Development of Green Engineering and Sustainability Curriculum for the School of Engineering at Christian Brothers University

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Abstract
As a member of the Association for the Advancement of Sustainability in Higher Education (AASHE), Christian Brothers University (CBU) is obliged to support the advancement of its sustainability initiatives throughout the University and in the community. The School of Engineering at Christian Brothers University has five basic engineering majors: Chemical/Biochemical Engineering, Civil and Environmental Engineering, Electrical/Computer Engineering, Mechanical Engineering, and Engineering Management. Under the support of federal government, local government, private industrial organizations, and academic groups, the School of Engineering established a new Sustainability Industry Advisory Board in 2014- 2105. The Sustainability Industry Advisory Board recommended adding a new "Sustainability" concentration to the B.S. in Engineering Management Program (BSEM). A couple undergraduate courses and projects have been developed. This paper is going to present the progress of this development including: (1) exploration of curriculum contents in green or sustainability; (2) expansion of curriculum for B.S. in Engineering Management Program-Sustainability Concentration; and (3) development of a number of sustainability-related research projects for BSEM's senior projects, including applications of agricultural and industry waste materials in treatment, investigating the effect of high temperature to drinking water bottles, and conducting a monitor program for stormwater flood control

Keywords: Sustainability, Curriculum Development, Sustainability Projects

Introduction
The terminology associated with "green" and "sustainability" has created a broad interest in the environmental community. This awareness has brought attention to the Christian Brothers University (CBU). As a Catholic Lasallian institution, CBU is dedicated to environmental stewardship as an integral part of service to the poor and to the promotion of social justice. CBU values and promotes inquiry into, action for, and education about sustainable living in all areas of university life and operation. CBU became a member of the Association for the Advancement of Sustainability in Higher Education (AASHE) to further its efforts on sustainability. With this membership, CBU has been obligated to support advancing its sustainability initiatives throughout the University and in the community.

The Sustainability Committee of CBU is a presidential committee created in 2010 to recommend, support, and advocate strongly for environmentally sound practices at CBU. These

practices are comprehensive, incorporating both the academic and physical components of the university. The Sustainability Committee is thereby responsible for promoting environmental awareness and responsibility to the entire CBU community, both in curriculum design and in the use of campus resources and facilities. Under the counsel of the Presidential Sustainability Committee, a Sustainability Industry Advisory Board in the School of Engineering was formed in 2014. During the annual committee meeting, the Board recommended adding a Bachelor of Science in Engineering Management (Sustainability Concentration) to its engineering program. The Sustainability Industry Advisory Board also provided their knowledge and expertise to assist the curriculum development of the Bachelor of Science in Engineering Management. In addition, it provided projects and research opportunity to students and faculty. This paper is going to present stewardships between the School of Engineering at CBU and the Sustainability Industry Advisory Board including: (1) development of curriculum for the Bachelor of Science in Engineering Management program; (2) reinforcement curriculum of Engineering Management Program- Sustainability Concentration; and (3) implement sustainability projects, such as applications of agricultural and industry waste materials in water treatment, investigating the effect of high temperature to drinking water bottles, and conducting a monitor program for stormwater flood control from the Engineering sustainability group.

Implementation Plan

The Sustainability Industry Advisory Board consists of governmental agencies, non-profit organizations, and industries. Eight members from Barnhart, Bayer, City of Memphis, Dixon Gallery, U.S. Army Corps of Engineers, Walmart, Greater Memphis Greenline, and Water Quality joined the committee. The objectives of this Board are to:

(1) Assist in integration of sustainability practices into educational curriculum
(2) Prepare students working with sustainable issues across various areas
(3) Provide knowledge of sustainability to our students
(4) Provide research opportunities to our faculty

Over the last two years, the Sustainability Industry Advisory Board has accomplished the following tasks to assist the School of Engineering:

1. Development of the Bachelor of Science in Engineering Management Program

At the first Board Meeting, the committee members recommended offering a Sustainability Concentration in B.S. Engineering Management program into our Engineering program. To start the Bachelor of Science in Engineering Management with Sustainability Concentration, several sustainability programs in the United States were selected and examined. The selections were based on the following criteria: (1) program missions; (2) academic course offerings; (3) sustainability and environmental awareness on campus (or campus environment); and (4) student life on campus. The programs include: Arizona State University: (Bachelor-Sustainability)[1], Acadia University: (Bachelor-Environmental and Sustainability Studies)[2]; Florida Institute of Technology: (Bachelor-Sustainability Studies)[3], Lipscomb University: (Bachelor-Sustainability Practice)[4], George Mason University: (Bachelor-Environmental and Sustainability Studies)[5], and Roosevelt University: (Bachelor-Sustainability Studies)[6].

After the objectives and missions of those programs were reviewed, the paradigm of our Bachelor of Science in Engineering Management Program was established. The course paradigm is listed in Table 1. The total credit hours for graduation are 122 credit hours. The program

combines multidisciplinary courses from the School of Engineering, the School of Science, the School of Business, and the School of Arts. The majority of the courses focus on Management and Business areas. This new "Sustainability" concentration was approved and added to B.S. in Engineering Management Program (BSEM) in 2014-2015 Academic Year.

2. Reinforcement of courses on sustainability;

When our Sustainability Industry Advisory Board reviewed the BSEM's sustainability concentration program at the second meeting, it found that several areas of our sustainability program needed to be strengthened. Those areas included:

(1) Introduction to Sustainability
(2) Sustainability principle and design
(3) Sustainability problem solving

Based on the recommendation of the Sustainability Industry Advisory Board, one undergraduate engineering course, sustainability projects, and independent study courses were created and added to the curriculum. The title of the undergraduate course is Sustainable Engineering Design and Application. The syllabus of the course and detailed course information is listed in Table 2. This course can serve as a program option or a program elective in senior year.

3. Provision of a number of sustainability-related research projects as sustainability projects

Three projects provided by the Sustainability Industry Advisory Board were implemented by BSEM students in 2014-2015. The objectives, procedures, and results of these projects are described as below:

(1) Rice Hull Adsorption

In 2012, after a three-year-long dispute, the city of Memphis was fined $645,000 by the U.S. Environmental Protection Agency for polluting the Mississippi River [7]. High concentrations of color with foaming discharged from a local wastewater treatment were identified as the pollutant sources. This project was to investigate a cost-efficient approach for color and foaming removal from wastewater effluent before discharged into the Mississippi River using activated rice hull collected from agricultural waste in the neighboring state of Arkansas.

The rice hull was activated through normal drying at 40^{o}C and thermal activation processes at 200^{o}C and 400^{o}C [8,9]. Rice hull particle size, aqueous contact time, pH, and temperature effects were investigated in the experiment. Five experiments for total phosphorus removal using rice hull were tested. The results are listed in Table 3, indicating that activated rice hull was consistent with total phosphorus removal in the wastewater effluent. Among those granular rice hull in granular activated carbon forms (GAC), 400^{o}C activated rice hull provided the highest removal efficiency; overall 45% of total phosphorus in the wastewater can be removed within six hours period. Table 3 shows that the average percentage removals of GAC-40, GAC-200, and GAC-400 were 26%, 37, and 45%, respectively. Because GAC-400 possesses the highest surface area, the highest percentage of phosphorus removal was expected.

The results of oil concentration as mg/l are shown in Figure 1. Overall GAC-400 in the neutral pH range for six hours can remove approximately 50% of oil/grease in the wastewater

Table1: Paradigm of Engineering Management in Sustainability Concentration

BACHELOR OF SCIENCE IN ENGINEERING MANAGEMENT (SUSTAINABILITY CONCENTRATION)

FRESHMAN YEAR Semester I	**Credits**
ENG 111 English Composition I	3
SPCH 125 Speech Communication	3
MATH 131 Calculus I	3
BIOL 107/L Environmental Biology/Lab	4
POLS 113 World Politics	3
CBU101 Orientation	0
Total	**16**
Semester II	**Credits**
ENG 112 English Comp II	3
PHYS 150/L Physics I	4
ME 121 Solids Modeling (May also take CE 111)	3
SOC 160 Cultural Anthropology	3
MIS 153 Intro to Computer Business Applications (May also take ECE/ME 112, ECE 101 or CS 171)	3
Total	**16**
SOPHOMORE YEAR Semester I	**Credits**
CHEM 115 & 115L Chemistry I and Lab	4
CE 201 Statics *	3
PHIL 324 Technology and Human Values	3
or	
PHIL 325 Environmental Ethics	3
HUM 210 Intro to Sustainability	3
ECON 214 Principles of Microeconomics	3
Total	**16**
Semester II	**Credits**
CE/ME 210 Mechanics of Materials *	3
Religious Studies Elective (200 level)	3
ENG Literature Elective	3
ECON 215 Principles of Macroeconomics	3
PHYS 251/L Physics II	4
Total	**16**
JUNIOR YEAR Semester I	**Credits**
ENG 371 Business Writing	3
PKG 410 Energy & Packaging Sustainability	3
ACCT 260 Financial Accounting	3
STAT 221 Elementary Statistics (May also take MATH 308……..	3
MGMT 337 Principles of Organization & Management	3
Total	**15**
Semester II	**Credits**
CE 317 Intro to Environmental Engineering	3
Program Option**	3
ACCT 270 Managerial Accounting	3
STAT 222 Intermediate Statistics	3
MGMT 352 Organizational Behavior & Management	3
Total	**15**
SENIOR YEAR Semester I	**Credits**
RS 331 The Spirituality and Ethics of Eating	3
CE 417 Environmental Engineering Lab	1
FIN 327 Financial Management I	3
BLAW 301 Business Law I	3
MKTG 311 Principles of Marketing	3
ENGR 431 Sustainability Project I	1
Total	**14**
Semester II	**Credits**
Engineering Elective***	3
BLAW 302 Business Law II	3
MKTG 418 Operations & Supply Chain Management	3
MGMT 498 Business Policy / Strategic Planning	3
ENGR 432 Sustainability Project II	2
Total	**14**
Total credits required for the degree	**122**

Table 2: Syllabus of Sustainable Engineering Design and Application

CE XXX- Sustainable Engineering Design and Application

Type: Required: _____ Elective: X Selected Elective: _____

2016-2017 Catalog Data: The principle of sustainability which are of concern to an engineer include: sustainability design, water quality, air quality, energy balance, sustainability modeling, energy conservation and development, and life cycle analysis. Oral and written communication skills are required. Prerequisites: CE 317. Offered in the Fall or Spring semester. *One semester; three credits*

Textbook: Striebig, Ogundipe, and Papdakis, Engineering Application in Sustainable Design and Development, CEGAGE Learning, 2016

Other Required Materials: None

Other References: None

Instructor: L. Yu Lin, Ph.D., P.E., Professor

Course Outcomes: Major emphasis of this course is placed on the identification and management of storm water. This course also provides juniors in Civil Engineering the concepts of hydrologic cycle, runoff generation, and flooding control design.

Topics:
1. Sustainability Engineering and Design
2. Analyzing Sustainability Using Engineering Science
3. Biogeochemical Cycles
4. Water Quality Impacts
5. Impacts on Air Quality
6. Carbon Cycle and Energy Balances
7. Models for Sustainable Engineering
8. Energy Conservation and Development
9. Sustainability and the Built Environment
10. Challenges and Opportunities for Sustainability in Practice

Contact Hours: Two seventy-five-minute sessions per week

Professional Component:

Category	**Math/Basic Sciences**	**Engineering**	**General Education**	**Other**
		X		

Design	**Significant**	**Some**	**None**
		X	

Realistic Constraints	**Economic**	**Environmental**	**Sustainability**	**Manufacturability**	**Ethical**	**Health & Safety**	**Social**	**Political**
	X	X	X		X		X	**X**

Relationship to Program Outcomes:

a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**K**
X	X	X	X	X	X	X	X	X	X	X

Prepared by: Dr. L. Yu Lin, P.E. **Date:** _____

effluent. As similar to other removal mechanisms, the finer particle can remove more oil/grease from the waste stream. Because of the higher adsorption capacity of rice hull, GAC-400 would provide superior capacity to remove oil and grease in the wastewater effluent. Oil and grease are insoluble substances and sometimes can be found on the top of the wastewater. When the oil droplet goes through the rice hull column, the filtration processes and biological processes on the surface of the activated rice hull would take action to remove the oil and grease from wastewater effluent. The effluent from the column was collected and tested for color study. The results of the test are plotted in Figure 2. Activated rice hull has a high potential to adsorb color from the wastewater effluent as well. Because the wastewater contains medium concentration of color, 50% deduction of color from the wastewater will improve the water appearance in the discharge. From this analysis, it indicates that activated rice hull is an efficient adsorbent for color removal. Three grams of GAC- 400 at neutral (or normal) wastewater range can treat almost one hundred and twenty liters of wastewater.

Table 3: Total Phosphorus Removal in Wastewater Effluent

	Run #1 P (mg/l)	Run #2 P (mg/l)	Run #3 P (mg/l)	Run #4 P (mg/l)	Run #5 P (mg/l)	Average P (mg/l)
Wastewater	6.10	6.42	6.23	6.18	6.55	6.30
GAC-40	4.50	4.62	4.96	4.73	4.37	4.64
GAC-200	4.00	3.99	3.89	4.34	3.79	4.00
GAC-400	3.20	3.67	3.61	3.41	3.35	3.45

(2) Drink Water Bottle Project

Bottled water has been widely consumed due to convenience and cleanliness. In 2008, bottled water sales accounted for about 8.6 billion U.S. gallons, which was about 29% of the U.S. beverage market. Bottle manufacturers have reduced the materials used through thickness reduction and clever structural design of water bottles [10]. During distribution and transport, bottled water is often placed in a high temperature environment. The experiment of **t**wo drinking water bottle sizes; 10 Fl. Oz. and 16.9 Fl. Oz., as shown in Figure 3, were crushed across a range of temperatures, from 32 ^{o}F to 125 ^{o}F. Three sets of bottles were placed in a temperature chamber at 150 ^{o}F, in refrigerator, and in freezer for about three hours. Another set of bottles were kept at room temperature. Bottle compression strength reduced at a rate of about 0.5 and 0.3 pound per 1 ^{o}F increase in temperature for the 10 and 16.9 Fl. Oz., respectively. Bulging was observed at the bottom of the 16.9 Fl. Oz. bottles. The bottle strength was stabilized at about 5 hours under 150 ^{o}F. However, leaks occurred shortly after the temperature was elevated

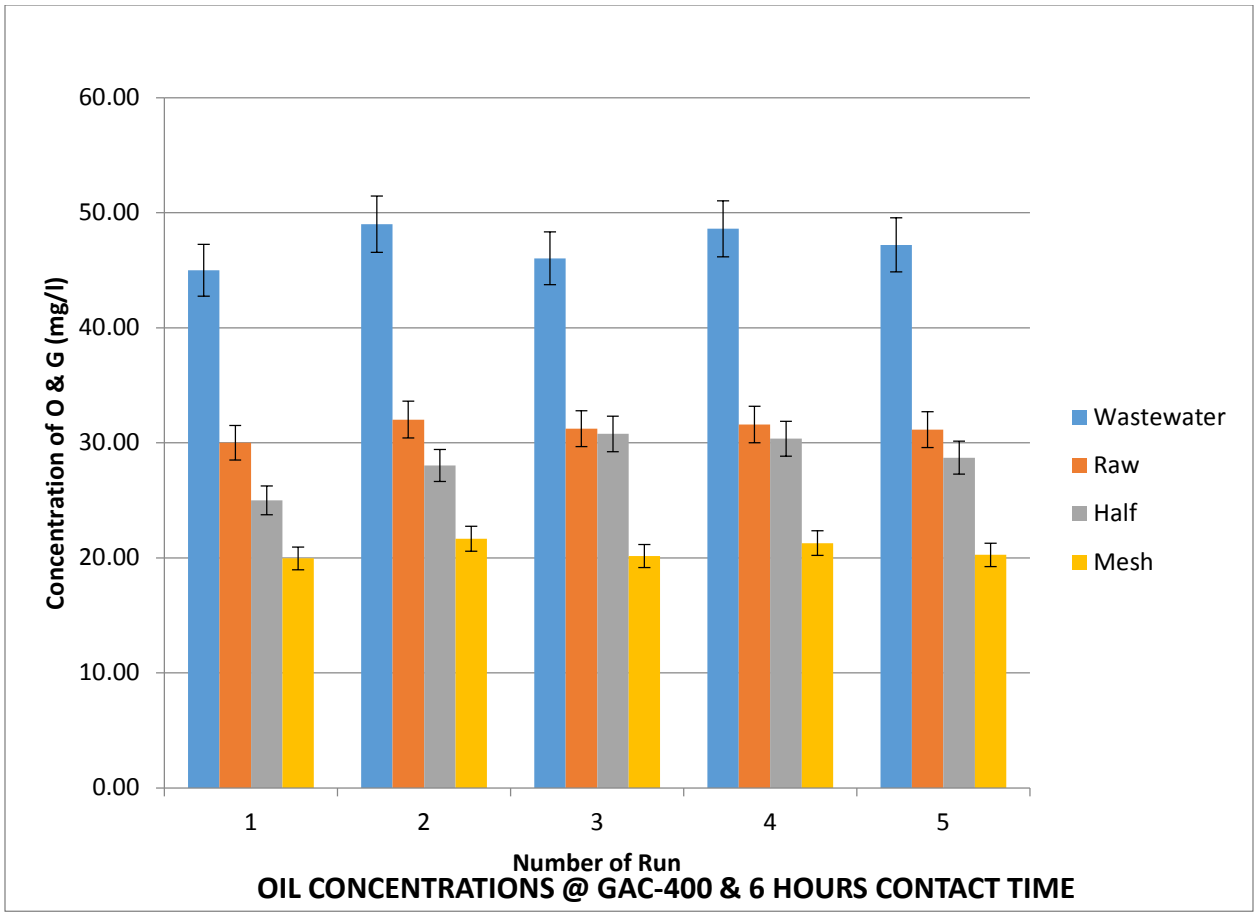

Figure 1: Oil Removal from Activated Rice Hull

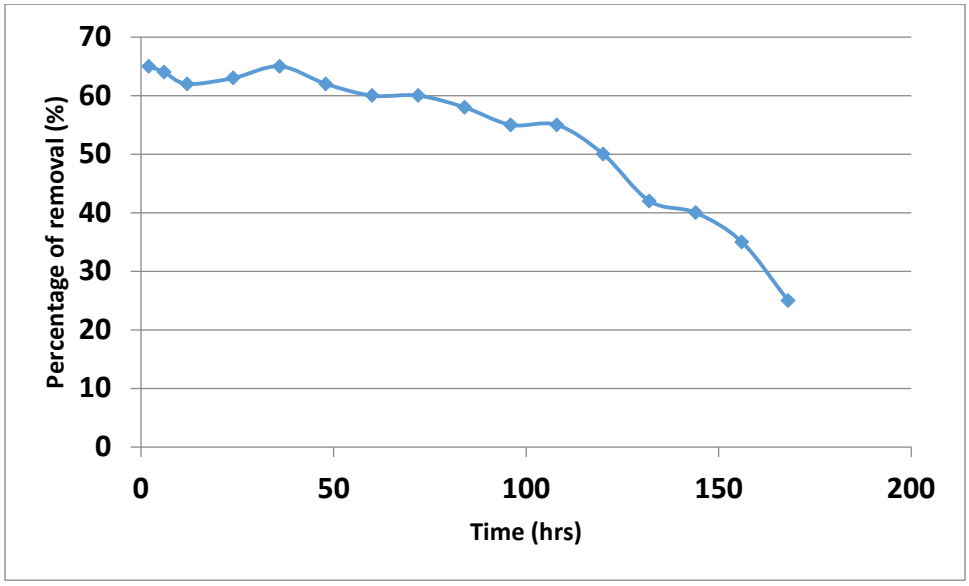

Figure 2: GAC-400 Equilibrium and Breakthrough Curve

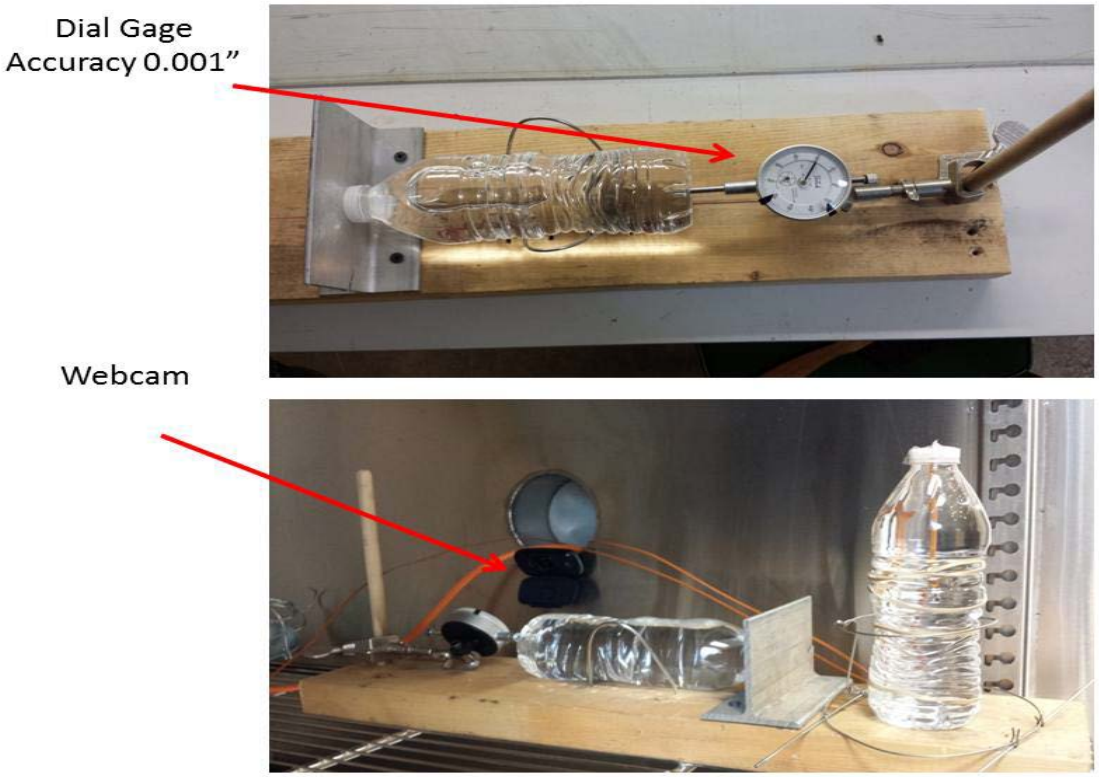

Figure 3: Drinking Water Bottle Experiment

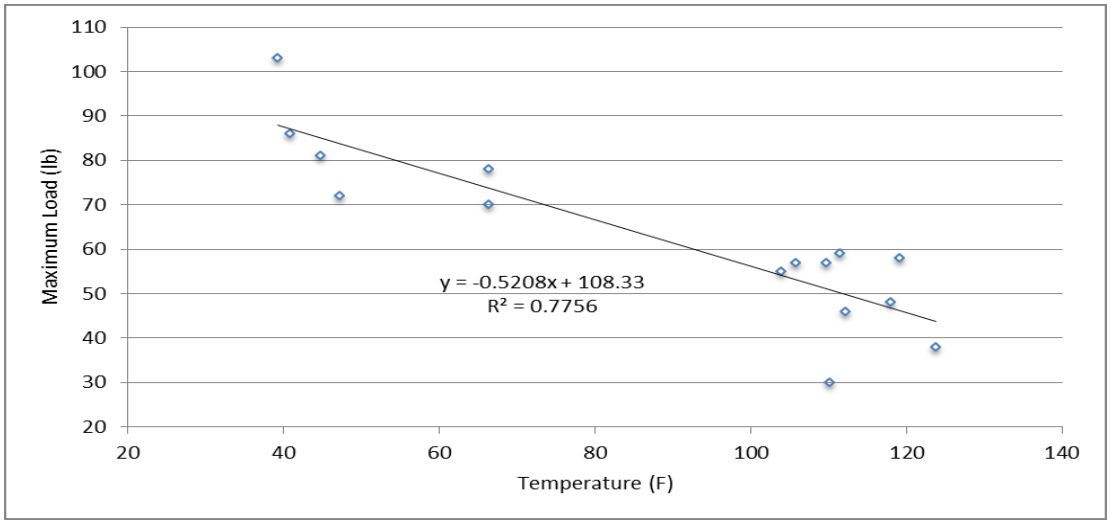

Figure 4: Strength vs Temperature for 10 Fl. Oz. Bottles

to 170 ^{o}F. In Figure 4, the strength per bottle of a 24-bottle pack was found to be about 25% more than that of single bottle strength [11].

(3) Stormwater Monitoring Program

The Lick Creek Watershed is located on the upstream of the Wolf River. The upstream of the watershed has experienced floods for a period of time. In order to relief the flood, the City of Memphis has decided to build a detention pond on the area. Christian Brothers University (CBU) is located at the corner of East Parkway South and Central Avenue in the City of Memphis. Because the surrounding Midtown area frequently experienced flooding, the City requested use of CBU's soccer field as a stormwater drainage basin. The facility will improve flooding conditions in the local area, but also relieve regional flooding in the Lenox Drainage District. The project was approved in October of 2008 and construction began in April of 2009. The designed drainage system (in Figure 5) consists of one 48" RCP pipe, one 72" RCP pipe, one 5' x 4' Box Culvert, 164' long concrete side discharge weir, two 42" RCP pipes, and inlet/out let control. The objectives of the project are to: (1) develop a stormwater monitor system for the detention basins located on CBU's soccer field; (2) monitor stormwater water quantity for twenty selected storms per year; (3) determine stormwater quality for those storms; and (4) analyze data and provide information to the City for future improvement. The project will be incorporated into coursework for the CBU Civil Engineering department, giving our students an opportunity to supplement classroom learning with observation and experience in the field.

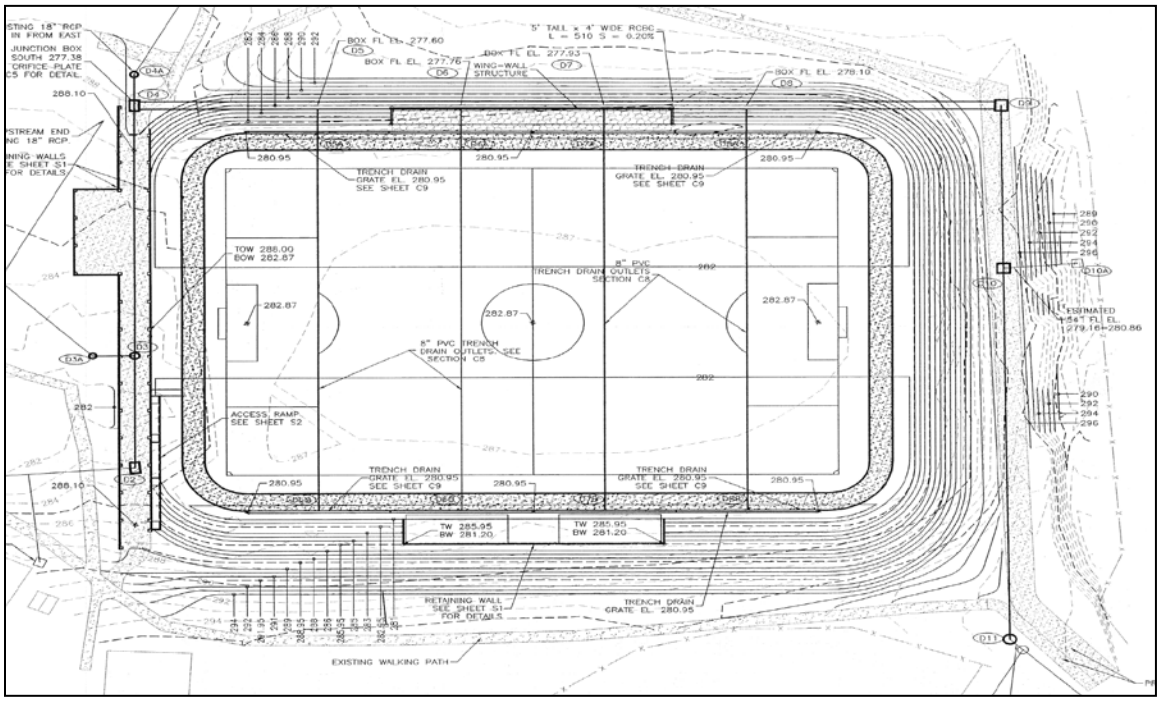

Figure 5: Drainage System on CBU Soccer Field

This stormwater monitor program consists of one RainWise rain gage, one Greyline DFM 5.0 flow meter, and two Sutron Stage-Discharge meters. The results of rainfall and flow meter are listed in Figure 6. Because of insufficient outlet control, the downstream neighbor had experienced minor floods. One of alternative suggested was to reduce the drainage pipe from 42 inches to 24 inches. It will allow less runoff to discharge to the downstream side and to increase runoff staying in the CBU soccer field. Because the outlet pipe was reduced to 24 inches, more back water will push flow into the CBU soccer field. The discharge through the open weir along the 5ft x 4ft box culvert would also increase. The original Stage Discharge Recorder was only installed at a 5 feet above the crown of the weir. In order to protect the Stage-Discharge Recorder, the Sutron Stage Discharge Recorder was raised by 2 feet.

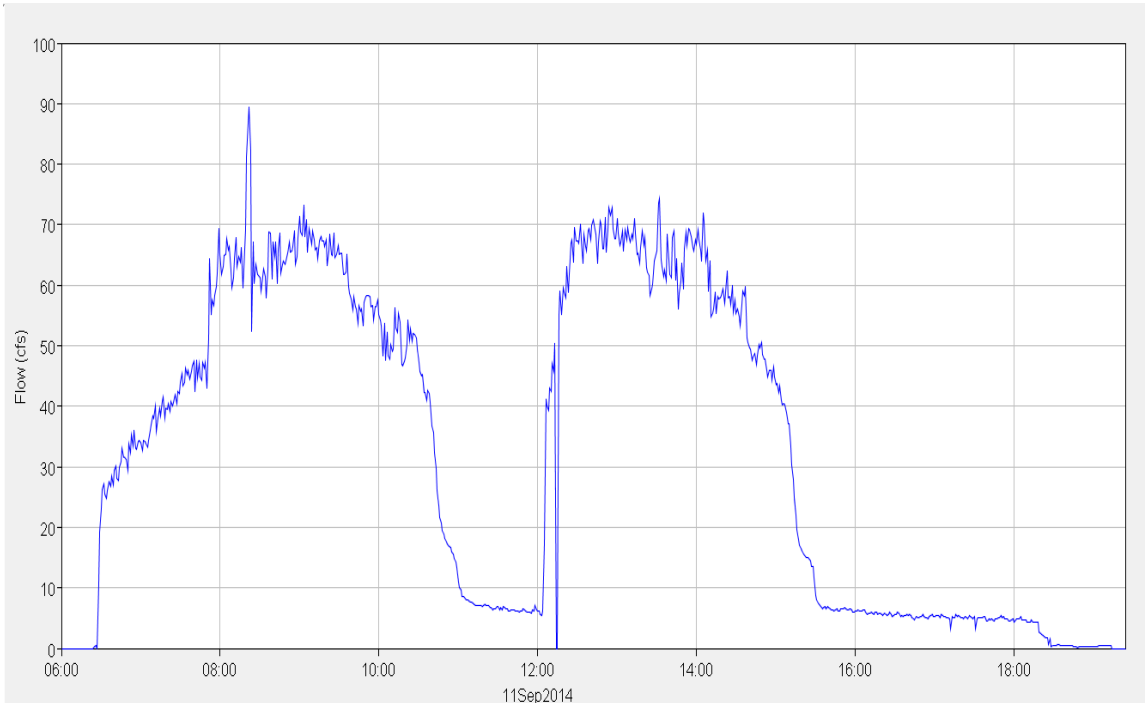

Figure 6: Flow Hydrograph on 9/10/2014

Conclusions

Christian Brothers University continues improving its sustainability program in order to meet our students' needs and to support the community. Under the assistance of our Sustainability Industry Advisory Board, a Bachelor of Science in Engineering Management with Sustainability Concentration was created after the first Board meeting in 2014. The program provides the additional option to our engineering students who are interested in environmental awareness and sustainability. In the second year, the Board continued providing their expertise to strengthen our sustainability components. A new engineering course: Sustainable Engineering Design and Application was added into the curriculum. Our students and faculty had the opportunity to work on real-world projects through our collaboration programs between the

University and our Board members. As a result, engineering students have increased awareness on sustainability value to their communities and the world.

Students have volunteered to organize events during America Recycles Day and Earth Week. They campaign for energy saving, recycling, global warming, environmental justice, flooding control, and promoting sustainability practices on campus through their experience from the course and projects. In the Fall of 2015, there are nine students officially enrolled in the BSEM program. Christian Brothers University will carry on the obligation and commitment to sustainability in the future that will have more positive impact to our campus.

Acknowledgements

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Biographical Information

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