WHITE PAPER

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

<u>Current projects</u>:
1) Long-Term Performance of GCLs Permeated with Aqueous Inorganic Solutions
2) Assessing the Use of Geosynthetic Clay Liners (GCLs) for Animal Waste Containment Lagoons
3) Membrane Behavior of Clay Soil Barrier Materials
4) Complex Chemical Mixtures - Environmental Transport and Fate
5) Metal Removal Capabilities of Passive Bioreactor Systems: Effects of Organic Matter and Microbial Population Dynamics
6) Evaluation of Hydrologic Models for Alternative Covers at Mine Waste Sites

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

<u>Formal courses at CSU</u>

CE 754	Special Topics: Geotechnics of Unsaturated Soils	1998	Spring
CE 558	Containment Systems for Waste Disposal	2000	Fall
		2001	Fall
CE 658	Remediation Systems for Subsurface Contamination	1998	Spring
		2002	Spring

<u>Professional Short Courses</u>

- *Liners and Covers for Waste Containment Facilities*, sponsored by ASCE Geo-Institute, (with Craig Benson, David Daniel, and Majdi Othman):
  Nov. 14-16, 2001, Atlanta, GA
  Nov. 6-8, 2000, Los Angeles, CA
  Nov. 8-10, 1999, Denver, CO
  Oct. 26-28, 1998, Rosemont, IL
- *Unsaturated Soils in Engineering Practice*, sponsored by ASCE Geo-Institute, Aug. 4, 2000, Denver, CO (with Craig Benson, Delwyn Fredlund, Sandra Houston, Fernando Marinho, and Ward Wilson).

Geoenvironmental Consulting Experience (list major projects only)**:**

- Large-scale block sample permeability testing for three compacted clay liner test pads at the Rocky Mountain National Arsenal (for Foster Wheeler Environmental Corporation, Rocky Mountain Arsenal, Commerce City, CO; Sept. 2001-March 2002).
- Evaluation of the potential effects of revised process water/leachate characteristics on the hydraulic conductivity of GCLs used for base liner at the Tailings Management Area (TMA) for the proposed Nicolet Mining Company's zinc/copper mine located near Crandon, Wisconsin (for Foth & Van Dyke, Green Bay, WI; October-November 2001).
- Technical consultant on the Tri-State permitting project (for GeoTrans, Inc., Westminster, CO; June 2001).
- Technical consultant on clay liner to leachate compatibility testing program for the enhanced hazardous waste landfill at the Rocky Mountain National Arsenal (for GeoTrans, Inc., Westminster, CO; June 2001).
- Large-scale hydraulic conductivity testing of conglomerate bedrock samples for the High Savery Dam Project in Wyoming (for Hollingsworth & Assoc., Inc., Sheridan, CO; April and December 2000).
- Served as member of 5-year review panel for evaluation of solidification and cover system remedy at the Shattuck Chemical Superfund Site in Denver (for S. Cohen and Associates, Inc., McLean, VA; June-November 1999)
- Provided technical expertise in support of the GCL compatibility testing for base liner at the tailings management area for the proposed Nicolet Mining Company (NMC) zinc/copper mine located near Crandon, Wisconsin (for Foth & Van Dyke, Green Bay, WI: March-April, 1999).
- Provided report on results of the testing of two soils being considered for use in the evaporation ponds at the Truba City, AZ, Uranium Mill Tailings Remedial Action disposal site as part of the groundwater remediation program (for MACTEC-ERS, 2597 B3/4 Rd., Grand Junction, CO, March-April, 1999).
- Provided technical expertise for field and laboratory determination of infiltration model parameters for Arroyo Pasajero Flood Area (for Shepherd Miller, Inc., Fort Collins, CO; Feb. 1998-Aug. 1998).
- Provided technical review comments on Bozeman Superfund Solvent Site study (for Flow Technology, Bozeman, MT; April, 1998).
- GCL compatibility testing for base liner at the tailings management area for the proposed Nicolet Mining Company (NMC) zinc/copper mine located near Crandon, Wisconsin (for Foth & Van Dyke, Green Bay, WI: Dec. 1997-April 1998).

Appraisal of Geoenvironmental Research, Education and Practice (limit to 1-2 pages)**:**

An appraisal of geoenvironmental research, education, and practice is difficult because the term "geoenvironmental" is loosely defined and poorly understood. As a result, geoenvironmental research, education, and practice suffer an identity crisis that must be formally resolved before the discipline can gain universal acceptance.

For example, the terms "environmental geotechnics" and "geoenvironmental engineering" are often used interchangeably, implying that both terms have the same definition, and include the same activities. However, in my opinion, these two terms represent different areas of research, education, and practice. The term "geoenvironmental engineering" is more broad-based and reflects the multidisciplinary aspects of soil-environmental problems from an engineering perspective, whereas the term "environmental geotechnics" is more specific and refers primarily to those aspects of soil-environmental problems from the perspective of geotechnical engineering.

For example, many professionals such as hydrogeologists, groundwater engineers, environmental engineers, geotechnical engineers, and others, may be involved with problems related to subsurface pollution. However, each of these professionals probably will be involved in different aspects of a specific problem, such as contaminant migration (hydrogeologist), well-head protection (groundwater engineer), chemical and physical treatment of waste streams (environmental engineers), and design and construction of waste containment facilities (geotechnical engineers). From a broad or multidisciplinary perspective, each of these individuals is a "geoenvironmental engineer or scientist" because each individual is dealing with some aspect of subsurface pollution. However, the expertise of each individual within the general field of "geoenvironmental engineering and science" obviously is not the same.

At the same time, each individual in this multidisciplinary viewpoint may have been formally educated in a different field. For example, a hydrogeologist is a geologist who specializes in the origin, age, and movement of subsurface water. This specialization distinguishes the hydrogeologist from other geologists who have essentially the same basic education in geology, but may have a more in-depth knowledge of some other aspect of geology, such as geomorphology. Therefore, hydrogeology refers to a sub-discipline of geology. In a similar manner, groundwater engineers deal with problems not related to the environment (e.g., well hydraulics and aquifer production), environmental engineering includes many other environmental topics not related to soils (e.g., air pollution, surface water pollution, design of sanitary treatment facilities, etc.), and geotechnical engineering encompasses many other diverse areas related to the design and construction of civil works (e.g., shallow and deep foundations, soil dynamics, slope stability analyses, and earth retaining structures).

From the perspective of geotechnical engineering, a geotechnical engineer whose primary responsibility is the design and construction of foundations may be considered to be a "foundation engineer". In a similar manner, a geotechnical engineer whose primary responsibility pertains to design and construction of clay liners and covers for waste disposal may be associated with a sub-discipline of "environmental geotechnics". While each individual within geotechnical engineering is a geotechnical engineer and, therefore, is educated to some minimum level in the essential subjects associated with geotechnical engineering, the expertise of each geotechnical engineer is not the same. Therefore, from the perspective of geotechnical engineering, the sub-discipline of geotechnical engineering whose primary focus relates to environmental issues is referred to as "environmental geotechnics".

Since Nature knows no bounds, the solution to most environmental problems will require the expertise of numerous geoenvironmental professionals. As a result, geoenvironmental engineering and science truly is a multidisciplinary profession. However, based on the above discussion, there may be a perception that the specializations of individuals who work in geoenvironmental engineering and science are the sole domain of those individuals. On the contrary, all geoenvironmental engineers and scientists should work to achieve a minimum level of knowledge in as many of the other specialized areas in geoenvironmental engineering and science as possible. The attainment of this breadth of knowledge will help to provide for the effective technical interaction between professionals, which is required for successful completion of geoenvironmental projects in a multidisciplinary setting. For example, individuals who are considered to be specialists in environmental geotechnics not only should possess the minimum level of knowledge which characterizes a geotechnical engineer but also should possess a minimum level of knowledge to effectively interact with hydrogeologists, groundwater engineers, environmental engineers, etc. The attainment of this knowledge will require the learning of subjects that generally are considered outside the scope of geotechnical engineering, such as contaminant transport, soil chemistry, and aqueous chemistry.

Why is the need for consistent terminology so important? One answer is that failure to have a clear and consistent terminology that immediately identifies one's research, education, and practice activities can result in misunderstanding that can lead to unwise or incorrect policy decisions. For example, the change in the name of ASCE's *Journal of Geotechnical Engineering* to the *Journal of Geotechnical and Geoenvironmental Engineering* in 1997 has often been criticized by those who opposed the change (and still do) on the basis that the name of journal should not include a sub-discipline of geotechnical engineering. They also argue that the name change has made the journal more specialized. However, as defined above, "environmental geotechnics" is the sub-discipline of geotechnical engineering, not "geoenvironmental engineering". As a result, the name change actually has expanded the scope of the journal, rather than made the journal more specialized.

Another example relates to the research funding. Based on the aforementioned definitions for "environmental geotechnics" and "geoenvironmental engineering", I would characterize the current funding available for geoenvironmental research as abundant, whereas the current funding available for research in environmental geotechnics is significantly more limited. For example, half of my current six research projects involve co-investigators from several other different disciplines, such as environmental engineering, chemical engineering, and chemistry and geo-chemistry, and two of the remaining three projects involve a co-investigator who also performs geoenvironmental research.

In summary, an individual whose primary education is that of a geotechnical engineer but who specializes in the solution to environmental problems related to soils may be identified from the perspective of the geotechnical engineering community as specializing in the area of "environmental geotechnics". At the same time, the same individual may be identified as a "geoenvironmental engineer" from the perspective of any other professional whose primary education is in a discipline other than geotechnical engineering, but who also specializes in the solution to environmental problems related to soils (e.g., hydrogeologist, groundwater engineer, environmental engineer, etc.). However, a "geoenvironmental engineer or scientist" whose primary formal education is not in geotechnical engineering would not be considered to work in the area of "environmental geotechnics". The adoption of these terms and the associated meanings described herein may help to alleviate the dilemma in terminology currently prevalent not only within geotechnical engineering but also within geoenvironmental engineering and science.

Perspective on Emerging Geoenvironmental Issues and Technologies (limit to 1-2 pages)**:**

Some of the emerging issues and technologies for geoenvironmental research:

- Sustainable containment systems (long-term containment)
- Non-landfill containment applications (e.g., CAFOs)
- Mobility and fate of unusual potential contaminants (e.g., priones and antibiotics)
- Verification/validation of models (e.g., dual-porosity models, hydrologic models for covers).
- Development of more usable modeling approaches (e.g., lumping).