Hanford's Radioactive Tumbleweed

After 44 years of storing radioactive wastes on site, DOE's temporary measures begin to look permanent; cleanup would cost "billions upon billions upon billions"

Richland, Washington

A badger broke through the security lines here at the world's first plutonium factory in 1959. He ignored all the warnings and dug a hole in one of the waste pits. After he left, rabbits began to stop by for an occasional lick of salt, but it was no ordinary salt they had found. Before long, they scattered 200 curies of radioactive droppings over 2500 acres of the Hanford Reserve.

The rabbit mess ranks near the top of the scorechart, says Allen Conklin, a former employee of this weapons facility, now a state radiological safety officer. It created "one of our largest contaminated areas," one that remains hot today with cesium-137 (half-life of 30 years) and strontium-90 (half-life of 28 years).

Hanford also has trouble with ground squirrels, burrowing owls, pocket mice, insects, and plants like rabbitbrush and tumbleweed. With roots that can grow 20 feet, tumbleweeds reach down into waste dumps and take up strontium-90, break off, and blow around the dry land. Most come to rest in a patch of sagebrush on site, says Conklin. "My concern is that they will build up in the environment, and, if there is a range fire, they may produce airborne contamination." The Department of Energy (DOE) and its contractors who manage the site "have been trying to evaluate the potential for tumbleweeds to go all the way to the river," he says. "They've started to get a better hold on the problem."

The task of chasing hot tumbleweeds does not fit with the image of a seamless engineered environment that Hanford folk aim to create. Yet it is a housekeeping chore that cannot be neglected, especially now that Washington and Oregon, the Environmental Protection Agency, Congress, and citizen groups have begun to peer deeply into methods of waste handling here.

Eight weeks ago, DOE gave up a long-held privilege. For the first time, it agreed to submit its secret weapons facilities to state and federal waste disposal rules. In the past, DOE and its predecessor, the Atomic Energy Commission, argued that the special nature of radioactive waste and the agency's need for security made it unwise to let outsiders become involved. In any case, DOE's standards were better, it was said, and the agency was exempt from environmental law under the Atomic Energy Act. But as stories of accidents and spills reached the press, Congress has become convinced that the weapons plants were not meeting the highest standards. Several investigations began.

In the ensuing furor, DOE Secretary John Herrington agreed on 1 May that the agency from now on will abide by the same standards that apply to everyone else. This decision, though commendable, will cost a lot of money. DOE Undersecretary Joseph Salgado was asked by Senator John Glenn (D–OH) on 17 June to guess what the price will be. Salgado said that reclaiming all of the weapons sites would cost "billions upon billions upon billions of dollars" and take "well into the next century" to complete.

At Hanford, the new regime will upset an agenda for disposing of highly radioactive wastes in tanks that has been taking shape over the past 5 years. More attention will now be given to cleaning up buried nonradioactive chemical wastes and low-level radioactive burial grounds.

For 44 years, managers of the plants on this remote bend of the Columbia River have emptied waste into 177 steel tanks and, with less foresight, into earthen ditches, trenches, cribs, ponds, swamps, underground drains, and deep wells. They have also buried long-lived transuranic waste (heavier than uranium, known as TRU) in boxes or drums that will soon corrode. The result is that—with or without local consent—Hanford has become a permanent radioactive waste site.

Unlike the futuristic waste repositories pictured in DOE brochures, this one is not engineered to last for millennia. The question is whether environmental barriers can be inserted now by a feat of retroactive engineering.

DOE is trying to decide at this moment how large a cleanup is needed to protect public health and live up to the new public demands. It is worried about the cost. According to Jerry White, director of waste management and a 22-year veteran at Hanford, it would cost $100 billion to restore Hanford to its "pristine condition." He said in a briefing last March that "DOE does not consider total cleanup to be reasonable" because its cost is "well above [the] agricultural value of [the] land and costs of all other reasonable alternatives." It is also about ten times DOE's entire budget.

A less ambitious but still a deluxe cleanup, leaving the soil-bound waste where it is and trucking the tank waste to a deep repository, would cost $17 billion. That is about the price of a space station or several aircraft carriers. Even a minimal cleanup, leaving the older waste where it sits in tanks and "stabilizing" it underground, would cost $2 billion to $3 billion.

This lesson in ecology and megawaste began in December 1942, when the U.S. government arrived here in the person of Lieutenant Colonel F. T. Matthias. He was a property scout and deputy to Lieutenant General Leslie Groves, commander of the Manhattan Project. After a 2-week survey of the nation, Matthias and Groves picked the small town of Hanford on the Columbia River as the place to build the nuclear reactors that would supply plutonium for the Nagasaki bomb.

In retrospect, it is clear that the first managers had only the sketchiest plan for waste disposal. They intended to keep the most highly radioactive liquids in tanks, both for safety and economic reasons. They eventually recovered valuable uranium from them. The less potent and economically useless liquids were to be dumped on the ground. Perhaps the worst mistake was the decision in 1945 to pump a large quantity of radioactive runoff down two deep wells directly into the aquifer.

This unconfined aquifer moves from the northwest to the southeast and east, flowing into the Columbia River. It passes directly under nine reactors perched along the riverbank and about 300 feet below the two plutonium separations plants in the center of the tract. These central factories are known as the 200 East and 200 West areas. The "200 areas" were put where they are because they are the messiest part of the operation, and it was hoped that spillage from them would not travel the 7 to 9 miles to the edge of the government's property.

"Disposal of liquid radioactive wastes from the separations plants (200 areas) at the Hanford Works has been a problem of paramount importance since the beginning of operations," says an internal review written in February 1950, 5 years after start-up. According to the authors, R. E. Brown and H. G. Ruppert, the volume of moderately radioactive liquids was so great that it "precluded the practicability of storing them in tanks." These wastes "contained insufficient amounts of radioactive elements for economic recovery." They were to be poured onto the ground. But before that could happen, three scientists pointed out that with rapid evaporation, the radioactive material would sit on the surface and become windborne.

The problem was solved by drilling two deep wells, one at 200 East and another at 200 West. In a period of 2 years, 11 million gallons of radioactive waste were sent through settling tanks and injected into the aquifer. About 7725 grams of plutonium went down the lines.

Courtesy of SEARCH

View from Hanford. *Amateur hydrologists from SEARCH drop flags in the Columbia River where tritium enters. The shore in foreground is about 7 miles from the plutonium plants.*

Brown and Ruppert judged this approach "a mistake," and it was recognized as such when the ground water 500 feet away from the eastern well was found to be radioactive. They describe the tainted area as "a gigantic, elliptical lens, up to about 60 feet thick, 2500 feet long, and 1000 feet wide." In 1950, the edge was moving to the southeast at about 500 feet a year. But at the same time, the short-lived isotopes were decaying. The report took an optimistic view, predicting that radioactive decay, the apparent immobility of plutonium (lucky thing, for plutonium-239 has a half-life of 24,000 years), and dilution would remove any threat to the public.

A DOE-sponsored investigation in 1981 found that the most intense concentration of plutonium (over 10 nanocuries per gram) seems to have moved no more than 6 meters from the well. But mobile isotopes like cesium-137 and strontium-90 have traveled further toward the river.

Both wells were closed in 1947, and managers substituted another cheap means of disposal known as "cribbing." In this process, wastewater is piped into enclosed wooden structures consisting of a series of cascading tubs. Heavy elements settle at the bottom and the rest goes off into the ground. The use of cribs continues today at Hanford, although ground dumping was described in 1950 as "a temporary but necessary expedient."

The system of cribbing and ground dumping went smoothly until the mid-1950s, when it was pushed too far. A problem arose when high-level wastes were recycled to salvage uranium. After treatment, they had no economic value and managers of the tank farm did not want to keep them. In a 1958 report, Hanford geochemists W. A. Haney and J. F. Honstead urged that the tank wastes not be dumped any longer. They recognized the "temptation to free expensive tank space" but warned that ground dumping had "objectionable and unevaluated features."

Many of these wastes were considered "uncribbable" because they contained sludge, undesirable chemicals, or high levels of radioactive cobalt-60. According to Haney and Honstead, plant managers began pouring radioactive waste into trenches beginning in 1944; by 1958, they had contaminated 18 different spots. About 27 million gallons containing 219 grams of plutonium and 97,000 pounds of uranium went directly into the soil.

Trench dumping was curtailed by the 1960s. But as it tapered off, Hanford began to have problems with the tanks. One hundred and forty-nine single-walled tanks of steel and concrete were built between 1944 and 1964 to contain high-level waste. Within 10 years they began to corrode and leak. At least 26 are "confirmed leakers" and over 30 are "of questionable integrity," according to a 1983 report. The first big spill occurred in 1956 when one tank lost 55,000 gallons of high-level waste. The biggest spill occurred in 1973, when tank 241-T-106 sprang a leak that went undetected and disgorged 115,000 gallons. In the lost liquid were 40,000 curies of cesium-137, 14,000 curies of strontium-90, and 297,000 curies of other fission products. Based on evidence from well samples, DOE believes the radiation is sitting quietly in the soil about 100 feet above the water table.

According to DOE's draft environmental impact statement on cleaning Hanford, dated March 1986, there are more than 200 areas where radioactive liquids went into the ground. Less than 5% have been analyzed. DOE estimates that the 24 sites most heavily contaminated with long-lived TRU isotopes hold about 190 kilograms of plutonium.

In addition, a large volume of dry TRU waste was buried at Hanford. Before 1970, no one planned to recover it, and officials now have no plan to dig it up. The 11 sites with the highest concentrations of TRU (over 100 nanocuries per gram) are thought to contain 350 kilograms of plutonium. TRU waste buried since 1970 is considered to be retrievable, although the containers were not designed to last more than 20 years. Presumably, they have begun to corrode. The five sites in this category hold 330 kilograms of plutonium.

DOE has not yet settled on a plan for dealing with the extensive ground contamination at Hanford. But one area where remedial work has begun is in the tank farms. All of the 149 leak-prone tanks are being drained, leaving behind a complex mixture of solids, sludge, and salt cake. The draining is well under way, although it will take a long time to remove all the moisture, and perhaps as much as 5% will remain. The effluent is being put into the 28 newer tanks.

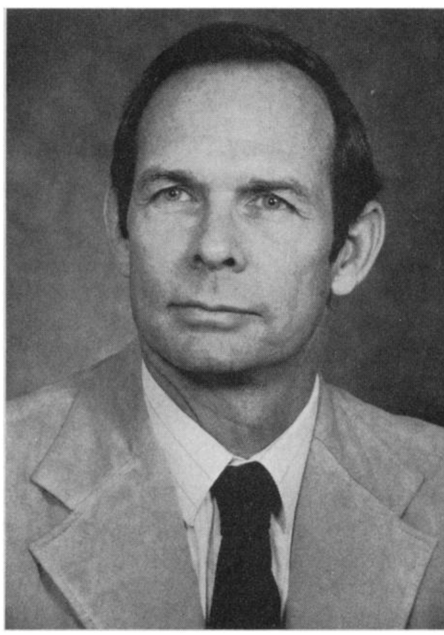
The one clear objective at Hanford is to concentrate this highly radioactive liquid in the new tanks and dispose of it in the style of the Savannah River Plant, by converting it to glass and pouring it in stainless steel cans (*Science*, 13 March, p. 1314). The cans will be sent to a deep repository, if one is built. The glass factory will have an effluent too, a stream of low-level radioactive liquid that will be mixed with concrete and buried at Hanford. There will be problems in getting the system approved and running, but DOE has promised to abide by all the hazardous waste laws on the books.

The difficult questions are what should be done with the sludge and salt left in the old tanks, and how should the contaminated land be cleaned? DOE's environmental impact statement describes a "reference alternative" that calls for burying most of these problems. Because it would be hazardous to hose out the old tanks (risk of leaks) or dig them out (radiation exposure to workers), DOE suggested that they be filled with rubble for internal support and buried. In addition, DOE proposed to attack only those TRU wastes that can be cleaned readily and packaged for a deep TRU burial shaft (the Waste Isolation Pilot Project, or WIPP) near Carlsbad, New Mexico. The rest would be covered over.

According to DOE's plan, a permanent barrier of soil, gravel, and broken basalt "riprap" would be piled over the waste. The top layer would be planted to help remove water by transpiration. Citing Hanford's very light rainfall, DOE calculates that no water would penetrate the zone where the wastes are buried. In addition to stopping capillary water movement, DOE claims, the riprap would defend against burrowing animals. To put off human intruders, DOE would erect granite monoliths all around the site bearing the legend: "Caution: Buried Hazardous Waste Below." At three levels in the earth, DOE would distribute thousands of porcelain discs inscribed, "Do Not Dig Here." The goal, as required by the Environmental Protection Agency, would be to ensure a safe rate of radionuclide release for 10,000 years.

"The barrier concept is valid," says Jerry White. "There's no question in my mind about that. The question is, can we build it to make it work the way the concept says, and can we prove to people that it will work?" White says DOE has enough experience and lab data to be confident that its model is right, but not enough to make outsiders confident.

For example, Bruce Blanchard, director of environmental project review for the Secretary of Interior, sent a sharply skeptical letter about the environmental impact statement to DOE last August. He wrote that the U.S. Geological Survey had "strongly rejected" a similar plan for disposing of TRU wastes in the 1960s, and that this was the reason for building the special WIPP repository in New Mexico. "Additional studies should be implemented and ongoing studies completed before any actions are recommended for disposal of single-shell tank wastes, pre-1970 TRU buried wastes, and contaminated soil sites," Blanchard said. He pointed out that DOE has not analyzed chemical waste dumps at Hanford, and that these could have a direct impact on radionuclide mobility beneath the barrier. Plutonium moves much faster when "complexed" with solvents. He concluded that DOE is not yet



Courtesy of DOE

Jerry White. *Director of waste management confident of waste isolation plan.*

prepared to begin this difficult project and that there are "too many unknowns."

This and other criticism from the states forced DOE to reconsider. According to White, no action will be proposed at present for the older tanks and the contaminated soil. "We are going to have to do some extensive performance testing of various barrier concepts. . . . We're going to have to come up with the data that shows, yes, we can build the barrier."

Meanwhile, DOE will consider new options, such as "sluicing" out the old tanks with high-efficiency scrubbers and converting soil wastes to glass in the ground by melting them in place. In situ vitrification, as it is called, is being tested on a large scale this month at Hanford. Project manager Vince FitzPatrick of Battelle's Pacific Northwest Laboratories says that by inserting electrodes in the ground and applying power, a TRU area more than 24 feet square has been solidified. At Hanford, the process will cost about $150 per cubic yard of glassified soil.

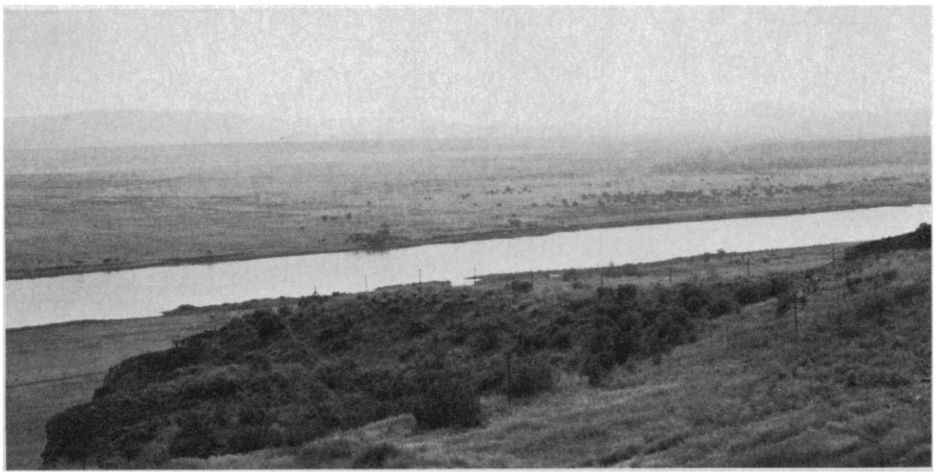
As DOE juggles its options for the future, it has come under intense pressure to halt the pollution that goes on right now. According to a report given to Congress in March, Hanford still dumps about 7 billion gallons of wastewater a year into cribs, ponds, and ditches. The main radioactive constituent is tritium, a form of hydrogen with a half-life of 12 years.

The leader of local efforts to stop this dumping is the Hanford Education Action League (HEAL), of Spokane. Although not technically expert, HEAL published a strong critique of Hanford's water models in 1986, written by Timothy Connor. It reads a bit like a detective story. Connor based his report on information in thousands of pages of historical documents he pried loose from DOE and on some clever fieldwork by Norm Buske and Linda Josephson, a husband and wife team.

Under the corporate name "SEARCH," Buske and Josephson investigate accidents for insurance companies. In 1983, they began investigating the water around Hanford. They collected data by floating down the Columbia River in a rubber raft and, guerrilla-style, snatching samples from the federal shore. There were tense encounters with guards carrying machine guns in the early days. Later, DOE teamed up with SEARCH in a joint sampling program. At the moment, SEARCH has asked to sample water near the old Hanford townsite, but has been turned down.

Connor thinks DOE does not want to discover the full extent of pollution at Hanford. As a result, Connor argues, DOE's data collection is random and its models, unrealistic. To the extent that assurances rest on computer models, he says, they cannot be relied on.

One historic and one current case illustrate his point. In his paper, Connor describes a problem that developed in 1984 when wastewater from the 200 West area was diverted into a freshly built crib. As he puts it, Hanford's present "collided with Hanford's past in a big way." The fresh, relatively clean water descended 100 feet in the soil, then hit a natural crusty barrier and traveled laterally toward a dumping ground that had not been used for 20 years. Deep below the surface, the water met a body of uranium (about 4000 kilograms had been dumped into the old crib). Acid had been dumped into the crib about a decade after



Old Hanford. *Trees mark the former town, emptied in 1943. Onshore to left is the riverbank where tritium enters the water from plants far in the distance.*

the uranium, a mistake obviously made in ignorance of the pit's earlier contents. The acid freed the normally immobile uranium from its bonds in the soil.

In 1984, the incoming water stirred the soup and pushed it sideways to an area where one of the original disposal wells, abandoned in 1946, had punched a hole in the crusty zone. The uranium went down the old well line and entered the ground water, causing radiation readings to zoom upward. Some of the contamination was pumped out, but, according to Connor, the ground water at this spot exceeds federal drinking water standards by a factor of 1300. A good system of monitoring and record keeping could have prevented this from happening.

Recently, HEAL and SEARCH have focused on the rate at which ground water drains to the river. In 1985 and 1986, Buske and Josephson went out into the river and, with little flags, tagged the springs where they claim radioactive material from the 200 areas flows into the river. This bank, near a marker called "rivermile 28," is just downstream from the old Hanford townsite and 7 to 9 miles from the alleged inland waste source. Buske thinks he has identified a "fast channel" of gravel that conducts water rapidly through the subterranean landscape. He calculates the travel time as 3 to 5 years, not 20 to 100, as the computer models predict. And he thinks there is evidence that radionuclides are carried by the water.

DOE concedes that tritiated water (containing a radioactive isotope of hydrogen) and a high concentration of nonradioactive nitrates appear at rivermile 28. But hydrologists at Battelle who run the monitoring program disagree that longer-lived isotopes come from the 200 areas, saying they may come from the N-Reactor's cooling water discharged into the river upstream. They reject the fast channel theory.

More recently, Connor and Buske pointed to 1982 data showing elevated readings of strontium-90 near rivermile 28, suggesting this might be more evidence for the fast channel. DOE and Battelle dismiss the notion that strontium-90 is moving from the dumping grounds to the water. Michael J. Graham of Battelle responded to Connor in a letter on 23 April: "Because of the low level of strontium-90 routinely measured before and after the 1982 sampling period, it is not believed that strontium-90 was actually present in these wells. . . ." The anomalous data have been tossed out.

Last year, Representative Les AuCoin (D-OR) asked the U.S. Geological Survey (USGS) to review the fast channel theory. After a 6-month, 25-person effort, the USGS reported in April that the evidence was insufficient to come down on one side or the other. The USGS rejected Buske's travel time estimate, but concluded that water probably does move from the dumping grounds to the river in 10 to 20 years, perhaps even in 6 years. It offered an alternate theory to explain how this might work and urged DOE to build a better three-dimensional water model. "It cannot be overemphasized," USGS noted, "that reliable results can only be achieved . . . if the model is based on reliable water-level and water-chemistry data throughout the area and depth of the aquifer." USGS stands ready to collect these data, but has not been invited to do so.

Jerry White emphasizes that the concentration of radionuclides in river water is minute, not enough to violate drinking water standards. He mentions also that the state of Oregon recently published a 20-year study of the Columbia River, concluding that public health has not been endangered by Hanford operations.

In addition, Jeffrey Serne of Battelle, a geochemist, asserts that it is most improbable that plutonium and other long-lived radionuclides in the soil will ever migrate from where they sit to the river in appreciable quantities. The only way a "break-

Catching steelhead. *Fisherman land trout downstream from the "tritium springs." Bass, whitefish, and sediment hold trace amounts of cobalt-60 from reactor discharges.*

through" of contamination might occur, he says, is through a sudden and massive shift to greater acidity in the soil. He cannot imagine that happening, and he sees no threat to public waters.

The point, Connor says, is not that public health is in danger, but that the traditional complacency about the environment at Hanford is no longer acceptable. Furthermore, he argues, 40 years of haphazard experience is not a good basis on which to make a 10,000-year prediction.

Hanford officials are anxious about the future, not only because of the many new tasks they are being given, but because of those that may be taken away. The N-Reactor, the last operating production reactor of the nine that were built, has been shut for safety improvements since January. DOE does not expect to get it running again until November. There is talk in Congress of closing it for good. If Hanford stops making plutonium, some say, it will lose its reason for being. That will not be good for the environment, according to William Jacobi, the president of the Westinghouse Hanford Company.

Jacobi takes over as chief contract manager of Hanford for DOE at the end of this month. He was quoted recently as saying: "In terms of a major investment in environmental cleanup, I think that will happen only if we can get the defense mission continued."

Members of Congress who are pressing to have DOE spend more money on cleaning up Hanford disagree. They see no need to make environmental concerns subservient to the military mission. Representative Ron Wyden (D–OR) calls this view "bizarre" and "typical of the thinking that has led to the problems that exist today."

And yet, the old hands may be right that if the glamour of weapons work is missing, it may be very hard to find the $5 billion, or $10 billion, or $100 billion that will be needed to reclaim this historic patch of land. ■ ELIOT MARSHALL

Supreme Court Strikes Down "Creation Science" Law as Promotion of Religion

The U.S. Supreme Court on 19 June delivered the coup de grace to Louisiana's Balanced Treatment Act, which sought to require that so-called "creation science" be given equal time with the teaching of evolution in the state's public schools.

The court agreed with two lower courts that the law "advances a religious doctrine by requiring either the banishment of the theory of evolution from public school classrooms or the presentation of a religious viewpoint that rejects evolution in its entirety." As such, it violates the First Amendment's prohibition on state promotion of religious beliefs, a majority of the Supreme Court justices concluded.

The ruling is the culmination of a 6-year legal battle that began when the Louisiana legislature approved the Balanced Treatment Act in July 1981. The law was carefully crafted in an effort to avoid the constitutional problems that eventually sank a similar Arkansas law in 1982. The Louisiana law required the teaching of the scientific evidence for creation alongside the teaching of evolution, and mandated that both be taught "as a theory, rather than as proven scientific fact."

In the end, however, the Louisiana law suffered the same fate as the Arkansas statute. It was struck down by a federal judge in January 1985 on the grounds that the teaching of "creation science" would be tantamount to the teaching of a particular religious belief. His ruling was upheld by a three-member panel of the Fifth Circuit Court of Appeals later that year and the full appeals court subsequently narrowly rejected a motion to hear an appeal of the panel's ruling. The case then ended up in the Supreme Court.

Seven of the nine justices agreed that the law's "primary purpose was to change the science curriculum of the public schools in order to provide persuasive advantage to a particular religious doctrine that rejects the factual basis of evolution in its entirety." The law was therefore judged clearly unconstitutional.

Chief Justice William Rehnquist and the court's newest member, Antonin Scalia, disagreed, however. In a lengthy dissent written by Scalia, they argued that the merits of the case had never been fully aired during the law's odyssey through the lower courts, and suggested that it should be sent back to the appeals court for further consideration. Scalia wrote that the majority's opinion rests on an "illiberal judgment," and called it a "*Scopes*-in-reverse."

The Supreme Court's ruling is expected to put an end to efforts to force the teaching of creationism through state laws. It will, however, do little to quell disputes over the selection and content of school textbooks, which is now the chief battleground over the teaching of evolution. ■

COLIN NORMAN

Plant Science Grant Program Nears Approval

After several years of planning, a new Plant Science Centers program is being initiated by the National Science Foundation, the Department of Energy, and the Department of Agriculture. Formal approval of the competitive grant program is likely in August and a solicitation could appear before 1 October.

The stated aim is to enhance the competitive position of American agriculture in world markets and to improve the production of renewable resources such as trees. Federal officials recognize that, to achieve this goal, the research community needs to better understand the structure of plants, control mechanisms related to growth and development, and how to limit unwanted environmental effects.

At the outset, the program will be funded with about $10 million, assuming that Congress concurs. This is only a small fraction of the $50 million that the Office of Science and Technology Policy envisioned 18 months ago when it first conceived of the program (*Science*, 17 January 1986, p. 212). The new initiative is meant to augment ongoing research in federal agencies and fledgling efforts such as NSF's biological centers program. But some existing plant research will be supported under the new plant program. Multidisciplinary research in complex carbohydrates, for example, would cease to be funded separately by DOE beginning in fiscal year 1988.

Grants will be made on the basis of peer review by NSF and the departments of energy and agriculture. The chief criteria are: the importance and uniqueness of the research; the prospect for merging training and research activities; and additional support that the applicant, industry, and other state or federal government agencies may provide. Industry and/or state involvement in projects can be in the form of joint research, providing equipment and supplies, or direct funding.

Areas of research that are eligible for grants include: plant biotechnology, microbial ecology, ecological processes, and rhizosphere dynamics. Other areas of plant science, especially areas of neglect, or pressing research problems will be considered. Awards are expected to range from $500,000 to $2 million per year for up to 5 years. In certain instances, a portion of these funds may be used to build special facilities to support research outlined in the grant application. ■ MARK CRAWFORD