

GUIDELINES FOR THE PREPARATION OF WHITE PAPER

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Geoenvironmental Research Experience (list projects in progress or completed within the past 5 years):

Completed:

1. Field demonstration of air sparging of perchloroethylene in a controlled test cell at the Groundwater Remediation Field Laboratory (GRFL) at the Dover National Test Site (DNST), Dover Air Force Base, DE
2. Laboratory study of surfactant enhancements for air sparging
3. Controlled pilot-scale evaluation of ozone sparging in a fence configuration for remediating a dissolved trichloroethylene plume.

Ongoing:

1. Hydrological Characterization and Modeling of Watersheds on the L'Anse Indian Reservation
2. Quantification of the Hydrogeological Factors Affecting the Occurrence of Uranium in Sandstone Aquifers

Geoenvironmental Teaching Experience (list related courses, including short courses, taught within the past 5 years):

1. Fundamentals and Design of Subsurface Remediation Technologies
2. Geohydrology
3. Groundwater Engineering
4. Flow and Transport in Porous and Fractured Media
5. Groundwater Quality Modeling
6. Senior Design Projects: (a) Design of an SVE system for Jet Fuel Contamination, (b) Modeling Groundwater Flows in Watersheds

Geoenvironmental Consulting Experience (list major projects only):

No major projects.

Appraisal of Geoenvironmental Education

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I first noticed the term *geoenvironmental* in a focus issue of *Civil Engineering* in the early 1990s. At the time I was an assistant professor in a geological engineering (GE) department, coming fresh off of obtaining a Ph.D. in environmental engineering (EnE). Earlier I had obtained B.S. and M.S. degrees in civil engineering (CE). My degrees were all from Michigan Technological University, and my transition to my tenure-track faculty position entailed primarily moving my books and files up one floor to my new department and learning about the GE curriculum. Despite my close proximity to the GE department while a graduate student, I had very little knowledge of about geological engineering practice and the GE curriculum. Geology was a given, but I had no concept of geophysics and was completely ignorant regarding their technical skills. I quickly learned that geological engineering was not completely different from my civil engineering background. In fact I reveled at how relatively easily I could apply my civil and environmental engineering background to geological engineering topics.

Many graduating geological and environmental engineers were getting jobs in geoenvironmental consulting, and a significant fraction of the GE alumni were switching from the petroleum industry to the geoenvironmental field. At the time, hydrogeology and groundwater engineering classes were required for both the environmental and geological engineering students to address this need for graduates with expertise in subsurface hydrology and engineering. Because of my multidisciplinary background, I was quite surprised in my course evaluations that I would consistently be accused of expecting too much geological background from the environmental engineering students and being reminded that “we are not environmental engineers” by the geological engineering students. Ironically, this dichotomy in attitudes paralleled many of the consulting firms that contacted me looking for graduates. They appreciated the skills that environmental engineers brought to their firm but were disappointed in their lack of geological understanding. On the other hand, they valued geological engineers because they were quite capable in geology (and geophysics) but wished they possessed even some basic environmental engineering skills pertaining to water chemistry and treatment. To address the needs of geoenvironmental consulting firms by enhancing skills in either program through technical or free electives was not an easy fix due to curricular constraints.

At this same time when geoenvironmental engineering job opportunities for our graduates were numerous, the environmental engineering program was overflowing with students. Enrollment management was emplaced and was making it very difficult for students to get into the BSEnE program. Because of the groundwater aspects of geological engineering, I was being approached by a number of students who really wanted to be environmental engineers but couldn't get enroll due to the limits on program capacity, so they were exploring switching into the BSGE program. They were somewhat hesitant because they wanted to be able to take more “environmental” classes but our curriculum was not flexible enough to allow them this latitude. A lot of the problem was caused by lower division prerequisites for the upper division technical electives, and the lower division classes were restricted to majors only. There were enough of these students that I and a colleague, Alex Mayer, who like me possessed degrees in CE and EnE but was a faculty member in GE, developed a nondepartmental engineering degree under the College of Engineering bachelor of science in engineering (BSE) program with a concentration in

geoenvironmental engineering. Alex and I were able to arrange a course curriculum based on parts of civil and environmental engineering (soil mechanics, fundamentals of environmental engineering, water chemistry, water treatment, surface water quality) and geological engineering (geology, sedimentology, geophysics, hydrogeology, site investigations, and groundwater engineering) that met ABET and MTU criteria for the BSE degree and it utilized only existing courses and satisfied all of the published prerequisite topics. This program was very popular with these students who could not get into the BSEnE program, and it also drew some students from the BSEnE as well as the BSGE programs. Groundwater consulting firms employed most of the BSE—Geoenvironmental Engineering graduates readily and afterwards asked for more. There were no new classes developed for the BSE-Geoenvironmental Engineering degree, so in some ways the students felt that their disciplinary identity was not as well recognized as their BSEnE and BSGE counterparts. Also, their development of integrated *geo and* environmental skills was no more unique than the BSEnE and BSGE students because there were no practice-oriented courses that made them unique. Developing abilities to synthesize geology, chemistry, geophysics, solid and fluid mechanics with environmental and geological engineering topics was left to their own volition.

There is certainly a professional niche where scientists and engineers with combined strengths in geological and environmental science and engineering can provide more effective analysis of geoenvironmental problems than can teams of different disciplines. That is, despite our admissions and awareness of the importance of each others' disciplines in multidisciplinary problems, we can not regularly integrate our specialized knowledge in a manner as openly as someone trained in multiple disciplines. This niche market is not being addressed directly through new multidisciplinary curricula but rather by modifying existing disciplinary programs (CE, EnE, and GE) to allow for some elective courses from complementary programs. For example, a web search will list many programs where there is a geoenvironmental *option* in civil and environmental engineering programs. Most of these do not include geology beyond the introductory level. Hydrogeology (physical and chemical, subsurface remediation, and geotechnical engineering) are common aspects in these options. Often *geoenvironmental* was listed in conjunction with *geotechnical* as if they were synonymous terms. Likewise there exist geoenvironmental options in geological engineering programs. These options are similar to the BSE-Geoenvironmental Engineering program that we developed here at MTU in that technical electives were drawn from the water treatment, geotechnical engineering, and regulatory aspects of civil and environmental engineering. Also, some included geophysics courses that emphasize shallow applications. There are far fewer GE programs (on the order of 20 in North America) and only a few list a geoenvironmental option. These do lack some basic environmental science and engineering topics, such as water chemistry and microbiology. Titled degrees in Geoenvironmental Science are available from only a few universities, and these emphasize upper division geology courses that pertain to hydrogeology and geologic hazards.

Do these options address the need to couple “geo” and “environmental” science and engineering skills to address geoenvironmental problems? I don't know. The demand for geoenvironmental scientists and engineers is probably too small to warrant a separate degree, although there would be advantages for an integrated multidisciplinary degree. As a footnote, the BSE-Geoenvironmental Engineering program here at MTU was closed solely because of the burden of assessing the program for meeting ABET2000 Criteria. Enrollments were too low to justify the added effort.

Perspectives on Emerging Geoenvironmental Issues and Technologies

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A primary geoenvironmental issue is the inability to characterize geoenvironmental systems adequately for utilizing predictive tools to evaluate alternatives and forecast events. An important feature of geoenvironmental problems that makes predictions so difficult is that the size of the areas of interest are too large to characterize hydraulically, mechanically, chemically, etc. at sufficient resolution to account for the predominant phenomena. For example, a primary obstacle in forecasting landslides and debris flows is the inability to adequately characterize unconsolidated deposits, such as ash, in terms of their facies geometry and orientation and mechanical strength. Yet the onset of a landslide event is subject to localized weaknesses prone to failure. The effectiveness of *in situ* remediation of subsurface contamination by any treatment agent is affected by the hydraulic properties and to varying degrees the chemical and microbiological conditions. Incomplete and inaccurate characterization of hydraulic properties of subsurface materials is probably the most important limitation to predicting chemical transport and remediation. For many contaminants the geochemical (and biochemical) conditions are also critical. Naturally occurring substances like arsenic and uranium are affected by the presence of tens to hundreds of other naturally occurring substances, all of which are impractical to quantify in every sample. Sanitary engineers realized early on the dilemma posed by dealing with a substance comprised of too many constituents to account for (sewage) and developed an empirical measure (biochemical oxygen demand, BOD) that represents the effects of wastewater in terms of the oxygen consumed. Analogous ways to represent geochemical conditions are needed for contamination characterization and monitoring. Technologies are needed to comprehensively and accurately characterize and monitor important subsurface conditions and properties. Advancements in geophysical techniques, their applications to the shallow subsurface, and the processing of geophysical survey data will be important for more comprehensive characterization. Studies are needed to ascertain the representativeness and transferability of geophysical measurements. Geographical information systems (GIS) is an important component of many geoenvironmental problems, ranging from plume transport to natural hazard modeling. Model interfaces should include the ability to exchange information with GIS tools. Characterization and monitoring data should be archived in a GIS format so that it can readily be utilized in modeling activities.

In situ remediation techniques (advanced oxidation and reductive dechlorination) that can broadly destroy low levels of contamination are promising approaches. Many of the more aggressive enhanced flushing techniques are still unable to achieve cleanup objectives. Although enhanced flushing might be quite effective at removing over half but usually less than 90% of the contamination, the residual continues to pose a threat to water quality. Contamination left behind after flushing is difficult to target because it is dispersed and relatively less accessible than the contamination that was removed. Optimal strategies may need to be employed in phases where the readily “removable” fraction is first removed using a flushing technique and then followed up by a long-term, low-level *in situ* destruction technique, preferably by adapting the existing system. Before gaining wider acceptance, more information is needed for *in situ* destruction techniques on their effectiveness, in terms of both the extent and the rates of reactions, the effects of natural constituents that scavenge reactants, and the reaction products.