The U.S. Educational Effort in Unsaturated Zone Hydrology

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The region of the earth below the land surface and above the water-saturated zone plays a major role in determining the behavior of hydrologic systems. To help educators and other interested individuals evaluate and continue molding the U.S. educational effort in the hydrology of the unsaturated zone, the AGU Hydrology Section Committee on Water in the Unsaturated Zone conducted a study of the number and level of university educational programs involved in unsaturated zone hydrology.

The basis for this report was the questionnaire shown here as Figure 1. A total of 189 questionnaires were sent to departments in schools of engineering, earth science, and agriculture. Nine of the 114 returns were rejected because of mistakes or duplication. The remaining 105 could be divided almost half and half into those from departments in schools of engineering and schools of earth science (58) and those from schools of agriculture (47).

The majority of respondents indicated their belief that unsaturated zone hydrology was covered adequately in their departments, but there is more question about this in schools of engineering and earth science than in schools of agriculture. Most engineers and geologists responding to the questionnaire indicated orimplied that unsaturated zone hydrology was too specialized a subject area to receive much attention at the undergraduate or master's degree level; the subject was considered to be oriented more toward science than toward engineering.

Given the present state of knowledge in unsaturated zone hydrology, it is very difficult to make reliable practical applications to engineering and earth science problems, which tend to involve large, highly heterogeneous areas. (However, it should be noted that

Under the four categories described below, please list the title, symbol, and credits (Q = quarter, S = semester) of relevant courses offered by your department. Indicate also whether the course is undergraduate (U), graduate (G), or both (UG) and whether it is primarily a lecture (L), a lab (LA), a lecture with a lab (LL), a seminar (S), or a reading (R) course. A typical answer to questions 1–4 would be Engineering Hydrology, CE 315, 4Q, U, L.

1. Courses in which more than 80% of the course content is in the area of unsaturated zone hydrology.*
2. Courses in which 50–80% of the course content is in the area of unsaturated zone hydrology.
3. Courses in which 20–50% of the course content is in the area of unsaturated zone hydrology.
4. Courses in which 5–20% of the course content is in the area of unsaturated zone hydrology.
5. In your opinion, is unsaturated zone hydrology covered adequately in your department?

   Yes_____ No_____ If no, why?_____

*For the purpose of this questionnaire we define unsaturated zone hydrology as that science which deals with the occurrence and movement of water below the surface of the earth and above the saturated zone.

Fig. 1. Questionnaire concerning U.S. university education in unsaturated zone hydrology. The questionnaire was answered almost entirely by teaching faculty as opposed to administrators.

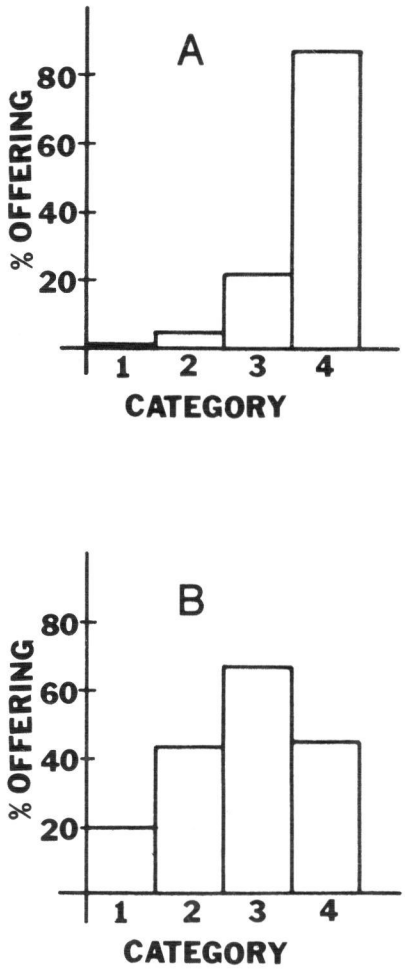

Fig. 2. Bar graphs indicating the percentage of respondents offering courses in each of the four categories listed in Figure 1. Graph A applies to schools of engineering and earth science, while graph B applies to schools of agriculture.

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existing problems demand that such applications be made.) More successful routine application has been made to agricultural scale problems, which deal directly with phenomena such as plant growth, water transport, and biological activity in the unsaturated zone. Undoubtedly, this has contributed to the present concentration of unsaturated zone hydrology courses in schools of agriculture and explains at least in part the fact that most such courses are offered beyond the introductory level only in schools of agriculture. Thus the question of whether we are training the types of people who can tackle our unsolved engineering and earth science unsaturated zone problems arises. Although many courses exist in schools of agriculture, are they taken by a sufficient number of nonagricultural students, and do they routinely produce hydrologists who are oriented toward engineering and earth science problems?

Although practically all departments provide introductory courses in unsaturated zone hydrology, 11 of 58 engineering or earth science respondents (half of the 22 who stated reasons for their dissatisfaction) believed that there was a lack of faculty strength and/or interest in unsaturated zone hydrology at their institutions. This suggests that in some departments a self-perpetuating situation may exist in which faculty untrained or uninterested in the unsaturated zone produces untrained or uninterested students. The information compiled from the completed questionnaires may be useful to these departments and to others for advising students and/or recruiting faculty.

Figure 2 is a bar graph indicating the percentage of departments offering one or more courses in each of the four categories listed in Figure 1. Figure 3 gives the number of course offerings per department. The ratio of undergraduate to undergraduate and graduate to graduate courses was 1 : 1.23 : 1.92 for schools of engineering and earth science and 1 : 1.68 : 1.68 for schools of agriculture. Thus most of the unsaturated zone courses in both engineering and agriculture tend to be aimed at advanced undergraduate and graduate students.

The difference in the results lies in the emphasis placed on the subject within the course itself (Figure 2). With a few exceptions, departments in the schools of engineering and earth science tend to devote only 5–20% of the course content to unsaturated zone hydrology (category 4). Some course titles are Surface Hydrology, Subsurface Hydrology, Hydrologic Transport Processes, Engineering Geology, Flow Through Porous Media, Water Resources Engineering, Hydrogeology, Groundwater and Seepage, Water Resources Systems, Water Resources Planning, Fluvial Geomorphology, Environmental Engineering, and Environmental Geology. Such courses touch upon unsaturated zone processes but do not present an in-depth study. Concepts briefly introduced are those related to water content, infiltration rate, water retention, evapotranspiration, and, possibly, unsaturated hydraulic conductivity.

In contrast, departments in schools of agriculture offer many courses devoted largely (>50%) to the unsaturated zone. Typical titles are Soil Physics, Soil-Plant Relations, Soil Science, Unsaturated Flow, Crop and Soil Science, Physical Environment of Crops and Soils, Physics of Soil-Water-Plant Relations, Water Status in Plants and Soils, Fluid Mechanics of Porous Media, and Drainage Engineering. It is not clear from the responses received how well the topics presented are aimed at the solution of general hydrologic rather than agricultural problems. For the most part these offerings appear to be classical soil physics courses, sometimes extended to include the plant and/or special engineering considerations such as drainage. These data suggest that even at the graduate level, students in many civil engineering or geology programs are unlikely to have an opportunity to study unsaturated zone hydrology unless they are able to take relevant courses in a school of agriculture or to undertake a directed reading program.

Another difference between schools of engineering and schools of agriculture is the amount of laboratory experience available to the student. Of 103 courses offered by schools of agriculture, 54 were lecture courses,

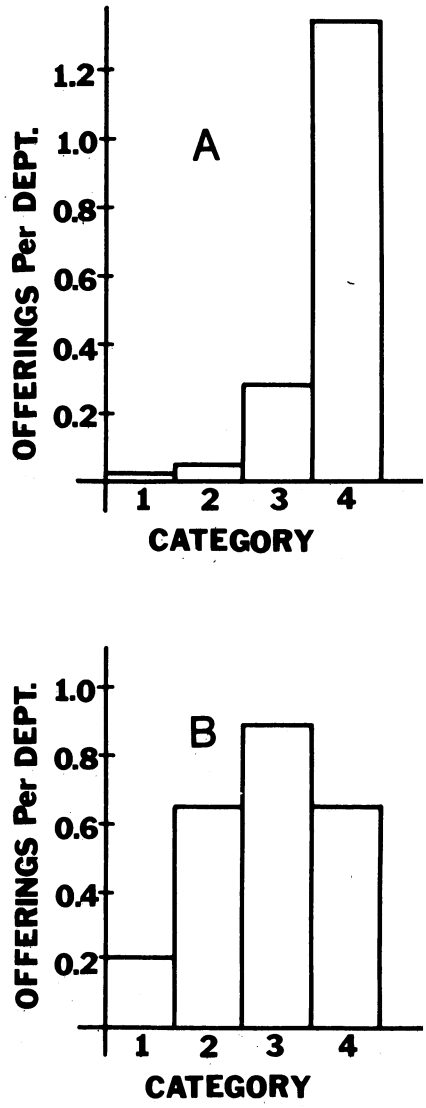

Fig. 3. Bar graphs showing the number of course offerings per department in each of the four categories listed in Figure 1 (i.e., the total number of courses in a given category divided by the number of respondents). Graph A is for schools of engineering and earth science, while graph B is for schools of agriculture.

45 were lectures with a laboratory, 3 were seminars, and 1 was a reading course. Of 101 courses offered by schools of engineering and earth science, 83 were lectures, only 14 were lectures with a lab, 3 were seminars, and 1 was a reading course. This indicates that most engineers and geologists receive little laboratory exposure to unsaturated zone phenomena, at least in courses within their own disciplines.

On the whole, departments seemed to be satisfied with their existing curriculum. Of the 47 respondents from

schools of agriculture, 74.5% thought that their present instructional programs in unsaturated zone hydrology were adequate, and 25.5% thought them inadequate. The comments listed were offered by at least one respondent. If more than one respondent listed a particular comment, the number is noted in parentheses. Those who were dissatisfied found their programs lacking in

- student interest
- laboratory exposure
- faculty strength and/or interest (2 respondents)
- number of required courses as compared to electives (2 respondents)
- emphasis on plant-soil-water relationships (2 respondents)
- number of courses (3 respondents)
- emphasis on solutions to unsaturated flow equations
- emphasis on plant growth and solute transport (2 respondents)

Several also felt that the existing courses at their institutions failed to integrate plant water transport and solute transport into the more classical soil physics framework.

Of the 58 respondents from schools of engineering and earth science, 66% indicated that they were satisfied with current programs, and 34% indicated dissatisfaction. It was common for a respondent to state that he was satisfied with the emphasis placed on unsaturated zone hydrology only in his particular curriculum, indicating that he was aware of the broader nature of the field but thought that most of it was too specialized for civil engineering or geology. Respondents felt that the educational emphasis placed on unsaturated zone phenomena was insufficient with respect to

- faculty strength and/or interest (11 respondents)
- attention to subject in program (3 respondents)
- availability of simple text material (since current research is highly specialized)
- student interest (3 respondents)
- coverage of plant-water relationships
- time to cover material
- departmental resources

A summary of the data from the survey reported here is available from the authors on request. Comments concerning any aspect of this report are also invited.

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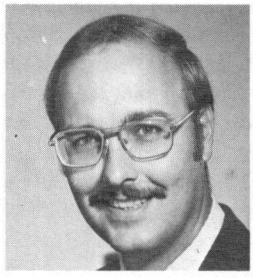

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