be set in a row and detonated simultaneously to produce an elongated ditch. Again, only one row-cratering experiment—Buggy at the Nevada test site in 1968 (SN: 3/23/68, p. 280)—has been performed.

Compounding the lack of knowledge further is ignorance of the effects of nuclear excavation on an area whose geology is untested.

But possibly the biggest technological headache of all is radioactivity.

Here a technological problem spills over into the political arena. Despite efforts to produce a clean explosive using mostly thermonuclear components, nuclear scientists and engineers have been unable to produce zero fallout from cratering blasts. And the Limited Test Ban Treaty specifically prohibits detonations in which radioactive debris would be carried beyond the borders of the country in which the device is exploded. To get around the fallout problem, the United States would either have to get the 101 signatories to agree to a revision or appropriate interpretation, or else scrap it.

With nuclear excavation ruled out, two potential routes are also precluded for at least several years to come: Route 17, which is 100 miles southeast of the Canal Zone and 44 miles long, and Route 25, which is in Colombia and 107 miles long. That leaves Route 10, five miles west of the Canal Zone and 48 miles long and Route 14 in the Canal Zone itself, 47 miles long.

Two problems with Route 14 are that a canal through it would permanently knock out the present Panama Canal and possibly cause ecological harm. These effects would result from lowering the level of Gatun Lake, which constitutes 20 miles of the canal's waterway and provides water storage to operate the locks. In addition, because Route 14 is so close to the present canal, construction on it could induce slides there.

Both Routes 10 and 14 pose political problems, since Panama contends any new canal requires a treaty; this is unquestionably true for Route 10. Also the Panamanian Government has stated that it does not want a canal at present.

"The Government is not interested at the present time," says one Panamanian official, "because the attention of the economy would be diverted. The Government has been trying to diversify so the economy wouldn't be dependent on the canal."

Another possibility is not to build the second canal but to augment the present one with additional locks and channels. "We think it's a poor solution," comments Sheffey. "A new lane of locks would only increase capacity about 50 percent, and this capacity could be exceeded by demand in 15 to 20 years after it is built." □

Ecology and the canal

If engineers are depressed about the gloomy future of a sea-level Isthmian canal, it presents a welcome breathing spell to marine biologists. Knowledge of ecological effects of such a canal is limited, and most discussion is still largely theoretical and often highly polarized. The delay will give scientists time for more studies—research that will be necessary in view of the near certainty that someday a canal will be built.

Scanty as the knowledge is, even the most sanguine researchers are convinced there is potential menace to both Pacific and Atlantic ecosystems. Most scientists, including members of a National Academy of Sciences committee appointed last summer to study the canal, believe a barrier, preferably of fresh water, should be built to prevent transfer of biota through any canal that is built.

Two kinds of speculation are going on. The first has to do with the possibility of great harm from migration of certain specific animals, such as the crown of thorns starfish and the *Pelamis platurus*, a brightly colored, sluggish and highly venomous sea snake (SN: 12/7/68, p. 578). Both creatures are now exclusively Pacific residents. The second, more general kind of speculation involves opposing theories about the way members of the whole spectrum of species from one side might interact with similar species on the other side.

Dr. Peter Glynn of the Smithsonian Institution's Tropical Research Institute at Balboa, Panama, reported this week that he had found a large infestation of coral-eating starfish on coral of Los Contrares Island west of the Gulf of Panama, the first fully verified report of the creatures in large numbers in the eastern Pacific. He is not certain whether the starfish are *Acanthaster planci*, the crown of thorns, or its eastern Pacific cousin, *Acanthaster elisi*, or even if there is any real difference.

The starfish have represented little menace in the eastern Pacific where there are few important coral formations. But Dr. William A. Newman of Scripps Institution of Oceanography says there is no telling what they might do if they get into the western Atlantic where there are 32 species of hermatypic—reef building—corals. There are 10 species in the western Pacific, where the crown of thorns has created havoc (SN: 3/28, p. 315).

"If the crown of thorns got into the Atlantic, there would be a very great risk of damage all the way from the Florida Keys to Rio de Janiero," says Dr. John C. Briggs of the University of South Florida.

Likewise with the *Pelamis platurus*, the paddle-tailed black and yellow sea snake. The snakes are not much of a menace on the Pacific side, where they usually stay well out to sea and where they are nearly immobile when beached by high winds. But no one knows what their habits would be in the Caribbean, and highly toxic as their venom is their very existence would be damaging to the tourist industry, says Dr. Howard L. Sanders of Woods Hole Oceanographic Institution.

Work by Dr. Ira Rubinoff, also of the Tropical Research Institute, indicates that large Pacific predators stay away from *Pelamis platurus*, but that Atlantic predators do not, at least under laboratory conditions. Thus the snake might initially be held in check in the Atlantic, but once predators acquired avoidance adaptations, then the snake might proliferate, says Dr. Sanders. But he concedes that there is no way to make surefire predictions about the sea snake or other creatures, including the bottom organisms he has recently been studying.

These two species represent just two specific threats. Robert W. Topp, a marine biologist with the Florida Department of Natural Resources, says there could be many more, including parasites that might be analogous to the sea lamprey which decimated unadapted Great Lakes fish when it was introduced through the Welland Canal in the 1930's, or a parasitic worm that seriously damaged sturgeon in Lake Aral in Russia when brought in by an alien sturgeon host.

There are also economically important species which could be affected in now unforseen ways. These include the important shrimp fishery in Pacific coastal areas of the Gulf of Panama.

Topp and Dr. Briggs represent the two sides of an on-going controversy over more generalized theories of biological interaction. Dr. Briggs is convinced that there is greater diversity of life in Caribbean—where temperature, salinity and other physical conditions are more stable than in the Pacific—and species from that side would prevail competitively over similar species in the Pacific, thus rendering these extinct. He says incursion of species from the biologically diverse Red Sea into the less diverse Mediterranean through the Suez Canal provides a model.

Topp says that the analogy is invalid, since far greater differences exist between Red Sea and Mediterranean species than between the historically

similar Atlantic and Pacific species. Although similar, these species have made fine adaptations to specific conditions, he says. Thus invaders from either side into the other would not be viable in the new habitats. He suggests both sides are saturated, with most ecological niches filled, whereas the Mediterranean was relatively unsaturated before the invasion from the Red Sea.

Dr. Sanders takes an in-between position, claiming that a variety of sometimes identical habitats exist on both sides and that species from one side would find hospitable habitats on the other. "But I would hesitate to say whether Atlantic or Pacific species would have the edge," he adds.

Scientists are immensely curious to find out which theory is correct, and this creates another kind of ambivalence. "To let the mingling take place would be the greatest biological experiment in the world," says Dr. Sanders. "But as a citizen, I have to recommend extreme caution. Anything could happen—from highly benign to utterly catastrophic." □

WEATHER MODIFICATION

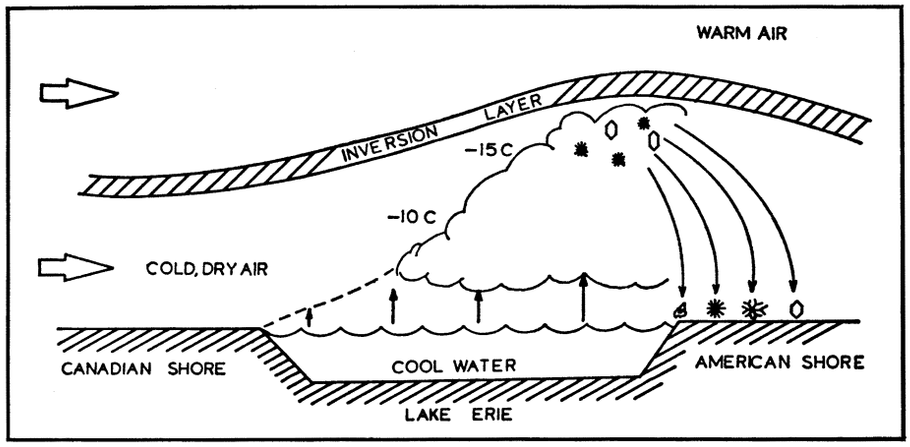
Becoming respectable

Weather modification has fought a nearly quarter-century-long uphill battle toward scientific respectability. The actions and claims of a few early private workers in the field, endowed with unrepressed overoptimism and a tendency to exaggerate evidence favorable to their commercial rainmaking operations, cast a stigma over the field that haunted it for years.

"Few fields have faced more painful birth or embattled infancy than weather modification," says Dr. W. Henry Lambright, a Syracuse University political scientist.

At the second National Conference on Weather Modification of the American Meteorological Society in Santa Barbara, Calif., this week (the first was in 1968) it was clear that scientists are now on firm ground when they say that cloud seeding influences precipitation in predictable ways.

The heritage of caution still remains. But Dr. Myron Tribus, assistant secretary of Commerce for Science and Technology and a long-time proponent of weather modification, took the occasion to review the status of the entire field. He concludes that the science is further advanced than is generally realized. And he proposes that the time has come to proceed to deliberate operational weather modification in two areas: the increase or decrease of snowpack in some mountains and the increase of rainfall in some tropical regions.



ESSA

Weather modification in Great Lakes project: A basically feasible concept.

Responsible for much of the new optimism is a series of snowpack augmentation projects carried out in the Colorado Rockies. Dr. Lewis O. Grant and his colleagues at Colorado State University have been conducting what is regarded as an admirably sophisticated scientific project in 400-square-mile area high in the mountains near Climax, Colo. The project involved first the development of a physical model of how air flows, how clouds form and how precipitation develops in the area.

Using this physical understanding they described how seeding should affect winter clouds under various conditions. Then they performed randomized seeding experiments. The results have been exactly in accord with the theoretical predictions.

On days when the temperature of cloud tops was minus 26 degrees C. or warmer, seeding has increased snowfall by 100 to 200 percent. The results are rated highly significant. The probability that the increase in the two independent samples at Climax could be due to chance is less than 1 in 100.

On days when cloud-top temperatures were colder than minus 26 degrees C. seeding has caused decreases in snowfall of about 30 percent. This too is in accord with theory, which implies a temperature-dependence of the ideal concentration of ice nuclei for precipitation. The colder the temperature, the lower the optimum ice crystal concentration. Seeding under these conditions produces an over-seeded cloud whose nuclei are so small the ice crystals don't fall; they evaporate. In the warmer clouds seeding produces the perfect concentration of ice nuclei to enhance snowfall.

Dr. Grant says he has also very recently obtained data indicating a statistically significant increase in stream flow attributable to the seeding in the basin where the project was conducted.

Dr. J. Owen Rhea and L. G. Davis of EG&G Inc. in Boulder, Colo., have produced similar results near Steamboat Springs, Colo. Seeding of warmer clouds has produced greater than 100 percent increases in snowfall at Rabbit Ears Pass. Seeding of colder clouds has decreased snowfall by about 24 percent.

The crucial importance of cloud temperature in seeding effects brings up the matter of statistical analyses of the results of seeding projects.

Mention of the name of Dr. Jerzy Neyman, the University of California at Berkeley statistician, still raises the hackles of modification enthusiasts. Many try to dismiss him; other say he is a highly regarded scientist and his arguments carry some weight. He and his associates have been saying for some time that the Whitetop experiment from 1960 to 1964 produced a net decrease of rainfall (SN: 2/14, p. 173).

But his statistical method lumps all seedings together, ignoring physical conditions. The point that Dr. Grant and others make is that the new understanding of physical mechanisms allows them to select, if they wish, only favorable warmer clouds for treatment.

"Even when I ignore physical mechanisms and mix up all my results, the pluses and minuses balance and I don't get any net effect," points out Dr. Grant. "But you wouldn't do actual operational seeding that way. As long as you understand the situation physically, you can select only the clouds that will give you more precipitation."

As a result of the striking successes of the snowpack experiments, the Bureau of Reclamation of the Department of the Interior plans to begin this fall an upper Colorado River pilot project to operationally increase the snowpack over a 3,300-square-mile area west of Wolf Creek Pass in southwestern Colorado by seeding the warmer winter clouds.

By 1976, Dr. Archie Kahan of the bureau's Atmospheric Water Research Program Office in Denver says, he intends to know how many additional