be within reason when compared with those reported by other sources. For example, Doolittle Construction estimated a rate of 146 square meters per hour. This was with a smaller crew and only one loader. Reeco indicated that their rate is about an acre a day or about 500 square meters per hour. The rate derived from McGraw-Hill's Dodge Guide was a little over 4000 square meters per hour. It should also be noted that these estimates are for scraping vacant land, which would normally take longer than scraping agricultural fields.

Dividing the hourly production rate into the hourly costs gives the cost in dollars per square meter. The total is $0.31, labor is $0.13 and equipment comes to $0.18 per square meter. Total costs per square meter reported by other sources were:

Doolittle Construction	$0.34
Science Applications (1978)	0.16
Reeco	0.24
McGraw-Hill	
Loose soil	0.26
Broken rock	0.61
Battelle (1978)	0.47
World Excavating	0.23

A.5.6 Plow

Both by mixing and turning the soil, plowing is an effective method of reducing radiation hazards from external exposure and inhalation. Since plowing is a relatively common operation for which much data has been collected, there is a considerable amount of information about plowing. Farm advisors and publications of agricultural extension services are good sources. For the present report, additional sources were contacted, including farm management consultants and academic sources.

There are various types of plowing operations, including chisel plowing, heavy discing, and mouldboard plowing. Mouldboard plowing is particularly appropriate for the purposes at hand because it turns the soil more than cutting it. This would be the most effective plowing technique to move surface-level contamination below the soil. Most plowing operations operate to depths of eight to ten inches, though some plowing is done to depths of 18 inches and 12-inch deep plowing is not uncommon. For plowing to greater depths - three feet deep and more - see the next section, A.5.7, concerning deep plowing.

The University of California, Division of Agricultural Sciences publication Custom Rates for Farm Applications gives the cost of plowing at $10-12.50 per acre in 1978 dollars. In 1982 dollars this amounts to $15.75 to $17.20 per acre, using the gross national product implicit price deflator to adjust to 1982 price levels. Using the upper end of this range and adjusting for an hour per shift for radiation control measures, we find the cost per square meter as

$$\frac{\$17.20/ac}{4046.7\ m^2/ac} \times \frac{8}{7}\ adj = \$0.0049/m^2$$

The indicated rate was about 1.8 acres per hour. This implies a coverage rate of

$$1.8\ ac/hr \cdot 4046.7\ m^2/ac \cdot 7/8\ adj = 6374\ m^2/hr$$

Iowa State University Cooperative Extension supplied results from 1983 Iowa Farm Custom Rate Survey which showed that mouldboard plowing averages about $10.70 per acre (in 1982 dollars). The cost ranges from $9.00 to 12.40 per acre. At $10.70 per acre, the adjusted cost per square meter is $0.0030. The approximate breakdown of these costs is 25% for labor, 55% for equipment and 20% for fuel. These figures were confirmed by King Management Company, a farm management concern in Des Moines, Iowa. This source added information about related operations. Chisel plowing to a depth of 12 inches costs about $0.0024 per square meter, and heavy discing to a depth of 12 to 18 inches costs about $0.0022 per square meter.

From this information, we take as representative a total cost of $0.004 per square meter. This is comprised of $0.001 for labor, $0.002 for equipment, and $0.001 for fuel. The hourly rate is 5000 square meters.

A.5.7 Deep Plow

Deep plowing here refers to plowing to a depth of about 36 inches, though there are procedures for plowing any depth up to 36 inches and deeper. In addition, there are a number of different techniques and terms associated with deep plowing, including ripping, subsoil, and slip plowing. Most deep plowing operations involve pulling one, two, or three shanks through the soil with a large tractor. Agristruction, Inc. operates a rig with seven shanks, over a 16.5-foot width, that rip to a depth of 32 inches. Some operations turn 36 inches of soil using a large mouldboard plow. For hard soil it is sometimes necessary to use a second tractor pushing or pulling the first. One source (Agristruction, Inc.) uses 14-foot shanks weighing a ton each to rip very hard soil up to five feet deep.

Deep plowing is not a particularly common farm operation. One region in which deep plowing is not uncommon is the Southern San Joaquin Valley in California. In this area deep plowing is used to break up a layer of hard pan below the surface in order to facilitate root penetration. Most deep plowing is done by custom farming companies that specialize in this type of work.

Because equipment, soil conditions, procedure, and plowing depth differed from source to source, cost estimates varied considerably. The lowest was equivalent to $0.008 per square meter, while the highest figure was $0.20 per square meter. Table A.5.7.1 summarizes the data collected. The figures are adjusted for reduced productivity and time taken for personnel and equipment protection due to radiation.

TABLE A.5.7.1. Deep Plowing Cost Data Summary

Source and Procedure	Rate (m^2/hr)	Cost (1982 \$/m^2)
Univ of Calif Coop Exten, "Costs to Estab. and Produce Walnuts"		
Shallow subsoil	--	0.0141
Univ of Calif Coop Exten, "Custom Rates for Farm Operations"		
Subsoil (36")	7588	0.0082
Rip (6')	--	0.0194
Agristruction, Inc.		
Rip soft soil (5')	5311	0.1130
Rip hard soil (5')	1328	0.1412
Can-Do Custom Farming		
Slip plow (18")	2479	0.10
Slip plow (36")	2833	0.20
Moorehead and Idell		
Slip plow (36")	4249	0.03
Battelle (1978), "Estimate of Potential Costs..."		
Plow (1 m)	--	0.06
Dave Price		
Slip plow (6')	2656	0.10
Mouldboard plow (52")	1770	0.11
Braden Farms		
Rip	6551	0.015
Valley Tractor Co.		
Plow (36")	6374	0.047
Plow (52")	3541	0.11
Valley Agricultural Consultants		
Slip plow	2479	0.022

The representative rate and cost are taken as 5000 square meters per hour and $0.06 per square meter. The labor cost is figured at $0.005 per square meter based on an hourly operator billing cost of about $25.00 per hour.

A.5.8 Clear

Clearing refers to removing the plant cover. This operation has two functions. The first is the obvious one of effecting a degree of decontamination since the removed plant cover will take with it a proportion of the radioactive particles. The second function of clearing is to facilitate the execution of subsequent operations. For agricultural fields, most crop cover is not likely to impede other operations. However, there could be cases in which this would not be the case. For example, corn at or near full growth would certainly pose an obstacle to other treatment measures.

Corn was, in fact, used as the representative crop to be cleared. For corn and for other crops, it appears that associated farm machinery offers the best possibility for the lowest-cost way to clear the crop. Clearing may therefore entail harvesting the crop. Conversation with a representative of the U.S. Department of Agriculture in Seattle, Washington indicated that for the purposes of clearing corn a swather may be the best option. This will bale the stalks to facilitate removal. The average cost per acre for this procedure is $94.28. This is broken down into $10.80 for baler twine, $21.42 for machinery and fuel, $25.89 for maintenance and repair, $2.95 for interest on equipment, and $33.22 for labor. Combining the non-labor costs under equipment, we get $61.06 per acre.

Swathing requires about 6.52 hours per acre, which is equivalent to 0.15 acres per hour. Multiplying cost per acre by this acres-per-hour figure gives the cost of swathing as $14.47 per hour. The hourly labor cost is $5.10, and the equipment cost is $9.36 per hour. Converting the acres-per-hour figure to square meters per hour can be done as follows:

$$0.15 \text{ ac/hr} \times 4046.7 \text{ m}^2\text{/ac} \times 7/8 \text{ adj} = 543 \text{ m}^2\text{/hr}$$

Dividing the hourly cost figures by this hourly production rate yields the cost of swathing on a per-square-meter basis. The total is $0.026. Labor accounts for $0.009 per square meter, and equipment $0.017.

This operation requires a farm equipment operator and a swather as the primary inputs.

A.5.9 Cover

This operation involves covering the ground with six inches of uncontaminated soil. This may be done to replace soil which has been removed as a radiation treatment measure, or the contaminated ground may be covered by the new soil. However this operation fits into a decontamination program, the soil cover will help reduce resuspension and external exposure.

The first step in this operation is the excavation of the earth that is to be spread in the treatment area. This excavation might be coupled with

contaminated-material disposal. If a pit is to be dug for disposing of contaminated soil or other materials, the removed soil might be usable for covering. The excavated soil would be hauled to the decontaminated site, dumped there, and spread by a front-end loader.

Means' Building Construction Cost Data 1982 (p. 29) lists several ways to accomplish bulk excavation. The least costly is to use a large (five cubic yard capacity) wheel-mounted front-end loader. This equipment can excavate and load 1480 cubic yards per day of medium soil. Noting that each cubic yard of soil will cover six square yards six inches deep, the hourly coverage rate is

$$\frac{1480 \text{ yd}^3/\text{day}}{8 \text{ hrs/day}} \times 6 \text{ yd}^2/\text{yd}^3 \times 0.836 \text{ m}^2/\text{yd}^2 \times 7/8 \text{ adj} = 812 \text{ m}^2/\text{hr}$$

Means calls for one medium-equipment operator at $24.95 per hour billing cost and half a building laborer at $19.40 per hour as the labor input. This totals $34.65 per hour. The front-end loader costs $100.38 per hour. The total hourly cost is $135.03. Dividing these figures by the hourly production rate gives costs in terms of dollars per square meter: total, $0.166; labor, $0.043; equipment, $0.123.

The cost of hauling is handled separately since it depends on the distance.

Means (p. 32) also supplies data for estimating the cost of spreading and grading the new soil. The inputs for this step are similar to the excavation step. The labor inputs are the same, but instead of a front-end loader, a 200-horsepower bulldozer is called for. The cost for this equipment is $78.04 per hour. The listed rate of 1000 cubic yards per day can be converted to square meters per hour with the following calculations.

$$\frac{1000 \text{ yd}^3/\text{day}}{8 \text{ hr/day}} \times 6 \text{ yd}^2/\text{yd}^3 \times 0.836 \text{ m}^2/\text{yd}^2 \times 7/8 \text{ adj} = 549 \text{ m}^2/\text{hr}$$

Dividing this hourly rate into the hourly cost yields dollars per square meter.

Table A.5.9.1 summarizes the foregoing results and shows the combined costs for excavation and spreading. Spreading is the more costly step, and as

TABLE A.5.9.1. Summary of Excavation and Grading Cost Data for Soil Cover

Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$)		
		Total	Labor	Equipment
Excavate	812	0.166	0.043	0.123
Spread and grade	549	0.205	0.063	0.142
Total	549	0.371	0.106	0.265

a result, 549/812 = 0.68 excavation crews would be used for every spreading crew.

A.6 ORCHARDS

Orchards possess two important characteristics affecting decontamination operations. The first is that orchards include ground, leaves, and branches, all of which would become contaminated. Since treatment of one of these may or may not have an adverse effect on another, decontamination of orchards can be more complex than for other areas. Second, the trees necessarily limit vehicular mobility and will completely preclude the use of large trucks.

A.6.1 Water

This operation involves applying water to orchard soil using existing flood irrigation equipment. Water will tend to drive soil contamination down below the surface, helping to reduce hazards due to resuspension and external exposure. It should be pointed out that some orchards have no irrigation system in place, while others may use some other type of irrigation such as drip or center-pivot sprinkling. Any irrigation involving sprinkling has the added advantage of moving some of the radioactive matter from the trees and foliage to the ground.

The sources of information for this operation are various cooperative extension publications including "Costs of Establishing and Producing Prunes," "Almond Production Costs on Class I Soils in Sacramento Valley, 1981," "Almond Production Costs on Class II and Class III Soils in Sacramento Valley, 1981," and "Costs to Establish and Produce Walnuts," all by the University of California Cooperative Extension. Another source was "Cost of Producing Apples in Central Washington," prepared by the Cooperative Extension, College of Agriculture, Washington State University. The information provided in these pamphlets is not always complete. For example, the third publication listed gives the total yearly costs for irrigation but does not indicate how many times the orchard was irrigated. In general, however, all the sources seem to be consistent with the information in the first pamphlet, which indicates about one man-hour of labor required for irrigation for each acre for each application. The cost of this labor was listed at five dollars per hour. Thus, the cost per square meter is

$$\frac{\$5/\text{ac} \cdot 1\ \text{ac}}{4046.7\ \text{m}^2/\text{ac}} \times \frac{8}{7}\ \text{adj} = \$0.0014/\text{m}^2$$

The hourly coverage rate is

$$1\ \text{ac/hr} \cdot 4046.7\ \text{m}^2/\text{ac} \cdot 7/8\ \text{adj} = 3541\ \text{m}^2/\text{hr}$$

A.6.2 Fixative - Aerial Application

Orchards pose a problem of how to apply liquid treatments such as water or a fixative to both the tree foliage and the ground. One technique is to apply these liquids from an airplane or helicopter. In general, however, any

fixative, regardless of the method of application, will have reduced effectiveness when the trees are in full leaf. It is essentially impossible to reach every surface with an even application. For this reason, it may be advisable to defoliate the trees before applying the fixative (see Section A.6.4).

There are also some important considerations with respect to the choice of fixative. If the area is to be decontaminated, and the existing trees are to be saved, then a non-toxic material should be used. On the other hand, the difficulty in achieving an even covering of fixative suggests that it may be desirable to use a material that remains sticky for a long time. This would tend to capture particles dislodged by wind or other means. Road oil and diesel oil remain sticky for a long time, but they would be damaging to the orchards themselves. A fixative that might prove appropriate is lignosite. This is relatively inexpensive, and it is non-toxic. However, it may not remain sticky for a sufficient length of time. (See Section A.7.1 for a discussion of fixatives and their characteristics and requirements for application.)

Because leaves and branches raise the total surface per gross land area, we increase the amount of fixative to be applied by 50%, bringing the application rate to 0.75 gallons per square yard. Increasing the amount of material by 50% per unit area also entails a 50% increase in the cost per square meter. As shown in Section A.7.1, the cost per square meter of lignosite at normal application rates is $0.06 per square meter. At the higher application rate the cost rises to $0.09 per square meter.

The cost of application is based on costs developed in Section A.8.1. The rate of application was estimated at 14,000 square meters per hour for an application of 0.4 gallons per square yard. Increasing the amount of fluid applied to 0.75 gallons per square yard will increase the application time by a factor of 0.75/0.4 = 1.875. The new application rate is

$$14,000/1.875 = 7467\ m^2/hr$$

Hourly labor and equipment costs can be found by further use of the data for aerial application in Section A.8.1. Multiplying the rate (14,000 square meters per hour) by the unit labor cost ($0.01 per square meter) and the unit equipment cost ($0.14 per square meter) gives the hourly costs for these input categories. They are $140 per hour for labor and $1960 for equipment. Dividing these hourly costs by the new application rate gives the adjusted unit labor and equipment costs:

$$\text{Labor:} \quad \frac{\$140/hr}{7467\ m^2/hr} = \$0.019/m^2$$

$$\text{Equipment:} \quad \frac{\$1960/hr}{7467\ m^2/hr} = \$0.262/m^2$$

Adding the costs of these two inputs to the material cost gives a total cost per square meter of $0.371.

A.6.3 Fixative - Ground Application

In the previous section, aspects of applying a fixative to orchards were discussed. In this section, the procedure and costs of application of fixative from the ground are presented.

Normal orchard farming procedures include activities that involve application of liquids to the ground and to the trees. For example, ground surfaces are often sprayed with herbicides for weed control using a seed sprayer. A blast sprayer applies chemicals to the tree foliage by spraying a very fine mist into the air. These two sprayers could be used for application of fixative.

In addition to various cooperative extension publications, information was obtained from California and Washington State cooperative extension farm advisors specializing in orchard crops. According to the orchard farm advisor in Butte County, California, costs relating to prune orchards are reasonably representative of orchard costs in general.

The University of California Cooperative Extension publication "Cost of Establishing and Producing Prunes" provides cost and rate data for prune production operations for a 100-acre orchard. For spraying the ground twice with herbicide, the total cost is $30.65 per acre. Subtracting the cost of materials ($24) and dividing by the total acres sprayed (one acre sprayed twice is equivalent to two acres) gives $3.325 per acre. This is comprised of $1.75 for labor and $1.575 for fuel and repairs. Converting these figures to a cost per square meter can be done as follows:

$$\text{Labor:} \quad \frac{\$1.75/\text{ac}}{4046.7 \ \text{m}^2/\text{ac}} \cdot \frac{8}{7} \ \text{adj} = \$0.000494/\text{m}^2$$

$$\text{Fuel:} \quad \frac{\$1.575/\text{ac}}{4046.7 \ \text{m}^2/\text{ac}} \cdot \frac{8}{7} \ \text{adj} = \$0.000445/\text{m}^2$$

These cost figures are relatively low primarily because a typical application of herbicide is only 50 gallons per acre as compared with a fixative application in the range of 0.2 to 0.5 gallons per square yard. The application of 50 gallons per acre is equivalent to

$$\frac{50 \ \text{gal/ac}}{4840 \ \text{yd}^2/\text{ac}} = 0.01033 \ \text{gal/yd}^2$$

To adjust the cost figures to a level appropriate for fixative, the costs will have to be multiplied by

$$\frac{0.4 \ \text{gal/ac}}{0.01033 \ \text{gal/ac}} = 39$$

Thus, the labor cost becomes \$0.0193 per square meter, and the fuel cost is \$0.0174.

The equipment cost is estimated differently, using the time to treat a unit area of land. The time to spray one acre once is 0.35 hours with 50 gallons of herbicide. The time required for a 0.4 gallons per square yard coverage would be 39 times longer, and with the adjustment for personnel and equipment decontamination the time would be

$$0.35 \text{ hrs/ac} \times 39 \times 8/7 \text{ adj} = 15.6 \text{ hrs/acre}$$

The hourly cost of the weed sprayer is \$0.50, and the cost of the 30-horsepower tractor to tow the sprayer is \$4.00 per hour. The total hourly cost is, therefore, \$4.50. The equipment cost per acre is

$$\$4.50/\text{hr} \times 15.6 \text{ hrs/ac} = \$70.20/\text{ac}$$

The cost per square meter is

$$\$70.20/\text{ac} \div 4046.7 \text{ m}^2/\text{ac} = \$0.0173/\text{m}^2$$

Adding the labor cost (\$0.0193/m^2), the equipment cost (\$0.0173/m^2), and the fuel and repair cost (\$0.0174) gives the total application cost per square meter of \$0.054. The 15.6 hours per acre time requirement is equivalent to a production rate of

$$\frac{4046.7 \text{ m}^2/\text{ac}}{15.6 \text{ hr/ac}} = 260 \text{ m}^2/\text{hr}$$

Similar calculations using data in "Cost of Producing Apples in Central Washington," released by the Cooperative Extension, College of Agriculture, Washington State University, generated a total cost of \$0.061 per square meter for application. Of this total, labor accounts for \$0.016 per square meter, equipment and repair \$0.034 per square meter, and \$0.010 for fuel.

These cost figures can be compared to the cost of fixative application using a large distributor tank truck as described in Sections A.5.1 and A.5.2. The cost data in A.5.2 show the cost for applying fixative at 0.75 gallons per square yard to be about \$0.0161 per square meter, excluding the cost of the fixative.

The cost of using the orchard spray equipment is considerably higher than that of using the large distributor tank truck because the former is designed for lower-volume applications in areas with restricted access. Since somewhat larger capacity equipment may be useable in some instances, we can view the cost with orchard spray equipment as an upper bound and the cost with the large distributor tank truck as a lower bound.

The pamphlet "Costs of Establishing and Producing Prunes" also provides information on the cost of spraying the trees using a blast sprayer. The time required to spray an acre twice is one hour. The labor cost is \$5.00, and fuel and repairs cost \$10.00. The amount of material applied is 350 to 400 gallons per acre per application. In addition, the sprayer and tractor together cost

about $7.00 per hour. Performing the same calculations as done on the ground spraying data, we get a cost of $0.00976 per square meter for labor, $0.01367 for equipment, and $0.01953 for maintenance and repairs. The implied rate is 512 square meters per hour.

Similar calculations were performed using data from the Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Producing Apples in Central Washington." The resulting labor cost is $0.0082 per square meter. The equipment cost is $0.0252 per square meter, and the cost of fuel is $0.0318 per square meter. The coverage rate is 610 square meters per hour.

Table A.6.3.1 summarizes the results of these calculations and presents representative costs and rates. The representative figures were calculated in four steps. The first was to convert the costs as shown to a dollars-per-hour basis by multiplying the rate by the cost per square meter. Second, the average rate and the average cost per hour for both steps were calculated from the two data sources. Third, the average dollar per hour figure was divided by the average rate to yield the representative dollars per square meter. Finally, the costs for the two steps were added to find the total cost per square meter. The representative combined rate was set equal to the rate of the more costly procedure - spraying the ground. This means that for every operator-tractor-weed sprayer crew there will be one-half an operator-tractor-blast sprayer crew.

Finally, there is the cost of the fixative to be applied. Aspects bearing on the choice of the fixative were discussed in the previous section, and following the reasoning there it is assumed that the fixative chosen is

TABLE A.6.3.1. Summary of Data for Spraying Orchards from the Ground, Excluding Material Cost

Source and Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$) Total	Labor	Equipment	Fuel
Univ. of Calif.					
Spray ground	260	0.054	0.019	0.017	0.017
Spray trees	512	0.043	0.010	0.014	0.020
Total	260	0.097	0.029	0.031	0.037
Wash. State Univ.					
Spray ground	305	0.060	0.016	0.034	0.010
Spray trees	610	0.065	0.008	0.025	0.032
Total	610	0.125	0.024	0.059	0.042
Representative					
Spray ground	280	0.058	0.018	0.027	0.013
Spray trees	560	0.055	0.009	0.020	0.026
Total	280	0.113	0.027	0.047	0.039

lignosite. Because of the increased total physical surface area per square meter due to tree foliage, the foregoing calculations relating to application assumed that more than the usual amount of fixative per square meter would be required. Those calculations assumed that spraying the ground and spraying the trees would each require about 0.4 gallons per square yard. At this application rate, the material cost for each spraying procedure would be about $0.05 per square meter. For the two procedures combined the cost would be $0.10 per square meter. This raises the total cost for the combined spraying operation to $0.2113.

A.6.4 Defoliate

According to the Cooperative Extension orchard farm advisor in Butte County, California, orchard defoliation is seldom done intentionally any more. The only time **it** is done is when very heavy wind is expected. Defoliation is a last step to prevent the trees from being blown down.

Defoliation is accomplished by spraying a zinc sulfate solution on the trees. The solution is prepared by mixing eight to ten pounds of zinc sulfate per 100 gallons of water. About 350 gallons of solution are applied per acre. The Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Establishing on Apple Orchard, Columbia Basin, Central Washington" lists the price of zinc sulfate at $1.35 per pound.

Mixing nine pounds per 100 gallons and spraying 350 gallons per acre means that 31.5 pounds of zinc sulfate are being applied per acre. The cost per square meter for the chemical is

$$31.5 \text{ lbs/ac} \times \$1.35/\text{lb} \div 4046.7 \text{ m}^2/\text{ac} = \$0.0105/\text{m}^2$$

Table A.6.4.1 summarizes the data from the University of California Cooperative Extension publication "Cost of Establishing and Producing Prunes" and the Cooperative Extension, College of Agriculture, Washington State University publication "Cost of Producing Apples in Central Washington." This is the same data used in the previous section for calculating the cost of applying fixative to trees. As shown, the hourly labor, equipment, and fuel costs are averaged along with the time to spray one acre with 350 gallons. This average time is converted to a rate in terms of square meters per hour and adjusted for one hour per shift lost to radiation control measures. This is done as shown:

$$4046.7 \text{ m}^2/\text{ac} \div 0.425 \text{ hr/ac} \times 7/8 \text{ adj} = 8331 \text{ m}^2/\text{hr}$$

Dividing this rate into the hourly cost figures gives the labor, equipment, and fuel cost per square meter. Adding the material cost brings the total to $0.0333 per square meter.

A.6.5 Leach

The general aspects of leaching were described in Section A.4.3. As in the case of leaching lawns, **it** seems the appropriate method for leaching orchards is first to apply a concentrated solution of the leaching agent to the

TABLE A.6.4.1. Summary of Data for Applying Defoliant to Orchard Trees

Source	Time or Rate	Cost (1982 $/m^2)					
		Units	Total	Labor	Equipment	Material	Fuel
Univ. of Calif.	0.5 hr/ac	$/hr:	---	5.00	7.00	---	10.00
Wash. State Univ.	0.35 hr/ac	$/hr:	---	5.00	18.43	---	23.29
Average	0.425 hr/ac	$/hr:	---	5.00	12.72	---	16.64
Representative	8331 m^2/hr	$/m^2:	0.0146	0.0006	0.0015	0.0105	0.002

soil and to follow this with an application of water. Following Section A.4.3, we base the calculations on ferric chloride being used as the leaching agent. Dick and Baker (1967) used this material in a 1% solution in their tests at the Nevada Test Site. Other chemicals could be used, notably EDTA.

The cost of applying ferric chloride is estimated here using the representative cost of applying fixative to the ground, which was developed in Section A.6.3. This cost is adjusted to account for the different amount of material applied.

Ferric chloride is normally sold in a 40% solution. One gallon of this mixture will cover 19 square meters to produce a 1% solution when 0.3 inch of water is applied to the soil. One gallon for 19 square meters is equivalent to 213 gallons per acre. Fixative application, at 0.4 gallon per square yard, is equivalent to 1936 gallons per acre. Thus, applying the leaching agent involves a fraction of the cost and time that applying'fixative does:

$$213 \div 1936 = 0.110$$

Adjusting the application rate with this factor gives 2545 square meters per hour. The labor cost is $0.00198 per square meter, and the equipment and fuel costs are $0.00297 and $0.00143 per square meter, respectively.

In addition to the cost of applying the leaching agent, there is also the cost of the leaching agent itself. This was calculated as $0.026 per square meter in Section A.4.3. Finally, the cost of applying water was estimated in Section A.6.1. The various costs for leaching are summarized and combined in Table A.6.5.1.

TABLE A.6.5.1. Summary of Leaching Data

Item	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment	Material	Fuel
Ferric chloride	--	0.026	--	--	0.026	--
Application of ferric chloride	2545	0.0064	0.0020	0.0030	--	0.0014
Application of water	3541	0.0014	0.0014	--	--	--
Total	2545	0.0338	0.0034	0.0030	0.026	0.0014

A.6.6 Scrape Without Tree Removal

This operation involves removing the top four to six inches of orchard soil without removing or damaging the trees. The requirement to work around the trees makes this operation significantly different from scraping agricultural fields (A.5.5) or vacant land (A.7.5). There are four principal ways in which scraping will be affected by the presence of trees. First, any earthmoving equipment used will have to be fairly small to **fit** between the trees. Second, such equipment will be limited in movement by the trees. Third, dump trucks will not always be able to get close to the spot where the scraping is being done. Fourth, shallow roots and the base of the trunk will require careful equipment operation **if** damage to the trees is to be avoided.

A workable procedure for scraping appears to be to have two laborers shovel soil from the base of the trees toward the center of the lanes between the tree rows. These would be followed by a small (0.75 cubic yard capacity) wheel-mounted front-end loader. The front-end loader would scrape up the top surface of the soil and remove the soil to a dump truck waiting at the end of the lane.

Means' Building Construction Cost Data 1982 provides data useful for estimatinq the cost of this **operation.** The hand shovelinq would require two building Taborers at $19.40 per hour each. A medium-equipment operator at $24.95 per hour and 0.5 building laborers are specified for operating the front-end loader. Total hourly labor costs (including fringe benefits) are $73.45. The front-end loader costs $24.00 per hour.

Estimating the rate is more conjectural. Means lists the output of the small front-end loader as 45 cubic yards per hour for bulk excavation of medium soil. As mentioned earlier, the orchard places severe limitations on the equipment's productive efficiency. On the other hand, the soil is likely to be relatively soft and light, and the terrain fairly flat and free of excess brush and weeds. Based on these considerations, we estimate the (unadjusted) production rate at 75% of that listed by Means. The coverage in terms of square meters per hour can be calculated as follows:

$$45\ yd^3/hr \times 0.75\ \text{eff. adj} \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ \text{adj}$$
$$= 148\ m^2/hr$$

In comparison, Ed Doolittle of Doolittle Construction Co. supplied data indicating a faster rate. This faster rate is largely the result of his specifying a larger-capacity front-end loader. He estimated that a front-end loader with a three cubic yard capacity could load a scoopful into a dump truck once every three minutes. This is equivalent to one cubic yard per minute or 60 cubic yards per hour. This is one-third more than the full rate given by Means for the smaller loader. Converting the Doolittle figure to square meters per hour, we get

$$60 yd^3/hr \times 6 yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ \text{adj} = 263 m^2/hr$$

Here we use the rate calculated from the Means data since the smaller equipment seems more appropriate in this situation. Further, the rate can be

adjusted with better information simply by changing the efficiency adjustment factor from 75% to a different level.

Dividing the hourly rate into the hourly labor and equipment costs generates their respective costs in terms of dollars per square meter: $0.496 and $0.162. The total cost per square meter is $0.658.

A.6.7 Plow

Section A.5.6 provides a general description of plowing as a decontamination technique. In an orchard, however, plowing will be hampered by the trees. Also, according to the Cooperative Extension orchard farm advisor in Butte County, California, unless the orchard has been cultivated on a regular basis, roots may be so shallow that any plowing-type operation may be impossible without severe permanent damage to the trees.

This source indicated that the particular plowing-type operation appropriate for orchards is called disc and float. This mixes more than turns the soil, and it limits damage to the root structure. A standard ten-inch disc harrow will mix the soil well to a depth of four to five inches. Floating does little more than leveling out the ridges left by the disc. The cost information provided indicated that normal orchard operations entail expenditures of about $100 per acre per year for discing and floating. The procedure is performed five times per year. The rate given was 2.2 acres per hour, but as will be explained, this is probably an inadvertent error and the rate is more likely 2.2 hours per acre.

In the University of California Extension publication "Costs to Establish and Produce Walnuts," the time required for disc and float five times is 2.2 hours per acre. This same rate is repeated elsewhere in the publication. The estimate of 2.2 hours per acre for performing the operation five times is equivalent to 0.44 hours to disc and float one acre once. The farm advisor's 2.2 acres per hour for five treatments implies one fifth of an hour to disc 2.2 acres once. In other words, the hourly coverage rate is 11 acres. This seems unreasonably high. Further, the publication-listed rate of 2.2 hours per acre is consistent with the listed labor cost of $11 per acre. This works out to $5.00 per hour, which is the normal agricultural labor wage rate.

At 2.2 hours per acre for disc and float five times, the rate in square meters per hour is

$$\frac{5}{2.2\ \text{hrs/ac}} \times 4046.7\ \text{m}^2/\text{ac} \times \frac{7}{8}\ \text{adj} = 8047\ \text{m}^2/\text{hr}$$

For comparison, the rate for plowing agricultural fields is 8500 square meters per hour.

"Costs to Establish and Produce Walnuts" lists the labor cost for discing and floating as $11.00 per acre and the fuel and repair costs as $15.75 per acre. In addition, a 60-horsepower wheel-mounted diesel tractor costs $7.00 per hour to operate, and the disc and float equipment cost $1.15 and $1.00 per hour, respectively. It is not clear if these figures include the cost of ownership, but since purchase price, depreciation, and interest are listed

separately, it appears that the hourly operation costs do not include these other items. The cost of the tractor is $20,000, and that of both the associated implements is $5,000, for a total of $30,000. This $30,000 comprises about 13.9% of the total $216,200 farm equipment investment. This source gives the depreciation and interest per acre for the total equipment investment as $216.00 and $151.34, respectively. Taking 13.8% of these figures as the share for discing and floating equipment, we get a depreciation cost of $30 per acre per year and $21 per acre per year for interest. The total of these two costs is $51.00. However, since this equipment is used for other farming activities besides discing and floating, only a fraction of this cost can be ascribed to that procedure, and, unfortunately, this source does not provide sufficient information to determine that fraction.

Another approach is to refer to Means' Building Construction Cost Data 1982. This source (p. 10) lists the monthly rent for a 65-horsepower wheel-mounted tractor equipped as an earthloader. Assuming that the additional five horsepower and the loader equipment are roughly equivalent in cost to the disc and float equipment, we take the monthly ownership cost to be $1875. Dividing by 336 hours per month, we get an hourly equipment ownership cost of $5.58. Total equipment cost is, therefore, the sum of this figure and the operation costs. The total is $14.73 per hour.

Dividing the hourly costs by the coverage per hour gives $0.006 per square meter for labor, $0.0018 per square meter for equipment, and $0.0020 per square meter for fuel and repairs. Adding these gives a total cost of $0.0044 per square meter.

A.6.8 Remove and Replace

The most costly orchard decontamination operation is removing and replacing the trees. This operation has three cost components. They are removal of trees, ground preparation and planting of trees, and the trees themselves. This operation might be done in conjunction with soil scraping. If this were the case, the appropriate stage for the scraping to be done would be after tree removal, but before ground preparation. Soil scraping with the trees removed is listed as a separate operation (see Section A.6.12).

Not included in the cost estimates here are the loss in income from unrealized crop sales. It is assumed that if orchard removal and replacement were necessary, the crop would not be safe for use. Another consideration is that the newly planted trees will not yield a marketable crop for several years. This loss in income, as well as the necessary post-planting orchard care costs, are accounted for in reduced property value. They are not counted as part of the removal and replacement operation cost.

Orchards differ considerably among themselves due to local conditions as well as the type of crop being raised. The two main factors which affect removal and replacement costs are the number of trees per acre and the cost of the trees.

The Cooperative Extension, College of Agriculture, Washington State University publication "Determining the Costs of Removing and Replacing Dead or

Damaged Commercial Fruit Trees" is the primary source of information about the removal of trees. The cost data were adjusted from 1977 to 1982 price levels. 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 Apoendix 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 square 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 square meters per hour is:

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

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

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

The equipment cost, calculated similarly, is $0.092 per square meter. The total cost for removing trees is, therefore, $0.194 per square 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.6.12) or covered with clean soil (see Section A.6.10), these operations would be done before this site preparation.

According to the Cooperative Extension publication "Determing 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:

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

Dividing the hourly coverage rate into the hourly costs gives:

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

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

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

Summing these gives the total cost of site preparation as $0.159 per square 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 square meters per hour. The costs per square meter are:

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

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

Total: $\$0.196/\text{m}^2$

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 square meter and adjusting for an hour per shift lost to radiation control measures, we get:

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

"Costs to Establish and Produce Walnuts" gives the preparation and planting costs as $227 per acre. This works out to $0.064 per square 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 square 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 square meter) with the figures from the University of California Cooperative Extension publications (prunes, $0.059 per square meter; walnuts, $0.064 per square meter; almonds, $0.05 per square 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 square meter. Adjusting this for an hour lost per shift due to the radiation, 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 square meter is 630 square meters per hour. The input costs in terms of dollars per square meter are:

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

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

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 square 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.6.8.1 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

TABLE A.6.8.1. Summary of Orchard Removal and Replacement Data

Item	fate (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

removal rate, 98 square meters per hour. This means that 98 ÷ 630 = 0.16 site preparation and planting crews would be used for each removal crew.

A.6.9 Radical Pruning

Radical pruning is an operation intended to remove radioactive contamination from orchards by removing significant portions of the trees themselves. 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.6.9.1.

TABLE A.6.9.1. 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 rate, the (unadjusted) time for one acre is

10.4 hr/ac x 817 adj = 11.9 hr/ac

This is equivalent to

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

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

Labor: $10/hr ÷ 340 m^2/hr = $0.029/$m^2$

Equipment: $14.13 ÷ 340 m^2/hr = $0.042/$m^2$

Total: $24.13 ÷ 340 m^2/hr = $0.071/$m^2$

A.6.10 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.5.9 for a discussion of the cost estimates.

A.6.11 Cover, Trees in Place

This operation is the same in principle to covering the soil with uncontaminated soil as described 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.5.9. 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 the program. 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 basic piece of equipment necessary is a small bulldozer or a small front-end loader to move the delivered soil out to the orchard and 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 square yards. The resulting coverage rate after productivity adjustment and conversion to square meters is

$$100\ yd^3/day \div 8\ hrs/day \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj$$
$$= 55\ m^2/hr$$

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 in square meters:

Labor: $73.45/hr ı 55 m^2/hr = $1.34/$m^2$

Equipment: $23.73/hr ı 55 m^2/hr = $0.43/$m^2$

Total: $97.18/hr ı 55 m^2/hr = $1.77/$m^2$

Table A.6.11.1 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.6.11.1. 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.6.12 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.5.5. However, because of the depressions and other irregularities in the soil resulting from tree removal, this operation will have a lower decontamination efficiency.

A.7. VACANT LAND

Vacant land refers to land with no structural or agricultural improvements. Ground cover consists 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.7.1 Fixatives

The term "fixative" refers to any material used to bind radioactive particles to a surface. Fixing radioactive contamination to a surface will prevent resuspension of the particles in the air by wind or by other physical disturbance. This will help prevent the spreading of contamination, recontamination of treated surfaces, excess contamination of equipment, and additional radiation hazard to personnel. There are a number of materials that could be used for this job, including petroleum-based products such as road oil, emulsified asphalt, and MC-70. Other products that might be useful include those that are sold for the purpose of dust control. These are sometimes called "dust palliatives," "dedustants," or "dust retardants" and include generic products such as calcium chloride, magnesium chloride, and calcium lignosulfate, and proprietary products such as Coherex and Compound SP.

In addition, there are other materials that could be used as fixatives, although that is not their primary function. For example, an application of strippable coating would be effective, though relatively costly (see A.1.6). Also, decontaminating foam could be considered a very short-lived fixative (see A.1.5). In some circumstances, even plastic sheeting or water could be used to prevent resuspension of radioactive particles. The important aspects in the choice and application of a fixative are discussed in the remainder of this section.

The use and costs of road oil as a fixative are presented elsewhere in this Appendix (e.g., Section A.I.IO) so it is not necessary to repeat in detail these findings. The essential points are that road oil can be used as a fixative, and the cost of the material is about $0.31 per square meter. The term "road oil" actually refers to a number of products having differing viscosities. These are classified as SCs, and common grades are SC-70, SC-250, SC-800, and SC-3000. Road oil does have certain disadvantages. It is quite messy and, in that respect, may diminish property values and raise cleanup costs. Also, because road oil contains a diesel-like dilutant, it is slow curing, remaining sticky for an extended period of time. This can be an advantage to the extent that it continues to capture, as well as hold, dust for an extended period. Finally, widespread application of road oil will have damaging environmental effects.

Another petroleum-based product, MC-70, is used by Reynolds Electrical and Engineering Company, Inc. (REECo), at the Nevada Test Site. According to sources at Chevron Asphalt Co. and Shell Oil Co., MC-70 is a "cut-back asphalt"; that is, asphalt diluted, or "cut back," with a kerosene distillate. There are several MC products, such as MC-70, MC-100, MC-250, MC-800, and MC-3000. The higher-numbered MCs have greater viscosity, which is controlled by the amount of dilutant. MC-70, being of low viscosity, has high penetrating power due to the relatively high proportion (45%) of dilutant.

MC-70 is applied at 110-135^{o}F. The normal coverage is from 0.1 to 0.5 gallons per square yard, more of the product being required when the soil is porous and absorbant. After curing, MC-70 will form a thin membrane over the soil surface. However, this membrane would break if someone were to walk on it or drive a vehicle over it.

Prices of MCs vary by grade (viscosity), location, and manufacturer. Chevron, which does not sell MC-70, said their price for MC-100 ranges from about $185 to $215 per ton with 255 to 260 gallons per ton (at 60 F). This comes to about $0.78 per gallon. Shell quoted a price of $165 per ton, F.O.B. their plant in California. At 7.93 pounds per gallon, this comes to 252 gallons per ton, or about $0.65 per gallon. Assuming an average coverage rate of 0.4 gallons per square yard, the cost per square meter works out to

$$\$0.78/gal \times 0.4\ gal/yd^2 \times 1.09\ yd^2/m^2 = \$0.34/m^2$$

for the Chevron price, and

$$\$0.65/gal \times 0.4\ gal/yd^2 \times 1.09\ yd^2/m^2 = \$0.28/m^2$$

for the Shell price. Since the Shell price is F.O.B. their plant, $0.34 per square meter is taken as a representative figure for MC-70 (or MC-100).

According to the source at Chevron Asphalt, emulsified asphalt may be a better choice for a soil fixative for three reasons. First, it does not have to be heated before application. Second, since it is water based, it is easier to handle. Third, it is less costly than road oil or MC-70. Prices range from $135 to $150 per ton according to Chevron and Shell. At 8.3 pounds per gallon, the per-gallon price is from $0.56 to $0.62. Applied at 0.4 gallons per square yard, the cost of the material would be from $0.27 to $0.30 per square meter. We take the higher figure as representative. Possible drawbacks to using emulsified asphalt are reduced penetrating power and a tendancy of the treated soil to ball up when a vehicle is driven over it.

Additional discussion of petroleum-derived fixatives is given in Section A.1.8 (tack coat) and Section A.1.9 (sealer).

Coherex is made by the Witco Co. This product is a liquid emulsion of petroleum resins, making a "clean" material compared with MCs, road oil, and emulsified asphalt. Further advantages are that Coherex is non-toxic and is diluted with water for application. In consequence, the environmental problems are significantly less with this product than with the other petroleum-based products. Coherex is commonly used on dirt roads and to protect stockpiles, such as those of coal, from producing dust.

Before application, Coherex is mixed with water in ratios ranging from one part Coherex to four parts water, to a ratio of one part Coherex to twenty parts water. The 1:20 ratio is used with frequent repeat applications, as would be necessary on surfaces with frequent vehicle or foot traffic.

When purchased in bulk, the price is $0.95 per gallon F.O.B. The shipping cost from the Bakersfield, California, plant to the state of Washington, a distance of about a thousand miles, would be about $0.30 per gallon. If we use this as a representative shipping cost, the total cost per gallon is about $1.25. The company's representative explained that a typical application would involve a dilution of five parts water to one part Coherex. This mixture would be applied at about 0.75 gallons per square yard. This implies a cost of $0.19 per square meter for the product and for shipping, but not including the cost

of application. The mixture is applied as a spray using water tank trucks. This 1:5 mixture would normally last for about six months, when the application should be repeated. Thereafter, annual applications should suffice. This means that, unlike other decontamination steps which, once accomplished, have permanent effects, the cost of the fixative is a function of the desired duration of the dust suppression. Further, since applications involve costs through time, the cost of a fixative of any particular duration requires discounting. The algebraic expression of the cost of a fixative requiring repeated applications with the timing pattern just described discounted back to the date of the initial application is

$$C = c_0 + \frac{c_{1/2}}{(1 + r)^{1/2}} + \frac{c_1}{(1 + r)^1} + \frac{c_2}{(1 + r)^2} + \ldots + \frac{c_{j-1}}{(1 + r)^{j-1}}$$

$$= \sum_{i = 0,\ 1/2,\ 1,\ 2,\ 3,\ \ldots}^{j-1} \frac{c_i}{(1 + r)^i}$$

where C = present value of fixative costs
c_i = cost of the i^{th} application
j = desired duration
r = discount rate

If the application costs are all the same, such that

$c_i = c$ all i

then

$$C = c \sum_{i = 0,\ 1/2,\ 1,\ 2,\ 3,\ \ldots}^{j-1} \frac{1}{(1 + r)^i}$$

Another product that could be used as a fixative is Compound SP, made by Johnson March, Inc. This is an organically based long-chain polymer. It can be sprayed on with an orchard sprayer or a spreader truck as is used to apply road oil. The result is a clear, crusty latex surface coating. Sold in 55-gallon drums, the liquid is applied undiluted at about 1 gallon for 100 square feet, which is equivalent to 0.09 gallon per square yard, or 0.11 gallon per square meter. Coated surfaces should have 24 hours to cure without rain. After that period, the coating will withstand heavy rain.

There are actually two SP products, SP-301 and SP-400. A coating of Compound SP-301 will last about a year. When buying in large quantities (more than 45 drums), the price is $2.15 per gallon. At one gallon per 100 square

feet, the cost per square meter is $0.23. With the addition of an assumed $0.30 per gallon shipping cost, the cost per square meter would be about $0.26. The present value of the cost of using Compound SP-301 as a fixative for a duration of j years can be calculated in the following manner:

$$C = c \sum_{i = 0, 1, 2, \ldots}^{j-1} \frac{1}{(1 + r)^i}$$

The terms here have the same definitions as before. This formulation assumes that each application has the same cost.

The other product, SP-400, is more concentrated and will last three to four years. At $3.95 per gallon, the cost per square meter is about $0.42. With a shipping cost of $0.30 per gallon, this cost per square meter will rise to $0.46. Assuming that each application will last for three years, the present value of the fixative cost for a duration of j years is

$$C = c \sum_{i = 0, 3, 6, 9}^{j-3} \frac{1}{(1 + r)^i}$$

Again, all terms have the same meaning as before, and it is assumed that each application will have the same cost.

Compound SP forms a coating over the soil, but this coating will not support a load. While it has some flexibility, if' it is deformed more than 0.25 or 0.50 inches, it will break. Once broken, wind can lift and rip the coating, because Compound SP does not penetrate the soil. Compound SP will transmit moisture, and it will not prevent plants from growing. In fact, sprouting plants will puncture the membrane and might reduce its effectiveness. Compound SP could be used on other surfaces such as roofs or walls. However, since the material will bind with the surface like paint, it cannot be removed easily.

The Dow Chemical Company makes and sells calcium chloride in pellet, flake, and liquid forms for the purpose of dust control. The trade names for these products are Peladow, Dowflake, and Liquidow, respectively. According to the manufacturer, calcium chloride works by attracting moisture from the air as it tries to return or remain in its natural liquid state. It then forms a thin liquid coating over the material on which it is placed. The moisture increases interparticle cohesion in the same manner as does water appplied to dusty soil. The chemical has a tendency to hold the moisture so that dust suppression is maintained. However, in very arid areas the soil will dry out, necessitating periodic applications of water.

Glenn Clayton, with REECo, advised that two products with which his company has had good success in dust suppression, and which he feels would also work well as fixatives, are Polybinder and magnesium chloride. Both of these products are purchased from Burris Oil in Las Vegas, Nevada. The following information on these two fixatives came from both sources.

Polybinder is a wood pulp product, sodium lignin with sugars. It is sold in liquid form at a price of $0.80 per gallon. With shipping, the cost comes to about $1.25 per gallon. The manufacturer indicated that Polybinder should be diluted with about an equal part of water. The source with REECo said that they applied Polybinder undiluted. This higher concentration is probably necessitated by heavy road traffic. An oil- or water-spreader truck is used to apply the fixative at about 0.5 gallons per square yard. Polybinder is applied at air temperature. The normal application rate at the Nevada Test Site is about 6,000 gallons per day per truck, which equals a coverage of 12,000 square yards per shift.

Magnesium chloride is sold at $0.50 per gallon. With shipping, the cost would be about $0.80 per gallon. According to the manufacturer, magnesium chloride should normally be diluted, with one part magnesium chloride to four parts water. The diluted solution is applied in the same way as Polybinder.

Both products work by drawing and holding moisture from the air. However, according to the source at Burris Oil, Polybinder works better than magnesium chloride. This is due in part to the stickiness of the sugars in Polybinder. Also, both these products have relatively short lives, lasting only about three months.

Using the $1.25 per gallon for the undiluted Polybinder and $0.80 per gallon for the magnesium chloride, we can calculate the cost of materials per square meter. For Polybinder the cost is

$$\$1.25/\text{gal} \times 0.5 \text{ gal Poly./gal diluted sol} \times 0.5 \text{ gal/yd}^2 \times 1.1947 \text{ yd}^2/\text{m}^2 = \$0.37/\text{m}^2$$

For magnesium chloride the cost is

$$\$0.80/\text{gal} \times 0.2 \text{ gal m.c./gal. diluted sol} \times 0.5 \text{ gal/yd}^2 \times 1.1947 \text{ yd}^2/\text{m}^2 = \$0.10/\text{m}^2$$

Except for MC-70, which has to be applied hot, the preceding fixatives 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 was presented earlier in this appendix, so it will not be necessary to repeat those calculations in detail. (See Sections A.1.3 and A.1.5.)

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 square yard. The resulting material cost is $0.19 per square

meter, including shipping. Application is with the same inputs as described in Section A.5.3. 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.5.3), 2192 square meters per hour.

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

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

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

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

A.7.2 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 square yards per day. Converting to square meters per hour and adjusting for one hour per shift for personnel and equipment decontamination gives a rate of

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

The hourly cost of labor is $17.45. Dividing by the hourly coverage rate gives a labor cost of $0.34 per square 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 square meter, the cost is $8.60 ÷ 52 m^2/hr = $0.17.

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

A.7.3 Scrape

The essential aspects of soil scraping are described in Section A.5.5. Here we assume the same hourly costs for the inputs to scrape soil on vacant land as on agricultural fields (Section A.5.5). 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 square meters per hour.

The input costs per square meter are easily calculated:

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

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

The total cost is $0.41 per square meter. The cost of hauling the soil away is calculated separately and is primarily a function of the distance to the dump site.

A.7.4 Water

The basic aspects of water application are described in Sections A.1.2 and A.4.2. The equipment used would be the tank distributor truck arrangement described in Section A.1.3.

Here we assume that the vehicle is able to maintain the same speed while spraying as used in Section A.1.3--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

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

$$= 1951\ m^2/hr$$

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

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

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

The total cost per square meter is $0.024.

A.7.5 Leach

The basic aspects of leaching as a decontamination operation are described in Section A.4.3. For leaching vacant land, a 5000-gallon tank distributor truck with spray bar would be used. This equipment is described in Sections A.1.3 and A.5.2. 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.1.3 and in the previous section, A.7.4, 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.7.4.

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

$$= 0.6 \times 1951 \text{ m}^2/\text{hr}$$

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

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

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

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

The material cost per square meter is calcula'ted in Section A.4.3 as $0.026. The total cost per square meter is $0.066.

A.7.6 Plow

Section A.5.6 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.5.6 and A.5.7.

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 square meter is

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

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

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

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

Labor: $\$0.007/m^2$

Equipment: $\$0.015/m^2$

Fuel: $\$0.006/m^2$

A.7.7 Deep Plow

Deep plowing is described in Section A.5.7. That section also describes the data available for this operation. For deep plowing agricultural fields, the representative cost is estimated at $0.06 per square meter. The cost for deep plowing vacant land will, of course, be greater. Agristruction advises that their cost per acre for deep plowing hard soil is $500 per acre. This is equivalent to $0.12 per square 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 square 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 $\$400/hr \div \$0.10/m^2 = 4000\ m^2/hr$. This rate is higher than the normal plowing rate (Section A.7.6) 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 square meter. The remaining cost, $0.094 per square meter, is for equipment.

A.7.8 Cover

See Section A.5.9 for a description of this operation and an explanation of the cost rate estimates.

A.8 WOODED AREA

A.8.1 Fixative

Fixatives are discussed in some detail in Section A.7.1. In addition, the problems of treating all surfaces of trees and ground were indicated in Section A.2.3 dealing with aerial application of fixative to orchards.

An appropriate choice of fixative appears to be lignosite. Here we temporarily assume an application rate of about 0.4 gallon per square yard of a 75% solution. The material cost for this mixture would be about $0.05 per square 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 most any exterior surfaces, if the area is sufficiently large. This could be done using aircraft that spray crops, or the larger planes that dump water and fire retardant on forest fires appears 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 square feet. This is equal to about 0.45 gallons per square 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 assure 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 square yard, this is equivalent to $0.24 per square 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 square 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 will probably be available. On the other hand, the necessity of applying fairly thin coats will slow the application rate somewhat. Therefore, 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 square meter for aerial application. Over a 24-hour period the gallonage would be enough for 395,071 square meters, or 16,461 square meters per hour.

Near the higher of these two cost figures were the rates charged by Columbia Aerial Ag Service of Pasco, Washington. To a commercial agricultural spray company, such as this one, the coverage of 0.4 gallons per square 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 square 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,

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

Since these costs are based on tachometer-hours, no adjustment is necessary to account for one hour per shift for equipment decontamination. The application cost per square meter is:

$$\$0.3869/\text{gal} \times 0.4 \text{ gal/yd}^2 \times 1.19599 \text{ yd}^2/\text{m}^2 = \$0.19/\text{m}^2$$

At 350 gallons every 21.25 minutes, the average hourly dump rate is 988 gallons. Adjusting for seven operating hours per eight-hour shift, the hourly rate is 864 gallons or 1808 m^2/hr.

While Carr Aviation of Pasco, Washington, was not able to supply as much detailed information as other aviation companies, they did supply their basic price schedule which can be converted to a dollar-per-gallon basis.

TABLE A.8.1.1. Charges for Aerial Application by Carr Aviation

Coverage (gal/acre)	Cost (1982 $)	$/gal
3	3.60	1.2000
5	4.40	0.8800
8	4.90	0.6125
10	5.40	0.5400

These prices do not include the cost of the chemicals. Further, since these prices are based on the cost of application per gallon rather than per hour, no adjustment for seven hours output per eight-hour shift is necessary.

The declining cost per gallon with increased coverage suggests that a very rough estimate of $0.50 per gallon for very large volumes would not be too low. It is quite possible that lower rates would be charged. At $0.50 per gallon, or $0.24 per square meter, these were the highest cost estimates for aerial application obtained. The information supplied by Carr Aviation was insufficient to estimate the rate of treatment.

Table A.8.1.2 summarizes the aerial-application costs on a per-gallon basis. The representative cost is taken as $0.32 per gallon, which is lower than the average of the separate cost estimates. The reason for this is that

application with the large-capacity planes used for fire fighting is more likely than with the smaller and higher per-gallon cost aircraft. Further, as explained earlier, the cost figures supplied by the Forest Service are for non-continuous operation and are therefore probably higher than would be the case in the event of continuous application of a fixative.

TABLE A.8.1.2. Summary of Aerial Application Cost Estimates by Source

Source	Cost (1982 $/gal)
U.S. Forest Service	0.50
Butler Aviation	0.23
Columbia Ag Service	0.39
Carr Aviation	0.50
Representative	0.32

Table A.8.1.3 presents costs on a per-square-meter basis. Also included is the cost of the fixative. These costs are based on a fixative application rate of 0.4 gallon per square yard. Different application rates would imply different costs.

TABLE A.8.1.3. Summary of Aerial Application of Fixative Cost Data(a)

Source	Cost (1982 $\$/m^2$)		
	Aer. App.	Fixative	Total
U.S. Forest Service	0.24	0.05	0.29
Butler Aviation	0.11	0.05	0.16
Columbia Ag Service	0.19	0.05	0.24
Carr Aviation	0.24	0.05	0.29
Representative	0.15	0.05	0.20

(a) Based on 0.4 gallon of fixative per square yard.

Estimates for the rate of surface treatment ranged from Columbia Ag Service's rate of 1808 square meters per hour to the Butler Aviation high-volume rate of 16,461 square meters per hour. Since the larger aircraft is more likely to be used, we take 14,000 square meters (6690 gallons) per hour as a representative application rate. A cost of $0.15 per square meter for the cost of application is taken as representative, bringing the total cost with the fixative to $0.20 per square meter.

The operations for decontaminating paved surfaces include vacuuming, flushing with water at various pressures, special chemical techniques, and road construction procedures. These are described in detail in this section.

The representative inputs include, for labor, one pilot, one flight crew, and two ground crews. The hourly cost of labor is estimated at $140 per hour. Equipment is one tanker airplane at $1960 per hour. The resulting costs per square meter are $0.01 for labor and $0.14 for equipment.

As mentioned earlier, this discussion has been premised on a standard application of lignosite - 0.4 gallon per square yard. However, tree foliage will greatly increase the total surface area for each square meter of ground. For this reason and because of the difficulty in achieving an even coating of fixative, a higher application rate will probably be necessary. If we assume one gallon of fixative per square yard, this will raise the costs by a factor of 1.0 ÷ 0.4 = 2.5 and lower the rate to

$$14{,}000\ m^2/hr \div 2.5 = 5600\ m^2/hr$$

The total cost is $0.495 per square meter. The labor cost is $0.025 per square meter, and equipment and materials cost $0.350 and $0.120 per square meter, respectively. We take these costs to be representative of fixative application to wooded areas.

A.8.2 Defoliate

Defoliation as a decontamination technique is described in Section A.6.6. Wooded areas will likely require a heavier application than orchards. Here we assume that a 50% greater application of materials would be used. As a result, all input costs would be increased by 50%:

Labor:	$\$0.0006/m^2 \times 1.5 = \$0.0009/m^2$
Equipment:	$\$0.0015/m^2 \times 1.5 = \$0.0023/m^2$
Materials:	$\$0.0105/m^2 \times 1.5 = \$0.0158/m^2$
Fuel:	$\$0.0020/m^2 \times 1.5 = \$0.0030/m^2$

The total cost per square meter is $0.0220. The rate is reduced by one-third:

$$8331\ m^2 \times 0.667 = 5554\ m^2/hr$$

A.8.3 Clear

Clearing involves removing trees and bushes. The data for this operation come from Means' Building construction Cost Data 1982 (p. 24). The labor specified for this operation and the hourly costs are:

1 Foreman @ $22.25	$ 22.25
4 Building laborers @ $19.40	77.60
1 Medium-equipment operator @ $24.95	24.95
Total labor	$124.80

The equipment listed for clearing and the hourly costs are:

1 Chipping machine	$ 16.11
1 Front-end loader	72.46
Total equipment	$ 88.57

The rate is given by Means as 0.60 acres per day. Converting to square meters per hour and adjusting for one hour lost per shift for personnel and equipment decontamination, we get:

$$0.60 \text{ ac/day} \div 8 \text{ hrs/day} \times 4046.7 \text{ m}^2/\text{ac} \times 7/8 \text{ adj} = 266 \text{ m}^2/\text{hr}$$

Dividing the hourly coverage rate into the hourly costs gives the costs in terms of dollars per square meter:

Labor: $\frac{\$124.80/\text{hr}}{266 \text{ m}^2/\text{hr}} = \$0.469/\text{m}^2$

Equipment: $\frac{\$88.57/\text{hr}}{266 \text{ m}^2/\text{hr}} = \$0.333/\text{m}^2$

The total cost per square meter is $0.802.

A.8.4 Grub and Scrape

The operation of clearing does not include removal of tree stumps, and as long as they remain, soil scraping using front-end loaders cannot be done effectively. Therefore, removing the stumps, a procedure called grubbing, is a prerequisite for mechanized scraping.

The source for grubbing is Means' Building Construction Cost Data 1982 (p. 24). The labor and the associated hourly labor costs for this activity are one medium-equipment operator and two heavy-truck drivers. Since the cost of hauling material is handled spearately in this work, we delete the two truck drivers along with the two dump trucks. The equipment for this procedure is one 1.5-cubic yard hydraulic excavator costing $70.51 per hour.

The production rate is given as 1.20 acres per day. The following converts this figure to square meters per hour and adjusts for one hour per shift devoted to personnel and equipment decontamination:

1.20 ac/day ÷ 8 hrs/day x 4046.7 m^2/ac x 7/8 adj = 531 m^2/hr

Dividing the hourly labor and equipment costs by the hourly coverage rate gives the costs in terms of dollars per square meter:

Labor: $\frac{\$24.95/hr}{531\ m^2/hr} = \$0.047/m^2$

Equipment: $\frac{\$70.51/hr}{531\ m^2/hr} = \$0.133/m^2$

Total: $\$0.047/m^2 + \$0.133/m^2 = \$0.18/m^2$

The cost and rate for scraping are taken to be the same as for scraping vacant land. These costs are shown in Table A.8.4.1. This table also shows the total costs for the entire grub and scrape operation. Since scraping is the more costly procedure, the rate for the whole operation is set equal to the rate for that procedure. This requires that 656 ÷ 531 = 1.24 grubbing crews are required for every scraping crew.

TABLE A.8.4.1. Summary of Grub and Scrape Data for Wooded Areas

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment
Grub	531	0.18	0.05	0.13
Scrape	656	0.41	0.18	0.23
Total	656	0.59	0.23	0.36

A.8.5 Manual Scrape

While use of earthmoving equipment for scraping is not feasible in wooded areas without first clearing and grubbing, scraping can be accomplished without clearing and grubbing if done manually. The inputs for this operation are simply a laborer plus minor hand equipment such as a shovel and a wheelbarrow. The hourly cost for a common laborer is $17.45, and we estimate $1.00 per hour to be sufficient to cover equipment.

The coverage rate will be highly variable, depending on such things as hardness of the soil, roughness of the terrain, and how far the soil has to be moved to dump trucks for disposal. Various rate estimates for hand excavation are given in Means' Building Construction Cost Data 1982 (pp. 29, 30). These figures vary from four to eight cubic yards per day for excavating pits or trenches. We assume a base rate of eight cubic yards per day. If the surface

is scraped to a depth of six inches, then each cubic yard represents six square yards of area scraped. Eight cubic yards per day, with adjustment for an hour per shift for personnel decontamination, is equivalent to:

$$8\ yd^3/day \div 8\ hrs/day \times 6\ yd^2/yd^3 \times 0.836\ m^2/yd^2 \times 7/8\ adj = 4\ m^2/hr$$

Dividing the hourly cost figures by the hourly coverage rate yields costs in terms of dollars per square meter:

Labor: $\frac{\$17.45/hr}{4\ m^2/hr} = \$4.36/m^2$

Equipment: $\frac{\$1.00/hr}{4\ m^2/hr} = \$0.25/m^2$

Total: $\$4.36/m^2 + \$0.25/m^2 = \$4.61/m^2$

A.8.6 Cover Scraped Land

Section A.5.9 discusses covering the ground with uncontaminated soil as a decontamination operation. If a wooded area has been cleared and grubbed, covering is essentially the same as it would be for vacant land. We use the same costs here. (See Section A.7.8.)

A.8.7 Cover Unscraped Land

Covering the ground with soil as a decontamination operation is described in Section A.5.9. This operation involves two basic steps, soil excavation and soil placement. The cost and rate of soil excavation are the same as those listed in Section A.5.9. Placement of soil by hand in a wooded area is essentially the reverse of manual scraping as described in Section A.8.5. We assume, however, that the placement rate is 50% faster than scraping. Table A.8.7.1 summarizes the cost data. The rate of the combined operation is set equal to that of the more costly suboperation, placement. This means that 6 ÷ 812 = 0.001 excavation crews would be needed for each placement crew.

TABLE A.8.7.1 - Summary of Data for Covering Wooded Areas with Uncontaminated Soil Without Grubbing

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment
Excavation	812	0.166	0.043	0.123
Placement	6	3.08	2.91	0.17
Total	6	3.24	2.95	0.29

A.9 EXTERIOR PAINTED WOOD WALLS

Exterior painted wood walls are representative of the exterior surface of the large part of residential structures as well as many commercial buildings.

A.9.1 Water Wash

This operation involves hosing the surface with water. The essentials of such a water wash operation are described in the discussions of similar operations in Sections A.1.2 and A.3.2. In this case no special equipment, such as pumps or special hoses to raise the water pressure or special nozzles, are required. Walls would be hosed using water from existing mains and plumbing. The labor required would be one common laborer whose hourly billing cost is estimated at $17.45 based on labor costs from Means publications. One dollar per hour should be adequate to cover equipment costs.

The cost per unit area depends on the coverage rate. We estimate a basic rate of 100 square feet in two minutes, but in addition, about 10 minutes per hour would be necessary for moving to new locations and attaching the hose. This implies a rate of 2500 square feet per hour. Converting to square meters and adjusting for one hour per shift for personnel and equipment decontamination, we get:

$$2500\ ft^2/hr \times 0.0929\ m^2/ft^2 \times 7/8\ adj = 203\ m^2/hr$$

Input costs on a dollars per square meter basis are found by division, as follows.

Labor: $$\frac{\$17.45/hr}{203\ m^2/hr} = \$0.086/m^2$$

Equipment: $$\frac{\$1.00/hr}{203\ m^2/hr} = \$0.005/m^2$$

The total cost is the sum of these two figures, $0.091 per square meter.

A.9.2 Wash and Scrub

Two sources provided information on costs and rates for washing and scrubbing walls. Northwest Janitorial Systems of Seattle, Washington, advised that they charged between $0.15 and $0.20 per square foot for wall cleaning. This cost applies to both interior and exterior walls. This source further indicated that the total hourly cost was about $15.00. These figures imply an adjusted production rate of about six to eight square meters per hour. We use a rate of six square meters per hour here. Assuming that labor comprises 80% of the costs, or $12.00 per hour, the labor cost comes to $1.72 per square meter. The equipment cost is $0.43 per square meter, and the total comes to $2.15 per square meter.

American Building Maintenance of Seattle, Washington, indicated both a higher rate (200 square feet per hour) and a higher hourly cost ($18.50 per hour). The adjusted coverage rate comes to 16 square meters per hour with a total cost of $1.14 per square meter. The labor cost is $0.69 per square meter, and equipment accounts for $0.45 per square meter.

Table A.9.2.1 summarizes this information and shows the representative cost and rate figures.

TABLE A.9.2.1. Summary of Data for Wash and Scrub of Walls

Source	Rate (m^2/hr)	Cost (1982 $/$m^2$) Total	Labor	Equipment
Northwest Janitorial Systems	6	2.15	1.72	0.43
American Building Maintenance	16	1.14	0.69	0.45
Representative	10	1.75	1.15	0.60

A.9.3 Fixative

A general discussion of fixatives is provided in Section A.7.1. For application to walls, Compound SP-301, with a cost of $0.23 per square meter, appears to be the best choice. Since this material can be applied in the same manner and with the same equipment as spray painting, the application cost is estimated on the basis of this activity.

The basic data source for fixatives is Means' Building Construction Cost Data 1982 (pp. 231, 236). The daily coverage rate is given as 4000 square feet. This converts to

$$4000 \text{ ft}^2/\text{day} \div 8 \text{ hrs/day} \times 0.0929 \text{ m}^2/\text{ft}^2 \times 7/8 \text{ adj} = 40 \text{ m}^2/\text{hr}$$

The costs are listed as $22.55 per hour for an ordinary painter and $2.00 per hour for the spray equipment. Dividing by the hourly coverage rate gives $0.555 per square meter for labor and $0.049 per square meter for equipment. Adding the cost of the fixative brings the total cost per square meter to $0.834.

A.9.4 Vacuum

Vacuuming as a decontamination technique is described elsewhere in this Appendix (see Sections A.1.1 and A.3.1). The primary source for data regarding the vacuuming of walls is American Building Maintenance of Seattle, Washington. This source advised that the hourly cost for this type of procedure would be $18.50 per hour with about $11.14 for labor. The hourly

coverage rate is between 800 and 900 square feet. This converts to an adjusted 69 square meters per hour.

Dividing the hourly cost figures by the hourly coverage rate yields costs per square meter: $0.16 for labor, $0.11 for equipment. The total is $0.27 per square meter.

A.9.5 Hydroblast

Hydroblasting uses a high-pressure water jet to scour surfaces. Power Master, Inc. of Seattle, Washington, utilizes two types of hydroblasting equipment for contract hydroblasting work. The type of equipment used depends on the nature of the job and the surface. One type puts out 30 gallons per minute at a maximum of 10,000 to 20,000 pounds per square inch. If the spray lance is kept moving, this will do minimal damage to the surface. However, there is a safety problem with this equipment. The considerable recoil on the lance makes it hard to hold, and the water jet could cut through a person.

The other unit is an ultra-high-pressure system, generating a water jet up to 55,000 pounds per square inch. However, since only 1.9 gallons per minute is expelled, there is little or no recoil, making the lance much easier to control. The lance can be operated with a rotating head that keeps the jet moving around in a six-inch diameter circle. This reduces the risk of boring a hole through the surface being blasted and permits cleaning with a six-inch wide swath.

Since either equipment can be operated at lower pressures appropriate for surfaces such as wood, the costs for the second system are used here as representative for hydroblasting. The basic charge is $96 per hour, including the operator. However, more than one lance can be operated with each of the 475-horsepower truck-mounted V-12 pumps. There is an additional charge of $44 per hour per lance, up to a maximum of five. The calculations here are based on a cost of $70 per hour per lance, which is consistent with two lances per truck.

The coverage rate per lance for this system is reported at about 20 feet by 20 feet in two hours. This comes to about 11 square meters per hour with adjustment for personnel and equipment decontamination.

The labor cost is $16.50 per hour, and the equipment cost (per lance) is $53.50. Dividing by the hourly coverage rate gives the labor cost as $1.55 per square meter and the equipment cost as $5.00 per square meter.

To this we add the cost of one common laborer at $17.45 per hour with a wet vacuum costing $1.00 per hour. The resulting total cost is $8.50 per square meter, of which $3.39 is for labor and $5.11 is for equipment.

A.9.6 High-Pressure Water

This operation uses equipment frequently employed to strip old paint from wood walls. A small portable pump is used to raise the water pressure. In addition, there is a spray wand with special nozzle for directing the water to

the surface. The cost for this equipment, based on rental information supplied by Handy Andy Rent-A-Tool in Seattle, Washington, is $600 per month. This comes to about $2.00 per hour.

The labor required is one common laborer at $17.45 per hour.

The coverage rate for this equipment was observed at about 90 square feet per hour for a thorough job of paint removal. With adjustment for one hour per shift for personnel and equipment decontamination, this is equivalent to 8 square meters per hour.

Dividing the coverage rate into the hourly costs gives $2.18 per square meter for labor, $0.25 for equipment, and $2.43 for the total.

A.9.7 Remove and Replace

For severely contaminated exterior painted wood walls, it may be necessary to remove and replace the entire surface. Normally this would be preceded by vacuuming and application of a fixative.

Removal and replacement involves three distinct steps for which costs and rates are estimated separately. These are removal of existing wall surfaces, replacement with new siding, and painting of new siding. The primary source for this operation is Means' Building Construction Cost Data 1982. This source provides mutually consistent data for all three procedures.

Exterior wood wall removal, according to Means (p. 371), requires one foreman at $22.25 per hour and two building laborers at $19.40 per hour each, for a total hourly labor cost of $61.05. Equipment would be those tools normally supplied by the workers themselves.

The production rate given is 700 square feet per day. After adjusting for one hour per shift for personnel decontamination, this rate converts to 7 square meters per hour. Dividing this into the hourly cost gives $8.60 per square meter, all of which is for labor.

According to Means (p. 162), replacement requires two carpenters at $24.35 per hour each. The total hourly labor cost is, therefore, $48.70. The hourly cost for power tools is given as $1.73. The total labor and equipment cost comes to $50.43.

The total hourly cost can be found by multiplying the hourly rate

$$750\ ft^2/day \div 8 = 93.75\ ft^2/hr$$

by the cost per square foot

$$93.75\ ft^2/hr \times \$0.89/ft^2 = \$83.43/hr$$

Subtracting the hourly labor and equipment charge from this total gives the hourly cost of materials:

$\$83.43 - \$50.43 = \$33.00$

The cost of materials is calculated as the difference between total and the sum of labor and equipment because Means reports total, labor, and equipment costs with markups for overhead. While overhead is implicitly added to material cost, the source does not provide information for direct calculation of the markup to be applied to materials. This calculation method yields the appropriate cost for materials with markup. The Means data requires this method be used in most every instance in which materials are part of the cost.

The hourly rate is

$$750\ ft^2/day \div 8\ hrs/day \times 0.0929\ m^2/ft^2 \times 7/8\ adj = 7.6\ m^2/hr$$

Dividing this rate into the hourly input costs yields costs on a square-meter basis:

Labor: $\frac{\$48.70/hr}{7.6\ m^2/hr} = \$6.41/m^2$

Equipment: $\frac{\$1.73/hr}{7.6\ m^2/hr} = \$0.23/m^2$

Materials: $\frac{\$33.00/hr}{7.6\ m^2/hr} = \$4.34/m^2$

The sum of these gives the total cost per square meter as $10.98.

Means (p. 231) indicates that painting wood siding with primer and one coat, including puttying, requires one ordinary painter at $22.55 per hour. The total cost per hour is found by multiplying the hourly rate

$$665\ ft^2/day \div 8\ hrs/day = 83.125\ ft^2/hr$$

by the cost per square foot

$$83.125\ ft^2 \times \$0.39/ft^2 = \$32.42/hr$$

The material cost is found by subtracting the labor cost from this total:

$$\$32.42/hr - \$22.55/hr = \$9.87/hr$$

The adjusted hourly coverage rate in metric units is

$$83.125\ ft^2/hr \times 0.0929\ m^2/ft^2 \times 7/8\ adj = 6.8\ m^2/hr$$

Dividing the hourly costs by the hourly production yields the costs in terms of dollars per square meter:

Labor: $\frac{\$22.55/hr}{6.8\ m^2/hr} = \$3.32/m^2$

Material: $\frac{\$9.87/hr}{6.8\ m^2/hr} = \$1.45/m^2$

The total is the sum of the input costs, or $4.77 per square meter.

Table A.9.7.1 summarizes the foregoing calculations and shows the total costs for the entire operation combining the three steps. Using the convention employed throughout this report, the most costly procedure determines the overall rate. Therefore, the rate for the entire operation is 7.6 square meters per hour. This means that 7.6 ÷ 7.1 = 1.07 removal crews and 7.6 ÷ 6.8 = 1.12 painting crews would be used for every replacement crew. Together, in these ratios, they comprise an entire removal and replacement crew.

TABLE A.9.7.1. Summary of Data for Removal and Replacement of Painted Wood Exterior Walls

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$) Total	Labor	Equipment	Materials
Removal	7.1	8.60	8.60	--	--
Replacement	7.6	10.98	6.41	0.23	4.34
Painting	6.8	4.77	3.32	--	1.45
Total	7.6	24.35	18.33	0.23	5.79

A.9.8 Remove Structure

In most severe cases it may be necessary to remove entire structures rather than attempt extensive decontamination operations. It should be noted that structure removal preempts any subsequent operation on any of the structure surfaces.

The primary information source for this operation is Means' Building Construction Cost Data 1982 (p. 372). However, the reported figures include allowance for hauling away of materials. Since hauling costs are estimated separately in this report, they must be deleted from the Means data. Excluding the specified heavy-truck driver and the dump truck, the specified labor requirements are one foreman at $22.22 per hour and two building laborers at $19.40 per hour each. The total hourly labor cost is $61.02. The only equipment specified are hand tools provided by the workers themselves.

The coverage rate is given at 360 square feet of floor area per day. This converts to

$$360\ ft^2/day \div 8\ hrs/day \times 0.0929\ m^2/ft^2 \times 7/8\ adj = 3.7\ m^2/hr$$

However, we wish to express the production rate in terms of exterior wall area. What is necessary is the ratio of exterior wall area to floor area. This can be estimated using residential factors used in Subroutine XFORM (see Appendix E). Factor h is the ratio of exterior wall area to roof area, and factor k is the ratio of floor area to roof area. Dividing h by k

$$h/k = 1.58/1.33 = 1.19$$

gives the ratio of exterior wall area to floor area. Therefore, the estimated hourly production rate is

$$3.7\ m^2/hr \times 1.19 = 4.4\ m^2/hr$$

Dividing the hourly costs by the hourly production rate yields the cost in terms of square meters of exterior wall area:

$$\text{Total} = \text{Labor: } \frac{\$61.02/hr}{4.4\ m^2/hr} = \$13.87/hr$$

A.9.9 Foam

The use of acidic foam as a decontamination operation is described in Section A.1.5. Also, the material cost is calculated there as $0.0753 per square meter for application and $0.0074 for removal, for a total material cost of $0.0827 per square meter.

Since the foam is applied with aspirated spray equipment as is paint, the application cost is taken as equal to the cost of applying a fixative to walls, which was estimated in Section A.9.3. Similarly, removal of the foam would be accomplished by vacuuming, the cost of which was developed in Section A.9.4.

Table A.9.9.1 summarizes these data and calculates the total costs for a foam treatment. Note that since the most costly procedure by convention determines the rate, 40 ÷ 69 = 0.58 removal crews would be combined with each application crew to make one foam treatment crew. The rate for the whole operation is 40 square meters per hour.

TABLE A.9.9.1 - Summary of Data for Foam Treatment of Painted Exterior Wood Walls

Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$) Total	Labor	Equipment	Materials
Application	40	0.6793	0.555	0.049	0.0753
Removal	69	0.2774	0.16	0.11	0.0074
Total	40	0.9567	0.715	0.159	0.0827

A.9.10 Strippable Coating

The basic functioning of strippable coating as a decontamination technique is described in Section A.1.6. In addition, the material cost was also calculated there at $1.77 per square meter.

Like foam and fixative application to exterior painted wood walls (see Sections A.9.3 and A.9.9), strippable coating would be sprayed on. However, this material requires an airless sprayer. Here, as in the previous section, we use cost figures developed in Section A.9.3 for the application cost.

Removal costs and rates require extensive estimation since this is not an activity for which there is much data. Removal would involve one common laborer at-$17.45 per hour, equipped with incidental hand tools. We estimate the removal rate at 35 square meters per hour. The cost per square meter, therefore, is

$$\$17.45/hr \div 3\ m^2/hr = \$0.50/m^2$$

In addition to application and removal, there is also the cost of disposal of the removed coating. This is discussed in Section A.3.5, and the cost estimates used there for centralized collection of the coating are used here. Ultimate disposal costs are calculated as separate hauling costs.

The costs and rates are presented and summarized in Table A.9.10.1. The overall rate is set equal to that of the most costly step, application. This

TABLE A.9.10.1. Summary of Data for Strippable Coating Treatment of Painted Exterior Wood Walls

Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$) Total	Labor	Equipment	Material
Application	40	2.37	0.55	0.05	1.77
Removal	35	0.50	0.50		
Collection	488	0.05	0.04	0.01	
Total	40	2.92	1.09	0.06	1.77

means that 40 ÷ 35 = 1.14 removal crews and 40 ÷ 488 = 0.08 collection crews would be combined with one application crew to form a complete crew for a strippable coating treatment.

A.10 EXTERIOR BRICK WALLS

Many decontamination operations for painted wood exterior walls are identical to operations applicable to brick walls. However, while operation costs and rates may be the same, the rougher texture and porosity of brick result in lower decontamination efficiencies.

A.10.1 Water Wash

See Section A.9.1.

A.10.2 Wash and Scrub

See Section A.9.2.

A.10.3 Fixative

See Section A.9.3.

A.10.4 Vacuum

See Section A.9.4.

A.10.5 Hydroblast

See Section A.9.5. Note that higher water pressures could be used on brick than on wood.

A.10.6 High-Pressure Water

See Section A.9.6.

A.10.7 Scarify

See Sections A.16.7 and A.14.8.

A.10.8 Remove and Replace

The general aspects of removing and replacing exterior walls are discussed in Section A.9.7. As in the case of removing and replacing exterior wood walls, Means' Building Construction Cost Data 1982 is the primary source of information.

Costs for the first step, wall removal, are estimated using Means data for concrete wall removal (p. 371) since no data are supplied for removal of brick walls. The labor specified is one foreman at $22.25 per hour and four building laborers at $19.40 per hour each. The total hourly labor cost comes to $99.85

For equipment, Means calls for an air compressor with air tools and accessories. These cost $18.00 per hour.

The rate for removing walls four to twelve inches thick is 220 cubic feet per day. Assuming an average wall thickness of eight inches, converting to metric units per hour and adjusting for one hour per shift for personnel and equipment decontamination yields a rate of 3.35 square meters per hour.

Dividing the hourly rate into the hourly costs results in costs per square meter:

Labor: $\frac{\$99.85/hr}{3.35\ m^2/hr} = \$29.81/m^2$

Equipment: $\frac{\$18.00/hr}{3.35\ m^2/hr} = \$5.37/m^2$

Total removal cost is

$\$29.81/m^2 + \$5.37/m^2 = \$35.18/m^2$

According to Means (pp. 114, 123), installing an eight-inch thick brick wall requires three bricklayers at $24.85 per hour each, two bricklayer helpers at $19.65 per hour each, and 0.25 carpenters for scaffolding construction at $24.35 per hour each. The total hourly labor cost totals $119.94.

The hourly material cost is found by subtracting the hourly labor cost from the hourly total cost:

$\$176.62/hr - \$119.94/hr = \$56.68/hr$

The rate in terms of square meters per hour is calculated in a straightforward manner based on 13.50 bricks per square foot. Along with adjustments, the rate is

$0.225\ M\ br/hr \times 1000\ br/M \div 13.50\ br/ft^2 \times 0.0929\ m^2/ft^2 \times 7/8\ adj$
$= 1.35\ m^2/hr$

Means' total cost per hour can be found by multiplying the number of thousand bricks (M) per hour by the total cost per thousand bricks laid. The daily output is listed at 1.8 thousand bricks. This comes to 0.225 thousand bricks per hour. The total cost per thousand bricks laid is $785. Therefore, the cost per hour is

$0.225\ M/hr \times \$785/M = \$176.62/hr$

Dividing the hourly production rate into the hourly costs converts the costs to a dollars per square meter basis:

Labor: $\frac{\$119.94/hr}{1.35\ m^2/hr} = \$88.84/m^2$

Materials: $\frac{\$56.68/hr}{1.35\ m^2/hr} = \$41.99/m^2$

The total cost per square meter is the sum of these two costs, $130.83 per square meter.

Table A.10.8.1 summarizes the preceding calculations and shows total costs per square meter for removal plus replacement. Since replacement is the more costly of the two constituent steps, its rate determines the rate of the overall combined operation. This means that 1.35 ÷ 3.35 = 0.40 removal crews would be used with one replacement crew to form the crew for the entire operation.

TABLE A.10.8.1. Summary of Data for Removal and Replacement of Exterior Brick Walls

Procedure	Rate (m^2/hr)	Cost (1982 $\$/m^2$)			
		Total	Labor	Equipment	Materials
Removal	3.35	35.18	29.81	5.37	--
Replacement	1.35	130.83	88.84	--	41.99
Total	1.35	166.01	118.65	5.37	41.99

A.10.9 Remove Structure

Structure removal is discussed in Section A.9.8. The difference in materials between buildings with exterior wood walls and those with brick walls has significant effect on costs and rates. Again, the basic data source is Means' Building Construction Cost Data 1982 (p. 372). In this case the maximum cost data for removal of a commercial structure are used.

The inputs for this operation are the same as discussed in Section A.9.8. Therefore, it is necessary to calculate the hourly production rate for building removal. Means lists a rate of 250 square feet of floor area per day. Again using factors from XFORM, but this time for commercial structures, we can estimate the ratio of exterior wall area to floor area:

$$h/k = 1.2/1.8 = 0.667$$

The hourly rate, adjusted and converted to metric units, is

$$250\ ft^2/day \div 8\ hrs/day \times 0.0929\ m^2/ft^2 \times 7/8\ adj \times 0.667$$
$$= 1.69\ m^2/hr$$

Dividing by the hourly rate gives the costs per square meter. Labor is \$47.81 per square meter, equipment is \$21.14 per square meter, and the total is \$68.95 per square meter.

A.IO.10 Foam

See Section A.9.9.

A.IO. 11 Strippable Coating

See Section A.9.10.

A.II LINOLEUM FLOORS

This surface is intended to be representative of resilient floor coverings in general, including linoleum, asphalt tile, and vinyl. Many of the operations on this surface are similar or identical to operations on other interior floor surfaces and, in some cases, operations on wall surfaces.

A.11.1 Vacuum

Janitorial cleaning and painting sources indicated that the rates of operations on floors are not much different from the rates on walls. Therefore, the cost of this operation is taken to be the same as vacuuming painted wood exterior walls. See Section A.9.4.

A.11.2 Scrub and Wash

See Section A.9.2.

A.11.3 Strippable Coating

See Section A.9 .10.

A.11.4 Foam

See Section A.9.9.

A.11.5 Fixative

See Section A.9.3.

A.11.6 Remove and Replace

In instances of severe contamination, removal and replacement of linoleum floor covering may be indicated. Data for this operation comes primarily from Means' Building Construction Cost Data 1982. The general range of these costs was supported by information fcm and discussion with sources at commercial floor covering businesses, including the Deluxe Carpet Company of Kent, Washington, and Long's Installations of Bellevue, Washington.

The crew specified for linoleum removal (p. 371) includes one foreman at $22.25 per hour and four building laborers at $19.40 per hour each. The total hourly labor cost comes to $99.85. Equipment is just those hand tools supplied by the workers themselves.

The rate, listed as 2500 square feet per day, after adjustments is

$$2500\ ft^2/day \div 8\ hrs/day \times 0.0929\ m^2/ft^2 \times 7/8\ adj = 25\ m^2/hr$$

Dividing the hourly labor cost by the number of square meters per hour gives the labor cost as $4.00 per square meter.

According to Means (p. 228), labor for replacement of the linoleum flooring is one floor tile layer at $22.55 per hour.

Material costs range from about $0.50 per square foot for asphalt tile on concrete underlayment to over $5.50 per square foot for vinyl tile. Here we use a cost of about $0.60 per square foot or $6.36 per square meter.

The rate is given as 540 square feet per day. With adjustments, this is equivalent to

$$540 \text{ ft}^2/\text{day} \div 8 \text{ hrs/day} \times 0.0929 \text{ m}^2/\text{ft}^2 \times 7/8 \text{ adj} = 5.48 \text{ m}^2/\text{hr}$$

Dividing this figure into the hourly labor cost yields a labor cost of $4.11 per square meter. Adding the material cost brings the total to $10.47 per square meter.

The foregoing is summarized in Table A.11.6.1, and the combined totals for the entire operation are presented. Note that 5.48 ÷ 25 = 0.22 removal crews would be used for each replacement crew.

TABLE A.11.6.1. Summary of Data for Removal and Replacement of Linoleum Floors

Procedure	Rate (m^2/hr)	Cost (1982 $/$m^2$)			
		Total	Labor	Equipment	Materials
Removal	25	4.00	4.00	--	
Replacement	5.48	10.47	4.11	--	6.36
Total	5.48	14.47	8.11	--	6.36

A.12 WOOD FLOORS

See Section A.11.

A.12.1 Vacuum

See Sections A.9.4 and A.11.1.

A.12.2 Scrub and Wash

See Section A.9.2.