# Graduate Student Handbook:
## Policies, Procedures, and Recommendations

**The University of Tennessee**
**Biosystems Engineering & Soil Science Department**

## Version 3.2

Revised April 2008

by

The Faculty of the Biosystems Engineering & Soil Science Department

The University of Tennessee
Biosystems Engineering & Soil Science Department
2506 E. J. Chapman Drive
Knoxville, TN 37996-4531

VOICE: 865.974.7266
FAX: 865.974.4514
http://bioengr.ag.utk.edu/

This Handbook is applicable to all graduate degree programs offered by the Biosystems Engineering & Soil Science Department, as follow:

- Biosystems Engineering – MS, PhD
- Biosystems Engineering Technology – MS
- Environmental and Soil Sciences - MS
- Plants, Soils, and Insects (Environmental and Soil Sciences Concentration) – PhD

# CONTACTS

Students are referred to the UT website (http://www.utk.edu/) for the most up-to-date listings of phone numbers and e-mail addresses.

**The University of Tennessee**
Knoxville, TN 37996-0220
Office Hours: 8:00 a.m. - 5:00 p.m.
Monday – Friday
General Information: 865.974.1000
Voice/TTD
URL: http://www.utk.edu/

**Disability Student Services**
Counseling Service
2227 Dunford Hall
865.974.6087; fax 865.974.9552

**Graduate and International Admissions**
Director
218 Student Services Building
865.974.3251; fax: 865.974.6541

**Center for International Education**
Director
1620 Melrose Avenue
865.974.3177; fax 865.974.2985

**Registrar**
209 Student Services Building
865.974.2101

**Veteran's Benefits**
209 Student Services Building
865.974.1507

**Transcripts**
209 Student Services Building
865.974.2101

**Veteran's Pre-College Upward Bound**
1914 Andy Holt
865.974.4466

**Financial Assistance**

*Assistantships:* Head of applicable department or program, see also http://gradschool.utk.edu/gradfund.shtml
*Fellowships and Scholarships:* Office of Graduate & International Admissions
*Loans, Work-Study:* Office of Financial Aid & Scholarships
115 Student Services Building
http://web.utk.edu/~finaid/ email: finaid@utk.edu
phone: 865.974.3131 fax: 865.974.2175

**Housing**

*Department of University Housing:*
405 Student Services Building
phone: 865.974-2571 fax: 865.974.1420
http://uthousing.utk.edu email: housing@utk.edu

# TABLE OF CONTENTS

# INTRODUCTION

Training graduate students is one of the most critical missions of the Biosystems Engineering & Soil Science Department. Graduate studies in the department are characterized by challenging coursework, independent research, the development of strong writing skills, and excellence at understanding and applying the scientific method. Successful completion of a graduate degree program also requires that students comply with a variety of formal requirements set forth by The University, The Graduate School, and the Department. The purpose of this handbook is to provide current and prospective students with information specific to all graduate degree programs offered by the Department.

## *Graduate Student Responsibilities*

Each graduate student must assume full responsibility for knowledge of rules and regulations of The Graduate School and of departmental requirements for their chosen degree program. All Biosystems Engineering & Soil Science Department graduate programs have requirements beyond the minimum established by The Graduate School.

The Graduate School maintains a website (http://gradschool.utk.edu/default.shtml) with pertinent information, electronic copies of the *Graduate Catalog*, *Grad Sources* (a guide to funding for graduate students), and up-to-date listing of deadlines, policies and procedures, and degree programs. The Graduate School website displays the latest information on Graduate School matters, some of which may supersede this handbook. Students are urged to keep abreast of current rules and regulations by visiting The Graduate School website at least once a semester.

A statement on graduate students' responsibilities is printed on the back of the student's admission status form. The statement is also available in the Graduate Catalog and in the Hilltopics Student Handbook (http://web.utk.edu/~homepage/hilltopics/).

## *Statement of Philosophy*

The faculty of the Biosystems Engineering & Soil Science Department offer advanced education and training exceeding that of the four-year baccalaureate of science or engineering degrees to promote the advancement of the fields of Biosystems Engineering, Environment and Soil Science, and associated applied technology. These programs are open to qualified individuals seeking advanced training in science and engineering related to biological resource production, soil science, and/or environmental protection.

## *Degrees Offered*

Master of Science in Biosystems Engineering (MS BsE)[1]
Master of Science in Biosystems Engineering Technology (MS BsET)[1]
Master of Science in Environmental and Soil Sciences (MS ESS)[1]
Doctor of Philosophy in Biosystems Engineering (PhD BsE)
Doctor of Philosophy in Plants, Soils, & Insects – Environmental and Soil Sciences Concentration (PhD PSI-Soils)

1 Thesis and Non-thesis option. Non-thesis only available for students not receiving research assistantships

## *Admission Requirements*

### Baseline Academic Requirements

Admission to Biosystems Engineering & Soil Science departmental graduate degree programs is contingent upon the following requirements, which differ between degree programs:

*All Degree Programs*

Documented capacity to successfully pursue advanced study – e.g., through letters of recommendation describing specific undergraduate accomplishments or professional experience.

Official documentation[2] of a grade-point average (GPA) from previous studies that meets the requirements of The Graduate School. International applicants on a non-immigrant visa cannot be admitted if their baccalaureate GPA is less than 3.0/4.0.

Official documentation[2] of Graduate Record Exam (GRE) scores.

*Biosystems Engineering Degrees*

Documentation that the applicant possesses a four-year baccalaureate degree in engineering or documentation that the applicant possesses a four-year baccalaureate degree in one of the physical, biological, or applied sciences along with coursework in the following major subject areas covered by the Fundamentals of Engineering (FE) exam[3]: Chemistry, Computers, Statics, Dynamics, Electrical Circuits, Engineering Economics, Fluid Mechanics, Mathematics (through differential equations), Mechanics of Materials, and Thermodynamics.

*Biosystems Engineering Technology Degree*

Documentation that the applicant possesses a four-year baccalaureate degree in one of the physical, biological, or applied sciences or technologies.

*Environmental and Soil Sciences Degree*

Undergraduate degree in soil science (including environmental soil science) or a "hard" science (including chemistry, geology, physics, or biology).

One semester of coursework in each of the following: organic chemistry, physics, plant physiology or microbiology, and statistics. Fifteen (15) semester credits in soil science courses (can take 1st year).

The departmental graduate committee, which is responsible for recommending student admission, will examine the complete application package, including GRE scores and GPA, when evaluating applications.

### Language Requirement

Applicants who received their prior degrees from institutions in non-English speaking countries, and whose native language is not English, must score 550 or higher on the Test of English as a Foreign Language (TOEFL) before admission will be considered; a computerized TOEFL score of 213 or higher is required; or an iBT score of 80 or higher. The TOEFL score must be less than two years old.

2 - Self-reported GPA or GRE scores are unacceptable, as are copies of transcripts or GRE scores sent to the student and forwarded to the department. Scores musts be sent directly from the institution to Admissions.

3 - Note however that professional engineering (P.E.) licensure in some states requires that the applicant have earned an undergraduate engineering degree from an ABET-accredited institution. Students intending to pursue the P.E. are urged to check with the appropriate state board of engineering regarding specific licensure requirements in that state.

## Admission Status

Graduate students are admitted into one of three categories: provisional, non-degree, or degree (M.S. or Ph.D.). Students in the provisional status are automatically changed to non-degree status upon earning at least a 3.0 grade-point average in all course work attempted at The University of Tennessee (graduate and undergraduate) including at least six hours of graduate work. A request for change of status from non-degree to degree must be submitted by the student to the Office of Graduate Admissions and Records upon satisfactory completion of the requirements as outlined in The Graduate School Catalog.

Applicants with a baccalaureate degree from an institution in the United States, who have a GPA below 2.7/4.0, can only be admitted on probation. International applicants on a non-immigrant visa cannot be admitted if their baccalaureate GPA is less than 3.0/4.0. The probationary status will be removed after completion of nine of more hours of graduate credit with a minimum GPA of 3.0. Failure to maintain a 3.0 while in this status will result in dismissal.

## *Housing*

The University maintains residential facilities. University housing is either within walking distance of the Agriculture Campus, or is served by bus. Several housing units are near bicycle trails that pass the Biosystems Engineering & Soil Science Department. Furnished and non-furnished university-owned apartments are available for married and single graduate students. Off-campus private housing is also available.

Prospective students desiring to discuss housing options and experiences may contact current graduate students through the Departmental Office. Other housing contacts are listed on the *Contacts* page at the start of this document.

## *Health Care*

Because of the critical role that graduate research and teaching assistants (and associates) play in the conduct of the University's core research and teaching activities, The University of Tennessee will provide health insurance to all GTAs and GRAs employed more than 25% time. Non-employee graduate students are urged to avail themselves and their dependents of a comparable insurance plan, as paying for hospital and medical care is the student's responsibility. Health insurance is required for foreign students. The Student Health Service website is < http://web.utk.edu/~shs/ >.

## *Financial Aid*

Graduate students typically have three primary responsibilities related to their pursuit of an advanced degree at the University: coursework, thesis or dissertation research, and assistantship or other employment responsibilities. Occasionally, students undertake research that is directly related to the work supported by a research assistantship. However, in many other cases, the research or teaching assistantship is not related to the research program. In these cases, it is expected that the student arrange work schedules and responsibilities to successfully meet all their obligations at the University. Consult with the major professor if there are any questions about research or work expectations.

The following types of financial aid are available:

*Extra-Departmental Funds*

Student loans and scholarships are available from extra-departmental entities. For more information on these types of funding, please contact the Financial Aid Office as listed on the *Contacts* page at the start of this document.

*Experiment Station Assistantships*

A limited number of graduate research assistantships funded by the Tennessee Agricultural Experiment Station are available. These assistantships provide a basic stipend plus payment of tuition and maintenance fees, however students on assistantship must pay all other applicable University fees, such as the engineering fee and the technology fee. Please indicate in your application if you are interested in an assistantship.

*Grant & Contract Supported Assistantships*

Many of the faculty in the Department receive competitive grant or contract funds that provide support for graduate assistantships. Specific information is available from the professor receiving the outside funds.

*Hourly Work*

Part-time work may be available for some of the on-going research projects. Details can be obtained by contacting the Departmental Office.

## *Graduate Student Organizations*

Graduate students are encouraged to continue their professional development by becoming student members and participating in the activities of relevant professional societies. Several potential organizations are listed alphabetically below; one or more faculty members in the Department belong to each of the organizations listed:

### ASABE – The Society for Engineering in Agricultural, Food, and Biological Systems

There is an active student branch of the ASABE at the Department. Annual membership dues are approximately $20.00. Student members receive the national ASABE newsletter and magazine as well as discounts on national meeting registrations. Graduate students regularly present posters and papers pertinent to their work at national meetings organized by ASABE.

### ASCE – The American Society of Civil Engineers

Students focusing in the area of irrigation, structures, and other civil-engineering-related subjects may be well served by joining ASCE and attending its annual meetings.

### ASEE – The Society for Engineering Education

Degree candidates who intend to pursue careers in engineering education are encouraged to join this organization. Annual national meetings – typically held in mid-summer – are clearinghouses for new approaches to engineering education. The annual regional meetings – typically held in late spring – are an excellent opportunity to meet engineering educators from around the southeast region.

**IBE – Institute of Biological Engineering**
Students focusing in the area of biosensors, bioprocessing, and other broadly related biological-engineering subjects may be well served by joining IBE and attending its annual meetings.

**IEEE – The Institute of Electrical and Electronics Engineers, Inc.**
Students focusing in the area of sensor and control system design may be well served by joining IEEE and attending its meetings.

**SAE – The Engineering Society for Advancing Mobility in Land, Sea, Air, and Space**
Students focusing in the area of power and machinery may be well served by joining SAE and attending its meetings.

**Sigma Xi – The Scientific Research Society**
Several members of the faculty are members of this honorary organization – students may be nominated to membership upon demonstration of excellence in research.

**SSSA – The Soil Science Society of America**
Students in the ESS and PSI-Soils degree programs can benefit greatly from membership in the SSSA. The primary purpose of the Society is to advance the discipline and practice of soil science by acquiring and disseminating information about soils in relation to crop production, environmental quality, ecosystem sustainability, bioremediation, waste management and recycling, and wise land use.

# DEPARTMENTAL GUIDELINES

## *Selection of a Faculty Advisor (Major Professor)*

Based on your research area of interest and background, a major professor will be assigned upon your admission.

## *Role of the Major Professor*

The major professor guides course selection, advisory committee formation, research, and thesis/dissertation preparation. The major professor is the official liaison between the student and the Graduate advisory committee, and between the student and administrative personnel.

## *Graduate Advisory Committee*

In addition to the major professor, the student is required to have a graduate advisory committee consisting of approved faculty members. The student's advisory committee serves: 1) to guide, inform, and counsel the student; 2) to discuss and approve a plan of study; 3) to discuss and approve a thesis, or dissertation, topic and research project proposal; 4) to review progress and provide advice during the student's research; and 5) to conduct the requisite oral and written examinations.

To avoid serious problems at later stages in their programs of study, students are strongly encouraged to develop close working relationships with their advisory committee members. To foster this, students are strongly encouraged to give regular progress reports (written or verbal) to all committee members. Because of the critical role of the advisory committee, MS-track students should establish their committees by the end of the first semester of study, while PhD-track students should establish theirs by the end of the first year of study.

### Master's Committee

The advisory committee for master's students shall consist of a minimum of three members having academic rank of Assistant Professor or above. Two, or more, members, including the major professor, are to be from the Biosystems Engineering & Soil Science Department, with at least one member having some teaching appointment. One, or more, may be from outside the Department. If a student selects a minor, one or more members must be from the minor Department. Because of the diverse nature of the departmental faculty, BsE masters committees must be chaired by a faculty member with disciplinary training in engineering; ESS masters committees must be chaired or co-chaired by a faculty member with disciplinary training in soil or environmental science; BsET masters committees must be chaired or co-chaired by a faculty member with disciplinary training in engineering or engineering technology.

### Doctoral Committee

The Doctoral advisory committee shall consist of a minimum of four members having academic rank of Assistant Professor, or above, and all members shall hold a Ph.D. degree. A minimum of three members of the advisory committee, including the major professor, must be approved by The Graduate School to direct doctoral research. Two or more members, including the major professor, are to be from the Biosystems Engineering & Soil Science Department. One or more members are to be from outside the Department. If a student selects a minor, at least one member must be from the minor Department. Because of the diverse nature of the departmental faculty, BsE doctoral committees must be chaired by a faculty member with disciplinary training in engineering, while PSI-Soils doctoral committees must be chaired by a faculty member with disciplinary training in soil science, environmental science, or a closely related discipline.

## *Plan of Study*

The Plan of Study is a guideline for coursework to be taken during the graduate program. Each Plan of Study is unique and should be developed in consultation with the student's advisory committee, to achieve the educational objectives of the student, and to comply with the requirements of the Graduate School. The Plan of Study should also reflect the research interests of a student. Because of the close relationship between a student's overall educational objectives and research interests, Ph.D. and M.S. thesis-option students should submit a Statement of Research Interests, along with a Statement of Personal Academic Interests and Goals, with the Plan of Study. Non-thesis M.S. students should submit a Statement of Personal Academic Interests and Goals. (Note: A Plan of Study may include provisions for minor requirements. For example, a statistics minor (M.S. or Ph.D.) is available. Consult the *Graduate Catalog* for detailed requirements of various minors.)

A clear timeline for completion of the degree is as important as the Plan of Study. Such a timeline protects the interests of students, faculty members, and the University, by ensuring that resources are directed towards the production of useful scientific and engineering data in a timely manner. The following tables list milestone events for each degree program covered by this handbook, along with

suggested dates (relative to starting date), for full time students. As soon as the major professor is selected, the graduate student should prepare a mutually agreed upon table with milestone dates appropriate to his or her program. Failure to achieve any milestone by the mutually agreed upon deadline dates may lead to loss of assistantship and/or dismissal from the graduate program. If a graduate student foresees missing a deadline date, immediate consultation with the major professor should occur.

**Table 1. Milestones in BsE, BsET, and ESS masters programs – Non-thesis option**

| Milestone | Predecessors | Deadline | Mutually Agreed-Upon Date |
|---|---|---|---|
| 1. Selection of Major Professor | | 2 months after program start | |
| 2. Selection of Committee | (1) | 3 months after program start | |
| 3. Plan of Study & Capstone Project Approved by Committee* | (2) | 5th week of 2nd Semester | |
| 4. Capstone Project Underway | (3) | 12 months after program start | |
| 5. Final Exam Scheduled | (4) | Approximately 15 months after program start (consult Graduate School website) | |
| 6. Capstone Project Completed | (3) | Prior to Final Exam | |
| 7. Final Exam | (5) | Approximately 17 months after program start (consult Graduate School website) | |

*See *http://gradschool.utk.edu/gradforms.shtml* for links to appropriate forms.

**Table 2. Milestones in BsE, BsET, and ESS masters programs – Thesis Option**

| Milestone | Predecessors | Deadline | Mutually Agreed-Upon Date |
|---|---|---|---|
| 1. Selection of Major Professor | | 1 month after program start | |
| 2. Selection of Committee | (1) | 2 months after program start | |
| 3. Research Proposal and Plan of Study Approved by Committee | (2) | Last day of 1st Semester | |
| 4. Admission to Candidacy Approved by Committee* | (3) | After 1st Semester or after nine hours of graduate coursework | |
| 5. Research Project Underway | (3) | Beginning of 2nd Semester | |
| 6. Coursework Completed | (4) | Typically one semester prior to graduation, but flexible per Graduate Committee | |
| 7. Data Collection and Analysis Completed | (5) | Typically 6 months prior to graduation, but flexible per Graduate Committee | |
| 8. Draft Thesis to Thesis Advisor [4] | (7) | 1 week prior to submitting to major professor | |
| 9. Draft Thesis to Major Professor | (8) | 2 months prior to Final Exam | |
| 10. Final Exam Scheduled | (9) | Approximately 1 month prior to Final Exam (consult Graduate School website) | |
| 11. Revised Thesis to Committee | (9) | 2 weeks prior to Final Exam | |
| 12. Final Exam | (11) | Approximately 23 months after program start (consult Graduate School website) | |

* See *http://gradschool.utk.edu/gradforms.shtml* for links to appropriate forms.

4 – Thesis Advisor is in the Graduate School, and ensures that theses and dissertations meet format requirements.

**Table 3. Milestones in BsE and PSI Soils doctoral programs**

| Milestone | Predecessors | Deadline | Mutually Agreed-Upon Date |
|---|---|---|---|
| 1. Selection of Major Professor | | 3 months after program start | |
| 2. Selection of Committee | (1) | 6 months after program start | |
| 3. Plan of Study Approved by Committee | (2) | Last day of 2nd Semester | |
| 4. Begin Research Relevant to Project[5] (e.g., literature, experimental, modeling) | (1) | Beginning of 2nd Semester | |
| 5. Research Proposal to Committee | (3), (4) | 12 months after program start | |
| 6. Schedule Comprehensive Exam; Provide Updated Research Proposal to Committee | (5) | 18 months after program start | |
| 7. Pass Written Comprehensive Exam | (6) | 19 months after program start | |
| 8. Pass Oral Comprehensive Exam, including Defense of Proposal; and Submit Admission to Candidacy | (7) | 20 months after program start | |
| 9. Begin Intensive Dissertation Research | (5) | 23 months after program start | |
| 10. Coursework Completed | (3) | 28 months after program start | |
| 11. Draft Dissertation to Major Professor | (9) | 2 months prior to Final Exam | |
| 12. Final Exam Scheduled | (10), (11) | Approximately 1 month prior to Final Exam (consult Graduate School website) | |
| 13. Revised Dissertation to Committee | (11) | 1 month prior to Final Exam | |
| 14. Final Exam | (13) | Approximately 35 months after program start (consult Graduate School website) | |
| 15. Dissertation Approved | (14) | Approximately 36 months after program start | |

* See *http://gradschool.utk.edu/gradforms.shtml* for links to appropriate forms.

5 - Particular attention must be paid to the requirement for continuous registration for Dissertation course credit (600). See *Graduate Catalog* for details.

## *Conducting a Research Project*

### Proposal

The Research Proposal is the initial and most critical part of every research project, and every graduate student must prepare one (non-thesis M.S. students must prepare an abbreviated proposal of their capstone project). The proposal will provide a justification of specific objectives and define a procedure for achieving each objective. An example of an appropriate Research Proposal is presented in Appendix B.

Graduate students should prepare a draft proposal based on their review of relevant literature, original thought, and discussion with the major professor and committee members. The draft proposal should be submitted to the major professor, and the proposal should be refined to the joint satisfaction of the major professor and graduate student. After this is done, copies should be distributed to the advisory committee for their signatures and approval.

For M.S. students (thesis option), the advisory committee will meet to discuss the merits of the proposed project and decide if it is appropriate for the stated educational objectives. For doctoral students, the advisory committee will incorporate consideration of the Research Proposal into the Comprehensive Examination. Formal approval of the Research Proposal will be coincident with passing the Comprehensive Examination. Thus, the Research Proposal must be submitted to the advisory committee before the Comprehensive Examination is administered because it will be covered in questions that are part of the doctoral Comprehensive Examination.

### Writing the Thesis or Dissertation

There are as many ways of writing a thesis or dissertation as there are combinations and permutations of faculty members and students. Keep the following points in mind: (1) Well written proposals generally lead to well written theses and dissertations – spend appropriate effort on the proposal to avoid wasted effort during the write up. (2) Memory fails – keep meticulous notes on the materials and methods employed, the experimental conditions, and the results. (3) Accidents happen – periodically back up all relevant notes (electronic and paper) and store the backup copies in a physically separate location from the originals. (4) Clear technical writing is the result of hard labor by the author – develop good writing skills through written class assignments, so that those skills are available when the thesis or dissertation is being prepared.

External review of the thesis or dissertation by an outside peer is suggested.

Contact the Thesis/Dissertation Consultant early, so that your thesis or dissertation will meet format requirements.

## *Registration*

Registration for course work each term is the responsibility of the student. Course registration should conform to the student's plan of study, and the minimum and maximum hours of registration as stated in the *Graduate Catalog*; particular attention should be paid by PhD students to the requirement for continuous registration for Dissertation course credit (600). Course selection for each term should be in close consultation with the major professor.

## *Dropping Courses*

The Graduate School has formal policies on withdrawing from courses (see the *Graduate Catalog).* The Biosystems Engineering & Soil Science Department has no formal withdrawal or drop policy, except that all requests for withdrawing from a course shall be approved by the major professor.

## *Thesis/Dissertation Distribution*

Besides the final approved copies that are submitted to The Graduate School, hardbound copies of the thesis/dissertation are to be presented to both the major professor and the department head. As a courtesy, a copy should be presented to each member of the advisory committee, and to individuals who made a significant contribution to the research. The student should ask each advisory committee member and contributor about his or her choice of bindings or electronic media.

## *Publication of Work in Peer-Reviewed Journals*

### Responsibility

Thesis-option M.S. students are expected to prepare and submit a manuscript of their research results for publication in a refereed professional journal. Doctoral students are expected to prepare and submit at least two manuscripts of their research results for publication in refereed professional journals. The graduate student shall obtain assistance from the major professor in planning, reviewing, revising, and submitting the manuscript. (In cases where students do not submit manuscripts within 3 months of graduation, the major professor may choose to write a manuscript for publication based on the thesis or dissertation, and chose to list him/herself as 1$^{st}$ author on the manuscript.) To facilitate publication of graduate student research, at the advisory committee's discretion, the thesis or dissertation may essentially consist of one or more manuscripts formatted to meet the requirements of The Graduate School. All manuscripts originating within the Department must be reviewed on several levels prior to submission.

### Assignment of Authorship

Normally, a graduate student who prepares a publication resulting from his/her thesis research will have senior authorship with the major professor listed as second author. However, first authorship should lie with the individual who made the greatest intellectual contribution to a particular manuscript. Thus, in cases where the graduate student has played a lesser role in the development of the research questions, or in intellectual development of the manuscript as a whole, the major professor may justifiably be listed as first author. As stated earlier, if the graduate student does not take the primary initiative in writing or revising a manuscript within 3 months of leaving the University, the major professor may publish results from the student's project and be listed as the senior author, even if the previously stated criteria are not met.

When publishing thesis or dissertation research, it is suggested that any persons meeting the following criteria[6] be considered for authorship:

All authors must have:

1. Given final approval of the submitted manuscript.
2. Participated sufficiently in the work to take public responsibility for part or all of the content.
3. Made substantial contributions to the intellectual content of the paper, as follow:
   *At least one of the following three:*
   - Conception and design
   - Acquisition of data
   - Analysis and interpretation of data

   **AND**

   *At least one of the following two:*
   - Drafting of the manuscript
   - Critical revision of the manuscript for important intellectual content

## *Research Data, Software, and Designs*

All research data, patents, software, designs, manuscripts, creations, etc. obtained and/or created by graduate students on University financial support are property of the State of Tennessee. All research data and other requested research findings must be submitted on a CD to the major professor before the student leaves the University. If any patents or publications are obtained directly from the student's thesis, both the student and major contributing advisor(s) are credited and may receive a percentage of the profits or royalties realized. The University of Tennessee Research Corporation (UTRC) establishes policies governing patents.

## *Use of Facilities and Resources*

Facilities and resources under the stewardship of the Biosystems Engineering & Soil Science Department are for support of the Department's teaching, extension, and research missions. Some departmental facilities and resources are, therefore, generally not placed at the disposal of any individual. The department head and/or faculty members establish policies governing facilities and resources.

## Secretaries

Graduate students are not assigned personal secretaries. The secretarial staff is not permitted to do typing of a personal nature, which includes typing of personal course work, theses, resumes, or dissertations. If a graduate student needs secretarial assistance for a work-related assignment, the student should submit the work through the major professor.

## Photocopying

Graduate student use of the Department's photocopier for course work, term papers, thesis preparation, or personal use is expressly prohibited. If approved by the student's major professor, the photocopier may be used only for direct support of departmental work-related assignments, or for professional meeting presentations.

---

6 - Guidelines are based in part upon the American Medical Association’s Guidelines for Authors.

Photocopiers for personal use are available in the Agriculture-Veterinary Medicine Library, in Ellington Plant Sciences Building, and at numerous nearby business locations.

## Computers

*All graduate students must abide by the University of Tennessee Information Technology Policy, available at http://oit.utk.edu/itp/. Failure to abide by these guidelines is grounds for loss of assistantship and/or dismissal from the graduate program.*

The Department makes computers available to graduate students as necessary to support their research program. However, the Department does not provide a computer for each student, and sharing of computers is normally necessary. Specific computer requirements related to research activities should be discussed with the faculty member directing that research. Depending upon needs and resources available, computers may sometimes be provided specifically for support of a particular program. Because these needs and resources may differ among research projects within the Department, all students may not have equal access to computers.

Some research activities may require storage of large data files. A departmental server is available for storage of such files. Disk space on this server is allocated to each faculty member in the Department; the faculty member is then responsible for authorizing access to the disk and maintaining the information stored therein. Students needing access to such file storage should contact their major professor.

The College of Agricultural Sciences and Natural Resources computer laboratory is located in Rooms 276 and 270 of the Biosystems Engineering & Soil Science Lab Building. It is available to undergraduate and graduate students for work related to their academic programs. Demand for this resource sometimes exceeds its availability, thus a priority list for access to the laboratory equipment is posted in the laboratory. Note that this is a college laboratory and is available for e-mail, access to the Internet, course work (including printing of assignments, laboratory reports, etc), and other academic activities. It may also be used, on an "as available basis" for research related activities. However, it should not be used to print theses, manuscripts, and similar documents.

Theses, research-based manuscripts, and similar documents should normally be printed on BEES departmental printers, such as are provided in room 107 and elsewhere, but only after confirming with the major professor that printing the particular document is approved. Commonly acceptable uses of departmental printers are listed below:

- Preliminary copies of a thesis or dissertation, such as would be distributed to a committee
- One final copy of a thesis or dissertation, to be copied later at the students own expense
- Preliminary copies of a research-based manuscript, for distribution to co-authors
- "Final" copies of a research-based manuscript for distribution to internal reviewers
- Final copies of research-based manuscript for submission to a peer-reviewed scientific journal

Students are encouraged to use electronic media, where appropriate, to communicate with their committee and with external peers. For example, in many cases, it is possible to circulate manuscripts in pdf format; check with the major professor or departmental computer support specialist for assistance in converting manuscripts to pdf format.

The major professor or department head may withdraw access to departmental printers, if the privilege has been abused. Abuse includes printing of non-research-related documents, or irresponsible printer use, such as reprinting entire large manuscripts when only a few pages needed revision.

## Office and Desk Assignments

The Department assigns available office and desk space to graduate students. When new students arrive, they should meet with the student records secretary and request a desk and office space. Any special needs for office space should be requested through the major professor to the student records secretary. Priority of office space is generally given in the following order: 1) full-time Ph.D. students, 2) full-time master's students, and 3) part-time graduate students.

## Office Supplies

Graduate student use of the Departmental office supplies for course work or for personal use is prohibited. Office supplies required for direct support of departmental work-related assignments may be obtained from the student's major professor.

## Shop

To use the workshop facilities, graduate students must obtain the permission of the shop supervisor. Each student must demonstrate to the shop supervisor the ability to proficiently and safely operate a particular machine before permission for use will be granted, however only shop personnel may operate certain machines.

Shop personnel are available to assist with construction of research apparatus. For a large project, plans (including detailed drawings) and a work request must be prepared and submitted to and approved by the major professor prior to submitting it to the shop supervisor. For small projects, or short-term assistance, requests are to be made directly to the shop supervisor.

## Statistical Consulting Services

The Statistical Consulting Center provides a variety of research support for graduate students at The University of Tennessee. For details on services offered, see their website: < http://oit.utk.edu/scc/ >.

## Research Space

The department head determines laboratory space assignments. Graduate students should request research or laboratory space though the major professor.

## Telephone

All graduate student offices have been equipped with telephones. No long distance calls may be placed on these telephones. Students should check with their major professor if they need to place a work-related long-distance call.

## Keys

Requests for keys must be made through the department for building and office entry and for cubicle drawer locks. If a student is required to have lab keys, the major professor will initiate the key request, which must be approved by the department head. A University-issued ID number is required for the request. Students are responsible for picking up keys at the Key Shop after requests have been processed. Keys must be returned to the Key Shop prior to graduation.

## Lockers

Lockers are also available in the Men's and Women's locker rooms for students who wish to use those facilities. In either case, locker users should tell the Front Office which locker they have selected. (Locks and stored items that appear to be abandoned in lockers are periodically removed.)

## Parking

All personal vehicles on campus must be registered with University Parking Services. Parking of personal vehicles in the area immediately behind the Biosystems Engineering & Soil Science Buildings is not permitted during normal work hours.

## Purchases

Permission, as well as an account number, must be obtained from the major professor before any purchases for a project are made with University funds. All receipts should be given to the Departmental Bookkeeper for accounting, and should include a chargeable account number (available from the major professor), the graduate student's name (legibly), and, if not provided by the vendor, a brief description of the item(s) purchased.

## Mail Service

The mailroom is located in Room 107 and is open from 8:00 AM to 5:00 PM. Mailboxes are provided for all graduate students, staff, and faculty members. Students should check their mailbox regularly. Much University and departmental communication is done through e-mail. It is the student's responsibility to obtain a UT e-mail account upon arrival at the Department. This can be done by going to < https://tmail.utk.edu/uact/register.asp > and following the instructions there.

## University Vehicles

The University maintains a motor pool for official local, in-state, or out-of-state travel. The Department also has several vehicles for local and in-state travel. Vehicles from either source may be reserved on an "as available" basis, but the major professor must approve all use of university vehicles. Furthermore, use of university vehicles is a privilege afforded graduate students who (1) possess a valid driver's license, and (2) are employed by the University. It is expected that the driver will observe all traffic rules and regulations. Fines and penalties resulting from violation of traffic rules will be at the offender's expense and will precipitate a strong reprimand, which may include suspension of driving privileges. Graduate students must demonstrate the ability to handle certain vehicles to the major professor before being allowed to operate those vehicles.

The State Board of Claims will not receive or consider claims for injuries sustained in state-owned vehicles by unauthorized passengers or drivers, or during unauthorized vehicle use. Student employees who drive state-owned vehicles and are concerned with their personal risk exposure in this area are advised to contact their insurance agent regarding the procedures for including the desired non-owned automobile liability coverage in their existing private automobile insurance.

## Travel Authorization

The driver and all passengers traveling out of state or overnight must have approved travel authorization granted by the department head. If a travel noticet is submitted through the departmental office and is placed on the central calendar, blanket authorization exists for in-state travel. Out-of-state travel authorization must be requested ten business days in advance of the departure

date. Anyone traveling on University-related business in a private vehicle must also have approved travel authorization from the department head. Request travel authorization electronically – students should check with the major professor or with the front office for details. International travel requires approval from the Vice-President, and should be coordinated though the major professor and department head.

## RIGHT TO KNOW PROGRAM

All employees and students of the University of Tennessee must be protected from exposures to hazardous chemicals through a combination of safety training and safe practices in the work place. A hazardous chemical is defined as any chemical that poses a physical hazard (fire, explosion, corrosion, reaction, etc.) or health hazard (toxin, irritant, carcinogen, mutagen, etc.) as defined in the OSHA Right-to-Know Law. Three laws govern the use of hazardous chemicals in University work places:

The **Right-to-Know Law** applies to all uses of hazardous chemicals that are not on a laboratory scale. Areas covered by the Right-to-Know Law include shops and manufacturing facilities. All persons in the work place must be trained regarding all hazardous chemicals in the work place prior to assignment, and at least annually thereafter. A material safety data sheet (MSDS) must be on file for each hazardous chemical and all containers must be labeled. All necessary safety equipment must be provided and used. Refer to Sections 3 and 9 of the Institute of Agriculture Health and Safety Manual. (http://bioengr.ag.utk.edu/safety/safetyplan/toc.htm)

The **Laboratory Safety Standard** applies to chemical manipulations carried out on a "laboratory scale" as defined in the OSHA regulations, which includes most University laboratories. A Chemical Hygiene Plan must be developed for each procedure, material safety data sheets (MSDS) must be on file for all hazardous chemicals, all persons conducting the procedure must be trained to do the job properly and safely prior to performing the procedure, and all necessary safety equipment must be provided and used. Refer to Sections 3 and 9 of the Institute of Agriculture Health and Safety Manual.

The **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** regulates the use of all pesticides. The Institute of Agriculture Pesticide Management Policy specifies the training and pesticide use requirements that apply to all employees and students of the Institute of Agriculture. All pesticide use must be conducted by, or under the direct supervision of, a certified applicator. All necessary safety equipment must be provided and used. Refer to Section 40 of the Institute of Agriculture Health and Safety Manual.

For more information, contact the work supervisor, department head, or the Institute of Agriculture safety officer (865.974.1153). Students may also visit the Safety Office website: http://safety.ag.utk.edu/

## ACCIDENT AND INCIDENT REPORTING

All accidents and incidents must be reported immediately in accordance with University policies and procedures. Failure to report an accident may result in loss of Workers Compensation benefits. Failure to report unsafe conditions may result in future injuries and/or property damage. To report an accident, incident, or unsafe condition, contact the work supervisor, department head, or the Institute of Agriculture safety officer. Refer to the following sections of the Institute of Agriculture Health and Safety Manual: the accident reporting guidelines inside the front cover and Section 10.

# STUDENT PROGRESS AND RETENTION

## *Departmental Examinations*

### Language Requirements

There is no foreign language requirement for any degree; however, due to the international nature of Biosystems Engineering & Soil Science, students are encouraged to take advantage of the language courses offered at the University.

All students are expected to use technical English effectively. Specifically, each student is expected to demonstrate effective oral communication in English as well as technical accuracy at all times. Proficiency will be evaluated during the Comprehensive Exam and defense of the thesis/dissertation examination. Additionally, the student's thesis/dissertation is expected to be an example of fluent written technical English.

### Comprehensive Exams (Doctoral)

**Timing:** The Comprehensive Examination will be given after the student has completed approximately three-fourths of graduate course work and prior to admission to candidacy. This examination is preliminary to the student's dissertation research; it should be taken late enough in a student's academic program to permit most of the graduate work to be covered on the exam, and early enough to permit modification of the student's program based on the results of the exam.

**Prerequisite:** A written research project proposal, approved by the major professor, must be submitted to each member of the student's Doctoral advisory committee at least two weeks before the scheduled date of the written portion of the Comprehensive Examination.

**Format:** The Comprehensive Examination will consist of two parts:

1. A written examination, administered over a period of one to three weeks, will be given at an agreed upon date. This examination will be prepared by the members of the Doctoral advisory committee at the request of the major professor. Individual committee members will prepare a set of questions and specify conditions (e.g., time limits, environment, etc.) under which the student must work while preparing answers. Individual committee members may request assistance from other faculty members in preparing the portion of the examination for which they are responsible. The exam will cover fundamental knowledge of the discipline. Parts of the exam may be in the context of the proposed research. The major professor will administer the exam with the response to each question graded by the committee member responsible for the question.

2. If the student passes all written examination sections, the Chair will then schedule an oral examination at a time agreeable to all concerned, typically one week after completion of the written examination. On the exam, the student will be tested on subject matter similar to that covered on the written exam as he/she defends the proposed dissertation research. Typically, this exam takes no longer than three hours. The Advisory Committee will serve as the examining committee. If the student passes the oral examination, he/she is then eligible for admission to candidacy for the Ph.D. degree.

After passing the Comprehensive Examination, the student should file for, and be admitted to, candidacy. This must occur at least one semester prior to graduation.

**2nd Examinations and Appeals:** If the student fails one or more of the written examinations, the Chair will convene the Advisory Committee to discuss an appropriate course of action. Among the alternatives to be considered are to administer another written examination in the area failed after giving the student additional time for preparation; to require additional coursework prior to administering an additional written examination in each of the areas failed; or to proceed with the oral examination with the understanding that appropriate remedial action will be required before admission to candidacy. If the student fails any of the written examination(s) for a second time, the student will be dropped from the graduate program. Likewise, if the student fails the oral examination twice, the student will be dropped from the program.

If a student feels he/she has been treated unfairly during any stage of the examination process, he/she has the right to appeal to the department head. The department head will review the examinations in question, seek advice from other departmental members and meet with the Advisory Committee to discuss the student's problems. The department head can suggest a re-examination or uphold the decision of the committee. Further appeal procedures are provided by The Graduate School.

## Final Defense of Thesis/Dissertation

A candidate presenting a thesis or dissertation must pass a final oral examination on all work offered for the degree. The candidate may also be required to pass a written portion of the final examination at the discretion of the major professor, or the advisory committee. The examination(s) is not merely a re-examination covering course material, but is a test of the candidate's ability to integrate material in the major and related fields, including the work presented in the thesis or dissertation. This examination must be scheduled in accordance with deadlines specified in The Graduate School website. The completed thesis or dissertation, in a form approved by the major professor, shall be distributed to all advisory committee members at least two weeks before the date of the final oral examination. The student’s advisory committee will conduct this examination. Members of the University faculty may attend the examination. In case of failure of the final examination, the candidate may not appear for reexamination until the following semester. The result of the second examination is final.

## Final Examinations for Non-Thesis Students

A non-thesis student must pass a final written examination, developed by the student's advisory committee, on all work offered for the degree. The examination is not merely a re-examination of course work, but is a test of the candidate's ability to integrate material in the major and related fields. This written examination will be followed by an oral examination (at the option of the advisory committee) and a presentation of the problem solved in lieu of a thesis. A report on the problem completed in lieu of a thesis must be made available to each committee member at least one week prior to the oral examination date. The oral examination must be scheduled through The Graduate School in accordance with the deadlines specified in The Graduate School website. The student’s advisory committee will conduct this examination. Members of the University faculty may attend the examination. In case of failure of the written or oral part of the final examination, the candidate may not appear for re-examination until the following semester. The result of the second examination is final.

### *Reasonable Term of Study*

The normal maximum time required to complete a full-time graduate program is two calendar years for master's students and three calendar years for doctoral students. Both the graduate student and the graduate advisory committee should strive to keep the reasonable term of study from being unduly exceeded.

### *Grounds for Dismissal*

Failure to meet deadline dates in a degree program sequence (as described in *Plan of Study* section of this handbook) may be grounds for dismissal from the graduate program.

Furthermore, a student who has less than a 3.0 GPA after the first 9 graduate credit hours (or any subsequent semester) of graduate study will be placed on academic probation. If the student has not made satisfactory progress (as specified in the student's probationary agreement approved by the advisory committee) toward developing an overall 3.0 GPA by the end of the second semester following probation, the student will be dismissed from graduate study in the Department.

The faculty may vote to dismiss a student from graduate study in the Department in cases of the student's intentional academic dishonesty; racial, religious, or sexual harassment; theft; workplace use of illegal drugs or alcohol; or other actions detrimental to the University.

### *Grounds for Withdrawing Financial Support*

Failure to meet deadline dates in a degree program sequence (as described in *Plan of Study* section of this handbook) may be grounds for loss of financial support. Students on work-related assistantships may be evaluated in writing by their faculty work supervisor at the middle and end of each semester. The student may be notified in writing of their work performance, and may respond to this evaluation. The student may be placed on financial-support probation at the mid-point or end of any semester for poor work performance, poor academic performance, or excessive dropping of courses. If after 6 weeks, satisfactory work performance has not been achieved, financial support will be withdrawn.

## PROFESSIONAL PERFORMANCE GUIDELINES

### *Employment Policy*

#### Experiment Station Research Assistantships

Graduate students supported by assistantships that are funded by the department may take up to nine hours of course work per semester, but not more than 24 hours per year. The appointments are salaried and classified as 12-month (i.e., year round).

The graduate student will be assigned a work supervisor (who may or may not be the major professor). Graduate students are expected to conduct and complete their work assignments in a professional manner.

There will be differences in work assignments. Some students will have what appear to be easier job assignments while others will appear to have more difficult job assignments. While gross inequities in job assignments are avoided, strict equality is typically not possible.

Students on the Department's payroll must report any other University employment to the department head. Specific procedures on reporting the hours worked are to be obtained from the Departmental Bookkeeper.

## Contracts and Grants

Graduate assistantships and/or fellowships funded through outside contracts and grants are sometimes available. Guidelines for these special assistantships may differ greatly from other departmental assistantships or employment. Specific information regarding work guidelines and benefits are available from the department head.

## Professionalism

A major objective of the graduate research and teaching program in the Biosystems Engineering & Soil Science Department is to instill professionalism in each student. A professional is a person who accepts responsibility, can direct the efforts of other people, and is self-motivated.

Graduate student employees may be asked to work on projects unrelated to their thesis topic, or at times provide limited non-academic work assistance to the staff of the Department. Graduate students must depend upon their own personal productivity and dedication to acquire the sense of pride and duty needed to succeed as a professional. Graduate students are directly accountable to their major professor, or work supervisor, for their work habits, and will be treated as fellow professionals whose ideas, concepts, and approaches are integrated into the final product.

## Office Hours, Holidays, Sick Days, and Vacations

At the start of each semester, the graduate student employee should establish working hours with the work supervisor. For the graduate student, flexible work hours are both a necessity and a privilege, and should not be abused. Graduate students do not punch a time clock and are expected to be highly task-oriented. The terms one-half, three-quarter, and full-time graduate assistantships designate a minimum of 20-, 30-, or 40-hour workweeks, respectively. A reality of graduate studies is that at times, all students work more than the minimum time. They also work at night, on holidays, and on weekends to effectively conduct a research project.

As part-time employees, students are not eligible for benefits such as accrual of annual (vacation) or sick leave. Thus, excused sick and personal absences are a departmental courtesy. Personnel management policies include the granting of time for graduate student recreational and personal activities, provided this does not interfere with the student's academic and/or research responsibilities. Graduate students should schedule any absences with their major professor and/or work supervisor to ensure that their absence will not conflict with their research activities. Holidays are established and annually published by the administration. Student employees on salary may observe the same holidays as other University personnel. Graduate student employees are to notify the Department Office when they are required to be absent due to illness or personal tragedy.

### Participation in Departmental Research Projects

All degree recipients (thesis option) are required to submit a thesis or dissertation containing the results of original research. In addition to thesis or dissertation research, students are expected to participate in other research projects of their major professor, advisory committee members, and fellow graduate students, as approved by the major professor. Many of the routine and specialized methods and techniques used in research are not taught in classrooms. Exposure to, and participation in, as much of the overall departmental research program as possible is considered an essential part of graduate education. Thus, to receive the greatest benefit from their program, each graduate student should provide substantial assistance in other research projects, and should solicit collaboration in their own research.

### Graduate Student Teaching Policy

All graduate students are encouraged to assist the teaching faculty in conducting classes. Exposure to leading all aspects of classroom activities will be highly beneficial to individuals throughout their careers. Graduate course credit is available to those students wishing to become highly involved in the teaching program. Please contact a member of the teaching faculty for more information.

### Seminar Participation

A significant aspect of graduate education beyond formal courses and thesis/dissertation projects is active participation in the professional community that exists within academic departments at universities. Student/faculty seminars are one of the professionally rewarding activities of this community. Accordingly, all graduate students are encouraged to participate in each Biosystems Engineering & Soil Science Department seminar regardless of whether they are registered for seminar credit.

### Attendance at Professional Meetings

Graduate students are encouraged to attend at least one national or regional professional meeting during their study program. They are strongly encouraged to present the results of their own research at these meetings.

## RIGHTS AND RESPONSIBILITIES

A graduate student at The University of Tennessee, Knoxville, is a person officially admitted to and currently enrolled in The Graduate School.

The programs, policies, courses, procedures, and minimum requirements of The Graduate School are described in the *Graduate Catalog* of The University of Tennessee, Knoxville, which is published annually. Other information, including deadline dates for change of registration and submission of material to meet graduation requirements, is published each term in The Graduate School website. In addition, many departments and programs have brochures describing their own policies and procedures, which may be more restrictive than the general regulations of The Graduate School. It is

the responsibility of each student to be thoroughly familiar with the regulations of The Graduate School, and of the appropriate department or program, so as to avoid complications and delay. It is the responsibility of The Graduate School and the Department or program to keep the related information as current as possible. Changes in overall policies are processed through the Graduate Council.

General rights and responsibilities applying to all students, both graduate and undergraduate, are discussed in *Hilltopics*, < http://web.utk.edu/~homepage/hilltopics/ >, and available from the Dean of Students Office. The following statement, included with each applicant's admission letter, covers specific rights and responsibilities pertaining to graduate students.

## *University Mission*

The University of Tennessee has a three-fold purpose: Teaching, Research, and Public Service. Each of these relates to graduate students, who are essential components in the implementation of University objectives. No student has the right to interfere with the learning process, another's research, or a public service program (as determined by the University).

## *Professional and Academic Standards*

Graduate students have the right to be informed of departmental, professional, and academic policies and procedures that affect them. Students should be informed of these policies during the initial term in which they enroll in a program. It is the responsibility of the student to be familiar with the college policies and procedures of The Graduate School, as described in the *Graduate Catalog*, and those of the college and department program. Students are expected to ask questions if any information is unclear, or not provided.

### Annual Evaluation

As needed, an evaluation may be conducted to determine progress and performance of the graduate program. Graduate students will be evaluated according to basic requirements of the program under which they enter. When either the student or major professor becomes concerned that a program is not progressing satisfactorily, a conference will be held to review the program and progress of the student. Departments or colleges may change program requirements and apply them to students already admitted, provided adequate notice is given and the requirements are not made retroactive to parts of the program already completed by the student.

### Termination

It is the responsibility of the student to meet the retention standards as set forth by The Graduate School and the program. Failure to maintain acceptable academic standards or appropriate professional behavior may result in termination from the program and/or from The Graduate School.

### Right to Major Professor and Advisory Committee

After meeting conditions stipulated by the department or program, a student has the right to participate in the selection of a major professor and a committee. It is the student's responsibility to ascertain the willingness of the major professor, and each committee member, to serve. Final responsibility for determining the major professor and composition of the committee rests with the academic unit and The Graduate School. The right to a committee may be rescinded if the student fails to demonstrate appropriate academic achievement and/or acceptable professional conduct, as determined by the department/program, or by The Graduate School.

### Academic Governance

The right to establish policies pertaining to academic programs is vested with the faculty. Students contribute in the decision-making process through representation on the Graduate Council, participation in committee efforts, and through contributions of their own initiative.

### Confidentiality of Records

Some records are confidential. Information concerning confidentiality may be found in the current edition of *Hilltopics*.

### Academic Integrity

University guidelines concerning Student Academic Conduct are published in the current edition of *Hilltopics*.

### Appeal

A graduate student at The University of Tennessee has the right to appeal any judgment or decision made within the University. The appeal procedure depends on the nature of the decision. The appeal procedure for disciplinary actions, for misconduct and professional, college, or university penalties associated with academic dishonesty (plagiarism, cheating, etc.) is outlined in *The Graduate Council Appeal Procedure*, available at the Office of Graduate Student Services.

Questions regarding the appropriate appeal procedure should be addressed to The Graduate School (865.974.2475).

## APPENDIX A. STATISTICS MINOR

A statistics minor (M.S. or Ph.D.) is available for graduate students in Biosystems Engineering & Soil Science graduate programs. Please refer to < http://bus.utk.edu/stat/igsp/index.htm > and associated links for details on this program.

# APPENDIX B. EXAMPLE RESEARCH PROPOSAL

## Groundwater Monitoring Well Network Design Using Fractional Factorial and Kriging Techniques

**ABSTRACT**
A comparison of two groundwater monitoring well network design procedures is proposed. A fractional factorial design technique will be applied to historical tracer tests. Information from the initially placed wells will be used to continue with the fractional factorial design and to gain spatial variability knowledge, which will subsequently be used with kriging techniques to develop a parallel design. Data from the historic densely monitored tracer tests will be used in conjunction with moment analysis to quantify the efficacy of the designs.

**KEYWORDS:** tracers, spatial-variability, moment-analysis,

**OBJECTIVES**
The goal to which this study will contribute is identification of a groundwater monitoring network design procedure that will yield maximum information about contaminant plume characteristics with a minimum number of sampling points. The specific objectives for this study are to evaluate and compare two network design procedures. One procedure requires a minimum of *a priori* information and is based upon fractional factorial concepts. This procedure has been named E4, (E4, 1991) by its developers. The second network design method to be evaluated is a kriging technique. Historic groundwater tracer tests data sets will be used to evaluate the two procedures. Data are available from several injected tracer tests on moderate to large (tens to hundreds of meters) scales. Use of such historic data will help assess validity of the procedures for application to any spatially varying groundwater parameters (e.g., groundwater constituent concentrations or groundwater elevations) on a small to regional scale.

**JUSTIFICATION**
Groundwater quality degradation has been of increasing concern over the past few years. Roughly 330,000 tons of pesticide, 10.6 million tons of nitrogen fertilizer, and 10 million tons of nitrogen through manures are applied to agricultural crops annually in the U.S. (Asmussen , 1984). Regional concern is present in the coastal plain area of the Southeast where sandy soils exacerbate the problem due to high rainfall intensity and leaching. Computer models such as GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) have been developed in response to this concern (Leonard et al., 1987). Non-agricultural practices have resulted in contamination due to hydrocarbons, radionuclides, and leachate from landfills.

These situations, whether concerning well defined pollutant plumes or general regional degradation, call for an assessment of the extent (both aerially and in terms of concentration) of the problem.

To understand the migration of pollutants in groundwater, tracer tests have been performed. These tests seek to gain knowledge into aquifer parameters that dictate how a pollutant plume behaves. In these tests a tracer is injected into an aquifer and the resultant plume is monitored. This requires the design of a monitoring well network.

Both of the above situations (pollutant monitoring and assessment, and experimental design) illustrate the need for groundwater monitoring well networks and their design.

Historically, the design of groundwater monitoring well networks has followed no procedure in general. Generally, common sense of geohydrologists has been the guide (LaBlanc, 1991). More defined approaches have used numerical models, sequential techniques, (multi)objective functions and kriging to aid in network design. All of these methods require some form of *a priori* information. Geohydrologic data may be unavailable or sparse and the acquisition of information can be costly. Need for a method that requires minimal information to design a network is evident.

Fractional factorial concepts can be applied to monitoring well network design. Traditionally, fractional factorial designs were constructed so as to ensure orthogonality among the factors. A method has been developed that performs nearly as efficiently without the constraint of orthogonality (E4, 1991). Use of this method requires only knowledge about the range (or design space) of interest and an idea of the response curve (e.g., spatial concentration surface in this proposed

application) to determine the minimum number of levels per factor necessary. Information gained from a monitoring well network designed using this method could be used to site subsequent wells either with the same procedure or with kriging.

**LITERATURE**

Various monitoring network design methodologies have been used historically. Perhaps the most frequently used approach has been the collection of hydrogeologic data to facilitate design. Most often, parameters such as hydraulic conductivity, groundwater gradient, and porosity have been estimated from data and used in Darcy's law to predict mean groundwater velocity (Garabedian, 1987; MADE, 1985). These parameters have also been used in two and three-dimensional analytical solute transport models whose purpose was to predict plume migration (Garabedian, 1987; MADE, 1985).

Most designs have used a sequential approach in locating monitoring wells. Typically, monitoring wells are densely located near the origin of the injection. This provides for maximum information by which a larger scale or appended design can be made (Killey and Moltyaner, 1988). Knowledge gained from data from the initial pulse are usually mean velocity, plume bounds, and ideas of dispersivity.

Other methodologies have used (multi)objective functions to site monitoring wells. In reality, all designs either explicitly or implicitly use some sort of objective function, often related to economics. A multi-objective monitoring network design for air pollution has been proposed (Trujillo-Ventura and Ellis, 1991). This could be transferred to groundwater applications. The objectives in this design are spatial coverage, probability of standard violation, data validity, and network cost. This method is fairly complex and presupposes knowledge of spatial and temporal distribution of pollutants.

Kriging uses this idea of spatial distribution to interpolate data. Kriging is an exact interpolator and has its origins in the mining industry where it has been used to estimate ore quality from limited samples (Journel and Huijbregts, 1981). It has been adapted to the hydro sciences (Delhomme, 1978) and has been suggested for use in environmental monitoring (Zirschky, 1985). The use of kriging for monitoring constituent concentration has been illustrated in a program for monitoring sediments in lakes (Lin and Roesler, 1988).

As mentioned earlier, kriging as with other monitoring well network design techniques assumes existing information. An algorithm (DETMAX) for the construction of fractional factorial experimental designs has been proposed (Mitchell, 1972). However, this procedure requires a model, which again presupposes *a priori* knowledge.

A recently developed design tool, E4 (E4, 1991), which is also based on fractional factorial concepts, offers potential for efficient design of groundwater monitoring networks. This modification of the traditional fractional factorial design requires a minimum of information for use. This algorithm provides highly efficient if not optimal designs for a variety of experimental conditions.

It is apparent that there is no consensus on a method by which to design monitoring well networks. With the increasing need to monitor groundwater quality and pollutant migration and fate, it is apparent that more research needs be done on methods which can be applied with a minimum of information.

**PROCEDURES**

Testing monitoring well network design procedures will be achieved by the use of data from historic tracer tests. Data sets are available from the Stanford/Waterloo natural gradient tracer test at Borden Air Force Base, Canada (Mackay et al., 1986), Twin Lake tracer tests (Killey and Moltyaner, 1988), the MADE-1 experiment in Mississippi (Boggs, 1991), the USGS Cape Code tracer test (Garabedian, 1987), and the Savannah River Labs in South Carolina (Haselow, 1991). Data from the above sources represent conservative tracers such as bromide, fluorinated benzoic acid tracers, as well as radioactive isotopes and halogenated hydrocarbons.

The basic approach will be to use the E4 method and the kriging method to select a small subset of monitoring wells from those in the existing data sets. Data associated with each well in the selected subset will be used to predict the boundaries and movement rate of the tracer plume. With the kriging approach, estimates of all the existing data will be made from the selected subset. The E4 approach will use only data from the subset of wells. Multiple trials will be made, each starting with a different number of specified sampling points. Each method will be evaluated on the basis of its ability to use a reduced number of wells and/or sampling frequency to produce the same information obtained from all wells in the existing data sets. For each data set the E4 method will be used to select initial sampling points in two or possibly three dimensions. These points will correspond to sampling points available in the existing data sets from densely sampled tests. Information gathered from this first round will be average plume velocity and extent, and concentration data. Spatial

concentration data from the selected subset of sampling points will allow for the initiation of a kriging method for subsequent design by enabling the construction of a variogram. Both the E4 method and the kriging method will be used to select additional monitoring points. At each snapshot, information gathered from both techniques will be compared with actual data.

Comparison will be made by comparing concentration surfaces developed from all wells in the actual data versus that obtained from the wells selected by the two methods. This will either be done from horizontal planes or from vertically averaged data. Error will be quantified in terms of integrated residuals between the concentration surfaces. With both methods, successively larger sampling points will be withheld and re-analysis made. With the E4 method, interpolation of the concentration surface will be linear, while the kriging method will allow for non-linear interpolation. By withholding various numbers of sampling points, an error versus number-of-sampling-point function will be constructed.

A final comparison of the E4 and kriging methods will be made. It must be noted that in this procedure, the E4 method is needed initially to gather information for the kriging design method.

**FACILITIES AND EQUIPMENT**

Facilities and equipment are housed at the University of Tennessee. Computer hardware includes PC's, and VAX and IBM minicomputers. Computer software that is, or will be, available include the E4 fractional factorial design package, universal kriging software, two and three dimensional graphic packages, SAS, and spreadsheet software. FORTRAN and BASIC compilers are also available.

**REFERENCES**


Asmussen, L. E. 1989. Potential Pesticide Contamination in Ground-Water Recharge Areas: A Model Simulation, IN *Proceedings of the 1989 Georgia Water Resources Conference*, University of Georgia, Athens, Georgia, May 16-17.

Boggs, J. M. 1991. "Database for the First Macrodispersion Experiment (MADE-1), Prepared by Tennessee Valley Authority for Electric Power Research Institute, report EN-7363.

Delhomme, J. P. 1978. "Kriging in the Hydro sciences," Advances in Water Resources, Vol. 1, No. 5, pp. 251-266.

E4 User's Guide Version 91.1. 1991. Evolutionary Software, Inc., Knoxville, Tennessee.

Garabedian, Stephen. 1987. "Large-Scale Dispersive Transport in Aquifers: Field Experiments and Reactive Transport Theory," Ph.D. Dissertation, Massachusetts Institute of Technology.

Haselow, J. 1991. Savannah River Labs, United States Department of Energy, personal communication, September 4.

Journel, A. G. and Ch. J. Huijbregts. 1981. *Mining Geostatistics*, London-Orlando: Academic Press.

Killey, R.W.D. and G. L. Moltyaner. 1988. "Twin Lake Tracer Tests: Setting, Methodology, and Hydraulic Conductivity Distribution," Water Resources Research, Vol. 24, No. 10, pp. 1585-1612.

LaBlanc, D. 1991. U.S.G.S., Personal Communication, Sept. 11.

Leonard, R. A., W. G. Knisel, and D. A. Still. 1987. "GLEAMS: Groundwater Loading Effects of Agricultural Management Systems," Transactions of the ASAE, Vol. 30, No. 5., pp. 1403-1418.

Lin, P.C.L. and J. F. Roesler. 1988. "A Demonstration of a Universal Kriging Program for Monitoring Sediments in Lakes," in Chemical and Biological Characterization of Sludges, Sediments, Dredge Spoils, and Drilling Muds, ASTM STP 976, Lichtenberg, J. A., et. al. Editors, Philadelphia, pp. 59-68.

Mackay, D. M., D. L. Freyburg, P. V. Roberts, and J. A. Cherry. 1986. "A Natural Gradient Experiment on Solute Transport in a Sand Aquifer 1. Approach and Overview of Plume Movement," Water Resources Research, Vol. 22, No. 13, pp. 2017-2029.

"Macrodisperion Experiment (MADE): Design of a Field Experiment to Investigate Transport Processes in a Saturated Groundwater Zone". 1985. Prepared by Tennessee Valley Authority Water Systems Development Branch, and Massachusetts Institute of Technology, Dept. of Civil Engineering, subcontractor, for Electric Power Research Institute, Report EA-4082, June.

Mitchell, T. J. 1974. "An Algorithm for the Construction of "D-Optimal" Experimental Designs," Technometrics, Vol. 16, No. 2, pp. 203-210.

Trujillo-Ventura, A. and J. H. Ellis. 1991. "Multiobjective Air Pollution Monitoring Network Design," Atmospheric Environment, Vol. 25A, No. 2, pp. 469-479.

Zirschky, J. 1985. "Geostatistics for Environmental Monitoring and Survey Design," Environment International, pp. 515-524.

# Index