Doing a Dirty Job—The Old-Fashioned Way

Earthquakes, dam collapses, toxic wastes—they're analyzed by outdated methods, partly because of technical conservatism

THE RESERVOIR BEHIND A NEWLY BUILT dam in Idaho is filled for the first time—and the dam collapses due to soil erosion engineers hadn't predicted. At Love Canal, investigators drill well after well in an effort to evaluate ground-water pollution—but completely miss the high concentrations of contaminant.

Why should blunders like this occur? After all, the engineers who evaluate soils aren't stupid. The problem is that in many cases they're relying on horse-and-buggy methods of analyzing soils. An example: the "blow-count" technique, which estimates soil properties based on the number of blows needed to drive a rod or hollow tube into the ground.

It's not that more sophisticated methods don't exist—in fact, some have been around for 20 years. But the practitioners who work in the field are slow to change—a conservatism due partly to fear of legal liability and partly to a lack of communication among the practitioners. As a result, says Gary Olhoeft, a geophysicist with the U.S. Geological Survey, "there is a great difference between the state of the art and the state of the practice."

In an effort to bring art and practice closer, chemical engineer Ben McCoy and civil engineer Kandiah Arulanandan, of the University of California at Davis, recently convened a workshop* at which developers and users of new soil evaluation methods compared results and discussed how to get their techniques into more general use.

At the workshop, Arulanandan pointed out that the resistance to new methods can be costly. For example, relying on predictions made by the blow-count method, the state of Wyoming recently spent $82 million to strengthen Jackson Lake Dam against the possibility of soil liquefaction in an earthquake—even though newer in situ and laboratory tests suggested liquefaction would not be a problem.

"They should have done more tests, rather than just relying on the blow count," says Arulanandan. The blow-count method is too conservative, he argues, and if it is used at dams across the nation, it will lead to the expenditure of billions of dollars, in many cases unnecessarily. "We have to [find] methods that will let us economically *and* safely build dams," he says.

What is needed in such cases are noninvasive means of "seeing" into the subsoil and evaluating the chemical and physical properties that bear on the problem. An example is an electromagnetic profiling technique that finally found the toxic plume at Love Canal. And that isn't the only one now available. Participants at the Davis workshop heard about several more that could fill the bill.

One such method, presented by Arulanandan and several former students, uses measurements of electrical conductivity and dielectric constant taken at the surface to identify the types of subsurface soil as well as the size, shape, and density of the soil's particles and pores. Those factors influence a range of soil behaviors, from performance in an earthquake to the capacity for conducting toxic contaminants.

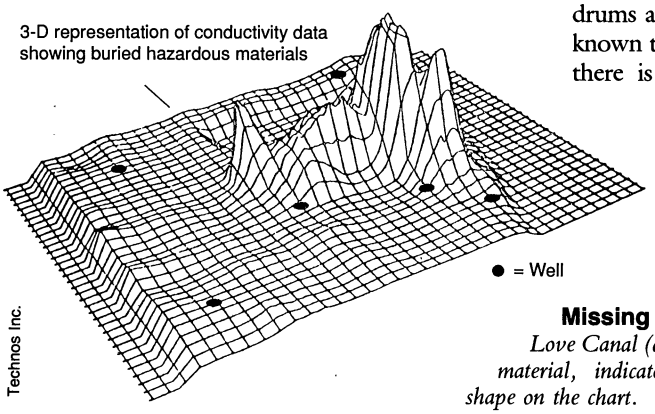
In studies made in China and the United States, Arulanandan and his colleagues have shown that their electrical method can accurately predict which soils will liquefy in a strong earthquake. By comparison, at the same sites, the blow count was too conservative, often predicting liquefaction where it did not occur.

Similar electrical measurements at lower frequencies can be used to follow plumes of toxic substances fanning out from leaky dump sites. USGS's Olhoeft showed that organic chemicals flowing through the soil change its electrical resistivity in characteristic ways that can be measured at the surface. Olhoeft has demonstrated the technique's ability to locate underground leaks of toluene, a common industrial solvent and component of gasoline.

Kenneth Stokoe, a geotechnical engineer from the University of Texas, Austin, presented a method called spectral analysis of surface waves. The technique uses seismic waves generated and detected at the ground's surface to provide information about the stiffness of subsurface soil layers. Although the method was developed for investigating the soils under pavements, in 1988 Stokoe used it at a landslide site in northern Italy's Valtellina Valley.

The Italian government was concerned that the material might slide again, but Stokoe's results suggested it was dense enough to present little hazard. Stokoe and his colleagues have been developing the technique for more than 10 years and using it with confidence in soils for 3 or 4. Yet, because of the conservatism inherent in this field, Stokoe expects it will take many years for the method to be widely accepted.

The same is true for another method: ground-penetrating radar. According to geotechnical engineer James Shinn, of Applied Research Associates in Vermont, that technique offers a means of visualizing cavities and weaknesses in the soil, as well as buried objects—such as pipes and drums at sites where toxic waste is known to be present. But although there is a huge literature on the technique, it is not yet widely used.



Missing the boat. *Six wells drilled at Love Canal (dark spots) failed to detect toxic material, indicated by the three-dimensional shape on the chart.*

One of the main reasons engineers move slowly in adopting new techniques is the legal and financial liability inherent in their profession. Using an evaluation procedure before it is adequately proven, says civil engineer Geoffrey Martin of the University of Southern California, would be analogous to a doctor's prescribing a new medication before it has been shown to be effective. If an evaluation proves to be wrong, the first question the engineer will be asked on the witness stand is whether he used a common-

*"Site Characterization for the Reduction of Disasters' Toll," a workshop sponsored by the Environmental Protection Agency and the National Science Foundation, and held at the University of California at Davis on 12 and 13 July.

ly accepted method. "The implications of what we do are so large," says Ronald Scott, a civil engineer from the California Institute of Technology, adding: "The potential for disaster, dam failures and so on, [is] the reason for the conservatism."

There is also another reason the newer, more sophisticated methods don't win immediate acceptance: barriers to communication between members of different disciplines. Soil scientists and hydrologists working on toxic wastes may be intimidated by geophysical techniques they don't understand and may not read broadly enough outside their area to be aware the techniques exist, says Olhoeft. His point was underscored by the fact that few participants in the workshop knew of an "expert system" program for personal computers, designed and published in 1988 by Olhoeft, that asks questions about the site to be investigated and then recommends the best evaluation methods for the specific job at hand. Most workshop participants were also unaware of several facilities operated by the Environmental Protection Agency and the USGS, where researchers can compare and validate site evaluation techniques.

Part of the communication problem stems from the number of different disciplines that overlap in the area of site evaluation, including geology; geophysics; physics; environmental, civil, chemical and geotechnical engineering; hydrology; and soil science, to name a few. "All [these disciplines] have got to talk to each other about the various methods and philosophies they have, if we are going to come up with unified systems which will be effectively utilized," Arulanandan says.

Arulanandan has another solution to some of the inertia in the field. He would like to see a national committee formed, and perhaps a national research center, to choose and develop the most promising site evaluation methods. This would not only serve to inform disparate disciplines but it would take the pressure off someone using a new technique to show later that it was accepted in the profession. But as a first step in that direction, the workshop provided mixed results. Though the discussion was lively and fruitful among the handful who stayed the 2 days, many other participants turned down the option to listen to perspectives from other fields, attending only the sessions in their own discipline. So the task of improving communication may be a tough one. But unless all those engineers and soil scientists can lay down their differences and establish a new, legally acceptable state of the art, it may be a long time before the blow count yields to methods that are better suited to the 1990s. ■ MARCIA BARINAGA

Academy Dumps on Waste Rules

Figuring out how to store the high-level radioactive waste produced by civilian power reactors may be a relatively straightforward engineering problem, but for policymakers it's a political nightmare. Two and a half years ago, Congress selected Yucca Mountain in Nevada as the site for a long-term disposal facility. But Nevada, which is not keen to house this particular federal project, has so far declined to issue permits for the necessary geological characterization of the proposed site. The result: the project is now stalled. And Nevada's foot-dragging—if a committee of the National Academy of Science is to be believed—is only the first of many problems that will dog the waste disposal program.

On its own initiative, the academy's Radioactive Waste Management Board released a position paper on 17 July describing the government's current process for choosing a disposal site as so "rigid" and "unrealistic" that it could prevent underground disposal of nuclear waste indefinitely. That's because the Department of Energy is presently required by Congress to design a repository that will hold waste securely—regardless of unforeseen problems or developments—for a period of 10,000 years. "It's a demand for scientific certainty without any chance for ongoing evaluation," says board member Glenn Paulson, a hazardous waste expert at the Illinois Institute of Technology. "The current process demands perfect foresight."

In particular, this approach—in which DOE's design must conform to Environmental Protection Agency regulations in order to meet Nuclear Regulatory Commission licensing requirements—assumes that preliminary geological assessments will suffice for the repository's lifetime, precluding the possibility of design changes once construction begins. "[T]his use of geological information—to pretend to be able to make very accurate predictions of long-term site behavior—is scientifically unsound," the academy report states.

Regulators should opt for a more flexible approach to repository design and operation, the report adds. Such a strategy would mean that "we design the best facility we can with our present understanding, so if problems develop we can catch them and fix them," Paulson says. Canada and Sweden now both follow a similar approach, combining the information obtained at each step of the construction process with that taken from other underground construction projects so that engineers can modify the repository design if necessary.

Because the current process of repository licensing is virtually doomed to fail, the report states, federal officials must realize that their choice is not between an "ideal" underground site and a less perfect one, but between storing high-level waste under ground and leaving it in surface storage, where public health risks are much higher.

EPA's waste disposal standards are now under review and open for public comment, so the statement's timing is "fortuitous," says academy board vice-chairman Charles Fairhurst of the University of Minnesota. The report recommends that in setting safety standards EPA use a "dose requirement"—a probabilistic estimate of radiation release—instead of its current qualitative requirement that the repository cause no more than 1000 cancer deaths in the next 10,000 years. In a similar vein, the report calls upon the NRC to consider relaxing its prescriptive design requirements in order to create regulatory space for design changes that might become necessary as construction proceeds.

Such recommendations are "a little naïve and ivory-towerish" because an open-ended design process would probably make the public uncomfortable, says Floyd Galspin, chief of the EPA's waste management standards branch. Although unanticipated problems will probably arise, "that's not a justification for not having goals and criteria from the beginning." Similarly, a DOE official in the civilian waste disposal program said the board is almost "too scientific" in its thinking. "They're challenging the regulatory process, saying that decisions of this sort should be in the hands of scientists and engineers and not in an adjudicatory framework." An NRC spokesperson said relevant officials "haven't read the report" and thus had no response.

Why did the committee feel the need to issue its statement? "My sense is that the board has become increasingly frustrated with the system we have here that almost sets itself up to fail," says Paulson. "We'd like to think that the paralysis in the system has led to such frustration that a call for fresh thinking might find fertile ground."

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