In addition, conversation with the Cooperative Extension orchard farm advisor in Yakima, Washington, provided supplemental descriptive information. Removal of trees is relatively straightforward, involving nothing more than tying the tree to a pickup truck or small tractor with a rope or a chain and using the vehicle to uproot the tree. However, it may be necessary to use a bulldozer and backhoe to remove large trees. The Cooperative Extension report mentioned above estimates the labor time for removing five trees at three man-hours, using two farm laborers. The 1982 cost for farm laborers is given in other Cooperative Extension publications mentioned elsewhere in this Appendix as \$5.00 per hour. The equipment time for removing five trees is listed as 1.5 hours. Assuming that a pickup truck costing \$9.00 per hour is used, the equipment cost is \$13.50. Dividing these costs by five, we get \$3.00 per tree for labor and \$2.70 per tree for equipment. The time required per tree is 0.3 hours.

Next it is necessary to estimate the number of trees per acre so that costs per tree can be converted to cost per sq meter. Various Cooperative Extension publications list representative numbers of trees per acre for various types of crop. The numbers vary widely. For example, typical walnut orchards may have 48 trees per acre, while there may be 269 trees per acre in a red delicious apple orchard. Other examples are almond, 75 per acre; apricot, 75 per acre; cherry, 108 per acre; orange, 136 per acre; fig, 95 per acre, kiwi, 150 per acre, olive, 97 per acre; peach, 108 per acre; pistachio, 130 per acre; and prune, 108 per acre. Here we assume 120 trees per acre.

Multiplying 120 trees per acre by 0.3 hours per tree for removal gives a time per acre of 36 hours. The rate in terms of sq meters per hour is:

$$\frac{4046.7\ m^2/ac}{36\ hr/ac} \times 7/8\ adj = 98\ m^2/hr$$

Dividing this into the hourly labor cost for the two workers gives:

$$\frac{2 \times \$5.00/hr}{98\ m^2/hr} = \$0.102/m^2$$

The equipment cost, calculated similarly, is \$0.092 per sq meter. The total cost for removing trees is, therefore, \$0.194 per sq meter.

Next to be considered is the cost of preparing the site for replacing the trees. Note, however, that if the soil is to be scraped (see Section A.1.2.12) or covered with clean soil (see Section A.1.2.10), these operations would be done before this site preparation.

According to the Cooperative Extension publication "Determining the Costs of Removing and Replacing Dead or Damaged Commercial Fruit Trees," two laborers and one pickup truck working for one hour are required for every five trees. In addition, this source calls for \$4.50 of new soil. The costs per hour are labor, \$11.00; equipment, \$9.00; and materials, \$4.50.

At five trees per hour, the coverage rate is:

$$\frac{4046.7\ m^2/ac}{120\ trees/ac} \times 5\ trees/ac \times 7/8\ adj = 148\ m^2/hr$$

Dividing the hourly coverage rate into the hourly costs gives:

$$\text{Labor: } \frac{\$5.00/hr \times 2}{148\ m^2/hr} = \$0.068/m^2$$

$$\text{Equipment: } \frac{\$9.00/hr}{148\ m^2/hr} = \$0.061/m^2$$

$$\text{Materials: } \frac{\$4.50/hr}{148\ m^2/hr} = \$0.030/m^2$$

Summing these gives the total cost of site preparation as \$0.159 per sq meter.

According to the same source, tree planting involves equipment to haul the trees such as a pickup truck and four laborers to dig the hole and drive the truck. The hourly labor cost is, therefore, \$20, and the equipment cost is \$9 per hour. Five trees can be planted in an hour. As with site preparation, the hourly coverage rate is 148 sq meters per hour. The costs per sq meter are:

$$\text{Labor: } \frac{\$5.00/hr \times 4}{148\ m^2/hr} = \$0.135/m^2$$

$$\text{Equipment: } \frac{\$9.00/hr}{148\ m^2/hr} = \$0.061/m^2$$

Total: $\$0.196/m^2$

A set of publications from the University of California Cooperative Extension provides additional information. They are "Costs of Establishing and Producing Prunes," "Costs to Establish and Produce Walnuts," and "Almond Establishment Costs on Class II and III Soils in Sacramento Valley." Because these pamphlets deal with establishing a new orchard rather than replacing an old one, no cost data were given for removing trees. Also, since these sources deal with establishment of an entire orchard while the other report is concerned with replacement of five trees, equipment, procedures, and costs differ. In particular, establishment of a whole orchard permits the farmer to take advantage of economies of scale in large equipment.

"Costs of Establishing and Producing Prunes" lists the total pre-plant and planting costs as $210 per acre. Converting to dollars per sq meter and adjusting for an hour per shift lost to radiation control measures, we get:

$$\$210/ac \div 4046.7\ m^2/ac \times 8/7\ adj = \$0.059/m^2$$

"Costs to Establish and Produce Walnuts" gives the preparation and planting costs as $227 per acre. This works out to $0.064 per sq meter. The report on establishing an almond orchard lists the cost as $181 per acre for soil preparation and planting. Using the same calculations, we get $0.051 per sq meter. Unfortunately, these sources do not provide information on costs by input or production rates.

Comparison of the total site preparation and planting costs from the Washington State University Cooperative Extension publication ($0.355 per sq meter) with the figures from the University of California Cooperative Extension publications (prunes, $0.059 per sq meter; walnuts, $0.064 per sq meter; almonds, $0.05 per sq meter) reveals a considerable discrepancy. The information from the first source is for operations on a limited scale. Also, the figures are described as illustrative, while those from the other sources are intended to be accurate estimates of actual costs. For these reasons, we take the base for estimating the representative total site preparation and planting costs as in the range of costs from the University of California Cooperative Extension publications: $0.060 per sq meter. Adjusting this for an hour lost per shift due to radiation control measures, we get

$$\$0.06/m^2 \times 8/7\ adj = \$0.069/m^2$$

Determining the representative rate and input costs is done as follows. The inputs specified by the Washington State University Cooperative Extension publication included six farm laborers and two pickup trucks. The methods employed in the larger-scale site preparation and planting activities implicit

in the University of California Cooperative Extension publications suggest greater capital intensity. Therefore, the crew assumed is one 60-horsepower wheel-mounted diesel tractor, with additional equipment such as a landleveler and a pickup truck. The total hourly cost of this equipment is about $22.00. Labor consists of one skilled farm laborer at $6.50 per hour and three farm laborers at $5.00 per hour. The total labor cost is $21.50.

The total hourly cost for labor and equipment is $43.50. The rate implied by this hourly cost and the $0.069 cost per sq meter is 630 sq meters per hour. The input costs in terms of dollars per sq meter are:

$$\text{Labor: } \frac{\$21.50/\text{hr}}{630\ \text{m}^2/\text{hr}} = \$0.034/\text{m}^2$$

$$\text{Equipment: } \frac{\$22.00/\text{hr}}{630\ \text{m}^2/\text{hr}} = \$0.035/\text{m}^2$$

The price of trees to be planted depends on the type of tree and the tree's age. Inspection of various publications from the Cooperative Extension, College of Agriculture, Washington State University, and the University of California Cooperative Extension revealed tree prices ranging from $1.50 for almond and fig trees to $8.50 for a kiwi tree. Other examples are apple, $4.10; walnut, $8.00; prune, $3.00; apricot, $2.00, cherry, $2.85; citrus, $4.35; olive, $1.55, peach $1.43; pistachio, $3.00; and pear, $1.52. We use the price of apple trees, $4.10, as representative. At 120 trees per acre, the cost per sq meter for the trees is:

$$\frac{120\ \text{trees/ac} \times \$4.10/\text{tree}}{4046.7\ \text{m}^2/\text{ac}} = \$0.122/\text{m}^2$$

Table A.1.2.8.1 presents the costs of the three cost components of orchard removal and replacement and the total costs. Removal is the most costly procedure, and therefore the rate for the whole operation is set equal to the removal rate, 98 sq meters per hour. This means that 98 ÷ 630 = 0.16 site preparation and planting crews would be used for each removal crew.

A.1.2.9 Radical Pruning

Radical pruning is an operation intended to remove radioactive contamination from orchards by removing significant portions of the trees themselves.

TABLE A.1.2.8.1. Summary of Orchard Removal and Replacement Data

Item	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment	Material
Removal	98	0.194	0.102	0.092	
Site preparation and planting	630	0.069	0.027	0.033	
Trees	--	0.122	--	--	0.122
Total	98	0.385	0.129	0.125	0.122

The Cooperative Extension, Butte County, California, orchard farm advisor advises that, with such pruning, at least one branch should be left unpruned. This will enable the roots to be fed and thereby keep the tree alive.

This source estimates that the cost to perform this operation would be about $250 per acre. This compares with normal dormant pruning costs of about $100 per acre, depending on the type of trees. This estimate for normal pruning costs was confirmed by three University of California Cooperative Extension publications, "Costs of Establishing and Producing Prunes," "Costs to Establish and Produce Walnuts," and "Almond Production Costs on Class II and III Soils in Sacramento Valley."

The farm advisor added that the rate of radical pruning would be about two acres per man-day. This rate is considerably faster than normal pruning rates. Data from the above-mentioned publications indicates that for prune orchards the rate would be about 0.30 acres per man-day, for walnut orchards that rate would be about 0.8 acres per man-day, and for almonds the rate would be about 0.67 acres per man-day. In addition, the cost figure given ($250 per acre) is difficult to resolve with the two acres per man-day rate because this implies a cost of $500 per day per worker.

In order to resolve these difficulties, we assume the $250-per-acre cost estimate to be accurate, but we estimate a slower rate consistent with the hourly costs of an appropriate set of inputs. In this matter, examination of the publications mentioned shows that only walnut pruning requires any special equipment. Because of the greater height of walnut trees, two powered towers to enable the upper branches to be reached are specified. For radical pruning, however, it is unlikely that towers would be necessary even for large trees. This is because radical pruning does not call for pruning the ends of the branches, but instead calls for cutting off the branches themselves. The equipment that would be necessary includes power and manual saws, ladders, and a pickup truck or a larger truck. The pamphlet "Cost of Producing Apples in Central Washington," by the Cooperative Extension, College of Agriculture, Washington State University, provides cost data on these items as shown in Table A.1.2.9.1.

TABLE A.1.2.9.1. Cost Data for Radical Pruning Equipment from the Cooperative Extension, College of Agriculture, Washington State University

Item	Cost (1982 \$/hr)
Pickup, 1/2 ton	8.04
Pruning tools	0.04
Ladders	0.10
Chainsaw	5.95
Total	14.13

We assume that two farm laborers, at \$5.00 per hour each, comprise the labor component of the inputs. Thus, the total hourly cost is \$24.13. At this hourly rate, the (unadjusted) time for one acre is

$$10.4 \text{ hr/ac} \times 8/7 \text{ adj} = 11.9 \text{ hr/ac}$$

This is equivalent to

$$4046.7 \text{ m}^2\text{/ac} \div 11.9 \text{ hr/ac} = 340 \text{ m}^2\text{/hr}$$

Dividing this hourly production rate into the hourly input costs yields:

$$\text{Labor: } \$10\text{/hr} \div 340 \text{ m}^2\text{/hr} = \$0.029\text{/m}^2$$

$$\text{Equipment: } \$14.13 \div 340 \text{ m}^2\text{/hr} = \$0.042\text{/m}^2$$

$$\text{Total: } \$24.13 \div 340 \text{ m}^2\text{/hr} = \$0.071\text{/m}^2$$

A.1.2.10 Cover, Trees Removed

This operation involves covering the ground with six inches of uncontaminated soil after the trees have been removed. Covering may or may not be done following scraping of contaminated soil. The covering operation is identical to covering agricultural fields. See Section A.1.1.9 for a discussion of the cost estimates.

A.1.2.11 Cover, Trees in Place

This operation is the same in principle as covering the area with uncontaminated soil, as in the previous section. However, with the trees in place, it would not be possible to use large earthmoving equipment without damaging the trees.

The operation has three steps, the costs of which are estimated separately. The first step is the excavation and loading of the uncontaminated soil. The estimated cost of this procedure was discussed in Section A.1.1.9. The second step involves hauling the soil to the site. This cost is a function of the distance the soil is to be hauled and is calculated separately in Section A.6.2. The third step is the spreading of the soil. The estimated cost of this procedure is developed in this section. Also, the combined excavation and spreading cost is calculated.

The basic source of information for this operation is Means' Building Construction Cost Data 1982. The primary piece of equipment necessary is a small bulldozer or a small front-end loader to move the delivered soil out to the orchard and to spread it. For a 75-horsepower bulldozer, Means lists the daily output at 400 cubic yards with a 50-foot haul. For a 150-foot haul the daily output is 200 cubic yards. In general, for most such equipment, an increase in the haul distance causes similar decreases in daily output. Here we assume that output is equal to half that of the 150-foot haul. The implicit assumption is that the average haul is 300 feet and the (unadjusted) output is 100 cubic yards per day. Assuming a coverage depth of six inches, each cubic yard of soil will cover six sq yards. The resulting coverage rate after adjustment for radiation control measures and conversion to sq meters is

$$100 \text{ yd}^3/\text{day} : 8 \text{ hr/day} \times 6 \text{ yd}^2/\text{yd}^3 \times 0.836 \text{ m}^2/\text{yd}^2 \times 7/8 \text{ adj} = 55 \text{ m}^2/\text{hr}$$

The bulldozer is listed (p. vii) as having a daily cost of $189.85, or $23.73 per hour.

For operation of the bulldozer, Means specifies one medium-equipment operator at $24.95 per hour and 0.5 building laborers at $19.40 per hour. In addition, another two building laborers would be required for handwork around the base of trees. The total hourly labor cost is, therefore:

1	Equipment operator	at $24.95/hr	= $24.95/hr
2.5	Building laborers	at $19.40/hr	= $48.50/hr
		Total	= $73.45/hr

Dividing the hourly coverage rate into the hourly input costs gives the costs per sq meter:

$$\text{Labor: } \$73.45/\text{hr} \div 55 \text{ m}^2/\text{hr} = \$1.34/\text{m}^2$$

$$\text{Equipment: } \$23.73/\text{hr} \div 55 \text{ m}^2/\text{hr} = \$0.43/\text{m}^2$$

$$\text{Total: } \$97.18/\text{hr} \div 55 \text{ m}^2/\text{hr} = \$1.77/\text{m}^2$$

Table A.1.2.11.1 shows the costs of soil excavation and spreading. The total for the two procedures is also presented. In order to equalize the rates of the two procedures, 0.07 excavation crews would be used for every spreading crew. The combined crew would consist of 1.07 medium-equipment operators, 2.54 building laborers, 0.07 front-end loaders, and one 75-horsepower bulldozer or small front-end loader.

TABLE A.1.2.11.1. Summary of Cost Data for Soil Covering in Orchard, Trees in Place

Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$) Total	Labor	Equipment
Excavate	812	0.17	0.04	0.13
Spread	55	1.77	1.34	0.43
Total	55	1.94	1.38	0.56

A.1.2.12 Scrape, Trees Removed

This operation would be used in conjunction with orchard removal and replacement. The execution of scraping with the trees removed is the same as scraping agricultural fields as described in Section A.1.1.5. However, because of the depressions and other irregularities in the soil resulting from tree removal, this operation will have a lower decontamination efficiency (see Appendix B, Table B.2).

A.1.3 Vacant Land

Vacant land refers to land with no structural or agricultural improvements. Ground cover is assumed to consist of primarily grasses and bushes rather than trees. This general description is meant to distinguish this land type from agricultural land and forest land, which are discussed separately.

A.1.3.1 Fixatives

Fixatives and their characteristics are described in Section A.1.1.2. Except for MC-70, which has to be applied hot, any of the fixatives discussed previously could be applied by either a distributor tank truck or water spray truck or by aircraft. A distributor tank truck would be preferable in that it

is capable of applying a more uniform coating. Much information on the costs and rates of application of liquids is presented elsewhere in this appendix, so it will not be necessary to repeat those calculations in detail. (See Sections A.1.1.2 and A.1.5.3.)

The representative fixative cost used here is based on a single treatment of Coherex at a ratio of one part Coherex to five parts water applied at 0.75 gallon per sq yard. The resulting material cost is $0.19 per sq meter, including shipping. Application is with the same inputs as described in Section A.1.1.2. Here, because of rougher terrain and greater distance to refilling location, we assume an average coverage rate 75% of that used for applying fixative to agricultural fields (Section A.1.1.3), 2192 sq meters per hour.

Dividing the hourly costs of labor and equipment by the coverage rate yields the costs in terms of area:

$$\text{Labor: } \frac{\$19.75/\text{hr}}{2192\ \text{m}^2/\text{hr}} = \$0.0090/\text{m}^2$$

$$\text{Equipment: } \frac{\$27.37/\text{hr}}{2192\ \text{m}^2/\text{hr}} = \$0.0125/\text{m}^2$$

Adding the input costs gives the total cost per sq meter as $0.2115.

A.1.3.2 Clear

Clearing vacant land of brush and small trees will remove radioactive particles that adhere to the removed material. In addition, clearing may be necessary before other operations such as scraping, fixing, or watering can be performed. Even if these operations could be done without clearing, their effectiveness would be increased by clearing.

The costs and rate for this operation are based on data presented in Means' Building Construction Cost Data 1982 (p. 24). This source specifies one common laborer with brush saw and rake to clear 565 sq yards per day. Converting to sq meters per hour and adjusting for one hour per shift for personnel and equipment decontamination gives a rate of

$$565\ \text{yd}^2/\text{day} \div 8\ \text{hr/day} \times 0.836\ \text{m}^2/\text{yd}^2 \times 7/8\ \text{adj} = 52\ \text{m}^2/\text{hr}$$

The hourly cost of labor is $17.45. Dividing by the hourly coverage rate gives a labor cost of $0.34 per sq meter.

A 35-horsepower gas-powered brush chipper with a six-inch cutter head is reported (p. 8) as having an hourly operation cost of \$2.80. The monthly rental rate is \$975. At 168 hours per month, rental comes to \$5.80 per hour. The total equipment cost is, therefore, \$2.80 + \$5.80 = \$8.60. In terms of dollars per sq meter, the cost is \$8.60 ÷ 52 m^2/hr = \$0.17.

The total comes to \$0.34 + \$0.17 = \$0.51 per sq meter.

A.1.3.3 <u>Scrape</u>

The essential aspects of soil scraping are described in Section A.1.1.5. Here we assume the same hourly costs for the inputs to scrape soil on vacant land as on agricultural fields (Section A.1.1.5). However, because of less even terrain and harder soil, we assume the average surface coverage rate for vacant land to be 75% of that for agricultural fields. The resulting coverage rate is 656 sq meters per hour.

The input costs per sq meter are easily calculated:

$$\text{Labor: } \frac{\$116.50/\text{hr}}{656\ \text{m}^2/\text{hr}} = \$0.18/\text{m}^2$$

$$\text{Equipment: } \frac{\$152.92/\text{hr}}{656\ \text{m}^2/\text{hr}} = \$0.23/\text{m}^2$$

The total cost is \$0.41 per sq meter. The cost of hauling the soil away is calculated separately (see Section A.6.2) and is primarily a function of the distance to the disposal site.

A.1.3.4 <u>Water</u>

The basic aspects of water application are described in Sections A.1.1.1 and A.1.9.2. The equipment used would be the tank distributor truck arrangement described in Section A.1.5.3.

Here we assume that the vehicle is able to maintain the same speed while spraying as used in Section A.1.5.3--one mile per hour. However, because of greater distance to water supply locations, we use a refill time of one hour. The result is an average coverage per shift-hour of

$$\frac{1\ \text{mi/hr} \times 5/6\ \text{hr spray} \times 5280\ \text{ft/mi} \times 10\ \text{ft wide} \times 0.0929\ \text{m}^2/\text{ft}^2 \times 7/8\ \text{adj}}{(5/6\ \text{hr spray} + 1\ \text{hr refill})}$$

$$= 1951\ \text{m}^2/\text{hr}$$

Using the same hourly labor and equipment costs, the input costs on a sq-meter basis are calculated as follows:

$$\text{Labor: } \frac{\$19.75/\text{hr}}{1951 \text{ m}^2/\text{hr}} = \$0.010/\text{m}^2$$

$$\text{Equipment: } \frac{\$27.37/\text{hr}}{1951 \text{ m}^2/\text{hr}} = \$0.014/\text{m}^2$$

The total cost per sq meter is \$0.024.

A.1.3.5 Leach

The basic aspects of leaching as a decontamination operation are described in Section A.1.9.3. For leaching vacant land, a 5000-gallon tank distributor truck with spray bar would be used. This equipment is described in Sections A.1.5.3 and A.1.1.2. In order to apply 0.3 inch of water, the vehicle's speed would need to be reduced from one mile per hour, as used in Section A.1.5.3 and in the previous section, A.1.2.5, to 0.6 mile per hour. In addition, we assume that increased distance to water supplies would raise the refill time to one hour. The net result of this is that the adjusted hourly coverage rate is 0.6 times the rate given in Section A.1.2.5.

$$\frac{0.6 \text{ mi/hr} \times 5/6 \text{ hr spray} \times 5280 \text{ ft/mi} \times 10 \text{ ft wide} \times 0.0929 \text{ m}^2/\text{ft}^2 \times 7/8 \text{ adj}}{(5/6 \text{ hr spray} + 1 \text{ hr refill})}$$

$$= 1171 \text{ m}^2/\text{hr}$$

With the same hourly labor and equipment costs, the costs per unit area are:

$$\text{Labor: } \frac{\$19.75/\text{hr}}{1171 \text{ m}^2/\text{hr}} = \$0.017/\text{m}^2$$

$$\text{Equipment: } \frac{\$27.37/\text{hr}}{1171 \text{ m}^2/\text{hr}} = \$0.023/\text{m}^2$$

The material cost per sq meter is calculated in Section A.1.9.3 as \$0.026. The total cost per sq meter is \$0.066.

A.1.3.6 Plow

Section A.1.1.6 describes plowing as a decontamination operation for agricultural fields. Where the soil is not too hard, plowing of vacant land can also be done. Where soil conditions warrant, a bulldozer with ripper shanks can be used in place of a normal wheel-mounted farm tractor.

Primary sources for this operation include various Cooperative Extension publications. "Almond Establishment Costs on Class II and Class III Soils in Sacramento Valley," published by the University of California Cooperative Extension, lists the cost of land preparation at \$100 per acre. A similar University Cooperative Extension publication, "Costs to Establish English Walnut Orchard in Sacramento Valley," estimates land preparation costs at \$50 per acre. Such land preparation involves shallow subsoil and discing, according to "Costs of Establishing and Producing Prunes," also published by the University of California Cooperative Extension. Subsoil and discing are described in Sections A.1.1.6 and A.1.1.7.

Based on these publications and another from the same organization, "Orchard Development Costs," we estimate the cost per acre at \$100. With adjustment for one hour per shift for personnel and equipment decontamination, the cost per sq meter is

$$\$100/\text{ac} \div 4046.7\ \text{m}^2/\text{ac} \times 8/7\ \text{adj} = \$0.028$$

In addition, we assume that the hourly cost of plowing vacant land will be somewhat higher than that for plowing agricultural fields. This is because, on average, heavier equipment will be necessary, more fuel will be required, and an operator of higher skill may also be necessary. The hourly cost used here is \$50, compared with \$34 for plowing agricultural fields. The implied coverage rate is

$$\$50/\text{hr} \div \$0.028/\text{m}^2 = 1770\ \text{m}^2/\text{hr}$$

Assuming the same cost shares for labor (25%), equipment (55%), and fuel (20%) as in plowing, the various input costs are:

Labor: $\$0.007/\text{m}^2$

Equipment: $\$0.015/\text{m}^2$

Fuel: $0.006/m^2

A.1.3.7 Deep Plow

Deep plowing is described in Section A.1.1.7. For deep plowing agricultural fields, the representative cost is estimated at $0.06 per sq meter. The cost for deep plowing vacant land will, of course, be greater. Agristruction advises that its cost for deep plowing hard soil is $500 per acre. This is equivalent to $0.12 per sq meter. However, Agristruction's costs tend to be higher than those provided by most other sources. This is apparently due to deeper plowing and harder soils plowed by Agristruction. Based on this figure, we estimate a cost of $0.10 per sq meter. Also, we estimate a higher hourly cost due to greater equipment wear, greater fuel use, and the possible need for heavier equipment. The hourly cost of $400 for deep plowing vacant land compares with $300 for deep plowing agricultural fields. The implied coverage rate is $400/hr ÷ $0.10/m^2 = 4000 m^2/hr. This rate is higher than the normal plowing rate (Section A.1.3.6) because much more powerful equipment is used.

The equipment operator will cost about $25 per hour according to Means' Building Construction Cost Data 1982 and Agristruction. This comes to $0.006 per sq meter. The remaining cost, $0.094 per sq meter, is for equipment.

A.1.3.8 Cover

See Section A.1.1.9 for a description of this operation and an explanation of the cost and rate estimates.

A.1.4 Wooded Land

A.1.4.1 Fixative

Fixatives are discussed in some detail in Section A.1.1.2. In addition, the problems of treating all surfaces of trees and ground were indicated in Section A.1.2.2 dealing with the aerial application of fixatives to orchards.

An appropriate choice of fixative appears to be lignosite. Here we temporarily assume an application rate of about 0.4 gallon per sq yard of a 75% solution. The material cost for this mixture would be about $0.05 per sq meter.

The most effective way to apply a fixative to a wooded area is by airplane. In fact, this method of application is appropriate for almost any exterior surfaces, if the area is sufficiently large. This could be done using

aircraft that spray crops; the larger planes that dump water and fire retardant on forest fires also appear to be practical. Large scale water drops used in fighting forest fires generally spread a load of 3,000 gallons over an area of from 40,000 to 80,000 sq feet. This is equal to about 0.45 gallons per sq yard - slightly more than called for. Dumping the fixative while flying at a greater speed, dumping the oil at a slower rate, or possibly dumping from a higher altitude would have the effect of spreading the material out more thinly over a larger area. A buildup of multiple thin layers of fixative should result in a fairly even application, though there is some uncertainty in this respect.

One cost estimate for aerial application came from the U.S. Forest Service in Portland, Oregon. They reported a cost of about $1.00 per gallon. However, this included the cost of fire retardant and other expenses involved in this fire fighting operation. Aerial application comprised about half these costs, or $0.50 per gallon. At a coverage rate of 0.4 gallons per sq yard, this is equivalent to $0.24 per sq meter.

A company with which that Forest Service office contracts for aerial fire fighting operations is Butler Aviation in Redmond, Oregon. The figures supplied by Butler Aviation implied a cost as low as $0.23 per gallon or $0.11 per sq meter. The considerable difference between these two cost estimates is surprising, especially since the two sources are involved in the same transaction. The difference appears to result from the way in which the service is contracted. Butler Aviation charges $1000 per day per plane and $2000 per flying hour per plane. The charges, being time-based, will result in a lower cost per gallon when more gallons per hour are dumped. The Forest Service's figures appear to be based on costs realized in actual operation. To the extent that Forest Service fire-fighting operations do not always involve continuous 24-hour, high-rate dumping, their costs per gallon will be higher than the possible minimum.

Butler Aviation's cost per gallon was calculated on the following basis. The capacity per plane is 3,000 gallons. The maximum dump rate is four loads per hour. This can be attained when the dump site is near the landing site. Decontamination operations would provide a situation in which it is likely that a fairly high and steady rate of operation could be maintained. An airbase for these operations close to the dump site would probably be available. On the other hand, the necessity of applying fairly thin coats will slow the application rate somewhat; a rate of three dumps per hour was assumed. Further, one hour in eight is assumed necessary for radiation decontamination treatment of equipment. Therefore, over a 24-hour period, there will be 21 hours of dumping. At 3 dumps per hour and 3,000 gallons per dump, 189,000 gallons will be dumped in 24 hours. The cost for this will be the $1,000 daily charge plus 21 times the $2,000 hourly charge. This will bring the total aircraft costs over a 24-hour period to $43,000. This is equivalent to $0.2275 per gallon or

$0.1088 per sq meter for aerial application. Over a 24-hour period the gallonage would be enough for 395,071 sq meters, or 16,461 sq meters per hour.

The rates charged by Columbia Aerial Ag Service of Pasco, Washington yielded costs closer to those from the U.S. Forest Service source. To a commercial agricultural spray company, such as this one, the coverage of 0.4 gallons per sq yard is considerably more than the 3 to 10 gallons per acre coverage to which they are accustomed--about 200 times more. Their charges are geared to the particular chemical and the coverage specified by the farmer. Converting their charges into a cost per gallon or a cost per sq meter requires a generous use of estimates and assumptions. According to Columbia Ag Service, their charges are roughly equivalent to $400 to $500 per tachometer-hour and they generally run one tachometer-hour every 1.25 clock hours. Average operating speed is 100 miles per hour. It normally takes 60 seconds to dump a load of 350 gallons, and five minutes is required for refilling the aircraft. In addition to the estimated flying time, 25 percent for "maneuvering" needs to be included. Assuming a target site 10 miles from the aerial operations base, the following is implied:

time to dump site	6 min
time for dump	1 min
time for return	6 min
time for maneuvering	3.25 min
total flight time	16.25 min

In addition:

time for reloading plane	5 min

This gives:

total time for 350-gallon dump	21.25 min

These figures are roughly consistent with the ratio of one tachometer-hour to 1.25 clock hours. At the rate of $500 per tachometer-hour, the cost per dump is:

$$\frac{16.25 \text{ min/dump}}{60 \text{ min/hr}} \times \$500/\text{hr} = \$135.42/\text{dump}$$

The cost of aerial application per gallon is, then,

$$\frac{\$135.4167}{350 \text{ gal}} = \$0.3869/\text{gal}$$