Senior Design Capstone Course: Collection of Projects with Featured Everglades Restoration Project

Entry for NCEES ENGINEERING AWARD for
CONNECTING PROFESSIONAL PRACTICE AND EDUCATION
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A B S T R A C T

Our **capstone courses**, "Pre-Senior Design and Professional Issues" and "Senior Design Project", are taken by students over a two-semester period. The first purpose of these courses is to give our senior students an understanding of **non-technical, professional issues**, such as how to work effectively in teams, good oral and written communication skills, and ethics. The second purpose is to give them an opportunity to complete a **comprehensive design of a civil and/or environmental engineering project**, whereby they do independent research, plan the project from conception to design, and learn skills beyond those that are taught in their regular coursework.

Civil and environmental engineering projects are multi-disciplinary by nature. It takes knowledge that goes beyond that of one faculty member. All students must eventually seek guidance from faculty other than the course instructor and also from professional practicing engineers; in fact, in this course, it is a **requirement for the students to have industry and faculty mentors** and to report weekly on their collaboration efforts.

In part because of this capstone course, our department and professional practitioners have fostered a mutually beneficial relationship over the years. This course is taught (or managed, rather) most effectively when professionals who are involved in design on a day-to-day basis volunteer their time for the students. Collectively, these volunteers represent a whole gamut of experts. **They help us by giving classroom lectures, donating real-world projects and background information, mentoring students, reviewing submittals, and judging oral presentations.** With the help of practitioners, students transition from well-defined, short, narrowly-focused assignments to an open-ended, detailed, multi-faceted project.

This submittal will explain the objectives of the course, the role of practicing engineers and faculty, course requirements, and types of projects that have been designed by students recently. For each project, a rating for the integration with licensed practice is given. This collection of projects includes a variety of topics and was supported by many faculty, engineers, and engineering firms/agencies. At the end of this submittal, a detailed description of a featured project, sponsored by the US Army Corps of Engineers, for the Florida Everglades Restoration is provided.

We appreciate NCEES for giving engineering programs this opportunity to showcase their partnership efforts, and we thank ABET, the engineering deans, ASEE, NAE, and NSPE for their partnership by being on the award jury. We hope that news of this award will encourage professionals to get involved with engineering students across the nation, because their time and sharing of knowledge make a difference.

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PROGRAM DESCRIPTION

Introduction

Our engineering department at our university is applying for this award because of the meaningful way in which we believe we are integrating licensed, professional practice and education. Our department is blessed to have an excellent relationship with engineers in our community and state who are willing to contribute to our academic efforts. Our best example of this partnership, which is the subject of this award submission, occurs in our two-course sequence, "Pre-Senior Design and Professional Issues" and "Senior Design Project." When combined, this "capstone course" is designed to give our senior students an understanding of non-technical, professional issues and also technical experience in the design of a civil and/or environmental engineering project. By integrating the knowledge and skills gained in undergraduate studies, the scope of the project is more detailed and comprehensive than typical projects that are assigned in senior-level design courses such as Concrete Design. Projects are completed in teams and over several months. Another purpose of the course is to fulfill the department's Program Outcomes, which are based on the American Board for Engineering and Technology (ABET) recommendations and include an ability to function on teams, to communicate effectively, to understand professional and ethical responsibility, to recognize a need for lifelong learning, and to use modern engineering tools.

The course aims to provide for students a project that mimics a "real" one. The challenge, however, is that civil and environmental engineering projects in practice are multi-disciplinary (e.g., structures, geotechnical, hydraulics, water resources, construction, transportation, and environmental). This goes beyond a particular faculty member's expertise. It is required, therefore, that the students seek help from several mentors who have practical experience in each area. To successfully integrate professional practice and education, educators must rely heavily on the local engineers' volunteerism and willingness to donate real-world projects and to freely give resources and advice to students. Faculty in our department believe that this one-to-one contact and mentorship develop strongly a student's professional abilities. Over the years, we have had tremendous support from many engineering firms, agencies, and individual engineers.

We are aware of other schools that require a similar course and have found that the teaching method and strategy vary widely. Our approach has evolved, as a result of continuous self-assessment, into a management strategy rather than a teaching one. To mimic a real-world experience, the students must gather their own resources, seek help from professionals, do research on their own, and set their standards. By doing so, they realize the complexity of a real-world project and the need for life-long learning. As one student design team stated, "This project helps us achieve life-long learning because it is not force fed to us, but rather it is all up to us about how good we want it to be." Again, mentorship from several faculty and practicing engineers goes far in enabling our students to complete realistic design projects that they proudly present at the year's end.

Course Description

Our capstone course is currently taught by a full-time faculty member who is a licensed Professional Engineer. The current instructor had seven years of design experience before beginning her career in academia, so she is able to share lessons from her firsthand practical experience and emphasize the importance of non-technical, professional issues. Students also receive help from other faculty members whenever needed; **10 out of 12 of our civil engineering faculty (and 10 out of 16 in the department) are licensed Professional Engineers**. Projects are sponsored or "donated" by professionals, or the faculty member creates the project based on a need in the community. Project scopes are tailored toward the students' area interests, and are multi-disciplinary in nature. The number of student design teams in one course ranges from six to twelve, with an average of four students per team. ***For the past four semesters, the instructor has managed 37 different teams, with over 160 students in total.***

Although the classes are large and the students work on different projects, the standards for submittals and presentations are the same for all teams. Teams receive weekly guidance from the instructor on topics such as presentation skills, correct engineering documentation, teamwork, responding to request for proposals, etc. The students are required to report weekly on their activities; to have faculty and industry mentors; to prepare a final submittal with calculations, formal descriptions, and explanation of alternatives; and to present to a panel of judges that consists of faculty and practicing engineers.

Encouraging students to recognize the need for non-technical skills is highly emphasized in the course. In Pre-Senior Design, covered topics include ethics; public health, safety, and welfare; social responsibility; introducing a speaker; dining etiquette; importance of licensure; procuring work; and shop drawing review. An excellent resource that the students use is the National Society of Professional Engineers (NSPE) website. The students review and present ethics cases and relate them to the NSPE Code of Ethics canons. The instructor uses the National Council of Examiners for Engineering and Surveying (NCEES) website to explain the importance of taking the Fundamentals of Engineering exam while in college and of becoming licensed professional engineers. The requirements for taking the exams, responsibility of the engineer, engineer's code of ethics, continuing education, and NCEES registration for licensing in multiple states are also discussed. Other important non-technical skills such as teamwork, project planning, and time management are inherent throughout.

Throughout the course, there are several professional practice components. As mentioned previously, mentors are invaluable. Guest speakers visit the class, also, to discuss the course topics. For example, a local engineer who normally provides continuing education courses (for a fee) visits the class and discussed ethics. The students long remember the examples of behaviors that are often deemed unethical, even if "innocent." Another local engineer presents on the topic of procuring work and the recent trend of outsourcing. A local contractor talks about the contractor-engineer relationship. One favorite presentation of the students is dubbed, "The Money Talk," where the owner of an engineering firm gives students advice on managing finances and explains the costs (e.g., overhead) associated with running an engineering firm. Another engineer gives a help session on the Land Desktop software. Also, a Career Services professional discusses resumes, interviewing, and professional etiquette. In other words, our students have greatly benefited from participation of many local professionals.

Practicing engineers are also involved throughout the project design process. We have several mentors who hold help sessions for the class and/or meet with the teams to provide assistance. The instructor makes contact with mentors before the semester begins and recommends these mentors to the students. The students often find additional mentors to help them. The students report on their activities and mentor involvement in their weekly progress reports. ***Over a two-semester period, the student teams reported that they sought help from over 29 mentors in our community.***

The students' performance is assessed by several written submittals and oral presentations. The final written submittal, properly bound and professional in appearance, includes a cover, transmittal letter, acknowledgements, table of contents, executive summary, and organizational chart. In the bulk of the report, the students are expected to explain/present the data gathered, comparison of alternatives, reasons for the selected alternative, and conclusions. All calculations (with proper documentation, page numbering, initials, etc.) are included, also. So that they demonstrate their ability to communicate in written form rather than solely "with numbers," the students must also include descriptions before each section of calculations to summarize their thought process and the meaning of what follows. Design drawings (11x17 or 24x36) prepared with computer aided design software, such as AutoCAD, are also submitted at this time. The students also prepare a 24"x36" poster that highlights and summarizes their project. These posters are put on display at the college during the following semester.

The students give several presentations throughout the course; in particular, they give a mid-term presentation on their project, and the instructor and peers provide comments and constructive criticism. ***The course culminates in a final, professional presentation to a large audience that includes faculty members, mentors, practicing engineers from the community, students, and guests.*** Students are well prepared and on their best behavior for these presentations. It is so pleasing to observe how much the students grow in their skills over the course duration. Their presentations are well outlined, the students smoothly handle slide and speaker transitions, and they show enthusiasm for their projects. The students highlight their strategies, design process, alternatives, and final design. ***Faculty and practicing engineers judge the students*** and grade the quality of the groups' work. The judges ask the students questions to test their competence in the subject presented, and the students must defend the choices that they made in their designs. The judges use a grading rubric that includes assignment of points and a place for comments on 1) introduction, 2) organization, 3) content/technical quality, 4) language/delivery/visuals, and 5) conclusions/handling of questions and answers. At the end of the questioning period, the judges provide feedback to the students on their delivery, followed by written comments and a score. ***Over a two-semester period, 22 judges (more than half of which were practicing engineers) volunteered their time.***

<u>Types of Projects</u>

The instructor decides in advance the topics of the projects that will be designed in a given semester. The projects can come from ideas from students, can be based on observed community needs, or can be provided by a practicing engineer/mentor. The projects can be specialized in nature, in which case the students are expected to provide more details in their solution. Or the project can incorporate many aspects of civil engineering, such as the development of a subdivision or commercial building site. Regardless, the students are expected to be fully engaged in the design process, by:

- Evaluating alternatives
- Integrating multiple disciplines into their design
- Iterating between analysis and design
- Developing teamwork and planning skills
- Adhering to deadlines
- ***Consulting with faculty and industry mentors***

As discussed, the success of our Pre-Senior Design and Senior Design course sequence is largely dependent upon involvement of faculty members and practicing engineers, in ways such as:

- Giving classroom lectures on ethics and professional practice issues
- Donating design projects for students to work on
- Team mentoring and providing design guidance
- Providing sources and references
- Reviewing written technical submittals
- Judging and providing comments on final presentations

Over 160 students in our department have worked on 37 projects since Fall 2007 (including Projects 26-37 which began last Fall semester and are still in progress). These projects are detailed in Table 1; information on the level of collaboration with professional practice is provided.

Table 1 – Senior Design Projects and Level of Collaboration

Team #	Project Type	Integration with Licensed Practice (5=highest, 1=minimum)	Community Need or Non-Engineers Involved	Project Sponsored by Engineer or Firm
	Design of a 3-story hotel (six sub-teams):			
1	Structures design	4		
2	Geotechnical design	3		
3	Civil site design / pavement design	3		
4	Stormwater design	3		
5	Construction scheduling, planning and cost estimate	4		
6	Environmental impact and friendly design	5		
7	Elementary school traffic study and design	5	✓	
8	Pedestrian trail bridge in remote area over a railroad design	5		✓
9	Hiking trail bridge design	3		✓
10	Stormwater evaluation of existing site and design	4		✓
11	Gas station remediation design	5		✓
12	Commercial building and site design	4		
13	Office building and site design	3		
14	Roadway improvement design	4		✓
15	Interstate bridge design	5		✓
16	Church and site design	5		✓
17	Parking garage design	4		
18	Sports complex design	4		
19	Vertical expansion of landfill design	5	✓	
	Constructed wetlands design (two sub-teams):			
20	Hydraulic design	4		✓
21	Geotechnical design	5		✓
	Bridge design to improve wetlands recharge (two sub-teams):			
22	Structure design	4		✓
23	Environmental impact and design	5		✓
	Bank design (two sub-teams):			
24	Site and stormwater design	2		
25	Structures design and construction	4		
	St. George Island (three sub-teams):			
26	Site design, transportation, boardwalks, and green design	*	✓	✓
27	Stormwater design and environmental impact	*	✓	✓
28	Wastewater treatment plant design	*	✓	✓
	Student Housing Project (four sub-teams):			
29	Structures (building) design	*		✓
30	Structures (garage) design	*		✓
31	Site, transportation, utilities, and stormwater design #1	*		✓
32	Site, transportation, utilities, and stormwater design #2	*		✓
33	Bridge design	*		✓
34	Tennis facility design	*		✓
35	Elementary school traffic study and design	*	✓	✓
36	Big Cypress National Preserve site design	*	✓	✓
37	Cabin design	*		✓

* Project began in Fall 2008. Level of integration with licensed practice will be assessed when project is completed.

This collection of projects demonstrates a high level of commitment by practicing engineers to our students. To conclude this submittal, a featured project, sponsored by the U.S. Army Corps of Engineers, is described. The project was completed and presented by four student teams in December 2008 (see Projects 20-23 in Table 1).

FEATURED SENIOR DESIGN PROJECT: EVERGLADES RESTORATION SPONSORED BY US ARMY CORPS OF ENGINEERS

Background

The Comprehensive Everglades Restoration Plan provides a framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades. It covers 16 counties over an 18,000-square-mile area and centers on an update of the Central & Southern Florida (C&SF) Project. The current C&SF Project includes 1,000 miles of canals, 720 miles of levees, and several hundred water control structures. The C&SF Project provides water supply, flood protection, water management and other benefits to south Florida. For close to 50 years, the C&SF Project has performed its authorized functions well. However, the project has had unintended adverse effects on the unique and diverse environment that constitutes south Florida ecosystems, the Everglades and Florida Bay.

The Water Resources Development Acts in 1992 and 1996 provided the U.S. Army Corps of Engineers (USACOE) with the authority to re-evaluate the performance and impacts of the C&SF Project and to recommend improvements and/or modifications to the project in order to restore the south Florida ecosystem and to provide for other water resource needs. The resulting Comprehensive Plan was designed to capture, store and redistribute fresh water previously lost to tide and to regulate the quality, quantity, timing and distribution of water flows. The Plan was approved in the Water Resources Development Act of 2000. It includes more than 60 elements, will take more than 30 years to construct, and will cost an estimated $7.8 billion.

As part of this overall plan, two projects were selected by the USACOE for the students to design: The Winsberg Farm Wetlands Restoration Project and the Tamiami Trail Modifications Project. For each project, there were two student teams, for a total of four teams.

Project Description

The Winsberg Farm Wetlands Restoration Project was included under Section 601 (c) of the Water Resources Development Act (WRDA) 2000. The Act requires a report to be reviewed and approved by the Secretary of the Army. This project provides for the construction of a 140-acre wetland east of Loxahatchee Wildlife Preserve in Palm Beach County. The feature will reduce the amount of treated water from the Southern Region Water Reclamation Facility wasted in deep injection wells. The facility is divided into two phases, with Phase 1 construction completed by the sponsor. **Two student teams worked on Phase 2 of the Winsberg Farm project: one team focused on the hydraulic design, and the other team focused on the geotechnical design.** See Figures 1 and 2. The teams coordinated often during the process. The overall goal of the project was to design a wetland to reestablish the natural environment and reduce the amount of treated wastewater lost to deep well injection.

The **Winsberg Farms hydraulic team's** goals were to maximize fresh water retention, optimize treatment, create habitat for native species, and create a stable and safe water balance with no stagnation. Their design criteria included the Palm Beach County Municipal Code, Environmental Protection Agency Manual for Constructed Wetlands, and South Florida Water Management District rules. The team's design included the following aspects:

- Developing the wetlands layout
- Design stage
- Mass balance
- Drainage
- Required spillway
- FEMA flood compensation
- Deep well injection design
- Recirculation design
- Service considerations
- Cost estimation
- Design of littoral zones for native plant species and deep zones

The **Winsberg Farms geotechnical team's** design considerations were flood control, erosion control, aesthetics (landscaping and odor control), environmental impact, integration with phase one, accessibility, and future population growth. The project had the following components:

- Earthen levee design
- Seepage calculations using Flownet
- Filter and filter pipe design
- Required earthwork calculations
- Cost estimate

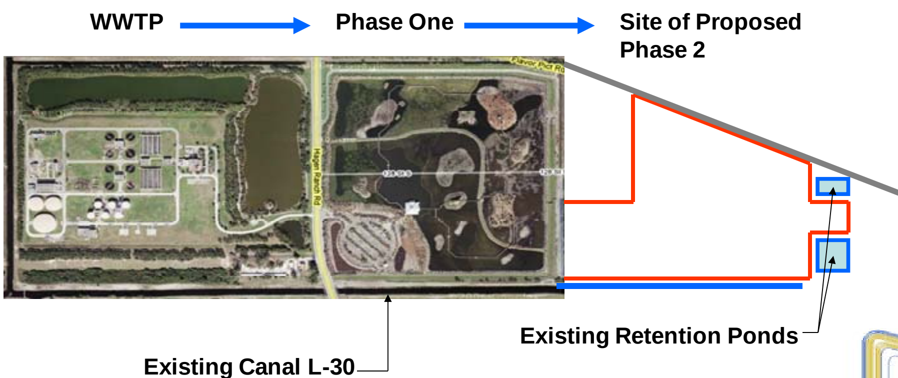

Figure 1 – Winsberg Farms Site

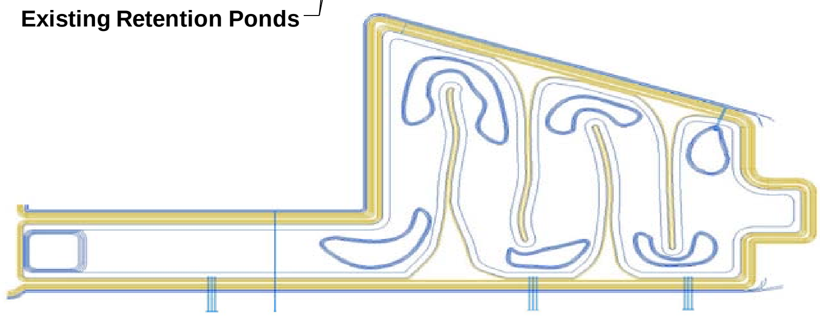

Figure 2 – Winsberg Farms Phase 2 Design

For the **Tamiami Trail Modifications Project**, one team specialized in the environmental engineering aspects, and another team designed a bridge as recommended by the first team. The **Tamiami Trail environmental team's** goal was to create a technical solution for the hydrological and ecological restoration of the Everglades National Park and mitigate for additional flooding impacts. Their scope included writing an environmental impact statement, a stormwater report, and a hydraulic report. They determined that a one-mile bridge would restore water flow. See Figure 3. Their project had the following features:

- Research on past and existing site conditions
- Determination of environmental consequences of their design (such as effects on surface waters, water quality, and protected species)
- Use of ten (10) hydrologic and ecologic performance measures (such as reduction in wildlife mortality and threshold average annual flow volumes)
- Evaluation of six alternatives

The **Tamiami Trail bridge team** designed a two-lane prestressed concrete flat slab bridge, with span lengths of 50 ft. They considered dead loads and truck loads and allowed for a water pipe to remove stormwater. They also designed the substructure and drilled shaft foundations. See Figure 4 for a cross section of the bridge.

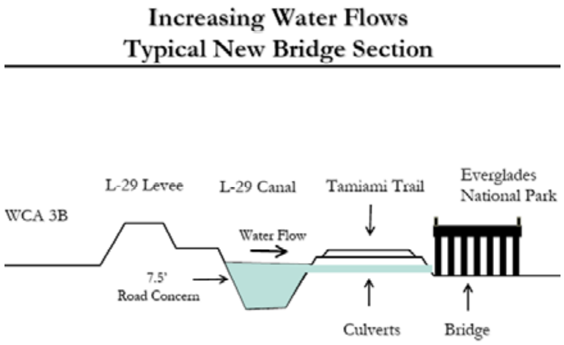

Figure 3 – Tamiami Trail Water Flow

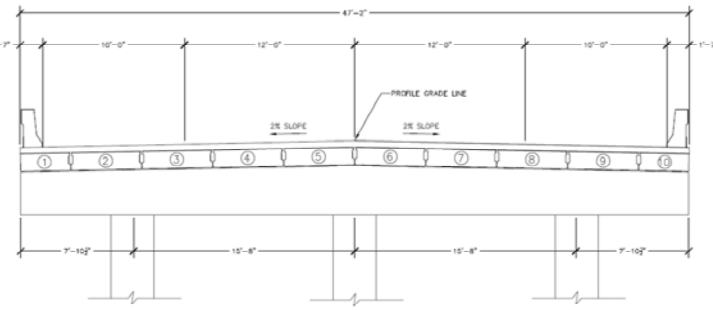

Figure 4 – Tamiami Trail Bridge Cross Section

<u>Meeting of Evaluation Criteria (specifically for Featured Project)</u>

Successful collaboration of faculty, students, and professional practitioners – *In short, the project would not have been as comprehensive or real-world without participation and enthusiasm from students, faculty and professional practitioners. USACOE provided plans and studies so that the students could review real-world engineering submittals and obtain background information for the project. There were about 11 participants in total from the USACOE, including civil engineers, geotechnical engineers, environmental scientists and engineers, a biologist, a lawyer, and an economist. Students visited the USACOE offices, and USACOE engineers visited the university to discuss the project; communications were also made by email. USACOE engineers judged the final presentations.*

Benefit to health, safety, and welfare of the public – *The overall goal of the project is to restore the natural flow to the Everglades, an environmental issue that has been of concern to Floridians for decades.*

Impact on raising social consciousness – *The students realized the complexity of real engineering projects and the need to consider the environmental impact of their designs and public concerns that arise as a result of large or environmentally-sensitive projects.*

Impact of partnering teaching and practice – *This partnering effort enabled the students' design project to be completed more comprehensively and realistically than a typical academic exercise. Because they received feedback throughout the design process, they were confident to present to the panel of judges. They also got a glimpse of the real practice of engineering in the discipline in their area of interest.*

Multidiscipline and allied profession participation – *Professional practitioners were involved from the beginning to the end of the project, by supplying the problem statement, background information, mentorship, and final evaluation/judging.*

Knowledge or skills gained – *The students learned to do research independently, to embrace the need for lifelong learning, to seek help from mentors, to plan all tasks needed to complete a comprehensive project, and to work effectively in teams*

Professional leadership (such as ethics or business conduct) – *All submittals were prepared and delivered in a professional manner, and they were reviewed and critiqued by professional practitioners*

Viability of technology used in the project – C*omputer programs such as PCSTABL for slope stability analysis, HEC-RAS for hydraulic modeling, and LEAP for bridge analysis and design were used.*