydraulics of the reservoir and the creek; a structural engineer that helped the students evaluate the DPR structures impacted by the variation in elevations and the design of new structures, and a geotechnical engineer that assisted the students in understanding the geology needed to support their design. These activities provided the students with leadership opportunities, hands-on engineering experience, and a chance to meet and work with practicing professional engineers.

These four facilitating engineers also gave periodic lectures and assignments in their respective areas of expertise. In addition to the technical lectures, faculty provided practical lectures on project design and organization, cost estimation, report writing, legal issues including the California Environmental Quality Act (CEQA), and presentation skills. The practical lectures provided the opportunity for the professional engineers to share examples from their personal experience that demonstrated the importance of each topic.

Another requirement for the course was that each student develops a portfolio to be used for job interviews. Registered engineers from the school faculty assisted students in preparing resumes, sample lab reports, and other documents for the portfolio.

A liaison from DPW, also a registered civil engineer, was very involved in the process as well. The liaison visited the school for the initial scope of work presentation, and later addressed the class at the DPW office regarding personnel issues and career development. At each stage DPW reviewed and commented on the Tech Memos and the senior design team would adapt the reports as necessary to address these concerns.

A final presentation of the findings and recommendations was made to a panel of faculty and representatives from the industry. This panel included a number of registered engineers that asked follow-up questions and provided the students with feedback on the technical merits of the report as well as the professionalism of the presentation. At the conclusion of this event, students had the opportunity to have lunch with the panel members.

Through these many avenues students gained insight as to the value of experience and professional registration.

Section III: Benefit to health, safety, and welfare of the public

Engineering codes of ethics commonly state in the first canon that the engineer shall hold paramount the health, safety, and welfare of the public. The change in the operations of the reservoir impacts structures and environments significantly affecting the health, safety and welfare of the public. In recognition of the significant aesthetic, environmental, and economic benefits to the community provided by lake, and to protect and enhance the health, safety and welfare of the public within the County of Los Angeles, this project was planned and executed through a professional, competent, and cost effective administration of the proposal to modify the elevations of the lake. This was accomplished by taking into account development review, recreational impacts, water supply impacts, public safety impacts using the lake, public safety impacts from flooding, public safety impact to the surrounding community and the airport, and traffic engineering. Furthermore, field trips to the reservoir and creek under the supervision of the facilitating engineers assisted the students in recognizing the issues firsthand and developing safe habits for field work.

Section IV: Impact on raising social consciousness

The solutions proposed by the senior design class were the most feasible for maximizing the return on the investment, creating the greatest benefit to the public, and addressing the importance of preparing to deal with future water supply issues. This includes the interest in water, one of our most important renewable resources. Water drives the health of our

environment, but its functioning is often fundamentally misunderstood. This project demonstrated sustainable rainwater, storm water, and runoff management for the benefit of an entire community while providing the community with recreational opportunity in an aesthetically pleasing and environmentally sound way.

Section V: Impact of partnering teaching and professional practice

A partnership between a department of public works, a civil engineering department, and professional practitioners created the opportunity for 23 civil engineering students attending the senior design class to participate in a public project that will be implemented and constructed according to the students' design. The selected project had to be completed in the design duration of the class time and be both challenging and meaningful to the students. Throughout the process, the students were expected to perform the work with guidance from both the faculty and the participating professional engineers. The class provided the students with real life experience in the field of civil engineering and the department of public works with design drawings and written specification to immediately advertise a project that has been thoroughly analyzed to meet the public needs.

Section VI: Multidiscipline and/or allied profession participation

All instructors in design courses are professional engineers demonstrating the desirability of licensure. The practitioners have over a hundred years of combined experience among them in environmental, hydraulic, hydrology, structural, and geotechnical engineering. Issues from all of these areas and more arose in the completion of this multidisciplinary project. The instructors worked closely with the students and guided them every step of the way. They introduced them to techniques and analysis not normally taught in a four-year civil engineering curriculum.

Section VII: Knowledge or skills gained

The students gained knowledge in multiple areas on this project. In addition to design knowledge for water structures and the application of engineering codes, they learned how to use the latest in technology. Additionally, they were exposed to drinking water sustainability issues, and health and safety issues. A visit to the reservoir and the dam with operational personnel gave the students an insight in the operation of a dam, a flood control system, and settling basins.

Perhaps of even greater importance were the skills gained in project organization and design, cost estimation, report writing, and presentation/public speaking. The students had to work as a team, both among themselves and with the facilitating engineers, in order to prepare deliverables in a timely manner. The students also gained knowledge of applicable building codes; local seismic, wind, and geological conditions; building materials; and the provisions of CEQA.

Section VIII: Viability of technology used

In addition to the HEC-HMS/ResSim and HEC-RAS software used for modeling, students gained experience with other current technology. During the field visits Global Positioning System (GPS) units were used to collect spatial data. This and other data were processed and analyzed using Geographic Information System (GIS) software. AutoCAD was used to prepare the structural modification drawings included in the final report. The SAP 2000 program was used to assist in the design of a boathouse structure. In all of these cases and others the importance of technology was realized and viable skills emerged.