Hydrogeology Lessons and Exercises for Introductory Physical-Geology Students

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ABSTRACT

Several lessons and exercises in applied hydrogeology were developed for an undergraduate physical-geology course. Designed for self-paced learning, the instruction module emphasizes fundamental principles which govern the occurrence and movement of groundwater and its constituents. Students learn how to apply these principles to typical groundwater problems. In completing the exercises, students utilize contouring skills and develop new skills that they can apply in other science and math courses. The module also illustrates the capabilities of modern personal computers for solving groundwater-flow problems.

Keywords: Education – computer assisted; engineering and environmental geology; geology – teaching and curriculum; hydrogeology and hydrology.

Introduction

Hydrogeology, the study of groundwater, continues to be the fastest growing branch of geology (Fetter, 1994). Despite its significance, most introductory physical-geology courses do not adequately address the subject of hydrogeology (Farvolden and Cherry, 1991). Furthermore, the subject is not taught in a format that allows students to solve groundwater problems. As a result, most do not learn to appreciate the relevance of the groundwater principles taught in lecture. A lack of instruction in hydrogeology is problematic because (1) groundwater contamination is a major environmental problem on a global scale, and (2) an inadequate emphasis in hydrogeology precludes a comprehensive education in the broader subject of physical geology.

To address this problem, the author has developed a module of hydrogeology lessons and exercises for an introductory physical-geology course. The primary objective was to teach the basic principles that govern the movement of groundwater and its chemical constituents. A secondary objective was to show the computational utility of modern personal computers for hydrogeology problems.

Background

Tinker (1989) has convincingly demonstrated a need for advanced courses in physical and chemical hydrogeology in undergraduate geology departments. From such courses, students can acquire skills that prepare them for graduate school or environmental consulting. For example, Smith (1986) developed

exercises in which students estimate aquifer parameters from pump-test data.

There are relatively few published examples of hydrogeology lessons and exercises in introductory geology courses. Tinker (1982) described an exercise in which students apply a numerical rating scheme to estimate the groundwater-contamination potential of surface impoundments. The students consider such factors as thickness of the unsaturated zone, type of material in the saturated zone, and anticipated groundwater-flow direction (inferred from topography). Ousey (1986) showed the utility of personal computers for modeling groundwater flow with spreadsheets. Participants studied the effects of single or multiple pumping wells in simple aquifers by hand-contouring numerical output.

The introductory module described in this paper teaches basic skills for evaluating groundwater-flow fields. Participants learn how to interpret water-table measurements and apply simple equations that govern flow. They also use the display capabilities of modern personal computers. A self-paced format was used to encourage creative problem solving. Jones (1980) taught an entire introductory geology course in a self-paced format and found no significant differences in apparent scholastic ability, exam results, or level of course satisfaction between self-paced and lecture versions of the course.

Module Description

Written lessons and exercises were distributed to approximately 150 students enrolled in an introductory physical-geology course. They were instructed to read the lessons and complete the exercises within a prescribed time frame. The lessons were organized as follows:

1. **Groundwater Flow:** origin and distribution of groundwater; confined and unconfined aquifers; variables (hydraulic head, hydraulic conductivity, and effective porosity) which control groundwater flow; calculating groundwater discharge and velocity; conceptualizing groundwater systems with flow nets.
2. **Groundwater Contamination:** expressing solute concentrations in groundwater; water quality standards; groundwater monitoring wells and sampling procedures; sources of groundwater contamination; contaminant transport in groundwater.
3. **Managing Groundwater Pollution:** source control and groundwater remediation methods.

The accompanying exercises were designed to show the relevance of principles described in the written lessons. The exercises included:

- **1. Analyzing a Groundwater-Flow Field:** drawing a water-table contour map from water-level data; constructing groundwater-flow nets; identifying recharge and discharge areas on flow nets; calculating hydraulic gradient and groundwater velocity.
- **2. Analyzing a Groundwater Contamination Problem:** constructing contaminant concentration contours from water quality data; inferring locations of probable contamination sources; predicting the growth of a contaminant plume.
- **3. Computer Particle Tracking:** deriving, displaying and interpreting hydraulic-head contours and flow paths for ambient and artificially stressed groundwater systems; tracking flow paths upgradient from recovery wells; downgradient tracking from potential sources of contamination.

Each exercise required utilization of principles covered in a preceding lesson. Monitoring-well data from a gasoline service station in Fort Worth, Texas were used in exercise 2. The data were obtained from a regional office of the Texas Water Commission. In completing the module, the students used contouring skills that they had acquired earlier in the course. The *QuickFlow*^{TM} (Rumbaugh, 1991) computer model was used in exercise 3. Using an interactive graphical menu, the students specified aquifer properties and pumping configurations. The software program displayed hydraulic-head contours and groundwater-flow paths (Figure 1), allowing students to visualize how the system responded to different pumping stresses.

The "capture zone" is a key concept that was conveyed in exercise 3. It defines the part of an aquifer that contributes water to a well. For various pumping configurations, students were asked to view the resulting flow field and outline capture zones (for single wells or groups of wells). In so doing, they employed the technique of reverse particle tracking, in which path lines are traced upgradient from their points of termination. Forward tracking, the tracing of flow paths in a downgradient direction, was used to choose between alternative landfill sites. For the latter problem, students were instructed to assume that the points of extraction were water-supply wells.

Discussion and Conclusions

An evaluation form was distributed to students who participated in the project. Their written feedback and completed exercises were used to evaluate the instruction module. The major findings are: (1) a lesson and exercise format is more effective than conventional lectures in fostering comprehension of the subject matter, (2) strategically paired lectures and exercises show the relevance of key concepts, (3) a self-paced learning format circumvents the need for several lectures to teach the subject, (4) computer-displayed flow nets help students understand how

Figure 1. Flow field induced by recovery wells (crossed circles) and injection trench (bold); contours in feet above mean sea level (1 foot = 0.31 meters).

groundwater moves under complex scenarios, and (5) using data from local groundwater-contamination problems can foster an appreciation of the relevance of key principles.

The groundwater module is most appropriate for the middle or latter half of an introductory physical-geology course. It should be administered after the students have studied rock structure, topographic maps, and the hydrologic cycle. In completing the module, students utilize and develop skills (for example, calculating gradient and velocity, expressing chemical concentrations, contouring) that they can apply in math, geology, and other science courses.

The module is an effective educational tool for introductory physical-geology courses. It fosters an understanding of basic principles of applied hydrogeology. By applying these principles to realistic exercises, students develop practical analytical skills. Problems to which these skills are applicable include evaluating groundwater remediation and siting contaminant repositories. The module also illustrates problem-solving capabilities of modern personal computers.

The module will be sent to readers who write to the author requesting copies. (Enclose a 9 x 12 SASE, please.)

References Cited

- Fetter, C.W., 1994, *Applied Hydrogeology*: New York, MacMillan, 691 p.
- Farvolden, R.N., and Cherry, J.A., 1991, Are geology departments prepared for the 21st century? *Geology*, v. 19, n. 5, p. 419.
- Jones, N.W., 1980, A comparison between lecture and self-paced general geology: *Journal of Geological Education*, v. 28, p. 235-237.

- Ousey, J.R. Jr., 1986, Modeling steady state groundwater flow: *Journal of Geological Education*, v. 34, p. 305-311.
- Rumbaugh, J.O., 1991, QuickFlow Analytical Groundwater Flow Model: Reston, Geraghty and Miller.
- Smith, S.M., 1986, Software for evaluating pumping tests: *Journal of Geological Education*, v. 34, p. 183-185.
- Tinker, J.R. Jr., 1982, An exercise in evaluating the contamination potential of surface impoundments: *Journal of Geological Education*, v. 30, p. 153-155.
- Tinker, J.R. Jr., 1989, Undergraduate education in hydrogeology: *Journal of Geological Education*, v. 37, p. 20-23.

About the Author

Paul F. Hudak is an assistant professor in the Department of Geography at the University of North Texas. He received a BS and MS in geology from Allegheny College and Wright State University, respectively, and a PhD in geography from the University of California, Santa Barbara. His current research interests include groundwater modeling and remediation.