Session 3253

A First Year Introductory Engineering Course with a Design Component

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Abstract

This paper describes a first year introduction to engineering course and the various components that are combined to fulfill the objectives of the course. The introductory course has been a required course for the past four years for all entering first year engineers and has undergone an evolution in order to meet the needs of both the students and the engineering division. The course has the primary objectives of providing a meaningful design experience to the students and to provide each student with an understanding of the various fields within the engineering profession. In order to accomplish this, a design project was selected that incorporates each of the four engineering disciplines (Chemical, Civil, Electrical and Mechanical) offered at Lafayette College. The project was to design and construct a water monitoring device that can be submerged in a river and collect data for extended periods of time. The course is broken into four blocks each taught by a faculty member from each of the four engineering departments. A total of 162 students were divided into eight sections. Students rotate through each of the blocks developing a portion of their design project within a design team of about five students. Each block has three components which are lectures, laboratories and computer aided design (CAD). The components are used to develop the capabilities of the students in a particular field of engineering through classroom lecture and laboratory work then to apply the newly developed capabilities to the design project. The final product of each block is a completed portion of the project through both the design and constructed phase. The final week of the semester is dedicated to the assembly, calibration and testing of the design project. Students make final oral presentations and submit a final written report on their project including both shop and final assembly drawings prepared during the semester on CAD.

Course evaluations conducted in part to address ABET 2000 Criteria(1), indicate that the objectives of the course have been met and students are in addition developing a sense of the engineering diversity within design projects.

Introduction

Experience obtained through advising sessions with students, has shown that most entering first year engineering students do not have an understanding of the various fields of engineering nor the engineering design process. In order to provide exposure to each of these topics a required course was adopted for all engineering majors at Lafayette College in the Fall, 1995 semester. The initial offerings of this course provided a design theme from which student design teams selected a design project. Through the course of the semester students attended lectures, laboratories, CAD classes and met as design teams to work on their project. Lectures focused on introductory topics in the fields of Civil, Chemical, Electrical and Mechanical Engineering. The laboratories were used to reinforce the material covered in the lectures by providing an active learning environment where students could participate in hands-on activities related to the lecture component. CAD classes taught the fundamentals of computer aided drafting and resulted in complete shop drawings used by the students in conjunction with their design project. Student design teams met each week with a faculty member and a technician to review the design and construction progress.

After three years a comprehensive review was conducted in order to assess the effectiveness of the course. The assessment indicated that while the course objectives were being met a significant strain was being placed on both faculty and technician staff in the design and construction of up to 32 different projects. In addition, links between each of the discipline specific lectures and laboratories and the design projects were not always apparent.

This paper will describe the various components of the course that resulted from the changes implemented in order to address specific issues identified in the three year assessment. Methods used in the course to assess both ABET 2000 Criterion 3 [(1)] and the goals and objectives of the course will also be presented to document the results of the implemented changes.

Description of the Course

The 14 week semester is divided into a one week introduction, four blocks (each three weeks in length) and a final wrap-up week. The four blocks address each of the four engineering disciplines available at Lafayette College (Civil, Chemical, Electrical and Mechanical). Within each block five lectures and two laboratories are scheduled in order to address discipline specific topics related to the design project. Additionally within each block two CAD classes are scheduled. The entering class was divided into four groups that rotated through each block. Upon the completion of a block each design team within the group had produced a component of the final project. The physical components were assembled and calibrated in the final week of the semester. Student design teams then provided both written and oral final reports. The oral reports were evaluated by local professional engineers.

In order to have greater control on the scope of the design project a single project was selected. This provides the opportunity to coordinate the lectures, laboratories and CAD assignments with the design and construction of the project. The selected project, a water quality monitoring device, incorporated each of the previously mentioned engineering disciplines. The following provides descriptions of each of the blocks and the components that were produced for use in the final design.

Civil Engineering Component

The Civil Engineering component provided students with an introduction into computer modeling using hydrologic models. The results obtained from these models included the depth and velocity of flow expected at the proposed site where the water quality monitoring device is to be placed. These parameters provided constraints in the design process including pressure range for pressure transducer selection, pressure transducer calibration upper limit and hydrodynamic design forces expected on the device. The modeling process consisted of two computer models TR-55 and HEC RAS.

The TR-55 computer model estimates the storm water runoff of a watershed for storms a given return period. Class lectures for this portion introduced the students to the hydrologic cycle, the continuity equation and the development of a mathematical model from a physical process. Students were provided with topographic maps, land use plans and soil contours of the watershed area. Digitizing the relevant information into CAD provided a translation of the various scales of the information given into a common scale for determination of land area required as input for the program. Students were also provided with historical information related to rainfall in the region and the statistical methods to determine return periods and the associated rainfall intensities. The concept of risk in the design process was then related to the probability that the design rainfall would be exceeded during the life of the monitoring device. The result of this component was a tabular hydrograph shown in Figure 1. The results of the TR-55 computer program were obtained in the first laboratory class of this block.

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Figure 1: Hydrograph resulting from the 100 year storm for study watershed.

The peak flow rate obtained from the tabular hydrograph was then used as input for the second program HEC RAS [2]. This program simulates the water surface profile of a stream, predicting water depths and velocities at prescribed cross sections. Students were introduced to the fundamental equations used in the computer models and the methods used to implement the equations with the data available. Information collected from the field with surveying instruments was provided to the students in order to develop input values for the program. Typical results obtained from the second laboratory of this block are shown in Figure 2 and Table1. The resulting depth of flow and flow velocity information obtained from this computer simulation were used as constraints in the design project.

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Figure 2: Stream cross section at point of monitoring device placement.

Plan: Plan 01 Reach: gopher Riv Sta: 2 Profile: 1 10/6/98						
W.S. Elev (ft)	310.23		Element	Left OB	Channel	Right OB
Vel Head (ft)	0.13		Wt. n-Val.	0.06	0.03	0.03
E.G. Elev (ft)	310.35		Reach Len. (ft)	63	61	55
E.G. Slope (ft/ft)	0.000321		Flow Area (sq ft)	10.63	667.64	95.34
Q Total (cfs)	2100		Flow (cfs)	6.44	1967.38	126.18
Top Width (ft)	166.17		Top Width (ft)	3.98	110	52.19
Vel Total (ft/s)	2.71		Avg. Vel. (ft/s)	0.61	2.95	1.32
Max Chl Dpth (ft)	6.33		Hydr. Depth (ft)	2.67	6.07	1.83
Crit W.S. (ft)			Wetted Per. (ft)	6.66	110.32	52.34
Conv. Total (cfs)	117223.3		Conv. (cfs)	359.5	109820.3	7043.4

Table 1: Tabular output from HEC RAS computer model for cross section at point of monitoring device placement.

Chemical Engineering Component

The Chemical Engineering component focused on the materials used in the construction of the design project. The properties of various materials were introduced and the variation of these properties when subjected to temperature change was demonstrated. Material testing was conducted on the three types of materials selected for use in the design project PVC, steel and aluminum. Material properties of tensile strength, impact strength, hardness and resistance to heat deformation were tested using standard testing procedures. Variations in the processes used in the manufacture of each of the materials was presented during the lecture component and the resulting variations in the material properties were investigated in the laboratory sections. An example of this was in the Rockwell hardness test where 1020, 1040 and 1090 annealed steel were tested. In addition the 1020 steel was tested both before and after quenching to determine the effects of various processes on the material properties. Table 2 shows the results from one design team's Rockwell hardness testing.

Material	Condition	Hardness (HRB)
1018	Annealed	72.7
1040	Annealed	86.3
1040	Normalized	94.1
1040	Quenched	119.4
1090	Annealed	96.5

Table 2: Results from the Rockwell hardness testing for various grades of steel.

Upon completion of the Chemical Engineering component the design teams had an understanding of the various materials used in the construction of the device and the advantages and disadvantages that were associated with each.

Electrical Engineering Component

The Electrical Engineering component of the design project consisted of the development of the data acquisition circuitry used in the device. The parameters of water temperature and pressure were selected as the values to be measured by the device. The pressure value is directly proportional to the water depth at the point in the stream where the measurement is taken. During the lecture portion of this block students were introduced to fundamental laws of circuits including Ohm's Law and Kirchhoff's Laws. These were applied to the circuits used in this project to monitor pressure and temperature.

The first laboratory introduced students to electronic measurement using a digital multi-meter to measure the variation in the resistance of a number of resistors marked as the same resistive value. The variation in the resistance was verified to be within the tolerances shown on the resistor. The resistors were then placed in a simple voltage divider circuit and the meter was used to determine the voltage drop across the resistor. Measurements of voltage, current and resistance in this exercise provided verification of Ohm's Law and Kirchhoff's Laws. Students were then instructed in the proper soldering procedures and soldered components onto a board.

Following lectures focused on the use of transducers to convert physical quantities into electrical quantities and the signal conditioning used to monitor the outputs of the transducers. Students were provided a MPX2050GP pressure transducer and a AD590 temperature transducer as the monitoring components of the water monitoring device. These transducers were selected because the pressure transducer is voltage based while the temperature transducer is current based resulting in different types of signal conditioning circuits to produce the required variation in output voltage used to monitor the two physical quantities. Figure 3 shows the circuit diagram of the monitoring device drawn in the CAD component of the course by students. Assembly and bench testing of this device was accomplished in the second laboratory of this block. The final circuit was imbedded inside a PVC tube with adequate channels for the transducers to sample the appropriate quantities.

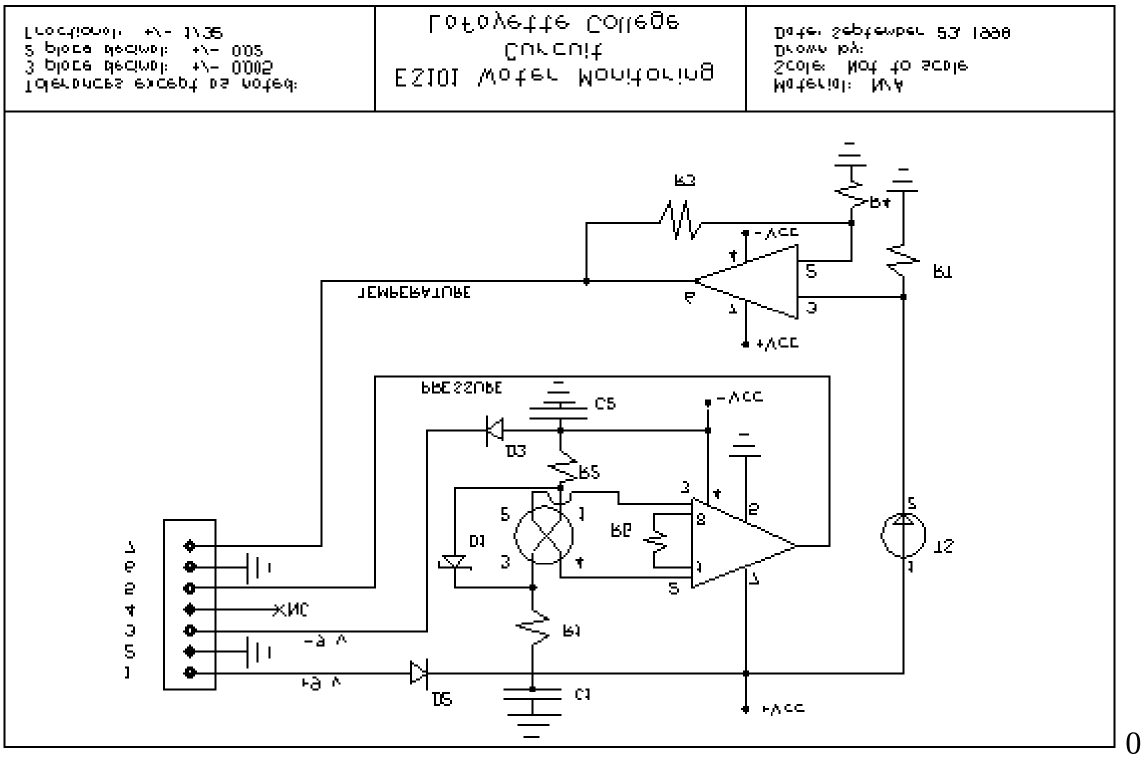
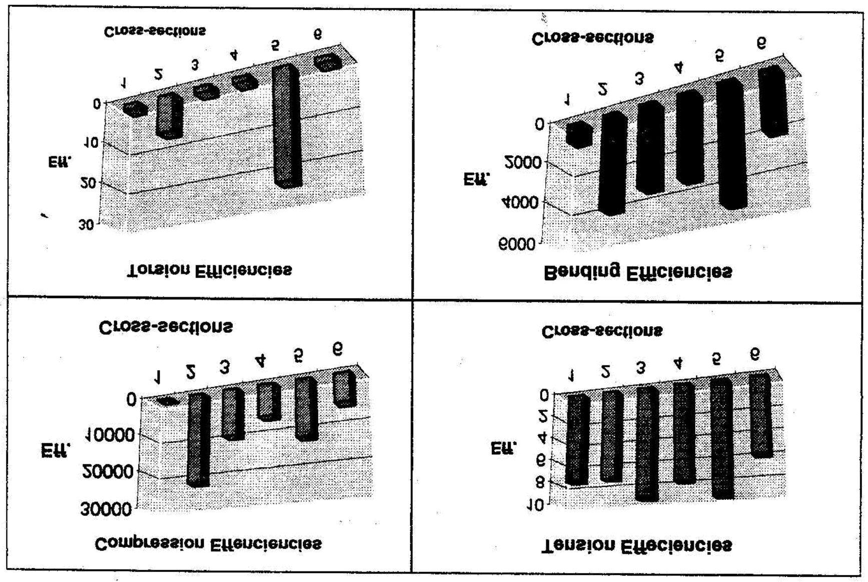


Figure 3: Circuit diagram of data acquisition system used in design project.

Mechanical Engineering Component

The Mechanical Engineering component of the course required the students to construct a structure, at least 8 inches in height, to hold the monitoring device. A base platform made from a steel plate and an L shaped steel cradle for the PVC tube holding the instrumentation were to be connected using various shapes of aluminum material supplied. Students were given aluminum tubing and a sheet of aluminum plate that could be cut and bent to form various shapes such as angle or channel. Initial lectures and the first laboratory focused on the effects that the shape of a cross section have on the maximum forces and moments that a member can withstand. The first laboratory tested six cross sectional shapes to find effective efficiencies related to compression, tension, torsion and bending.   Sample results for each test are shown in the graphs in

Figure 4.



Cross Section Number	Cross Section Shape
1	Solid Rectangular
2	Round Hollow
3	Channel
4	T-Beam
5	Square Hollow
6	Angle

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Figure 4: Examples of results obtained from laboratory testing of various cross sectional shapes.

The lectures following the first laboratory focused on determining the forces on the members of a structure when subjected to various loading conditions. Students developed an understanding of the interactions of both compressive and tensile forces within a structure. Using this and the results obtained from the previous laboratory the design teams designed a structure to support the instrumentation system. During the second laboratory of this block each design team built and tested the support structure. The final assembly was subjected to a 100 pound thrust load and a 40 foot-pound torsional loading. Failures of the structures at these loading conditions required re-design and re-construction of the structure. An example CAD drawing of one of the student designed structures is shown in Figure 5.

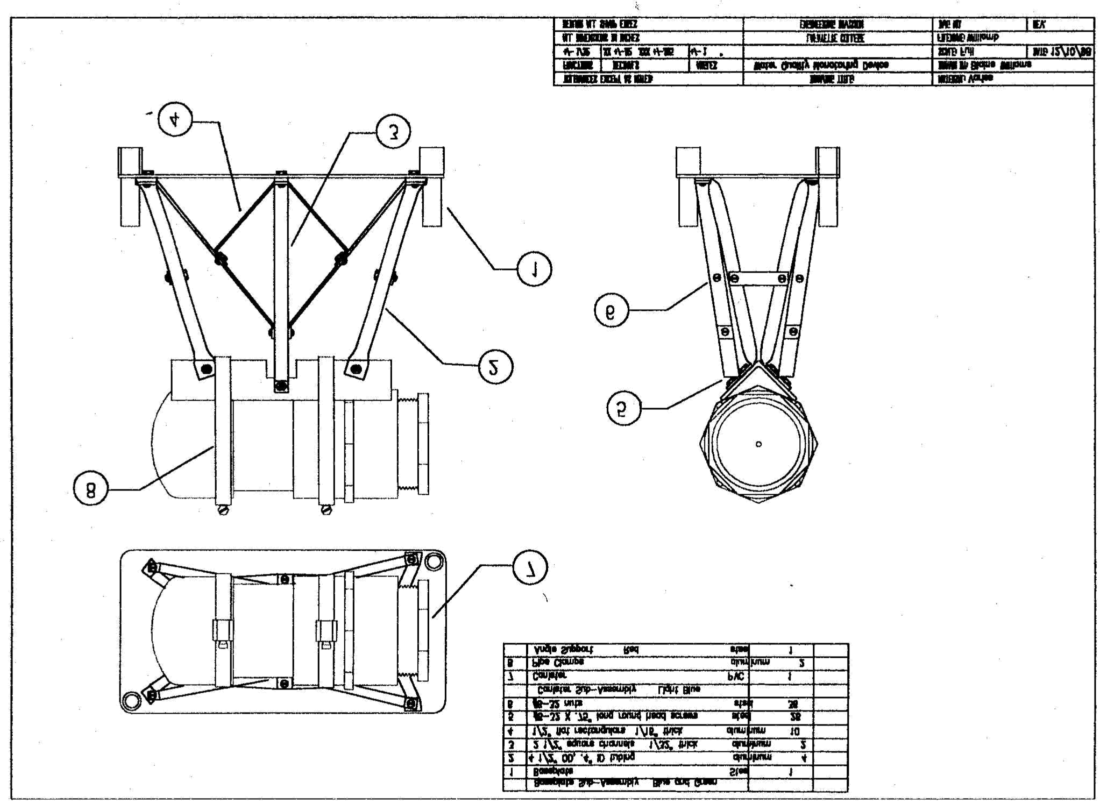

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Figure 5: Example drawing of design project.

The CAD Component

Unlike the discipline specific three week blocks of the course the CAD component was distributed over the entire semester. Students started with basic drawing fundamentals and quickly moved to more complex aspects of the AutoCAD software. Examples of student CAD drawings are provided as Figures 3 and 5 in this paper. Direct links were maintained between the CAD classes and the design projects. Since various components of the project were selected in advance of the course, drawing blocks were created and saved in a library to be used by students when they had reached a point in the course where they incorporated that particular component into their drawing. Drawings were also used to communicate ideas and proposed plans among members of the design team and to faculty and technicians.

Other Components of the Course

The Introduction to Engineering course also stressed other important topics common to all engineering fields. These topics included technical report writing, oral presentations, working as interdisciplinary design teams and communication using electronic media including the world wide web and e-mail. Introductory classes in the first week of the course introduced the students to the e-mail facility on campus and the means to access the world wide web. Each of these electronic media were used throughout the course by students and faculty to communicate and to research information sources available. Special lectures were scheduled during the semester to instruct students in methods of technical report writing and oral presentations.

The final week of the semester was dedicated to review in preparation for the final exam and in the assembly and calibration of the water monitoring device. Each team completed the assembly of the device and calibrated both the temperature and pressure transducers in the laboratory.

Course Assessment

Assessment of the course was conducted to provide feedback from the students in order to continue to improve the course and to document student progress in meeting ABET 2000 Criteria. Three mechanisms (a survey, student interviews and external reviewers) were used to obtain the desired information.

A survey form shown as Figure 6 was distributed to all the students prior to the final examination. Seven issues are addressed on the form with the first six having checked responses that provide a measure of the student's improvement during the semester on each issue. All areas surveyed showed an average improvement of approximately one rating category. Issues 2 and 3 provided the largest average improvement of approximately 1.5 rating categories indicating that the objective of introducing the

FIRST-YEAR ENGINEERING STUDENT SURVEY

(Indicate your response by placing an "X" in one block in each row of the tables below.)

Issue 1. Please compare your ability to function as a team member in the solution of a meaningful open-ended design problem at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 2. Please compare your level of understanding of the nature of engineering at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 3. Please compare your level of understanding of the nature of the various engineering disciplines represented at Lafayette (A. B. in Engineering and B. S. in Chemical, Civil, Electrical and Computer, and Mechanical) at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 4. Please compare your level of understanding of the role and importance of math and science in engineering at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 5. Please compare your level of comfort and experience with technical writing skills at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 6. Please compare your level of comfort and experience with oral presentation skills at the beginning of this semester and today.

Time	Poor	Below Average	Average	Above Average	Excellent
Beginning of Semester					
Today					

Issue 7. What else should the faculty know about your experience this semester? Is there something else that you have learned that you believe is important? Is there something that you think you should have learned but didn't? How can we improve the student experience during this semester in the future?

Figure 6: Survey form used to assess Introduction to Engineering.

students to the various disciplines within engineering was being met. Students also indicated through their responses to issue number one that they had improved their ability to function as a team member in an engineering design project the second goal of the course. This form also addressed specific outcomes within ABET 2000 Criterion 3 as shown in Table 3.

ABET Criterion 3	Survey Issue
a) an ability to apply knowledge of mathematics, science and engineering	4

d) an ability to function on a multi-disciplinary teams	1
g) an ability to communicate effectively	5 & 6

Table 3: ABET Criterion 3 categories addressed in student survey.

Students were interviewed by Engineering Council consisting of the Director of Engineering and Department Heads of each engineering disciplines. Eight students were picked at random and met with for approximately one hour with Engineering Council. This meeting proved very useful in developing ideas for the improvement of the course. Suggestions included taking the finished product into the field for testing, scheduling conflicts and concerns about a cumulative final. Discussion related to ABET 2000 Criterion 3, including items d and g, were also discussed and documented in minutes from this meeting.

Oral presentations made by the student design teams at the end of the semester provided an opportunity to evaluate various aspects of the course and the level to which the students had progressed. Professional engineers from the local area were asked to evaluate the presentations. Presentations were 15 minutes in length and addressed how each of the components of the course was used in the design, construction and calibration of the semester project. Presentations were rated by the external evaluator and a faculty member in nine separate categories. These categories were designed to provide an assessment of the following ABET 2000 Criterion 3 items.

an ability to apply knowledge of mathematics, science and engineering
an ability to design and conduct experiments, as well as to analyze and interpret data
an ability to design a system, component or process to meet desired needs
an ability to function on multi-disciplinary teams
an ability to identify, formulate and solve engineering problems
g) an ability to communicate effectively
an ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

The average response for all evaluators in all 9 categories for all of the student presentations was a 3.09 (3.00 = Above Average; 4.00 = Excellent).

Conclusion

The Introduction to Engineering course offered in the Fall, 1998 semester adopted significant changes to previous offerings in order to provide coordination between lectures, laboratories, CAD class and the semester design project than found in previous offerings of the course. This was primarily accomplished by selecting one design project and building a prototype prior to the beginning of the semester. Course material related to the design project could then be incorporated into each of the three week blocks taught by faculty from each of the engineering disciplines. The necessary skills required to produce CAD drawings required in the course could also be defined and scheduled into classes. In addition common components of the project that were made or purchased for the students could be drawn and saved into a drawing library for student use at the appropriate time during the semester. The single project also decreased dramatically the time required by both faculty and technicians in the design and construction of what in previous years was 32 different projects.

Assessment indicated that the objectives of the course were met and that students had demonstrated various skills required by the ABET 2000 Criterion 3. External evaluators of the student presentations were very impressed and provided an overall average rating of 3.09 on a scale of 0 - 4.00. Assessment also indicated that some improvements could be made in the course. The identified areas of improvement are expected to be addressed in the next offering of the course.

References

URL http://www.abet.org/eac/eac2000.htm; ABET Engineering Criteria 2000, 17 pages.

URL http://www.waterengr.com/hec.htm, The Hydrologic Engineering Center's River Analysis System, Version 2.1, 2 pages.