rich in carbon, this line of research is important in understanding how carbon dioxide is being removed from the atmosphere and stored as deposits of organic carbon in the ocean at the edge of the continental shelf.

Present research continues to study the processes that move contaminants in the coastal zone. The scope of studies has been expanded to include the Pacific Ocean off California. Special interest is in those processes that transport materials across the shelf and into deeper waters of the open ocean, where their direct impact with humans and natural coastal systems is minimized.

Benefits This continental-shelf dynamics program benefits many users, including:

- *DOE.* DOE is responsible for cleaning up several sites containing materials associated with earlier nuclear activities through the Formerly Utilized Sites Remedial Action Program. Data developed by the continental-shelf dynamics program are a key element in deciding whether sea disposal is safe. The program has also provided models to predict the fate of spilled materials, such as the oil from the Argo-Merchant. The information developed is also used by other agencies involved in modeling oil spills. Moreover, the modeling capability provides crucial information required to support the leasing of offshore tracts for oil development.
- *State and Federal regulatory agencies and utilities.* In Washington and Oregon, the program identified sites where industrial activities might harm the razor clam fisheries. Work at the Scripps Institution of Oceanography helped establish the chlorine release standard for the California coast. Studies at the University of Washington have shown that mercury is rapidly removed in coastal waters and could, therefore, be safely released at higher levels than previously anticipated. In the past, floatables in municipal wastes drifted onto the beaches of Long Island, closing more than 100 kilometers of beaches and causing an estimated $20-million (1976) loss in the tourist and related industries. The coastal-shelf model predicted the path of the wastes and showed that dumping farther off-shore or storing wastes for later dumping during favorable conditions could help avoid these damages.
- *Fishing Industry.* Based on a consideration of fronts, temperature, and upwelling, the coastal-shelf dynamics work helps determine where the fish are located. The impetus for fishery development was provided by a NOAA Sea Grant, and the information was provided by the coastal-shelf dynamics program. Dockside values of fin fish which landed in Georgia rose from less than $38,000/year from 1969 to 1975 to over $230,000/year from 1976 to 1979. The program has similarly benefited fin fisheries in South Carolina.

  In 1976 there was a major kill of shellfish along the New Jersey coast with estimated damages of $50 million. The coastal-dynamics program investigators identified the conditions and implemented an early-warning system in case similar conditions recur. Fisheries experts estimate this knowledge would enable them to save one-half of the shellfish. It is estimated that the peculiar oceanic conditions that lead to fish kills would occur about one year in ten.

Tracing Pathways of Nuclear Wastes in the Life Cycle Small amounts of transuranic elements produced by nuclear energy activities may move through the environment and back to humans or other biological organisms. (Transuranic elements are those with atomic numbers greater than uranium; they are radioactive and can be toxic to humans.)

Hundreds of tons of transuranic elements, mostly plutonium, have been produced since World War II as a part of nuclear weapons production. Small losses to the environment from processing have occurred. Such losses have been studied at the Savannah River Laboratory and the Savannah River Ecology Laboratory. Plutonium emitted from a nuclear fuel separations plant is followed through the aquatic and terrestrial environments, and its dose to humans from ingestion is assessed.

Plutonium particles from the Savannah River nuclear fuel separations plant attach to dust particles. Concentrations of these particles in the air provide potential annual doses of less than 1 percent of the natural background at the plant boundary. Wheat, corn, soybeans, root crops, and tobacco grown in plutonium—containing soil—had the most plutonium on the surfaces, not in the edible part, of the plant. The potential dose from plutonium to humans eating these crops after more than 20 years of Savannah River operation is less than from naturally occurring radioactive potassium-40 in the same soil.

Measurements in sediments, biota, and water in estuarine systems near the Savannah River indicate that plutonium concentrations in this watershed are not different from those of watersheds with no nuclear facilities, even though the Savannah River is near one of the highest concentrations of nuclear facilities in the United States.

The results of all transuranic cycling research up to 1980 have been compiled in a book entitled *Transuranic Elements in the Environment: A Summary of Environmental Research on Transuranium Radionuclides Funded by the United States Department of Energy Through Calendar Year 1979*, [ed. by Wayne C. Hanson (DOE Technical Information Center), DOE/TIC-22800, 746p, 1980]. These research results, plus later scientific papers, form a valuable data base on transuranic cycling in the environment. Perhaps equally important is the evolution of a group of scientists who can answer questions about transuranic elements that arise from civilian and military applications of nuclear technology.