A Futuristic Megalab in Wyoming

Basic research designed to answer environmental health questions is usually conducted in laboratories at the bench. Bench research allows financial investors, scientists, and society to maximize control over experiments, develop experimental procedures, and test hypotheses in a safe and cost-effective manner. However, results of experiments conducted at the bench may not be representative of what happens when the same experiments are repeated on a commercial scale or in the larger and more complex natural environment.

To evaluate how results of laboratory experiments differ from those obtained at a large scale, scientists conduct pilot plant and field tests. Such large-scale tests are expensive, may take years to complete, and are difficult to control. In addition, results are often site specific because of variability in geologic formations and local differences in topography, soils, climate, water, vegetation, and human activity. Regulatory agencies in the United States, therefore, generally require that basic research be field tested at a variety of sites and under different environmental conditions before data are made available to the public.

A Better Way
In 1988 the Colleges of Agriculture and Engineering of the University of Wyoming in Laramie constructed a five-story high Environmental Simulation Laboratory (ESL) with an environmental simulator room that was 20 feet long and 10 feet deep. The ESL was designed to bridge the gap between bench-top scale and field-scale experiments. The size of the ESL enables scientists at the university to place large soil embankments comprised of materials representative of different continental locations entirely within the huge structure. Climatic conditions representative of different locales can still be done then be simulated to evaluate modeling predictions without waiting for the natural extremes in weather that occur at field sites.

The University of Wyoming’s five-story ESL has four major components. First, a large space where soil embankments can be custom designed takes the form of two concrete holding vessels (lysimeters) 7.3 m long x 3.0 m wide x 3.0 m deep. Second, an environmental chamber 3 m high encloses the two lysimeter cells. Air temperature, rainfall, relative humidity, and radiant flux capable of simulating sunlight for growing vegetation are precisely controlled by computer.

The third component of the ESL gives scientists the capability to simulate and measure the water cycle within or over soil embankments. Rainfall simulators are located between the banks of plant grow lights inside the environmental chamber. A two-story high water storage supply and disposal tank are below the lysimeters. Separate drain systems and storage tanks collect rainfall splash from the environmental chamber walls, rainfall runoff from soil embankments, and soil embankment drainage while measuring all runoff by weight and volume. A pump connected to the large storage tank circulates water of definable quality through the environmental chamber as variable streamflow.

The fourth component is a computerized climate modeling program that runs the environmental chamber and a data retrieval system. These programs control the temperature and relative humidity of the environmental chamber, the rate, intensity, and distribution of rainfall, the light to dark cycle of the chamber, and measure, collect, and store all environmental chamber atmosphere and soil embankment data.

Why Now and Why Wyoming?
The ESL arose from concern about maintaining a stable oil supply for the United States in the 1970s and 1980s. Although oil shale rock located in both the eastern and western United States has the potential to supplement petroleum needs, the common method of removing it by extreme heat results in waste products greater than the void left by mining. In addition, this waste may contain environmentally damaging chemicals and may harden like cement when contact with water. The U.S. Department of Energy (DOE) thus initiated a program to investigate safe disposal of waste from the commercial oil shale industry.

An aggressive bench-scale research program was being conducted that proved that the waste material often acted like cement when water was added. It was believed this concretelike material would shed water as surface runoff, or, at best, any water entering a waste pile would move through it very slowly. However, because of the difference in scale between the experiments conducted in laboratories and the reality of large commercial disposal operations, a science review team in 1985 concluded that laboratory experiments should be increased in size. As a result, DOE determined that large-scale disposal of solid wastes should be evaluated by building massive embankments that would be physically stable over geologic time, minimize the release of hazardous chemi-
Storm Clouds Gather

Construction of the ESL began in January 1988. It was tested from July through September. By the first of November, the ESL oil shale waste embankments were constructed as close as possible to those at the Rio Blanco OSL Oil Shale Company site in western Colorado. All Rio Blanco temperature, relative humidity, and sunlight climatic data were physically modeled on an hourly basis. These modeled data were then applied to the atmosphere over the oil shale waste embankments in the ESL 24 hours a day for over 2 years.

Rio Blanco precipitation data were applied as storm events of under four or over four hours’ duration. The rate of falling precipitation was modeled so that the under-four-hour event followed a rainfall distribution like that recorded for western thunderstorms. The over-four-hour event followed a rainfall distribution like that recorded for longer duration frontal storms. The storms were applied on the same date as recorded at Rio Blanco but about a year later in the ESL. Snowpack water entering the embankments was estimated for lysimeters at Rio Blanco in the spring of each year just after the ground thawed. The water content of the embankment in late fall was subtracted from that recorded just after spring thaw, and the total difference was applied as a storm event of over four hours. After simulating the Rio Blanco 24-hour continuous climatic data set for 2 years in the ESL, extreme rainstorm and freezing cycles were applied over the ESL waste embankments. These experiments evaluated change in the rate of water movement through the embankment under different conditions.

Capabilities of the ESL

The ESL can produce rapid changes in temperature and relative humidity over a wide range of temperatures because air is exchanged 40 times per hour while being passed through cooling, heating, and steam-generating cycles. Chamber temperatures can be regulated between -26°C and 48°C. Control becomes more difficult near the temperature extremes.

Lighting provided by 24 metal halide lights produces solar radiant flux up to 53,000 lumens/m² (97 watts/m²) and is between 390 and 700 nm wavelength. The light produced is approximately 80% of natural sunlight. The light quality is proportioned to be adequate for plant growth. Different numbers of lights come on and off to represent sunlight cycles from dawn to dusk.

Rainfall can be produced at rates between 0 and 127 mm/hour. Raindrop size distribution does not change with rainfall intensity, and raindrop velocity is delivered to the surface at approximately 80% of that observed in natural rainstorms. The distribution of raindrop sizes is similar to that of runoff-producing storms in the midwestern United States.

Initial Results

Experiments in the ESL have already shown that results of small-scale simulations in the laboratory are not entirely applicable to the actual environment. For example, the movement and storage of rainwater in waste embankments were different from what was expected based on bench-scale results obtained in 1986. The hard concretelike waste material, mixed with 15% water when it was placed in the lysimeters, absorbed water so fast that it took more than 50 mm/hour of rainfall to cause surface runoff. It appears that the lysimeter waste may transport water about two orders of magnitude faster than what was observed in bench-scale tests.

Even though the ESL simulated transportation behavior of water in the Rio Blanco field site, water entering the oil shale waste embankments at Rio Blanco never traveled deeper than about 1 m. Most of this water came from winter snowpack melt each spring. The Rio Blanco site did not have enough yearly rainfall to sufficiently saturate the embankments. In fact, in one field lysimeter where topsoil was added and planted with vegetation, no snowmelt or rainfall entered the shale waste, and the topsoil was dry by fall after the plants quit growing. These findings suggest other alternatives for keeping water from entering shale waste besides modifying the characteristics of the waste material by mixing the waste with water prior to the placement of disposal piles. It would likely take years to verify how waste shale and water...
I interact deep within disposal piles under dry climatic conditions like those at Rio Blanco.

Using the ESL, University of Wyoming researchers were able to apply wet conditions like those found in the west at higher elevations and in the eastern United States. When a set of constant-rate storm events, with rain falling at more than 65 mm per hour, was applied to the waste embankments, water moved steadily downward, and drainage occurred after several storms. Not surprisingly, freezing of the embankments to about 1 m deep and subsequent thawing greatly increased the rate at which water entered the waste. Surface runoff from storms was much higher when the embankments were frozen.

Samples of the ESL waste embankments showed that waste material strength was less than that found in bench-scale tests of the same material. Water and age had changed the physical characteristics of the original material. The engineering community now has the information needed to help commercial-scale industries design safe oil shale waste disposal piles.

**Future Uses**

The ESL will likely be used in the future to help solve environmental issues of national importance, such as protection and clean-up of surface and groundwater, remediation of contaminated landscapes, disposal of solid and hazardous wastes, and restoration of the biological function of ecosystems such as degraded wetlands. Scientists hope the ESL will provide a focal point for scientists from around the world to work on common environmental problems. The ESL provides a unique opportunity to explore environmental science on a global scale. Access to the ESL will enable innovative technologies developed at the bench to be tested quickly at a reduced cost.

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