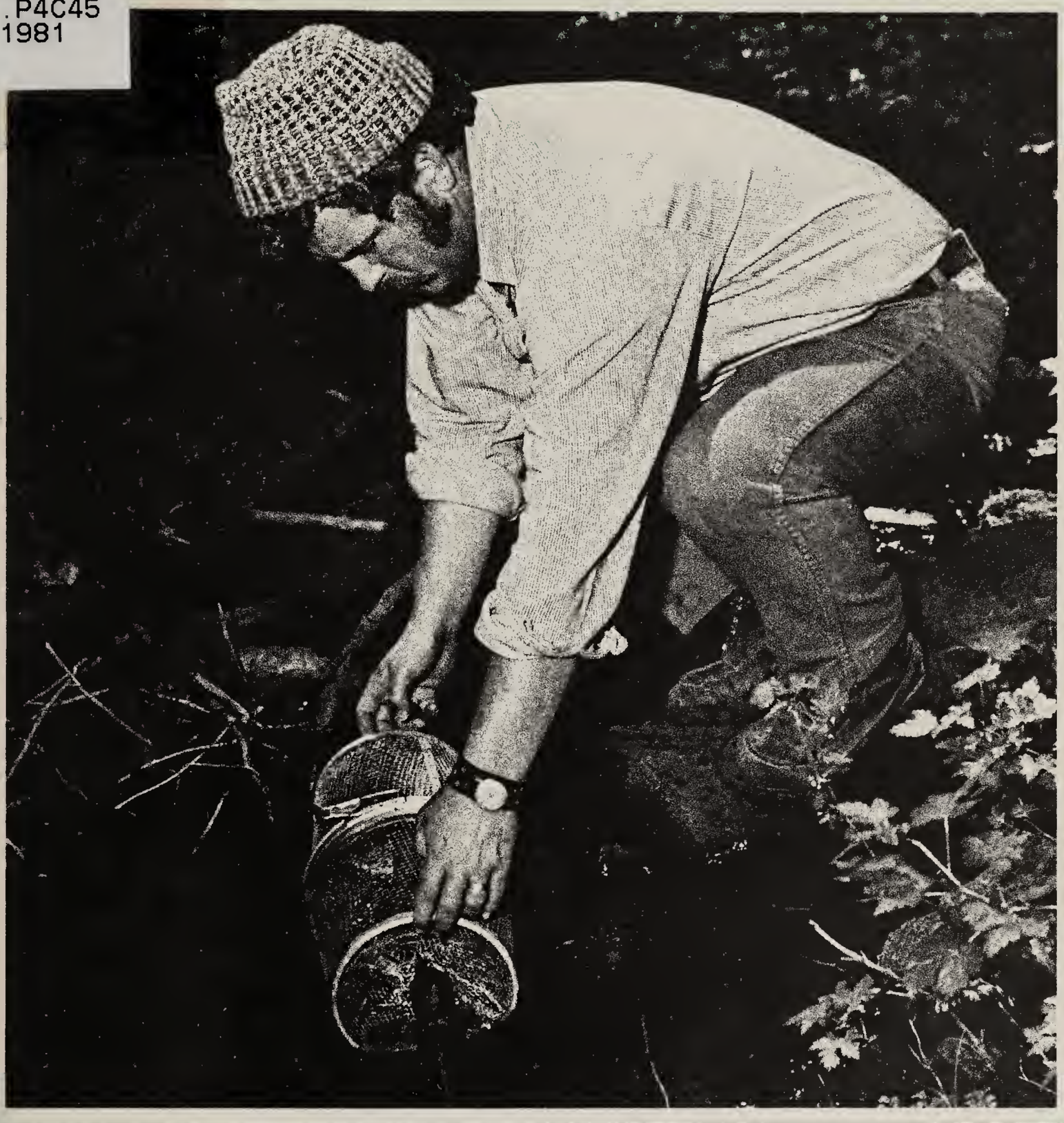

Environmental Monitoring Program

1974 Cooperative Douglas-Fir Tussock Moth Control Project

PACIFIC NORTHWEST REGION
USDA • FOREST SERVICE

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Environmental Monitoring Program

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Summary Report

PACIFIC NORTHWEST REGION
USDA • FOREST SERVICE

PORTLAND, OREGON • APRIL 1981

Contents

Acknowledgments

More than 200 people, including personnel of State and Federal agencies and various public and private organizations, private citizens, State Governors and legislators, contributed materially to the environmental monitoring program.

Key supervisory personnel, participating organizations and authors of environmental monitoring studies are identified in the following pages. A complete list of field monitors is included in the appendix. Emergency funding assistance by the Pacific Northwest Regional Commission enabled Oregon, Washington and Idaho agencies to purchase critical equipment and materials to initiate sampling on a timely basis.

Special recognition is due W. W. (Woody) Benson, Idaho Department of Health and Welfare, who gave many hours of the last few months of his life to make the environmental monitoring program a success.

Preface

In the summer of 1974, the USDA Forest Service, in cooperation with the States of Oregon, Washington and Idaho, treated almost 421,000 acres of forest land with DDT to control an outbreak of tussock moths, one of the most destructive defoliators of Douglas-fir and true fir.

This project was the largest all-helicopter aerial forest insect control project ever conducted in the Pacific Northwest. It was also one of the most controversial, predominately due to the use of DDT which had been banned for most uses in the U.S. because of its well-documented direct and residual effects on nontarget organisms.

The tussock moth spray program was accompanied by an intensive environmental monitoring program, also the largest of its kind. In response to the widespread public interest in the spray program and its potential environmental effects, this report summarizes the design and findings of the environmental monitoring program.

Readers are cautioned to recognize the limitations inherent in summarizing scientific data. Any analysis, interpretation or extrapolation of the data beyond that provided in this summary report should be based upon the complete studies conducted as part of the environmental monitoring program.

Single copies of individual monitoring studies referenced in the following pages are available to interested researchers without charge from:

Regional Forester
USDA Forest Service
P.O. Box 3623
Portland, Oregon 97208

Introduction

The Douglas-fir tussock moth, *Orgyia pseudotsugata*, is an insect native to western North America. Periodic population explosions have resulted in destructive defoliation of the moth larvae's primary host trees, the mountain variety of Douglas-fir, white fir and grand fir.

The tussock moth was first reported in the United States in 1906. The first outbreak was reported in Nevada in 1927. The following year an outbreak of epidemic proportions resulted in severe damage to Douglas-fir stands over a 40-square mile area in central Idaho. A concurrent outbreak in eastern Washington ultimately resulted in the loss of an estimated 300 million board feet of timber. By the advent of the 1970's, tussock moth outbreaks of varying magnitudes and destructiveness had been reported throughout much of the range of its primary host trees.

Approximate range of Douglas-fir tussock moth.

▒ Host type

● Major outbreak areas

□ Known collection points and/or small outbreaks as of 1973

During the summer of 1971, tussock moths began proliferating in forests of the Pacific Northwest. Beginning in the Okanogan and Wenatchee Valleys of Washington, and subsequently in other parts of eastern Washington and neighboring Oregon and Idaho, moth populations of epidemic and subepidemic proportions attacked Douglas-fir and true fir stands. By the end of 1973, approximately 800,000 acres of standing timber had been damaged; tree mortality was extensive on 88,000 acres and moderate damage was sustained on another 292,000 acres. Concentrations of tussock moth egg masses found in the fall of 1973 indicated another 649,000 acres of forest would be damaged the following year.

At the time of this outbreak, DDT was the only man-made insecticide proven effective against tussock moths on a large scale. DDT was first sprayed from airplanes to control the tussock moth in Oregon, Washington and Idaho in 1947. It was used against outbreaks of the insect up through 1965, when the last serious outbreak prior to 1971 occurred. Other insecticides had been used experimentally by the early 1970's, but never with clearly favorable results.

DDT has been used very widely against a great variety of pests. Between 1944 and 1972, an estimated 26 million pounds had been sprayed over the nation's forests alone. Beginning in the early 1960's, concurrent with

Adult male tussock moth.

Young tussock moth larvae on cocoon.

The female tussock moth lays a mass of eggs on a branch of a host tree in late July or August. The eggs hatch late the following spring, releasing one-eighth-inch long hairy larvae, many of which are scattered by the wind. The larvae feed on fir foliage, eating at a rapidly accelerating rate after their fifth moult. In late July or August, they form pupae. Roughly two weeks later, adult moths emerge, mate, and lay eggs, to continue the cycle. By eating the needles of a fir tree, the moth larvae can reduce the growth of the tree, kill the top of the tree or kill the whole tree. Often, trees weakened by moth damage are subsequently attacked and killed by bark beetles.
The moth populations are eventually attacked by viruses, parasites and/or predators, and most tussock moth outbreaks subside after three years; serious forest damage can occur prior to and during subsidence. Some outbreaks have lasted four years or longer.

Full grown tussock moth larva.

(Top) Tree branch defoliated by tussock moth larvae; recovery doubtful. (Bottom) Tree branch with loss of lower old growth foliage to tussock moth larvae prior to spraying and new upper growth saved by DDT spraying.

the publication of Rachel Carson's *Silent Spring*, there was widespread and growing public concern about the effects of DDT on nontarget organisms. Residues in wild birds and animals close to spray sites, thinning of the shells of birds' eggs, residues in other animals as far away as Antarctica all contributed to the concern.

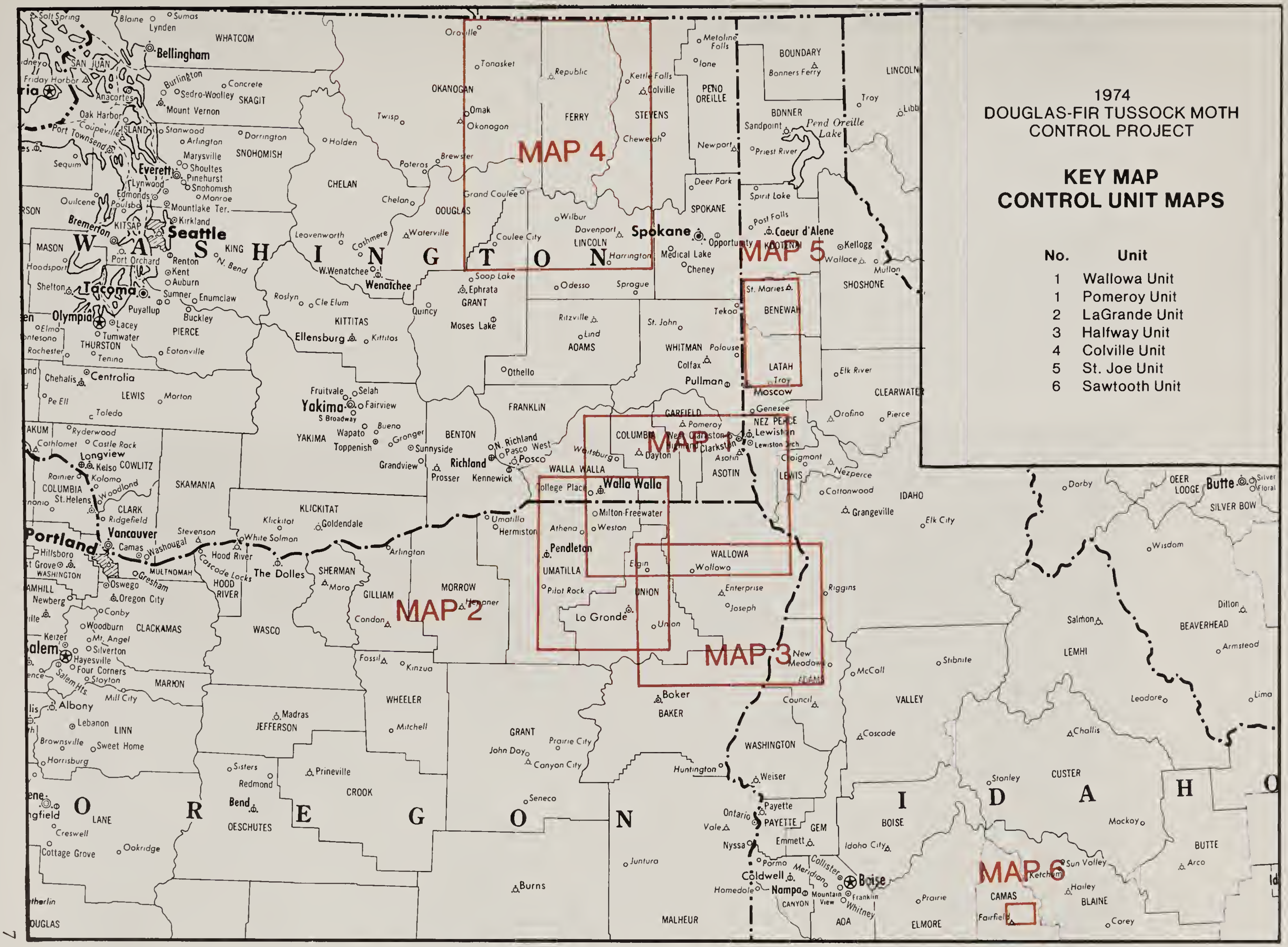
In 1972, the U.S. Environmental Protection Agency cancelled virtually all uses of DDT. That same year, however, Congress gave the EPA power to allow use of any cancelled pesticide by a Federal or State agency under emergency circumstances. In 1973, the U.S. Department of Agriculture, of which the Forest Service is a part, applied to the EPA for permission to use DDT against the tussock moth outbreak in the Northwest. The EPA refused. Other chemical and biological insecticides were sprayed over infested areas on a test basis, but none proved notably effective.

In early 1974, the USDA, joined by the States of Washington and Oregon, again applied for permission to use DDT to control the tussock moth outbreak. After a series of public hearings — at which strong opinions were expressed both for and against widespread spraying of DDT — the EPA gave its consent.

The DDT was to be mixed with fuel oil and sprayed from helicopters at a concentration of 0.75 pound of insecticide per acre. After studying the distribution and concentration of egg masses, the presence of viruses effective against the moths, and topographical or other physical features readily recognizable from the air, it was decided to treat 464,200 acres in Oregon, Washington and Idaho. Ongoing monitoring of moth populations revealed declines in some areas, resulting in a reduction of the total acreage actually treated to 420,944 acres.

The following map shows the general location of the areas sprayed. The appendix contains maps detailing actual areas sprayed.

DDT was applied from June 9 through July 1, 1974. Total cost of the spray project was $2,980,000 or $7.08 per acre. The Federal government paid all costs of treatment on Federal lands; costs for treatment of State and private lands were shared by Federal, State and


1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
KEY MAP
CONTROL UNIT MAPS
No. Unit
1 Wallowa Unit
1 Pomeroy Unit
2 LaGrande Unit
3 Halfway Unit
4 Colville Unit
5 St. Joe Unit
6 Sawtooth Unit
MAP 1
MAP 2
MAP 3
MAP 4
MAP 5
MAP 6
WASHINGTON
OREGON
IDAHO

private landowners, generally on a 50-25-25 basis. Surveys made after the DDT was applied indicated treatment was almost 99% effective in controlling tussock moths. The spray program and the events leading up to it are described in detail in *1974 Cooperative Douglas-fir Tussock Moth Control Project*.[1]

The Environmental Monitoring Program

Significant public concerns about the tussock moth control program focused on DDT's capacity to damage nontarget organisms. Reflecting that concern, the States, Forest Service and the EPA required the spraying to be accompanied by an environmental monitoring program.

The monitoring program evolved to be the largest such undertaking ever carried out in the United States. It involved the work of some 200 people from 30 different agencies and groups. The program was coordinated by a Federal-State Interagency Monitoring Committee. The Forest Service provided an overall monitoring coordinator, and State coordinators were provided by the Idaho Department of Health and Welfare, the Oregon Department of Environmental Quality and the Washington Department of Ecology.

The Interagency Monitoring Committee established three basic goals:

- To ensure that DDT was applied safely and restricted to the target areas;
- To observe accumulation of DDT residues[2] in the environment;
- To determine the biological effects — or absence of effects — resulting from this accumulation.

To achieve these three goals, an extremely broad range of field studies was made. DDT levels were studied in the air, on forest vegetation, in the aquatic environment and in drinking water supplies. Samples of the following were also collected and analyzed for DDT residue: black aboreal lichen, domestic

[1] Graham, D. A., Mounts, J. and Almas, D., 1975. 1974 cooperative douglas-fir tussock moth control project, Oregon-Washington-Idaho. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

[2] DDT and its analogs p,p^{1}DDD, p,p^{1}DDE, opDDT and p,p^{1}DDT.

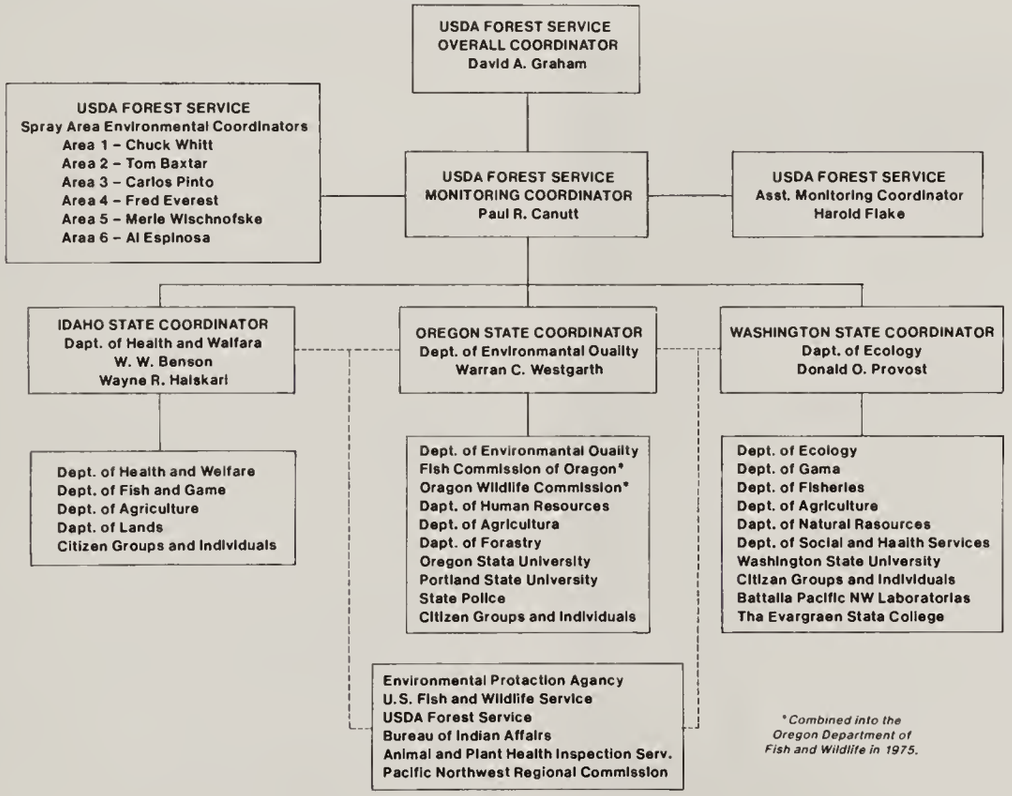
sheep, mule deer, elk, fish, coyotes, shrews, deermice, chipmunks, dark-eyed juncos, American robins, blue and ruffed grouse, the eggs of mountain bluebirds and common flickers and the eggs and blood plasma of kestrels and several accipiters.

To ensure the information collected would be reliable, usable and credible, efforts were made to standardize the collection, recording and analysis of data, to centralize data storage, and to place the overall program under a system of quality assurance.

Washington Department of Social and Health Services in Wenatchee. Quality assurance was supervised by the EPA's Region X laboratory in Seattle and the Oregon State University Department of Agriculture Chemistry Laboratory in Corvallis.

Special forms were designed for the recording of field and laboratory data. The information from those forms was placed in STORET, the Environmental Protection Agency's water quality data storage and retrieval system. The information in STORET

ORGANIZATIONAL CHART SHOWING COORDINATION REQUIRED AND AGENCIES PARTICIPATING IN THE ENVIRONMENTAL MONITORING PROGRAM



The Interagency Monitoring Committee organized a quality assurance committee composed of representatives from State laboratories of Oregon, Washington and Idaho. The quality assurance committee established methods for sampling, sample handling, preservation and analysis.[3]

Laboratories selected to perform the analyses were the Idaho Department of Environmental and Community Services in Boise, the Oregon Department of Agriculture in Salem, and the

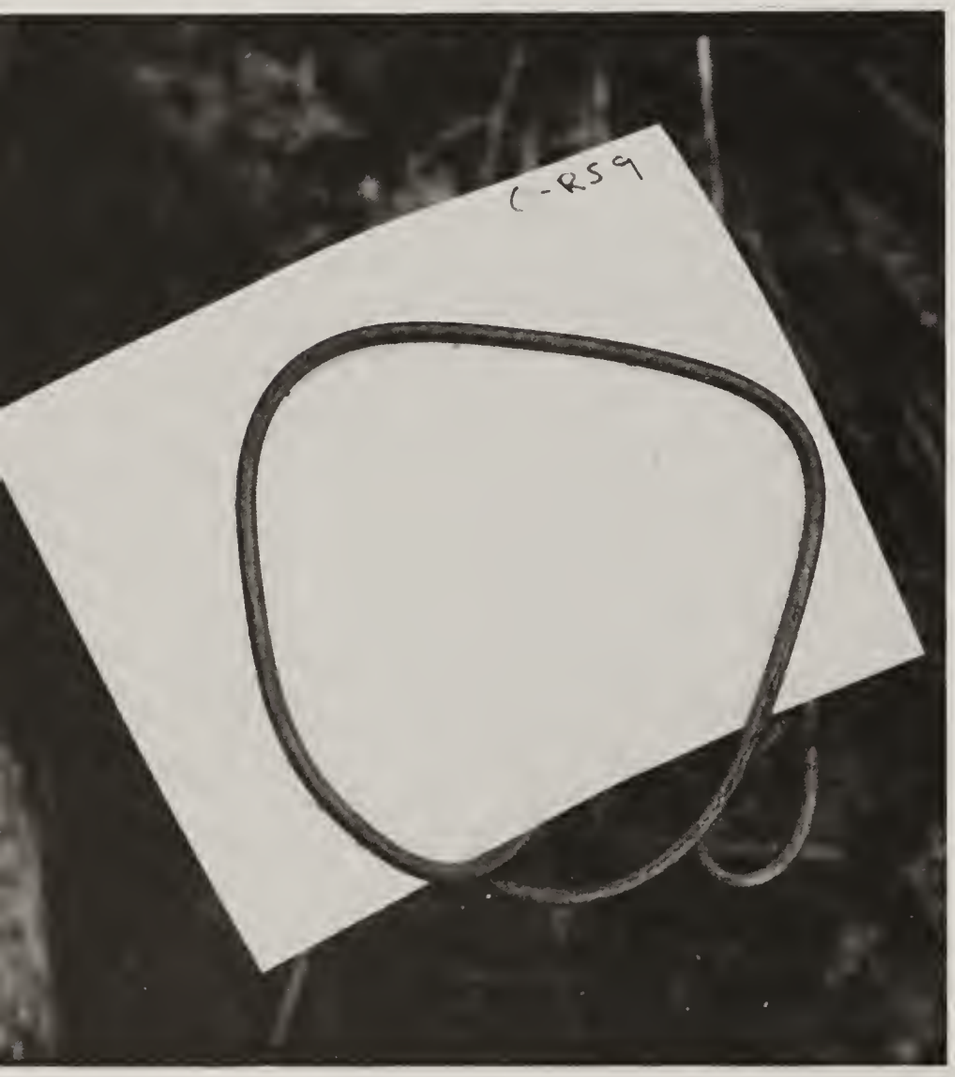
can be retrieved directly through more than 200 different terminals located throughout the United States. The DDT monitoring data can be selected according to sample types, project units, sampling stations, time, sample number, survey type or individual collector.[4]

[3] Gaylor, Arnold, 1978, DDT tussock moth quality assurance program, Environmental Protection Agency, Seattle, Washington.

[4] To ensure awareness of any specific conditions or problems which might affect the data, the Forest Service Environmental Coordinator, State Coordinators or individual researchers should be contacted prior to use of the data.

The environmental monitoring plan stressed the crucial distinction between *residue* monitoring — the relatively simple determination of DDT levels before and after spraying — and *effects* monitoring — the much more difficult determination of the effects those DDT levels had on living organisms.

The plan noted that effects monitoring requires more time and resources, but that only it can answer the many questions raised about the use of DDT. It requires the data base established by residue monitoring, plus both short- and long-term studies of population changes and reproductive success. Most studies conducted under the environmental monitoring program concluded in 1975; one extended to 1979.



Spray deposit cards were strategically placed throughout the sprayed area to monitor both the area sprayed and the amount of DDT formulation reaching the ground.

Some acute effects of DDT use may be noticeable in the short run, but the effects of prolonged exposure to sublethal amounts — such as the well-known eggshell thinning in raptor populations — require years to assess. To gauge the overall environmental effects of the tussock moth spray program, it would have been necessary to set up a monitoring and research project that continued for up to ten years.

The extensive field studies produced a great deal of information, little of it surprising, some of it of unknown significance.

Immediately after spraying, elevated DDT levels were observed high in the air, on forest foliage, in the water and organisms of some streams (not in watersheds contributing to human drinking water supplies); residue levels dropped most quickly in the air, flowing water and most vegetation, but persisted for an extended period on the forest floor. The spraying clearly killed large numbers of aquatic and terrestrial insects almost immediately, and significantly reduced the population of at least one species of soil organism, but had no observable long-term effects on insect life. Fish and other aquatic organisms retained relatively high levels of DDT for extended periods, but suffered no observable damage. One study indicated some frogs were killed.

Coyotes absorbed little of the insecticide. Chipmunks and deermice retained significant levels for long periods, but without noticeable effects. Shrews displayed high levels of DDT, and one study found a decline in the density of the observed shrew population.

Although DDT residues led to marked thinning of the shells of kestrel eggs, data were too limited to draw conclusions about the effect on kestrels' ability to reproduce. Goshawks, Cooper's hawks and sharp-shinned hawks captured in and adjacent to the spray area contained much higher levels of DDT residue in their blood plasma than did the kestrels.

Lambs, wild deer, elk, and grouse contained concentrations of DDT well above the maximum tolerance level set by the Federal

government for meat intended for human consumption.

In many cases, elevated levels of DDT in the bodies of birds or animals declined shortly after spraying but remained higher than pre-spray levels for more than a year. The long-term effects of those sublethal concentrations of DDT are unknown. Several researchers emphasized, in fact, that the spraying might have produced effects that their methodology, period of study or the sheer difficulty of observation did not permit them to see.

The following discussion briefly summarizes, and in part synthesizes the objectives, methods and findings of the studies conducted as part of the environmental monitoring program.

Air

Levels of DDT in the air were monitored at stations scattered widely in Oregon, Washington and Idaho by Kenneth C. McDonald and Warren C. Westgarth, Oregon Department of Environmental Quality.[5] Air samples were taken before spraying, and then a total of 244 were taken afterward, 202 in Oregon, 23 in Idaho and 19 in Washington. The standard sampling device consisted of a polyfoam plug enclosed by an aluminum tube through which the airflow was measured.

The original plan was to obtain air samples at each station within 24 hours of spraying, but spraying schedules were sometimes not established far enough in advance to get samplers set up. Last minute changes in spray schedules due to weather conditions or other problems caused some loss of coordination, and various delays finally lengthened the schedule to such an extent that lack of materials and time forced a break in sampling about June 25. As a result, some data collected reflected only approximate DDT levels.

In addition, some samplings disclosed DDT levels that could not be attributed directly to the tussock moth spray program. In certain cases, pre-spray levels of DDT were probably the results of previous spraying and/or the drifting of DDT that had been used nearby for the spraying of peas, one of the few uses of DDT still permitted by law.

In other cases, samplings indicated that significant amounts of DDT had drifted several miles from the tussock moth spray areas. However, it was impossible to determine which of the six spray areas it had drifted from. For example, there was no way of knowing whether some of the DDT measured at Troy, Oregon came from the Wallowa Unit in Oregon or the Pomeroy Unit in Washington. Researchers noted that good meteorological data, particularly wind direction and speed, would have been extremely valuable for interpreting the data. Any future monitoring of spray programs, they suggested, should include wind recording instruments.

Most of the DDT sprayed ended up in the forest environment. Conversely, at least some of the DDT deposited in the forest environment ultimately found its way back into the air.

To study the resuspension of DDT in air shortly after spraying, a ram-air high volume sampler was flown over spray areas on the Confederated Tribes of the Colville Indian Reservation for four consecutive days.[6] The sampler included a glass fiber filter to trap particulate DDT and a backup filter of polyurethane foam to absorb vapor. DDT from the spraying was found as high as 3,000-5,000 feet above the spray areas. DDT concentrations decreased with height but were sometimes borne upward by convective plumes. The greater proportion of the DDT found was in particulate rather than vapor form.

In a separate, non-air related study, researchers reported there was some evidence independent of the monitoring program which suggested DDT residues in New York rain water in late summer and fall of 1974 originated with the tussock moth spray program.[7]

[5] McDonald, K. C. and Westgarth, W. C., 1976. Air monitoring for the tussock moth-DDT spraying program. Oregon Department of Environmental Quality, Portland, Oregon.

[6] Orgill, M. M., Petersen, M. R. and Sehmel, G. A., 1974. Some initial measurements of DDT resuspension and translocation from Pacific Northwest forests. Batelle Pacific Northwest Laboratories, Richland, Washington.

[7] Herman, S. G. and Bulger, J. B., 1978. The effects on non-target organisms of a 1974 forest DDT application in the American Northwest: a three-year study of insects, songbirds and shrews. The Evergreen State College, Olympia, Washington.

Forest Vegetation

To determine the rate at which DDT evaporated or otherwise disappeared from vegetation and the forest floor after spraying, a year-long study was conducted in five of the six spray units by D. G. Moore, L. A. Norris and B. R. Loper, USDA Forest Service.[8]

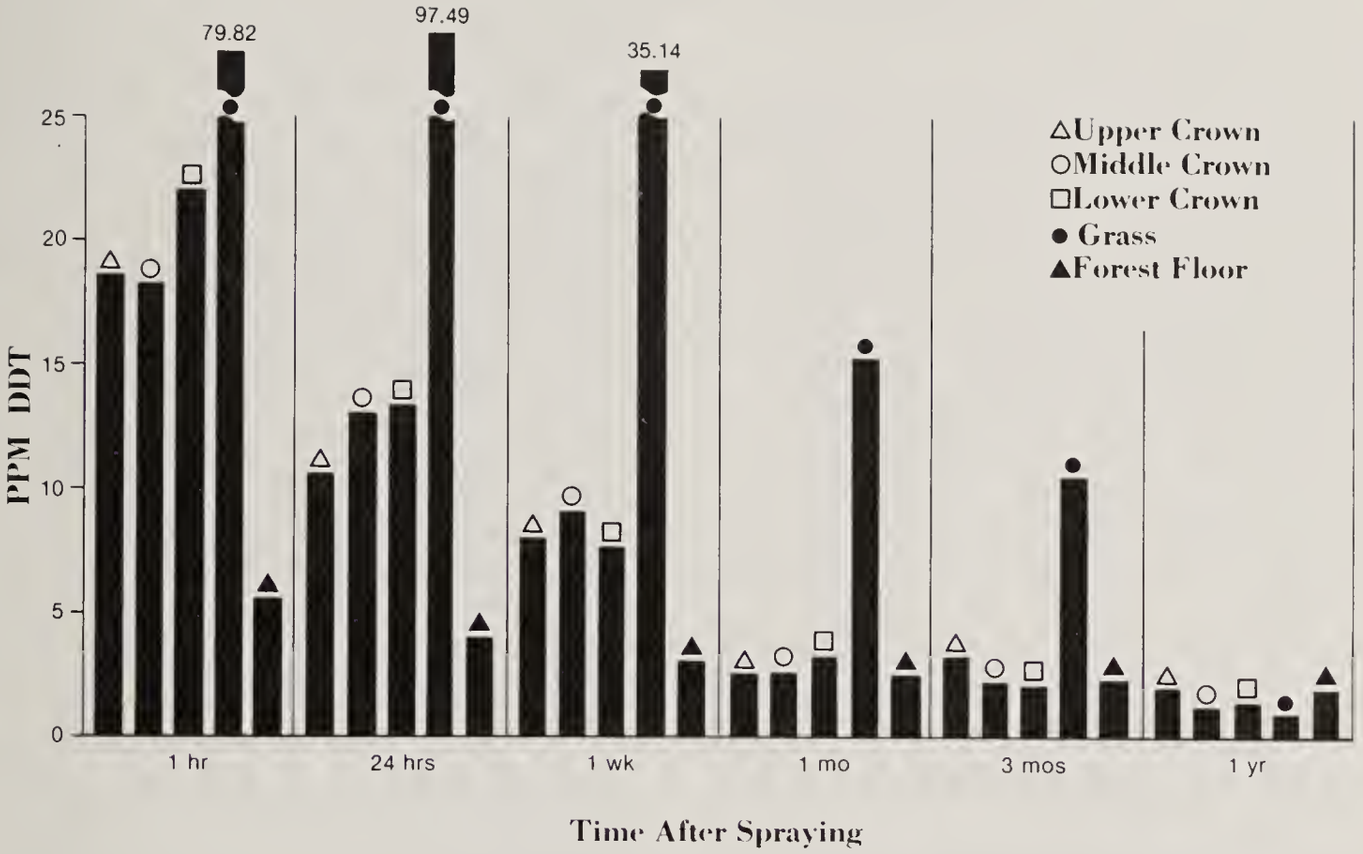
Sample branch tips were taken from the upper, middle and lower crowns of 50-75 foot tall Douglas-fir or true firs in all study areas, along with grass clippings from the ground beneath the trees and samples of the forest floor. Samples were taken before spraying, and then 1 hour, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, 1 week, 2 weeks, 3 weeks, 4 weeks, 3 months and 1 year after spraying. Heavy snow prevented collection of a 6-month post-spray sample.

The samples were analyzed in an effort to answer five basic questions: (1) Did the concentration of DDT on foliage decrease significantly over time, as had been suggested by laboratory studies? (2) To what extent did position in the tree or ground-level vegetation influence the rate at which DDT residues dissipated or decomposed? (3) Did the amount of DDT residue on the forest floor decrease significantly during the first 30 days after spraying? (4) Did differences in elevation and microclimate result in significant variation in the decomposition rate during the first 30 days after spraying? (5) Did the rates of concentration and dissipation at 30 days, 3 months and 1 year agree with the data obtained after a DDT spraying in 1965?

DDT residues were found in all but one of the pre-spray samples, probably the result of earlier spray programs. Pre-spray residue levels ranged from 0.01 parts per million to 0.35 ppm on conifer foliage, 0.0 ppm to 0.12 ppm on grass and 0.08 ppm to 0.87 ppm on the forest floor. (One part per million is equivalent to one drop in 13 gallons.)

The post-spray samples revealed a wide range in the amount of spray material

[8] Moore, D. G., Norris, L. A. and Loper, B. R., in preparation for publication. DDT residues on vegetation and forest floor material in eastern Oregon and Washington and northern Idaho, 1974-1975. Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Corvallis, Oregon.



Mean post-spray residue levels on conifer foliage, grass and forest floor of the Wallowa and LaGrande, Oregon, St. Joe, Idaho and Pomeroy, Washington spray units, 1974-75. All pre-spray samples contained less than 1 ppm DDT.

intercepted by various portions of the forest canopy and floor. Maximum DDT residue levels ranged from 7.71 to 48.67 parts per million on upper crown foliage, 7.69 to 50.87 ppm on middle crown, 8.09 to 63.92 ppm on lower crown, 36.78 to 263.29 ppm on grass, and from 3.03 to 10.95 ppm on the forest floor.

Although the highest levels of DDT residue had been expected in the first set of post-spray samples, researchers observed that in many cases, the highest concentrations were actually found in samples taken 6, 12, 24 or even 48 hours later. Small increases in the levels of DDT residue at later sampling times were attributed to normal variation in residue levels on the material being sampled. Larger increases were attributed to the application of additional spray material either by second sprayings or by drift from adjacent spray areas.

On all of the vegetative material sampled, DDT residues decreased most rapidly during the first 30 days after spraying. On grass, DDT residue levels at the end of one year were close to pre-spray concentrations. On the forest floor, however, 35.7% of the DDT residue deposited initially was still present at the end of a full year.

Total DDT residues diminished at essentially the same rate at all five study locations for each kind of sample material. Residue concentrations on grass showed the greatest decreases in the first year after spraying; residues on the forest floor decreased the least during that period.

In this study, the mean concentration of DDT on the forest floor after one year was 1.33 ppm. Coincidentally, that was exactly the mean concentration found on the black aboreal lichen after 50 weeks.

The lichen, actually an alga and fungus growing together, is found hanging from trees, and is eaten by some members of the Colville Confederated Tribes in traditional stews, puddings and teas. Because the lichen is consumed by human beings and, secondarily, because it is consumed by deer, Merle G. Wischnofske, USDA Forest Service, studied DDT residues on lichens growing in the Colville spray area in eastern Washington.[9]

Samples of the lichen were taken from five trees in each of three locations at different elevations above sea level. DDT residues were measured before spraying, one week after spraying, then in the fall of 1974 and the spring of 1975.

Pre-spray DDT concentrations in all samples were less than 0.01 ppm. One week after spraying, the mean level of DDT was 5.65 ppm for the entire study area. After 15 weeks, the mean level dropped to 4.40 ppm, and after 50 weeks to 1.33 ppm.

The Federal government's 1974 maximum allowable concentration of DDT on beet greens, spinach and other foods similar to the black lichen was 7 ppm. One week after spraying, four of the lichen samples exceeded that level, and 15 weeks after spraying, two of the samples exceeded it. By the end of 50 weeks, no sample showed DDT levels higher than 3.07 ppm, suggesting that from the fall of 1974 to the summer of 1975, precipitation had removed much of the DDT, and that by the spring of 1975, black lichen throughout the area had what the Federal government considered a tolerable level of DDT.

Terrestrial Invertebrates

Several environmental monitoring studies were designed to gauge the impact of DDT on nontarget soil- and tree-dwelling invertebrates, predominately insects.

Esther H. Gruber and Ellen M. Benedict, Portland State University, investigated the effects of DDT spraying on soil organisms in the Wallowa-Whitman National Forest in northeastern Oregon.[10] One-pint samples of forest floor litter and grass-soil layers were taken before spraying, then 2 days, 1 month, 3 months, 1 year and 15 months afterward. Organisms were extracted from the samples with heat, and sorted manually into the appropriate biological taxa.

The researchers felt that most of their findings were inconclusive, possibly because they had established too few monitoring or control stations, and possibly because the organisms found were not sorted with sufficient precision. The one type of organism for which they obtained unequivocal results was the pseudoscorpion. Pseudoscorpion densities decreased after spraying and remained low during the entire monitoring period.

The investigators suggested that pseudoscorpions might be particularly good indicators of the effects of DDT because they are predators, and therefore are affected by insecticide that is absorbed and concentrated further down in the food chain. They noted that earlier research on grassland soil animals had found that DDT destroyed nontarget invertebrate predators.

Another insect study focused on the parasitic wasp, *Agathis pumila*, which had been released to control the larch casebearer in some forest areas scheduled for spraying with DDT. To determine the impact of DDT spraying on this introduced parasite, Richard F. Schmitz, USDA Forest Service, studied densities of the casebearer, *A. pumila*, and native parasites on both sprayed and unsprayed plots.[11]

Eighteen inch-long sections of branches were taken from the upper crowns of larches. In the laboratory, researchers counted the number of spur shoots and casebearers on each branch.

[9] Wischnofske, M. G., 1975. Monitoring DDT residues on black aboreal lichen *(Alectoria jubata)*. Colville tussock moth project, U.S. Department of Agriculture, Forest Service, Wenatchee, Washington.

[10] Gruber, E. H. and Benedict, E. M., 1976. The effects of DDT on non-target soil organisms in northeastern Oregon. Department of Biology and Environmental Sciences, Portland State University, Portland, Oregon.

[11] Schmitz, R. F., 1976. Monitoring the effects of DDT spraying for Douglas-fir tussock moth control on the larch casebearer and its parasites. Intermountain Forest & Range Experiment Station, U.S. Department of Agriculture, Forest Service, Moscow, Idaho.

Casebearer pupae were raised in the laboratory and watched for evidence of *A. pumila.*

After sampling 37,767 larch spur shoots, Schmitz concluded that from May 1974 to May 1975, the density of larch casebearers had decreased from 20 per 100 shoots to 9 per 100 shoots, and on most of the study plots, the numbers of native parasites increased sharply. Casebearers decreased and parasites increased on both sprayed and unsprayed plots, however, so it was impossible to correlate the findings with the presence or absence of DDT. Schmitz postulated that the casebearer population might have been affected by climatic conditions.

There did not seem to be any correlation between the density of larch casebearers or native parasites and the presence of *A. pumila.* There was an apparent correlation between the density of *A. pumila* and the spraying of DDT. The highest rate of parasitism occurred on the spray plot which received the highest dosage of DDT, and while *A. pumila* density declined after the first post-spray measurement, it remained greater than the pre-spray density.

Schmitz suggested this finding was hardly conclusive, since only one plot known to contain *A. pumila* had been sprayed — others had been scheduled for spraying but had not actually been sprayed because tussock moth populations there had declined — and that plot had received only a light dosage of DDT (0.15 gallon DDT formulation per acre). Because of the small sampling and light dosage, the effect of DDT on the rate of parasitism remained unclear. Schmitz recommended that if DDT were used again, more extensive tests be made to determine the relationships between casebearer and *A. pumila* densities and the dosage of insecticide.

A third study found no ambiguity in the relationship between DDT application and a variety of insect species. As part of a more comprehensive study, Steven Herman and John Bulger examined sprayed and unsprayed plots in northeastern Oregon.[7] From DDT residue on spray cards they concluded that DDT concentrations on the two sprayed plots they studied were no more than two-thirds and one-third of the intended dosage, that even at such low levels the destruction of tussock moth

Boxes were placed on the forest floor to collect falling insects affected by DDT spraying.

larvae had been almost complete, and therefore, that even lighter dosages would probably have sufficed. They also found that DDT had proven extremely destructive of nontarget insects. Within the first three days after spraying, high mortality was observed among lepidopteran larvae, hemiptern nymphs, aphids, dipterans, sawflies and parasitic hymenoptera. Many of those groups continued to decline in number for up to two weeks, and population effects on some arthropod groups persisted for at least a year. The significance of these prolonged effects is not known.

Birds

Before the decision was made to implement the proposed tussock moth control program, testimony at public hearings and comments on the environmental impact statement clearly indicated there was strong concern about the potential impact of a DDT spray program on birds. In response to that concern and corroborating evidence provided by past research, the monitoring program included assessments of DDT residues in and effects on kestrels, accipiters, forest grouse and a variety of songbirds.

The kestrel was a particularly logical object of study. It was the most abundant raptor, or predatory bird, in the target area, and DDT in the environment had long since been shown to have harmful effects on raptor populations. In laboratory tests, DDT had produced both thinning of eggshells and actual egg loss. There had never been a field study of the effects of a single DDT spraying on a raptor population, so the 1974 tussock moth spray program offered an opportunity for unique research.

Populations of kestrels were studied extensively in northeastern Oregon and northwestern Idaho by Charles J. Henny, U.S. Fish and Wildlife Service; Morlan W. Nelson, Tundra Films; and Stephen R. Gray, U.S. Fish and Wildlife Service.[12] Adult kestrels were captured in live traps baited with live mice in

Nest boxes were employed to facilitate monitoring the DDT spray program's effect or lack of effect on reproductive success of house wrens and bluebirds.

[12] Henny, C. J., Nelson, M. W. and Gray, S. R., 1976. Impact of 1974 DDT spraying for tussock moth control on American kestrels — a preliminary report. U.S. Fish and Wildlife Service, Denver, Colorado. And Henny, C. J., 1977. Birds of prey, DDT, and tussock moths in Pacific Northwest. Trans. No. Am. Wildl. Res. Conf. 42:397-411.

1974, 1975, and 1976, and blood samples taken without sacrificing the birds. The samples were iced. Plasma was drawn off, frozen, taken to a laboratory, and analyzed.

Nest boxes were placed in the spray area, in adjacent areas, and in a control area far removed from the spray area. Kestrels laid eggs in the boxes during the first nesting season after the spraying, in the spring of 1975. One egg was chosen at random from every clutch of eggs found in a nest box, and analyzed for both shell thickness and the presence of DDT. The remaining eggs were monitored to see how many hatched, and how many of the resultant fledglings survived.

Henny and his colleagues had not expected much DDT to build up in a relatively short period. But in fact, DDT was detected in the plasma of two adult kestrels sampled only four days after spraying, suggesting that the insecticide had almost immediately entered the kestrels' food chain.

Blood samples were taken from kestrels both before and after spraying in three different locations: within 1.5 miles of the spray area; from 1.6 to 6 miles from the spray area; and beyond 6 miles. Before spraying, kestrels in all three locations had DDT residues at a mean level of 0.11 parts per million in their blood.

Samples taken from 2 to 40 days after spraying showed no increase in DDT residue levels in birds more than 6 miles from the site, while birds from 1.6 to 6 miles away had DDT residue levels elevated to only 0.18 ppm. Within 1.5 miles of the spray area, however, blood levels of DDT more than doubled to 0.27 ppm. Samples taken the following year showed radically different concentrations and distributions of DDT. Beyond 6 miles, the mean blood level was 0.24 ppm, and from 1.6 to 6 miles, it was 0.23 ppm. Within 1.5 miles of the sprayed area, the mean blood level was 0.78 ppm DDT, or more than seven times pre-spray levels.

The researchers suggested that the elevated DDT levels found in 1975 blood samples taken at distances of more than 1.5 miles from the spray area might partially be accounted for by drift of the DDT when applied, by movement of the insects, birds and mammals on which the kestrels fed, or by movement into and out of spray areas by some of the kestrels themselves. Within the 1.5 mile radius, they considered both the 1974 and 1975 DDT residue levels in blood significant.

What impact those DDT residue levels had on the kestrel population was unclear. There was, however, an extremely clear effect on kestrel eggs. Eggs within the spray area contained roughly five times the DDT residue of eggs outside the area. A sampling of 12 female birds showed a close correlation between DDT residue in the blood and DDT residue in the eggs. The increase in DDT residue was accompanied by a marked thinning of eggshells. Eggshells within the spray area were 10.4% thinner than the control eggshells.

The data obtained during this study were too limited to be conclusive about the effects of observed DDT residue levels on kestrel reproductivity. However, the data suggested that much lower levels of DDT and its metabolites were required to cause an initial 10% thinning of eggshells than originally anticipated. Other research reported eggshell breakage in kestrels began to occur when eggshells became more than about 22% thinner than normal, and that no North American raptor population in which shells had thinned 18% or more had been able to maintain itself in a stable, self-perpetuating state.

The researchers cautioned that there might have been both short- and long-term effects they hadn't observed. They noted the possibility that females with relatively high levels of DDT in their bodies may not have nested in 1975, or that their eggs may have broken soon after being laid. DDT levels in the blood of females that were known to have laid eggs ranged from 0.05 to 0.35 ppm, while some females not associated with nests contained blood levels above 1 ppm. There was no way of identifying birds that did not attempt to nest or that laid eggs which broke before investigators visited the nest. Both the failure to nest and the immediate breakage of eggs might easily have occurred unobserved.

Henny and his colleagues reported that mean DDT residue levels in the blood plasma of kestrels captured in the spray area peaked at 0.78 ppm in 1975 (one year after spraying) and declined to 0.51 ppm in 1976. The number of

blood samples collected from accipiters — goshawks, Cooper's hawks and sharp-shinned hawks — was too small for statistical analysis; however some trends were apparent.

Blood samples collected from accipiters contained much higher mean levels of DDT residue than found in kestrels. Mean residue levels in 1975-76 samples from the sprayed area were 2.03 ppm for goshawks, 2.99 ppm for Cooper's hawks and 4.75 ppm for sharp-shinned hawks. These levels were respectively 2.6, 3.8 and 6.1 times the peak 1975 mean residue level found in kestrels, prompting researchers to express concern about the potential effects of DDT spraying on all three accipiters studied. Henny suggested it was noteworthy that broken eggs were observed in the nest of one Cooper's hawk. A 6-year accipiter field study was completed in 1979 and a final report is in preparation.

Some of the nest boxes established to attract American kestrels attracted common flickers and mountain bluebirds instead. This afforded researchers the opportunity to collect DDT residue and effects data on these species incidental to the research targeted on kestrels.[13]

Flicker and mountain bluebird eggs were collected from nest boxes in northeastern Oregon and northern Idaho in 1975, one year after spraying. Samples were taken from the spray area, 0.1 to 1 mile from the spray area, and 10 or more miles from the spray area.

DDT residues were found in all common flicker eggs. The mean was 0.58 ppm and the range from 0.26 ppm to 1.29 ppm in samples from the spray area. In samples taken 10 or more miles away, the mean DDT residue level was 0.24 ppm and the range 0.07 ppm to 0.70 ppm. There was no evidence of eggshell thinning; eggshell thicknesses were nearly identical in spray and nonspray areas.

All sampled mountain bluebird eggs also contained DDT residues. Levels ranged from 0.27 ppm to 5.08 ppm (mean: 1.67 ppm) 16-50 miles from the spray area, 1.15 ppm to 5.39 ppm (mean: 2.61 ppm) 0.1-1 mile from the spray area, and 1.20 ppm to 16.2 ppm (mean: 5.29

[13] Henny, C. J., Olson, R. A. and Meeker, D. L., 1977. Residues in common flicker and mountain bluebird eggs one year after a DDT application. Bulletin of Environmental Contamination and Toxicology 18(2):115-122.

ppm) in samples taken within the spray area. Eggshell thickness was not measured due to the small size of the eggs.

The researchers concluded that differing DDT residue concentrations in common flicker and mountain bluebird eggs primarily related to the birds' different food habits. Approximately 50%-70% of the common flicker diet is animal matter, compared to more than 90% for the mountain bluebird. The researchers noted that DDT residue levels in mountain bluebird eggs were quite similar to residue levels found in kestrel eggs from the same spray area, which might be expected as the two species have similar food habits during the summer months.

Two other studies of birds also showed elevated DDT residue levels that persisted for more than a year. These studies revealed no short-term impact on reproductive success.

David J. Lenhart, U.S. Fish and Wildlife Service, measured residue levels in dark-eyed juncos, American robins and blue and ruffed grouse in all six of the major spray areas.[14] The U.S. Fish and Wildlife Service coordinated sample collection by State and USF&WS personnel. The birds were killed with shotguns and kept as cool as possible in the field before being frozen and ultimately analyzed by gas chromatography at State laboratories. Samples were collected within the 30 days before spraying, then from 30 to 60 days after spraying, and finally 1 year later. The study was designed to measure DDT residue levels (based on whole body weight), not to investigate any sublethal or long-term effects of those residues.

Juncos are migratory forest birds that feed on both seeds and insects. Presumably, they would display DDT residue levels that were typical of insect-eating birds. The juncos taken before spraying had mean background DDT levels of 0.24 ppm. Thirty to sixty days after spraying, the level had risen to 6.91 ppm, or some 29 times pre-spray background levels. One year post-spray, the mean DDT residue level was still 2.48 ppm, ten times higher than the pre-spray level. For no apparent reason, DDT levels in birds collected from the Colville spray area in eastern Washington were three times higher than the average levels found in other areas studied.

Robins are not basically forest birds, but they do feed frequently in forest openings, and they were found in reasonably large numbers in all spray areas. They feed on earthworms and ground dwelling insects, and presumably take DDT into their systems by eating worms and insects that have been contaminated.

Robins, which migrate to and from the spray areas, were found to have a mean background level of 0.61 ppm DDT. After spraying, the mean rose to 4.39 ppm, with two robins containing more than 23 ppm DDT. A year later, the mean was 3.76 ppm, more than five times higher than the pre-spray level. Like the juncos, robins from the Colville, Washington spray unit showed the highest DDT residue levels one year post-spray of all areas studied.

Unlike the robins and juncos, which migrate, the grouse live year-long in the forest. None of the 14 grouse collected before spraying contained DDT residues at the analytical level of 0.01 ppm. After spraying, the mean level of DDT residue increased to 2.99 ppm, at least a 300-fold increase over pre-spray levels. The highest recorded level was 37.47 ppm. A year after spraying, the mean DDT residue level was 1.14 ppm, more than 100 times higher than before spraying.

The results of this study were roughly what had been expected, based upon earlier research on DDT in the forest environment. No dead birds were found; however, two robins collected between 30 and 60 days post-spray contained DDT residue levels in excess of 23 ppm. Other studies on robins have shown that DDT poisoning must be suspected when DDT residue levels reach 30 ppm or more. It is possible that DDT-related deaths of some birds occurred unobserved.

Based on whole body weight residue data, it was assumed that DDT levels in muscle tissue of a significant number of grouse exceeded the 5 ppm considered the maximum tolerable in meat intended for human consumption, and that levels in grouse fat were many times higher.

Without direct reference to residue levels, a

[14] Lenhart, D. J., 1977. Residues of DDT in forest birds associated with the 1974 DDT-tussock moth control program. U.S. Fish and Wildlife Service, Portland, Oregon.

study by D. Calvin McCluskey and Jack Ward Thomas, USDA Forest Service, and E. Charles Meslow, USDI Fish and Wildlife Service, focused on the impact of DDT on reproduction of house wrens and mountain and western bluebirds living in grasslands adjacent to sprayed areas.[15] All three species live primarily on insects during the summer, the time spraying took place. They were attractive subjects for study because they were numerous, they readily accept nest boxes, and they nest at heights from 3.9 to 6.6 feet above the ground, making their nests easily accessible.

The study was designed to determine if there was any significant decline in the number of eggs laid or hatched, or in the survival of young birds following the spraying of DDT. If there was a decline, the researchers hoped to determine whether it had been caused by a decrease in the size of the insect population, or by DDT present in insects eaten by the birds.

Study areas were located north of Wallowa, Oregon, and northeast of LaGrande, Oregon. Flying insects were caught in net traps in spray and control areas both before and after spraying. In addition, grasshoppers were trapped in spray and control areas during the following year. Immediately after spraying, capture rates of flying insects declined by 80.7% on sprayed areas compared with 41.9% on untreated areas.

To gauge the reproductive success of the three birds, 550 nest boxes placed in spray and control areas were monitored during 1974 and 1975. Each box the birds used was checked to determine the number of eggs laid, the percentage of eggs that actually hatched, and the percentage of young that survived to become fledglings.

Despite DDT's observed effects on insect populations, it had no noticeable immediate or second-year impact on reproduction of the insect-eating birds studied. The researchers cautioned, however, that their findings should not be taken as evidence that the DDT had done or could do no harm. They pointed out that applications of DDT at levels that did not seem to interfere with the reproduction of bluebirds or house wrens still contributed to the overall level of DDT in the environment, and could be concentrated and passed along through the food web.

Herman and Bulger[7] studied the direct effects of DDT on songbirds in their study of breeding birds, the success rates of bird eggs or young, and the presence or absence of dead birds on both sprayed and unsprayed plots. They examined study plots in northeastern Oregon, both before and after spraying in 1974, and again in 1975.

In 1974, 17 bird species occupied 111 individual territories on the unsprayed plots before spraying occurred, and 16 species occupied 116 territories afterward. On the sprayed plot, 21 species occupied 122 territories before spraying and 19 species occupied 95 territories afterward. The following year, the numbers of occupied territories declined in both plots, but the decrease on the sprayed plot was about two and one-half times as great as the decline on the unsprayed plot.

There was no discernible effect on 1974 or 1975 reproductive success of the species studied. These findings agreed with the observations and experimental results of other research. Passerines generally do not exhibit the same eggshell thinning that occurs among some species of raptorial and fish-eating birds.

The researchers found no effect on nestling survival in a small number of nests studied in 1974. In 1975, fledgling success was nearly identical in the sprayed and unsprayed plots.

While the researchers did not find any significant effect on birds' reproductive success, they did find evidence of birds killed outright by the DDT spraying. Despite the known difficulty of locating dead birds, between July 7 and August 6, 1974, 14 dead or dying birds were found on about 16 acres of one spray plot. No dead birds were observed after equivalent searching of the unsprayed plot. Of the 13 dead birds recovered, only 3 were fresh and large enough to provide meaningful brain samples for analysis. DDT residues of 54 ppm, 56 ppm and 460 ppm were found. DDT seemed to be the cause of death in all three cases. Two birds were observed in

[15] McCluskey, D. C., Thomas, J. W. and Meslow, E. C., 1977. Effects of aerial application of DDT on reproduction in house wrens and mountain and western bluebirds. PNW-228, Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Portland, Oregon.

tremors on the sprayed plot, and whole-body residues in the remaining dead birds recovered — those for which brain analyses were impossible due to their small size — were generally higher, considering age and species, than residues in apparently healthy birds collected in the same area with shotguns or mist nests.

Noting that it would be inappropriate to extrapolate these observations directly to the entire acreage treated with DDT during 1974, the researchers nonetheless took these findings as proof that the DDT spray program had caused widespread and significant mortality among passerine birds in the year of application. With hindsight, they noted some of the effects they observed had been predictable; past research indicated that passerine mortality and population declines had been associated with virtually every previous forest application of DDT.

The researchers emphasized the difficulty of finding dead birds, and suggested that they had found considerably fewer than all the dead and dying birds on the acreage they searched and patrolled. Dying passerines probably seek shelter as they near death, hiding under logs and near the bases of trees. Under those circumstances, they could be invisible to a researcher. Birds that die in the open or in light cover are also hard to find. Dead birds are subject to rapid decay and predation, so that without constant attention to an open area, their disappearance would be rapid and complete.

Herman and Bulger noted that most earlier studies of DDT applications had led to conclusions that effects on birds were limited to dosages of five pounds or more per acre; their own work extended those levels well below one pound per acre. They concluded that residues of DDT were transported to ecosystems far beyond the tussock moth spray area by migrating birds.

No effects on nestling survival were observed in studies conducted as part of the environmental monitoring program.

Mammals

Residues of DDT were measured in seven different species of mammals, including small and large predators and wild and domestic animals commonly used as human food.

W. R. Heiskari, Idaho Department of Health and Welfare, studied DDT residues in coyotes.[16] A large mammal predator, the coyote occupies the extreme top of the food web, concentrating small mammal species and the chemical substances in them. The coyotes were collected by fieldmen of the Animal Damage Control Division of the U.S. Fish and Wildlife Service during the normal course of their predator control program. One sampling was done before spraying, one 4 months, and one 10-12 months after spraying. Coyotes were taken at three sites in Oregon, two in Washington and one in Idaho. Laboratory analysis was performed on a cube of meat taken from the skinned thigh of each coyote.

In Oregon, no coyote showed DDT residues of even 0.01 part per million either before or after spraying.

In Washington, 4 of 17 coyotes showed DDT residue levels of at least 0.01 ppm before spraying, with the highest level 0.10 ppm. Four months after spraying, 1 coyote had a residue level of 0.75 ppm, and 18 others had no detectable DDT residue. By the spring of 1975, 1 coyote contained 0.02 ppm, and 16 others contained no detectable DDT.

In Idaho, 3 of 20 coyotes sampled had DDT levels above 0.01 ppm before spraying, with the highest level 0.06 ppm. Four months after spraying, 6 of 10 coyotes sampled showed detectable levels, with a high of 1.27 ppm DDT. By the spring of 1975, 10-12 months after spraying, only 1 of 10 samples had an elevated DDT residue level, 0.02 ppm.

Smaller predators, the shrews, are also at the top of the food web. They were subjects of two separate studies, one of which also covered small mammals further down the food chain.

James J. Kirk, Oregon Department of Human Resources, studied DDT residues in shrews, deermice, and chipmunks.[17] Samples of all three were taken in all spray project areas. Shrews were captured in pitfall and snaptraps, deermice in snaptraps and live traps and chipmunks in both kinds of traps and by shooting. Samples were taken in May and June 1974 before DDT spraying occurred, and subsequently in July, September, October and November 1974, and May and June 1975. Additional shrews were collected in the LaGrande and Halfway, Oregon areas in the spring of 1976.

Concentrations of DDT varied widely among the three species, with shrews displaying much higher levels than deermice and chipmunks.

Before spraying, both deermice and chipmunks had mean DDT residues of 0.02 ppm. Three weeks after spraying, deermice had a mean DDT level of 0.36 ppm, and chipmunks 1.72 ppm. After 3 months, DDT residue levels had declined to 0.18 and 0.32 ppm respectively, and after 50 weeks to 0.07 ppm and 0.19 ppm respectively.

Kirk observed that post-spray DDT residues declined in deermice and chipmunks at about the same rate, and that the rate of decline decreased with time. Mean DDT residues in chipmunks could be expected to return to pre-spray levels later than those in deermice, mainly because the initial post-spray residues were higher in the chipmunks. His extrapolations indicated a return to pre-spray levels in just over 2 years for deermice, and just over 17 years for chipmunks, but he noted that the reliability of those extrapolations was probably poor.

The shrews began with a mean background level of 0.22 ppm DDT, much higher than either deermice or chipmunks. Mean levels at 2, 17 and 50 weeks were 72.53 ppm, 0.92 and 7.97 ppm respectively. The first post-spray figure was inflated by two very high individual readings, including one of 630.64 ppm, and the third figure by an individual reading of 28.04 ppm.

Reasons for the fluctuating DDT residues in shrews were unknown. The first post-spray

[16] Heiskari, W. R., 1976. Predator mammals — coyotes. Idaho Department of Health and Welfare, Boise, Idaho.

[17] Kirk, J. J., 1976. DDT residues in small animals. Oregon Department of Human Resources, Portland, Oregon.

residues seemed skewed toward lower values, possibly reflecting the deaths of some shrews with higher DDT residues. The high deermouse population observed in the spring of 1975 might also have reflected mortalities among the shrews — which may feed partly on deermouse young. The deaths of shrews within the spray plots, followed by the migration of other shrews into the plots, might have accounted for the apparently low autumn residue levels. The relatively high pre-spray residues might have resulted from biological concentration through the food chain.

Kirk advanced that the high variability and small sample size might have obscured the true trends of DDT residues in shrews. He concluded that the apparent rise in residues by the spring of 1975 could not be explained by the available data.

In their more comprehensive study, Herman and Bulger[7] observed what appeared to be a clear decline of the shrew population on a sprayed plot. They captured shrews from both sprayed and unsprayed areas with tumble-in traps, which were simply open cans set in the ground.

On the sprayed plot, their shrew captures declined from a pre-spray level of 1.84 per 1,000 trap hours to an October post-spray figure of absolute zero. The unsprayed population also declined during that period, but only from 2.79 to 0.82 captures per 1,000 trap hours. After September, no shrews at all were taken on the sprayed areas in 38,054 trap hours, while 8 were taken in the unsprayed area in fewer than half as many hours.

Similar population trends were observed in 1975. During the entire year, 38 shrews were captured on the sprayed area at a rate of 1.36 captures per 1,000 trap hours, while 93 were captured on the unsprayed area at a rate of 3.34 per 1,000 trap hours.

The researchers concluded that DDT application in their study area had caused the deaths of shrews, that the population had not recovered a year later, but that some shrews had persisted there as late as the summer of 1976.

The monitoring program found no evidence that the tussock moth control program resulted in damage to large browsing and grazing animals, but there were long-lasting DDT residues, which potentially had more direct human significance than the residues reported in some smaller mammals.

Mule deer and Rocky Mountain elk are the principal big game species in the areas treated with DDT. In a study by C. F. Martinsen, Washington State Game Department, deer and elk were sampled during the 1973, 1974, and 1975 hunting seasons in both Washington and Oregon, and their fat analyzed to determine concentrations of DDT residues.[18]

There were no Federal standards for an acceptable level of DDT in wild animal fat; the standard employed for domestic livestock was 5 ppm.

The samples taken before spraying showed low levels of DDT- 0.02 ppm in deer and elk in northeastern Oregon, and 0.01 ppm in the animals sampled in Washington. Those levels were much lower than the mean of 0.26 ppm DDT found in 1963, when DDT was still in widespread use.

After spraying, DDT residue levels in sampled animals rose sharply, even in control plots 10 to 20 air miles from the nearest spray area; residue levels in animals from control plots ranged from 0.06 ppm to 11.71 ppm with a mean residue level of 2.11 ppm in 1974.

Four months after the initial spraying of DDT, animals sampled from Washington spray plots contained from 0.78 ppm to 52.48 ppm DDT. Oregon samples ranged from 0.97 ppm to 50.70 ppm.

By 1975, DDT residue levels in all animals sampled from spray and control plots had dropped below the 5 ppm tolerance level established for domestic livestock used for human consumption.

Although no deaths of either deer or elk could be attributed to the DDT spray program, Martinsen observed that the winter after spraying had been very mild. Therefore, the animals had not been otherwise placed under stress which would have resulted in potentially harmful rapid metabolization of fat containing DDT into their systems.

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[18] Martinsen, C. F., 1975. Results of the DDT-tussock moth monitoring study for mule deer and elk in the Blue Mountains of Oregon and Washington from 1973 through 1975. Washington State Game Department, Olympia, Washington.

Martinsen summarized the evidence by noting that in general, DDT residue levels in deer and elk had been well above the domestic livestock standard of 5 ppm during the period immediately after spraying and throughout the first winter. He suggested that if DDT were used in the future, more emphasis be placed on notifying hunters about the precautions to be taken when using harvested game, and that responsible government agencies take a more definite stand on pesticide contamination and human consumption of the contaminated meat.

While hunters eat appreciable numbers of deer and elk from the DDT spray areas each year, domestic sheep are one of the principal animals in the area raised expressly for human consumption. Sheep ranchers in and near the spray areas were concerned about possible buildups of DDT in their animals. Sheep with DDT residues of more than 5 ppm in their fat could not legally be sold for human consumption.

To answer the questions about the impact of DDT spraying on sheep raised for market, Gerald S. Strickler and Paul Tresham, USDA Forest Service, monitored residue levels in the kidney fat, muscle tissue and fat, rumen contents and feces of lambs grazing sprayed and unsprayed forest range northwest of La Grande, Oregon.[19]

Snowberry, the forage plant most common to all areas grazed by the lambs, was sampled for DDT residues 1 week before spraying and then 1, 3, 8, and 14 weeks afterward, with a final sampling in June 1975.

DDT residues on snowberry plants varied widely. Small amounts of the insecticide were found on all samples before spraying and on the unsprayed control plot at all sampling periods. On the sprayed plots, DDT residue concentrations after 1 week ranged from 1.14 ppm to 105.08 ppm, with a mean of 17.53 ppm. The mean residue level increased to 20.87 ppm after 3 weeks, fell to 9.26 ppm at 8 weeks, rose to 11.35 ppm at 14 weeks, and was down to 0.22 ppm, similar to that on the control plots, one year after spraying.

Two days after spraying, five 20-lamb test groups were trucked to the sprayed area, tagged and left to graze. A control group of 20 lambs was trucked to and began grazing an unsprayed area six air miles from the nearest sprayed plot. After grazing on the sprayed plot for 1, 2, 6, 10, and 14 weeks, three lambs from the respective test group(s) were slaughtered and analyzed for DDT residues.

Throughout this study, total mean DDT residues in control lambs were near minimum detectable amounts (0.01 ppm) in rumen, fecal and muscle tissue, and very low (less than 0.1 ppm) in kidney fat and muscle fat. These levels correspond closely to DDT residue levels measured on unsprayed vegetation.

Kidney fat had the highest concentration of DDT residue of all the body parts tested in all of the lamb test groups grazed in sprayed areas. After 1 week on sprayed forage, lambs had mean DDT concentrations of 11.72 ppm in muscle fat and 16.22 ppm in kidney fat. At 2 weeks, mean residue levels rose to 28.93 ppm in muscle fat and to 33.84 ppm in kidney fat. At 6 weeks, mean residue levels were 36.39 ppm and 26.06 ppm respectively. Ten weeks after spraying, the mean concentration of DDT in muscle fat was 30.24 ppm and in kidney fat 14.33 ppm. Even after 14 weeks, mean residue levels were 17.83 ppm and 27.07 ppm respectively.

The residue level in muscle tissue itself was low, but it increased the longer sheep grazed on the sprayed forage. Evidently, most of the residue found in muscle tissue samples actually came from fat retained on the tissue.

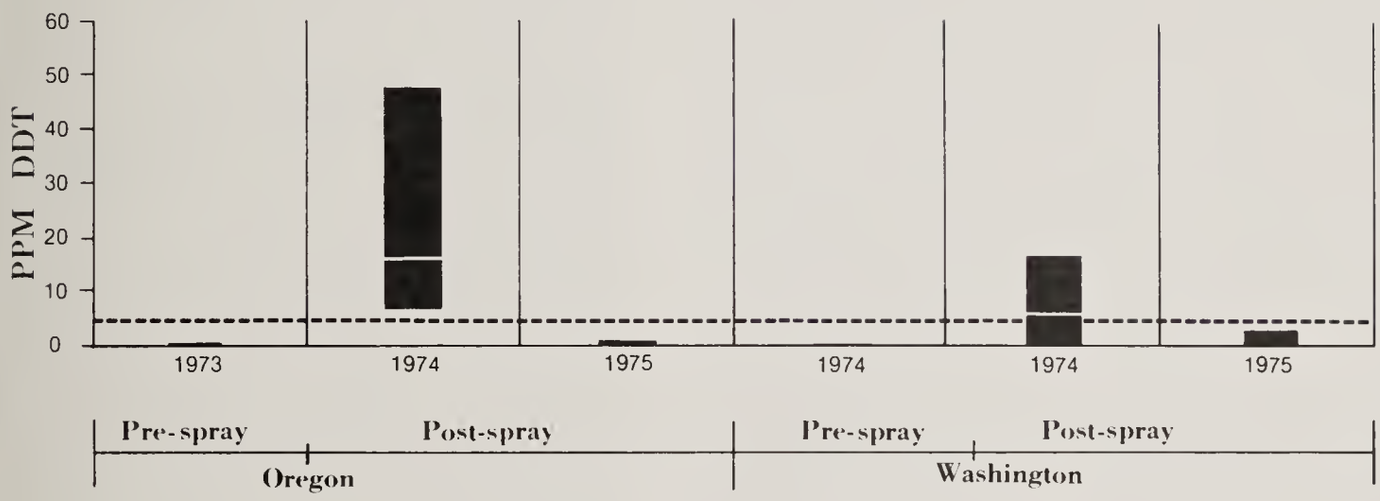
DDT residues in kidney fat of lambs that grazed sprayed forage, 1, 2, and 6 weeks declined rapidly after the animals were moved to unsprayed forage. Residue levels declined slowly in lambs that had grazed 10 and 14 weeks in the sprayed area before being moved to unsprayed forage. The mean residue level in lambs that grazed unsprayed forage 6, 10, and 14 weeks actually increased 10, 6, and 2 weeks respectively after the animals were removed from unsprayed forage. Similar increases were noted in muscle samples. The researchers noted those increases coincided with and followed a 2-week period when the lambs were put on dry feed, and might have resulted from physiological processes related to the change

[19] Strickler, G. S., and Tresham, P., 1975. Program report, monitoring DDT residues in vegetation and sheep, 1974 Douglas-fir tussock moth project. U.S. Department of Agriculture, Forest Service, Range and Wildlife Habitat Laboratory, La Grande, Oregon.

from a succulent forage.

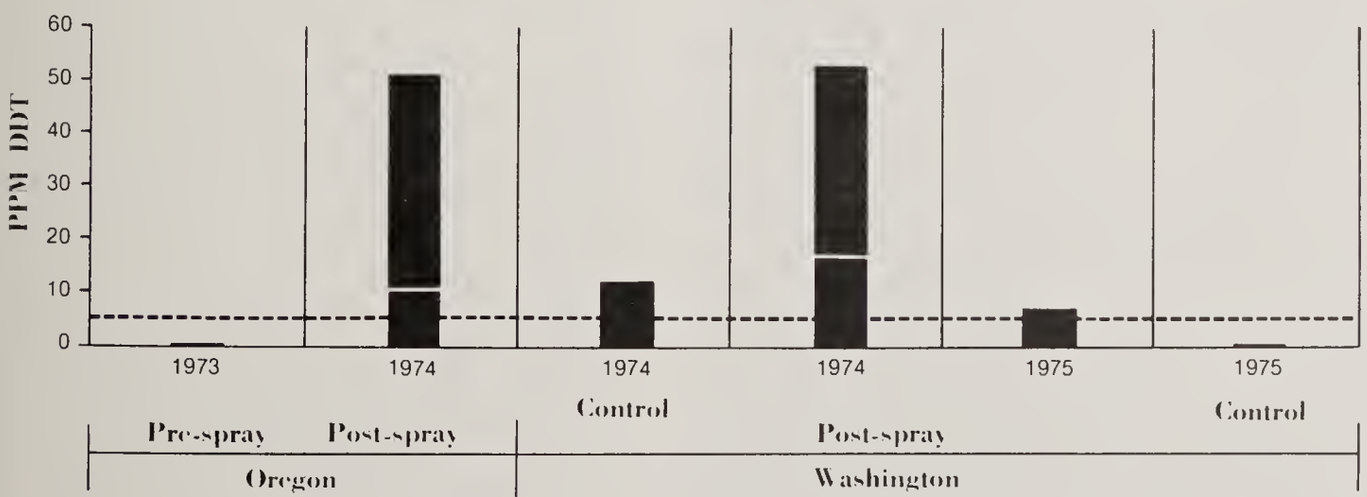
At the time of this study, the tolerance level for DDT residue in the fat of livestock marketed for human consumption was 5 ppm.

Deer



Mean ---5 ppm Tolerance Level for Domestic Livestock

Elk



Pre- and post-spray DDT residue levels found in fat of elk and deer sampled in Oregon and Washington, 1973-75.

The mean DDT residue level in muscle fat of lambs that grazed 1 week on sprayed forage and then 1 week on unsprayed forage was 8.34 ppm. The mean residue level in this test group dropped to 3.89 ppm after 3 weeks on unsprayed forage.

Mean DDT residue levels in muscle fat of lambs that grazed sprayed forage 2 weeks dropped below the 5 ppm tolerance level by the end of the fourth week on unsprayed forage. Except for one test group, lambs that grazed sprayed forage for 6 weeks retained DDT residue levels in muscle fat in excess of 5 ppm 14 weeks after being placed on unsprayed forage. Mean DDT residue levels in muscle fat of lambs grazing 10 and 14 weeks on sprayed forage still exceeded the 5 ppm tolerance level after 18 and 14 weeks respectively on unsprayed forage.

Virtually no DDT was found in 14 embryos and well-developed fetuses of ewes that had 0.7 ppm to 19.0 ppm DDT residue in their own kidney fat, indicating little DDT was passed on to developing fetuses.

Aquatic Environment

Efforts were made to prevent the direct application of DDT into major lakes and water courses; 100 foot-wide buffer strips were provided on either side of larger streams and rivers. Seven separate studies were conducted to determine how much and with what effect DDT entered the aquatic environment.

Drinking water supplies near the spray areas were objects of special concern. Watersheds supplying drinking water for human use lay within the Halfway spray unit in Oregon and the St. Joe spray unit in Idaho. Inside the watersheds, plans called for the spray to be applied with extreme caution. In addition, the Environmental Protection Agency required: (1) monitoring of surface water for evidence of DDT residue, (2) establishment of a mechanism for immediately notifying public water supply utility superintendents of spraying mistakes within the watersheds, and (3) development of a contingency plan for supplying safe drinking water if normal supplies were contaminated by DDT.

No spraying mistakes deposited the insecticide directly in water supplies and the emergency plans were never used. Before the tussock moth control program began, Wayne R. Heiskari, Idaho Department of Health and Welfare, found detectable levels of DDT in three water supplies located near areas where DDT had been used heavily on peas.[20] Two different water supplies showed low but detectable levels of DDT after the spray program (0.01 parts per *billion* to 0.02 ppb). None of the DDT concentrations observed within the watersheds was considered a risk to human safety.

Monitoring for DDT residues in potable water supplies was undertaken in limited areas for a limited purpose. Much broader in scope was a sampling of the total aquatic environment — not only water, but also sediment, vegetation, and a wide range of organisms — in streams in all three states. The methods employed and the results of these tri-state general monitoring activities were compiled and synthesized into one report by Harry B. Tracy and Douglas Freeman, Washington Department of Ecology.[21]

Two index streams and one control stream were chosen in each major spray block. One sampling station was established on each control stream and three on each index stream. Samples were taken shortly before spraying, on or shortly after spray day, 90 days after spraying, and one year after spraying. Water samples were taken in 1-gallon jars. Sediment and vegetation were sampled in 10-gram and 50-gram amounts. Tissue from animal species, including fish taken with electroshockers, was sampled in amounts of not less than 10 grams. A small number of samples of mussels and fingerling salmonids were taken from live boxes placed in the streams.

In addition to water, bottom sediments and aquatic vegetation, the sampling categories included benthic (i.e., bottom-dwelling) organisms, fish and "miscellaneous species." The last category included frogs, crayfish, whitefish and freshwater mussels. If other

[20] Heiskari, W., 1976. Potable water supplies — public and private. Idaho Department of Health and Welfare, Boise, Idaho.

[21] Tracy, H. B. and Freeman, D., 1977. General monitoring activities, aquatic environment. For inclusion in: The 1974 cooperative Douglas-fir tussock moth control project, Oregon-Washington-Idaho; State of Washington, Department of Ecology, Office of Water Programs, Olympia, Washington.

species could not be obtained for a given sampling, the miscellaneous species were used to fill the gap.

Concentrations and persistence of DDT varied widely from one part of the aquatic environment to another. In water, DDT levels rose 291-fold on spray day, then declined rapidly to pre-spray levels, reflecting the flushing action of the flowing streams. In bottom sediment, DDT residue levels proved erratic. The sediment in some streams was highly organic, while in others, it was primarily sand or gravel. The organic material had a much greater capacity for retaining DDT, and it yielded much higher residue levels than sand or gravel.

In general, smaller streams and impoundments seemed to hold DDT residues for longer periods than did the larger ones. Relatively small creeks and reservoirs that do not experience annual flushing yielded the control samples containing the highest DDT residue concentrations.

Both aquatic vegetation and benthic organisms contained a great deal more DDT on spray day than pre-spray levels — but the concentrations declined rapidly and had returned to, or close to, control levels within a year.

The miscellaneous species, as a group, showed the highest DDT levels on spray day, and in those species, DDT concentrations remained well above pre-spray and control levels throughout the year.

Fish also retained elevated DDT levels throughout the year. The pesticide concentration in fish increased sevenfold on spray day, rose even higher in the next 90 days, and was still five times higher than the control level after a year.

Looking at effects rather than residue levels, it was not surprising that the aquatic organisms which responded most dramatically to the presence of DDT were insects. Two separate studies observed the effects of DDT spraying on aquatic insects in Oregon creeks.

N. H. Anderson, Oregon State University, monitored the effects of the spraying on aquatic insects in Butcher Creek, a shallow, 30-foot-wide stream in the spray unit near

Biologists used electroshocking to collect fish for DDT residue analysis.

LaGrande, Oregon.[22] Insect samples were collected in small-mesh drift nets anchored with rocks.

The area was sprayed with DDT at approximately 5:30 a.m. June 21. A 100-foot unsprayed buffer strip was left along both sides of the stream. In the four-hour interval after spraying, the observed number of aquatic insects drifting downstream was about 9,000 insects per hour, compared with only 1,600 per hour during the previous night — despite the fact that insect drift rates are typically higher at night, especially for mayflies, which formed a major part of the drift population.

The extreme drift during that four-hour period included the total range of aquatic insects. Although representatives of all the orders of common aquatic insects appeared in the samples, the increase in drift associated with the DDT spray was overwhelmingly composed of mayfly and stonefly larvae.

Caddisfly larvae drift increased from 1.4 per hour before spraying to 96 per hour during the four hours immediately afterward. They were insignificant on a numerical basis, but because of their relatively large size, they accounted for a significant portion of the biomass in the total post-spray drift.

The effects of the spraying were visible for only a short time. Anderson noted that samples taken June 24 and 25, three and four days after spraying, indicated that the aquatic insect drift had returned to pre-spray levels.

Despite reservations and qualifications about the monitoring program, Anderson indicated he was convinced the DDT spraying had had an immediate effect on aquatic insects; despite all precautions taken during spraying and the leaving of an unsprayed buffer strip along the stream, the remarkable increase in the numbers of dead mayflies and stoneflies within four hours of spraying indicated DDT had drifted to the stream.

Herman and Bulger[7] observed somewhat different effects on Wallupa Creek, which was known to have received DDT drift. They observed little effect on stream insects, except for black flies, which had suffered a drastic reduction in numbers immediately after spraying, but the population had begun to recover two to three weeks later.

On Shamrock Creek, which had been sprayed directly, they reported that the number of insects taken in seven drift nets increased from 4.5 per hour some 12 hours before spraying to 402 per hour some 2 hours afterward. After 6 hours, the number dropped to 335 per hour and after 20 hours to 145 per hour. Almost all aquatic insects seemed to have been eliminated from that portion of the stream, and no significant recovery of the insect population could be detected a month later.

Harry B. Tracy and Dennis M. McGaughy, Washington Department of Ecology, studied the effects of DDT residues on aquatic organisms in three Washington streams.[23]

Almost simultaneously with the onset of DDT spraying in the Ninemile Creek main-stem watershed, the number of insects in drift samples rose from the pre-spray average of 0.03 insects per cubic foot of flow to 4.43 insects per cubic foot of flow, nearly a 150-fold increase. The abnormally high post-spray drift counts continued for more than 24 hours after the initial increase of DDT in the water.

Spraying in the watershed spanned three days; DDT concentrations in the water of buffered Ninemile Creek peaked on the third day at 3.39 ppb compared to 1.39 ppb on the first day of spraying. Insect drift rates on the third day, however, held at 1.0 insects per cubic foot of flow, indicating there had been a significant reduction in the insect population over the three-day period.

Post-spray benthic samples suggested a reduced insect population, but insects were still present, and recovery of the population was in progress 90 days post-spray.

Similar trends in DDT residue levels in water and insect drift rates were observed in the South Fork Ninemile Creek which was also buffered, but residue levels and drift rates were considerably lower than in the main-stem

[22] Anderson, N. H., 1975. Effects of DDT aerial spraying for tussock moth on aquatic insect populations. Entomology Department, Oregon State University, Corvallis, Oregon.

[23] Tracy, H. B. and McGaughy, D. M., 1975. Aquatic monitoring of the 1974 tussock moth DDT aerial spray project in Washington State. State of Washington, Department of Ecology, Olympia, Washington.

Ninemile Creek. Almost simultaneously with spraying, drift samples peaked at 2.85 insects per cubic foot of flow; within five days counts returned to near pre-spray levels. Average counts of insects in drift samples increased from 27 per cubic foot of flow in pre-spray samples to 1,675 on spray day to 143 three days after spraying. Post-spray benthic samples indicated a significant population of insects still present and that recovery of the population was underway 90 days post-spray.

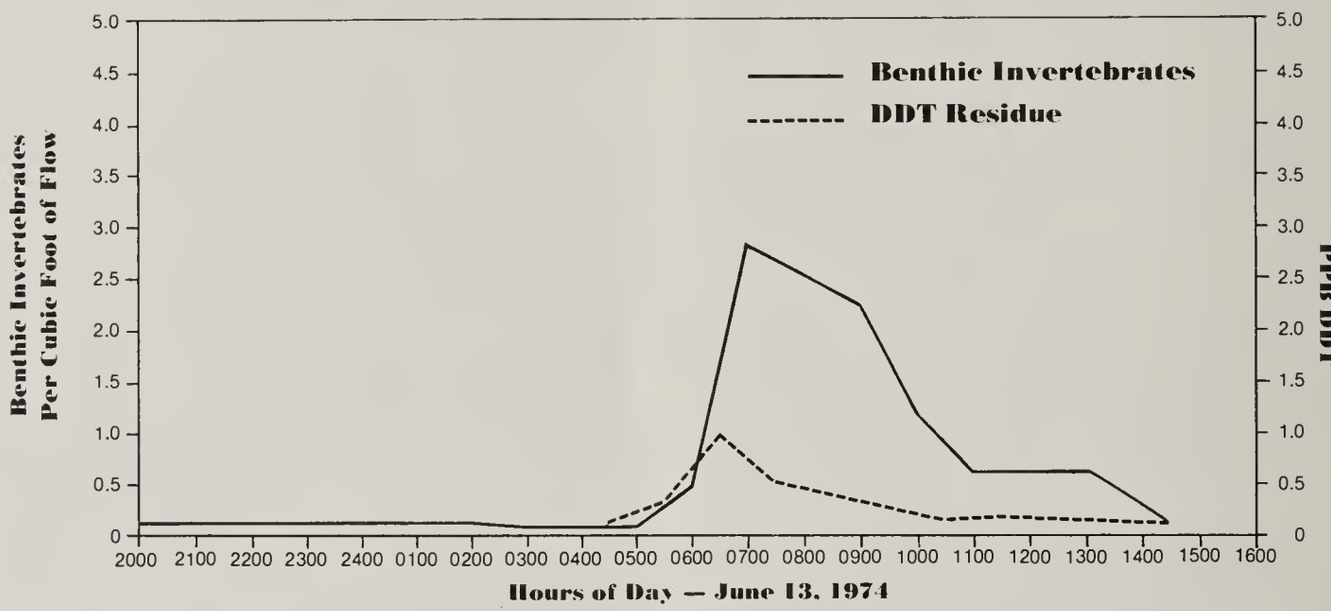
The highest levels of DDT in the streams monitored under this study were reported in George Creek, which was not provided with a protective buffer zone as were Ninemile Creek and its south fork. George Creek was not originally scheduled for monitoring; therefore, no pre-spray samples were collected.

On spray day, DDT concentrations in the water of George Creek peaked at 148.1 ppb and insects counted in drift samples peaked at 13.42 insects per cubic foot of flow. By approximately noon on spray day, DDT concentrations had declined to 2.1 ppb and insect counts had declined to 2.08 insects per cubic foot of flow. Several miles of George Creek were surveyed for evidence of dead or stressed fish but none were observed. Ninety-day post-spray benthic samples averaged 80 organisms per square foot, indicating considerable recovery of insect populations.

The researchers noted that the DDT spraying placed the aquatic environment under severe stress, whether or not buffer strips were employed. Minor concentrations of DDT resulted in dramatic increases in the number of insects in drift counts and radical alterations in insect diversity within the study area. No information was collected on effects downstream from the study area. Immediate or short-term effects on fish appeared minimal. The long-term effects on the streams studied are not known.

They concluded that more quantitative information was necessary to make a realistic assessment of the impact of DDT spraying on the aquatic environment. That further study geared to strike a delicate balance among DDT concentrations, buffer strip widths and aquatic insect mortalities, conceivably could eliminate much of the damage to the aquatic environ-

Small mesh nets were anchored in streams to collect drifting aquatic insects.



Benthic insects in drift samples per cubic foot of streamflow and DDT concentrations in water in relation to time of day, South Fork of Ninemile Creek, Washington.

ment associated with DDT aerial spray projects.

A study by James J. Kirk, Oregon Department of Human Resources, indicated that western spotted frogs also were affected by exposure to DDT.[24] No formal plans had been made to monitor populations of the western spotted frog, but several dozen frogs were seen in and around a small pond within one of the areas to be sprayed with DDT. Almost one month after spraying, 20 dead frogs were found on the bottom of the pond concentrated around a submerged spring box.

The dead frogs and several live frogs from the pond were sampled for DDT residues. Residue levels in dead frogs ranged from 2.20 parts per million to 12.7 ppm compared with 0.83 ppm to 2.28 ppm in live ones. The presence of dead frogs after the spraying, the reduced frog population in the pond, and the higher residue levels in dead frogs than in live ones all suggested that DDT had been responsible for the deaths of some western spotted frogs. However, the presence of live frogs a few weeks and then two years after the spraying suggested that DDT had not exterminated the entire population.

No biological damage among fish was observed or inferred in a study reported by Cliff Bosley, U.S. Fish and Wildlife Service.[25] Fish samples were collected from Owhi Lake on the Colville Indian reservation, the Sanpoil arm of Lake Roosevelt behind Grand Coulee Dam, the mouth of the Walla Walla River and the Grande Ronde River. The fish were analyzed for DDT residues, and results compared with residues found in the Columbia River drainage in 1972 and 1973 as part of the ongoing National Pesticide Monitoring Program.

The fish were collected by experimental gill net or by hook and line. Samples were collected immediately before spraying, 30 to 60 days after spraying, and one year after spraying. Three of the four sites were expected to receive some DDT from the spray program. Owhi Lake, used by the Colville Confederated Tribes for raising eastern brook trout brood stock, was designated a sensitive area and excluded from the spraying plan.

Nevertheless, some DDT seemed to have drifted into the Owhi Lake drainage. Pre-spray DDT residues in fish from the lake averaged about 0.01 ppm, while post-spray residues rose

[24] Kirk, J. J., 1976. Mortality of western spotted frogs *(Rana pretiosa)* following DDT application. Oregon Department of Human Resources, Portland, Oregon.

[25] Bosley, C. E., 1977. Results of pesticide residue fish monitoring completed as part of the national pesticide monitoring program. U.S. Fish and Wildlife Service, Nordland, Washington.

to an average of 0.018 ppm, or some 12 times more than pre-spray levels despite precautionary placement of activated charcoal in the lake's principal feeder creek. A year later, fish sampled contained residues only about twice those found in pre-spray sampling.

Post-spray DDT residues in eastern brook trout eggs were considerably less than those found in the post-spray whole fish samples. The mean concentration of DDT in the eggs was only 0.05 ppm, as opposed to 0.18 in the fish. Researchers found this a little surprising, in view of the fact that spraying had occurred just before the egg maturation period. The concentrations found were not considered high.

In fish taken from the Sanpoil arm of Lake Roosevelt, pre-spray DDT concentrations averaged about 0.06 ppm. Mean residue levels rose to about 0.36 ppm immediately after spraying, then dropped in one year to 0.24 ppm. The pre-spray residue levels were comparable to those found in 1973 at the Grand Coulee sampling site on the Columbia River; post-spray residues were some five times more than 1973 levels.

In fish from the Grande Ronde River, DDT residues exhibited patterns similar to those observed in samples from the Sanpoil and Owhi Lake stations. From a pre-spray mean of 0.03 ppm, residue levels rose to 0.50 ppm shortly after spraying, then dropped during the year to 0.15 ppm.

In general, the sampling stations noted a sharp rise in DDT residue levels in fish immediately after spraying, then a decline to only 0.02 to 0.08 ppm above pre-spray levels. The only exceptions to the general pattern were carp from the Walla Walla River. These fish exhibited the highest levels of DDT *before* spraying, and DDT residues declined over the ensuing year. There was no apparent explanation for this anomaly in carp, which was the only species that contained relatively high concentrations of DDT both before and after spraying.

Overall, the residue levels found in fish from the various sampling sites were not considered high. Nevertheless, the researchers suggested it could be assumed that as one progressed upstream toward the spray plots, the ratio of

Rainbow trout and a variety of other fish were collected and analyzed for DDT residues.

spray drift to water volume would increase, and residue levels in fish would consequently be higher.

Irv Jones, Fish Commission of Oregon, now Oregon Department of Fish and Wildlife, monitored effects of DDT spraying on the margined sculpin *Cottus marginatus*, a small, spiny freshwater fish that lives only within 180 miles of rivers and streams in two Oregon drainage basins.[26]

Because some 65 miles of its habitat lay downstream from the spray areas, a special effort was made to protect the sculpin and to monitor its response to DDT spraying. Two-hundred-foot buffer strips were routinely left along larger streams within spray areas.

Within the drainages inhabited by the sculpin, buffering was also provided along 20 miles of 13 smaller streams that wouldn't ordinarily have been so protected.

McKay Creek and Meacham Creek in the Umatilla River drainage were checked for sculpins in 1975, the year after the spraying, and again in 1978. During the first survey, sculpins were found in McKay Creek but not in Meacham. The second survey identified sculpins in both streams. Both surveys found healthy populations of dace and salmonids in both streams.

Jones observed that the absence of the sculpin from Meacham Creek during the 1975 sampling was open to question because the sampling effort had been minimal. Despite the unknown significance of the Meacham Creek data, it was concluded that the presence of the sculpin and other fish in both pre- and post-spray sampling indicated that buffering of streams helped to prevent long-term damage to the sculpin and other fish in the Umatilla River system.

[26] Jones, I., 1978. Special fish habitat protection (draft). Oregon Department of Fish and Wildlife, Portland, Oregon.

Prepared for Forest Service • USDA • Pacific Northwest Region by Ed Chaney, consultant, Eagle, Idaho

Appendix

Monitors for the 1974 Tussock Moth Spray Program

Agte, Steve D.
Idaho Department of Fish and Game

Bachman, Rob
Washington Department of Natural Resources

Bartels, Ron
Oregon Department of Fish and Wildlife

Baxter, Tom E.
USDA Forest Service

Bogatich, Vince
U.S. Fish and Wildlife Service

Bolles, Robert E.
Oregon Department of Environmental Quality

Bosley, Clifford E.
U.S. Fish and Wildlife Service

Brady, Charles
Idaho Department of Health and Welfare

Burnhardt, John
Washington Department of Ecology

Cannon, Wes
Idaho Department of Fish and game

Canutt, Paul R.
USDA Forest Service

Chandler, G. L.
Oregon State Police

Coggins, Vic
Oregon Department of Fish and Wildlife

Cornwell, Alfred C.
Oregon Department of Agriculture

Deardorff, George E.
U.S. Fish and Wildlife Service

Delipierre, Bill
U.S. Fish and Wildlife Service

De Nike, Ed
Washington Department of Ecology

Duncan, Dennis
Oregon Department of Environmental Quality

Espinosa, Fernando Al
USDA Forest Service

Everest, Fred H.
USDA Forest Service

Flake, Harold W.
USDA Forest Service

Fowler, Pat
Washington Department of Game

Frazier, Brent
Oregon Department of Human Resources

Goodnight, Bill
Idaho Department of Fish and Game

Harryman, J.
USDA Forest Service

Hartwell, Harry D.
Washington Department of Natural Resources

Heiskari, Wayne R.
Idaho Department of Health and Welfare

Hose, Alan
Oregon Department of Environment Quality

Hubbard, Bill
Washington Department of Game

Humphries, Dick
Oregon Department of Fish and Wildlife

Jankowski, Jerome Edward
Idaho Department of Health and Welfare

Jones, Irving
Oregon Department of Fish and Wildlife

Kemp, Mike
Oregon Department of Fish and Wildlife

Kessler, Jim
Private Landowner

Kittle, Lew
Washington Department of Ecology

Kirk, James J.
Oregon Department of Human Resources

Kollias, Van Anthony
Oregon Department of Environmental Quality

Laws, Albert
U.S. Fish and Wildlife Service

Lenhart, David J.
U.S. Fish and Wildlife Service

Livingston, Jay N.
Washington Department of Natural Resources

Livingston, R. Ladd
Idaho Department of Lands

Martinsen, Fred
Washington Department of Game

McCall, Merley F.
Washington Department of Ecology

McCollister, Russell D.
Idaho Department of Health and Welfare

McCluskey, Cal
USDA Forest Service

McDonald, Ken
Oregon Department of Environmental Quality

McGaughy, Denny
Washington Department of Ecology

McGlothlin, Marvin L.
Oregon Department of Environmental Quality

McHugh, Robert A.
Oregon Department of Environmental Quality

McMasters, Michael J.
Idaho Department of Health and Welfare

McNeill, Sam
Idaho Department of Fish and Game

Moore, V. H.
Oregon Department of Fish and Wildlife

Morton, E. K.
Oregon Department of Fish and Wildlife

Orme, M.
USDA Forest Service

Page, Dave
Idaho Department of Fish and Game

Pederson, Dick
Oregon Department of Fish and Wildlife

Penske, Bruce
Idaho Department of Fish and Game

Phelps, Jim
Oregon Department of Fish and Wildlife

Pillow, Braden
Oregon Department of Environmental Quality

Pinto, Carlos
USDA Forest Service

Rohweder, Ron
Oregon Department of Fish and Wildlife

Rogers, Kim
Oregon Department of Environmental Quality

Rubenser, Albert L.
U.S. Fish and Wildlife Service

Sandquist, Kevin C.
Washington Department of Natural Resources

Schwartz, Charles
Idaho Department of Health and Welfare

Simmon, Dick
Washington Department of Game

Stiffarm, Douglas
Washington Department of Game

Tanner, D. L.
Idaho Department of Fish and Game

Tatham, Chris
Washington Department of Game

Thurman, Rich
USDA Forest Service

Tracy, Harry B.
Washington Department of Ecology

Thresham, Paul
USDA Forest Service

Tulloch, H. Edwin
Idaho Department of Health and Welfare

Weaver, Wendell
U.S. Fish and Wildlife Service

Wendt, Charles B.
Bureau of Indian Affairs

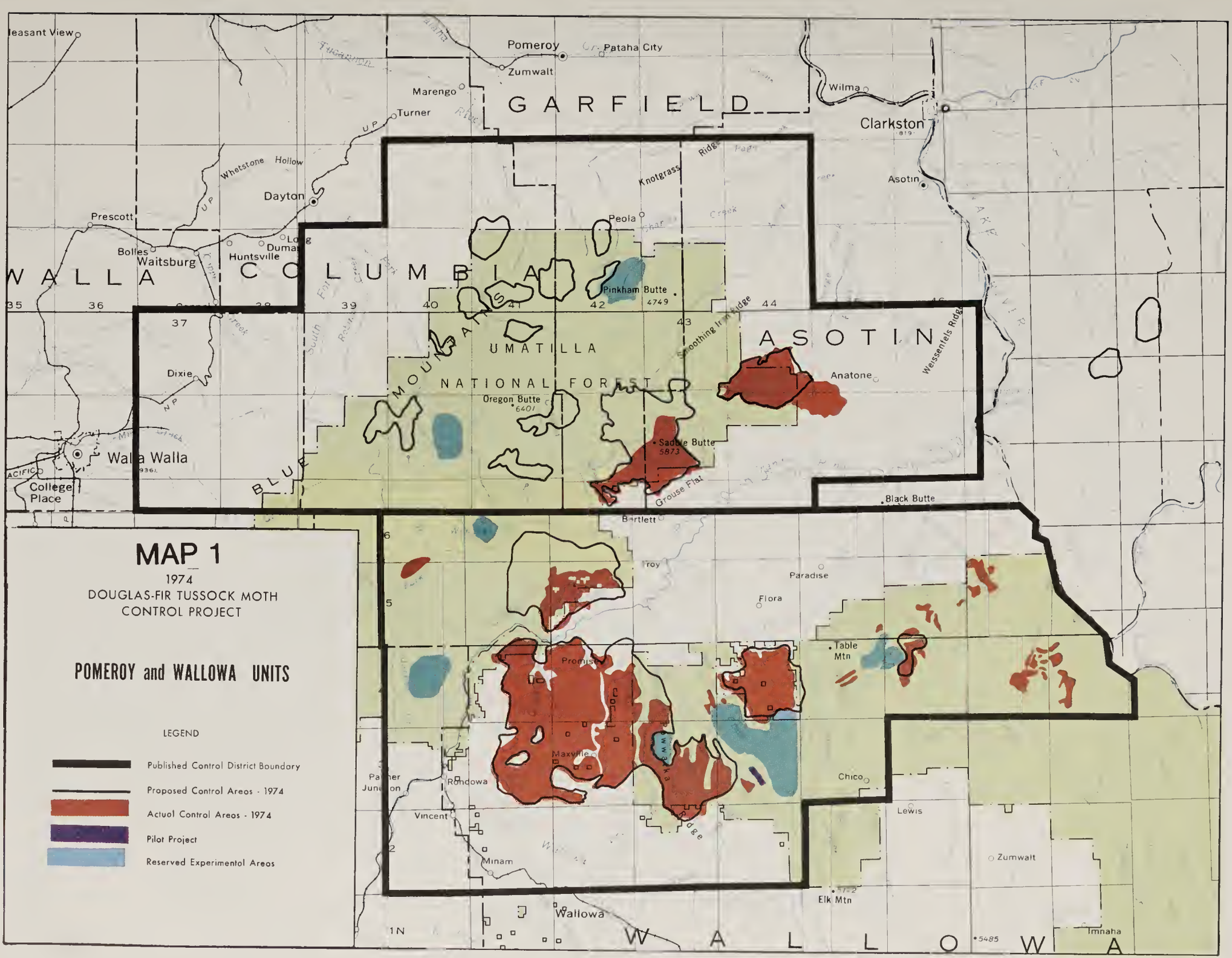
West, Duane C.
Oregon Department of Fish and Wildlife

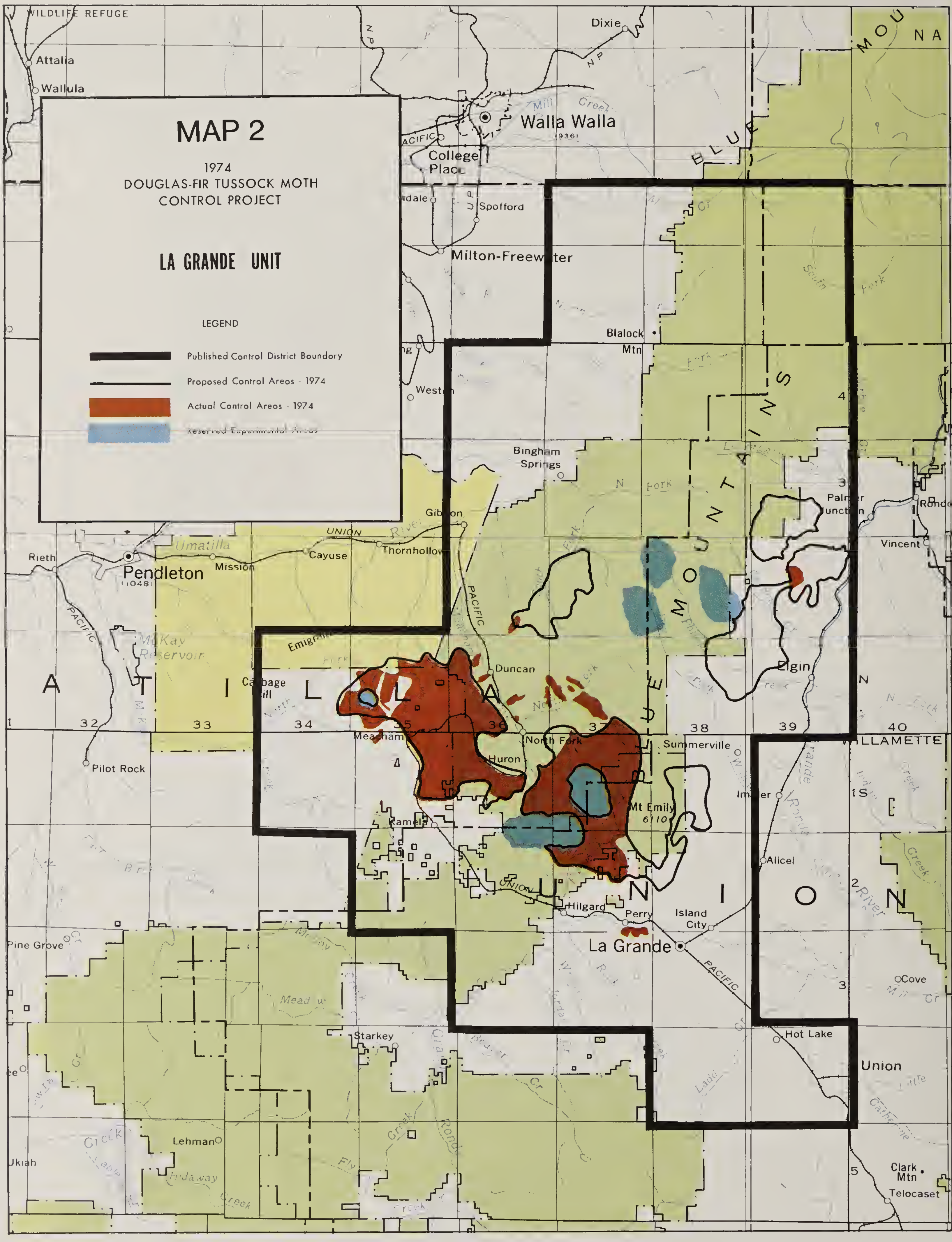
Westfall, Robert T.
Oregon Department of Environmental Quality

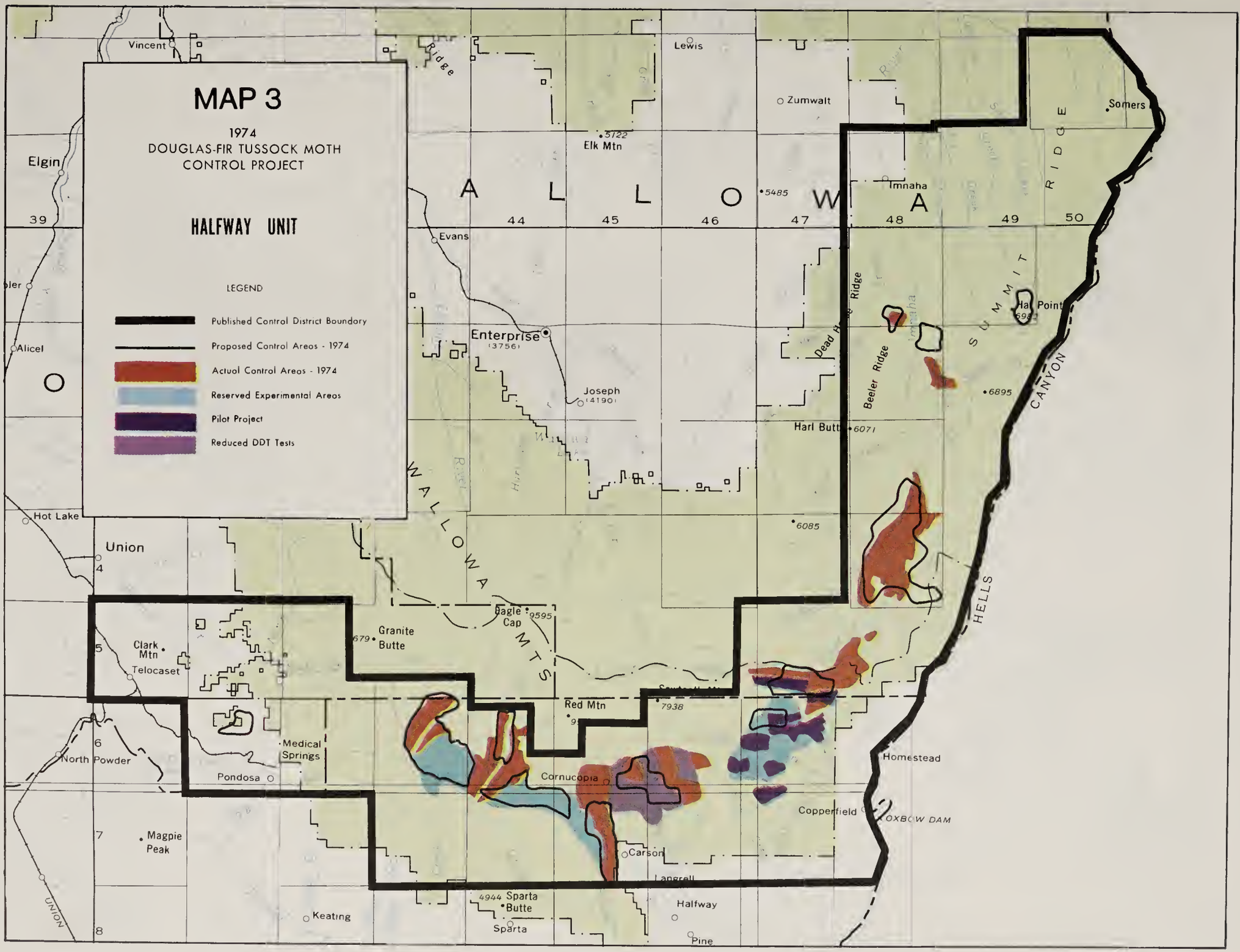
Westgarth, Warren C.
Oregon Department of Environmental Quality

Wischnofske, Merle Gene
USDA Forest Service

Witty, Ken
Oregon Department of Fish and Wildlife


MAP 1
1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
POMEROY and WALLOWA UNITS
LEGEND
Published Control District Boundary
Proposed Control Areas - 1974
Actual Control Areas - 1974
Pilot Project
Reserved Experimental Areas
GARFIELD
COLUMBIA
WALLA WALLA
ASOTIN
WALLOWA
UMATILLA NATIONAL FOREST
BLUE MOUNTAINS
Pomeroy
Pataha City
Zumwalt
Marengo
Turner
Wilma
Clarkston
Dayton
Prescott
Bolles
Waitsburg
Huntsville
Peola
Knolgrass Ridge
Asotin
Pinkham Butte
4749
Anatone
Oregon Butte
6401
Saddle Butte
5873
Grouse Flat
Black Butte
Dixie
Walla Walla
College Place
Bartlett
Troy
Paradise
Flora
Table Mtn
Promise
Maxville
Rondowa
Vincent
Minam
Chico
Lewis
Zumwalt
Elk Mtn
Wallowa
Imnaha
5485


MAP 2
1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
LA GRANDE UNIT
LEGEND
Published Control District Boundary
Proposed Control Areas - 1974
Actual Control Areas - 1974
WILDLIFE REFUGE
Attalia
Wallula
Dixie
Walla Walla
College Place
Spofford
Milton-Freewater
Blalock Mtn
Weston
Bingham Springs
Gibbon
Thornhollow
Cayuse
Mission
Pendleton
Rieth
McKay Reservoir
Cabbage Hill
Meacham
Duncan
North Fork
Huron
Kamela
Summerville
Imbler
Mt Emily
Alicel
Elgin
Palmer Junction
Rondo
Vincent
Hilgard
Perry
Island City
La Grande
Pilot Rock
Pine Grove
Starkey
Lehman
Ukiah
Hot Lake
Union
Cove
Clark Mtn
Telocaset
WILLAMETTE
BLUE MOUNTAINS
UMATILLA
UNION
PACIFIC


MAP 3
1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
HALFWAY UNIT
LEGEND
Published Control District Boundory
Proposed Control Areas - 1974
Actual Control Areas - 1974
Reserved Experimental Areas
Pilot Project
Reduced DDT Tests
WALLOWA
Vincent
Lewis
Zumwalt
Somers
Elk Mtn
5722
Elgin
Imnaha
5485
Evans
Enterprise
(3756)
Joseph
(4190)
Alicel
Dead Horse Ridge
Beeler Ridge
SUMMIT RIDGE
Point
6895
CANYON
Harl Butte
6071
Hot Lake
Union
6085
WALLOWA MTS
Eagle Cap
9595
Granite Butte
679
Clark Mtn
Telocaset
Red Mtn
7938
HELLS
Medical Springs
North Powder
Pondosa
Cornucopia
Homestead
Copperfield
OXBOW DAM
Magpie Peak
Carson
Langrell
4944
Sparta Butte
Sparta
Keating
Halfway
Pine
UNION
39
44
45
46
47
48
49
50
4
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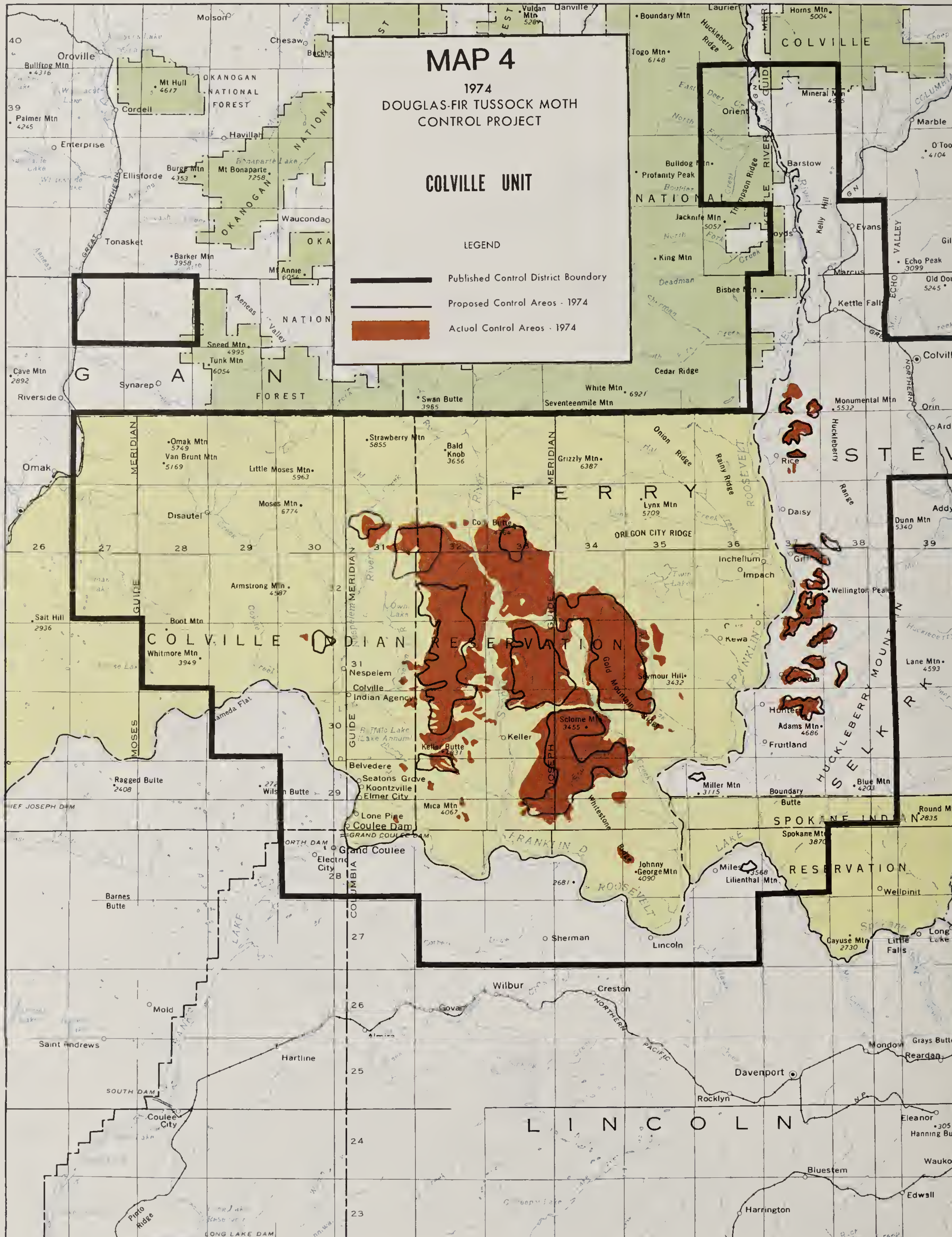
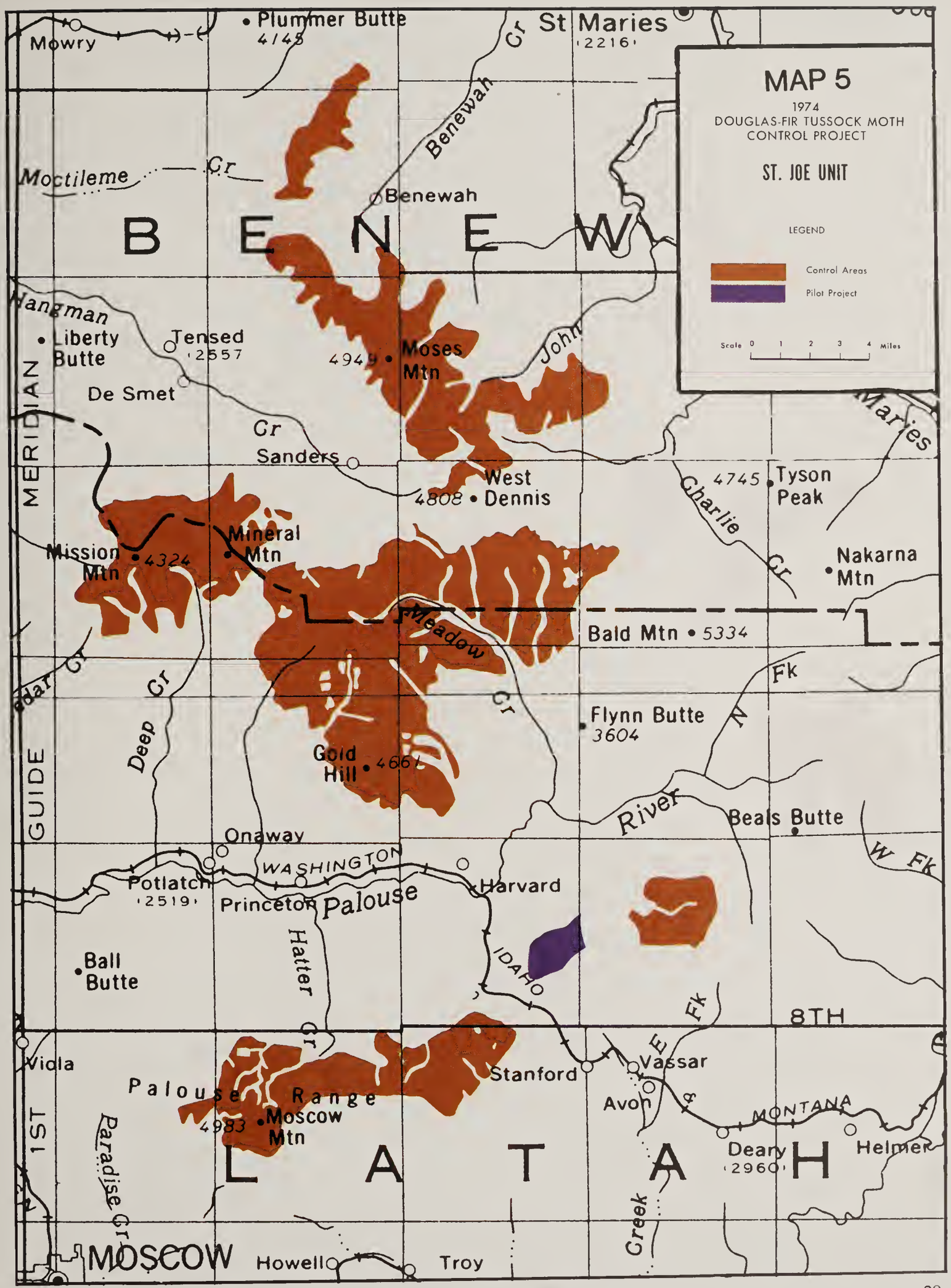
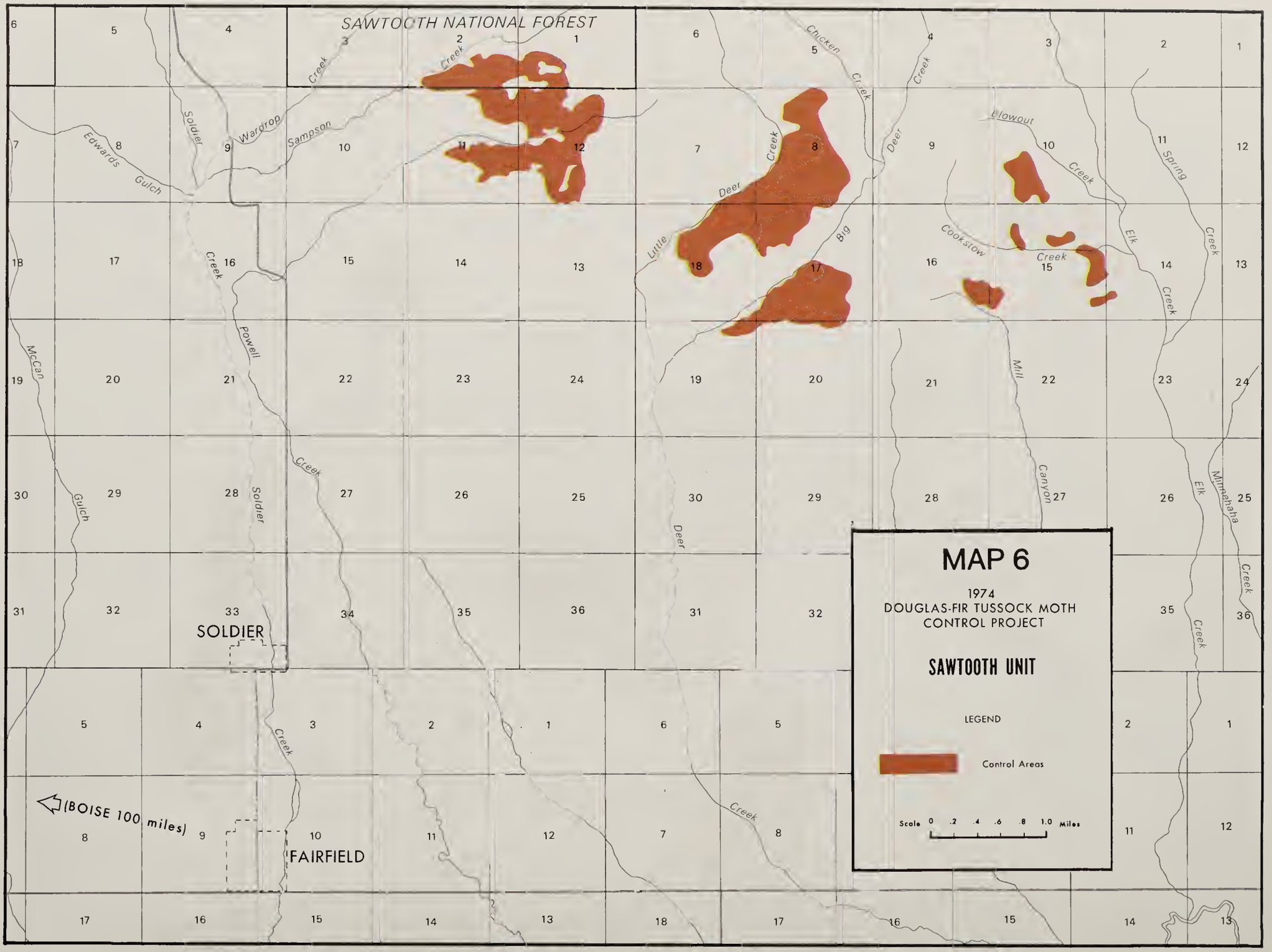
6
7
8



MAP 4
1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
COLVILLE UNIT
LEGEND
Published Control District Boundary
Proposed Control Areas - 1974
Actual Control Areas - 1974
OKANOGAN NATIONAL FOREST
COLVILLE NATIONAL FOREST
F E R R Y
COLVILLE INDIAN RESERVATION
SPOKANE INDIAN RESERVATION
L I N C O L N
S T E V
Oroville
Tonasket
Omak
Riverside
Nespelem
Keller
Coulee Dam
Grand Coulee
Wilbur
Creston
Davenport
Hartline
Sherman
Lincoln
Inchelium
Kettle Falls
Marcus
Colville
Wellpinit
Harrington


MAP 5
1974
DOUGLAS-FIR TUSSOCK MOTH
CONTROL PROJECT
ST. JOE UNIT
LEGEND
Control Areas
Pilot Project
Scale 0 1 2 3 4 Miles
Mowry
Plummer Butte
4148
St Maries
2216
Benewah Cr
Moctileme Cr
Benewah
BENEWAH
Hangman
Liberty Butte
Tensed
2557
De Smet
MERIDIAN
Moses Mtn
4949
John
Cr
Sanders
West Dennis
4808
Tyson Peak
4745
Charlie Cr
Nakarna Mtn
Mission Mtn
4324
Mineral Mtn
Meadow Cr
Bald Mtn
5334
Flynn Butte
3604
Deep Cr
Gold Hill
4661
GUIDE
River
Beals Butte
Onaway
WASHINGTON
Potlatch
2519
Princeton
Palouse
Harvard
Ball Butte
Hatter Cr
IDAHO
8TH
Vidla
Stanford
Vassar
Avon
MONTANA
Palouse Range
Moscow Mtn
4983
LATAH
Deary
2960
Helmer
1ST
Paradise Cr
MOSCOW
Howell
Troy
Creek



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