planted in the dry saline/clay environment found on mined land at the Navajo Mine in the Four Corners region of New Mexico and the Jim Bridger Mine in Wyoming, have survived better than any existing native plants. Current efforts include the development of optimum cultural practices and machine-harvesting methods for Atriplex seed. Commercial production of large quantities of improved hybrid seed is possible in the near future. A similar project was conducted on prime farmland (rather than on arid desert) at the Burning Star Mine in southwestern Illinois.

Benefits Coal companies, under the exemptions to current regulations allowed in some states, are beginning to use these innovative land reclamation methods. Proposed changes in requirements by the Office of Surface Mining will make these new methods available to all United States' coal firms.

Current estimates indicate that as much as 45 percent of the strippable coal reserves in the midwestern United States lies beneath prime farmland used for crops, areas similar to the OHER test area in southern Illinois. The method prescribed under the Federal performance standards for returning surface-mined land to row crop production is to remove and stockpile the topsoil, segregated by soil horizon, and then replace the horizons in their original order once mining is completed and the overburden is regraded. Not only is this elaborate procedure very expensive, but research shows that it is counterproductive.

The experiments performed at the Burning Star Mine in southern Illinois have so far revealed no difference in crop yield between segregated and mixed soil materials: removing, storing, and replacing the soil horizons did not increase productivity any more than dumping newly dug and mixed soils from the bucket-wheel excavator ("wheelspoil") directly onto previously mined land in a single operation. The ANL land reclamation program has calculated the cost of the latter procedure as $22,700/hectare in 1979, compared to $61,800/hectare for the practices mandated by the Office of Surface Mining.

If the above benefits are extrapolated for 20 years, the present value of the benefit would be $2.3 billion.

The amount of surface-mined coal from western fields was about 200 million tons in 1980 (assume that western coal is mined at a rate of 58,800 tons/hectare). The actual cost of land reclamation at a typical western surface coal mine, the Jim Bridger Mine in Wyoming, is about $54,400/hectare, of which earth-moving costs constitute about 75 percent. The direct-application method would save about one-half of this latter amount or $20,400/hectare. The potential benefits summed over 20 years would have a present value of almost $600 million.

Cheaper land reclamation offers at least two other types of social benefits of enormous significance: (1) the environmental damages avoided, such as habitat destruction, soil erosion, siltation of waterways, and visual degradation, and (2) the improved market position of an abundant domestic resource—coal—in relation to imported oil, and the associated favorable impact on the United States balance of payments and on National Security.

Detection and Measurement of Environmental Effects

Detecting Change Over the Ages The quantitative ratio of one radioactive isotope of an element to another isotope (radioactive or stable) of the same element can be used to date or trace the movement of the material containing those isotopes. The source of the radioactive isotopes may be geologic, continually generated naturally through cosmic-ray activity, or man-made, originating from weapons-test fallout or accidental releases. Many questions can be addressed using isotope ratios; for example, the age of volcanic ash on the ocean bottom, the rate of glacier building, the age of the Antarctic ice, the age and source of the water at the bottom of the ocean, groundwater age and motion, the speed of land erosion, the speed of winds traversing the atmosphere, and the exchange rate from the stratosphere of the Northern hemisphere to that of the Southern, to mention a few.

Two important applications of isotope ratios are the long-range tracing of effluents and establishing a historical baseline for assessing the impact on the world ecosystem of the recent buildup of radioactive and nonradioactive effluents.

History Beginning in the 1950's, the AEC undertook basic research using isotope ratio analysis techniques to understand the long-term dynamics of environmental processes. For example, W. S. Broecker and his colleagues used carbon-14/carbon-12 ($^{14}C/^{12}C$) ratios to estimate that the mean residence time of carbon dioxide in the atmosphere is about 7 years. Bottom water in the Atlantic turns over once in about 500 years and in the Pacific once in about 1000 years.

In 1958 Goldberg suggested the use of ionium/thorium ratios ($^{230}Th/^{232}Th$) to measure the accumulation of deep-sea sediments. A year later, he discovered silicon-32 in marine sponges and, with it, determined the rate of accumulation of silicious deposits. Perhaps his most important discovery, published in 1972, was the use of lead-210 for dating glaciers, currently the most widely used technique for dating recent (i.e., the past 100 years) lake and coastal marine sediments. In 1973 he and his colleagues published on the use of $^{228}Th/^{232}Th$ to show that many, if not most, lake and marine sediments have mixed, indicating a greater than anticipated role of bottom-living organisms in stirring up the bottom. Other OHER contractors have since found "bomb plutonium" 5 to 15 centimeters below the surface of sediments laid down over many