separately manned. There was a nozzle at the end of each 1-1/2-inch line, of course. This source reported the cost of 1-1/2-inch hose at $1.30 per foot and the cost of 2-1/2-inch hose at $1.70 per foot. These costs include couplings and their attachment to the hose. Without including the Y-valve or the nozzles, the cost for this apparatus comes to $900.

The general magnitude of these prices is confirmed by a company which specializes in fire hose equipment, Sherman Supply and Salvage Co. in Seattle. Its price information is presented in Table A.1.5.3.1. A standard length of hose is 50 feet and prices include couplings. Double jacket hose will handle higher pressures than single jacket and will wear longer when the hose is being dragged.

Periodic replacement of the worn-out hose would cost somewhat less than the amounts given because the fittings could be reused. On the other hand, the Seattle Fire Department is skeptical whether a fire hose would last even as short a period as two weeks with constant dragging over pavement. For this work we used a figure corresponding to $1000 for every 2 weeks of continual use. The additional cost is to account for incidental equipment expenditures such as personnel water protection clothing. The equipment cost per hour, then, is:

$$\frac{\$1000}{2\text{ wk} \times 7\text{ days} \times 24\text{ hr}} = \$2.98/\text{shift-hour}$$

TABLE A.1.5.3.1. Calculation of Hosing Equipment Costs

Item	Quantity	1982 $ Price	1982 $ Cost
2-1/2 Inch Hose, 50 Foot Length, Double Jacket	6	$75	$450
1-1/2 Inch Hose, 50 Foot Length, Double Jacket	6	$55	$330
Y Fitting 2-1/2" - 2x1-1/2" with Valves	1	$86.59	$ 86.59
Industrial Fog Nozzle, with Valve	2	$22.50	$ 45.00
Total			$911.59

Source: Sherman Supply and Salvage Co., Seattle, Washington.

Adding this to the cost of labor brings the total cost per hour to $20.43. Dividing this by the average hourly production gives a cost per sq meter of $0.021.

Owen et al. (1967) report detailed performance information for firehosing, but no cost data. The most important of these results for the purposes at hand concerns removal of particles in the 44-to-88 micron size range from roughly textured asphalt or concrete using a 1.5-inch fire nozzle with a 5/8-inch bore. Nozzle pressure was 75 pounds per sq inch, and the initial contaminated mass loading was 5 grams per sq foot. Under these conditions, the amount of water used was 0.22 gallon per sq foot, which is equivalent to a 0.35-inch coverage of water. The reported "working rate" was 450 sq feet per hour, but the effective rate--taking into account support services and 20 minutes to disconnect from one hydrant, move, and reconnect to the next--was 270 sq feet per minute. This works out to 16,216 sq feet per hour, which is in reasonable agreement with the unadjusted rate reported from Spokane Community College. This figure, therefore, includes the 20 minutes.

Owen et al. (1967) suggest additional adjustments to compensate for fatigue. Coverage rates should be reduced by 20 percent where: a) 4-hour shifts are planned for persons obviously not conditioned to physical labor, or b) 8-hour shifts are planned for experienced and properly conditioned crews. No adjustment was recommended for well-trained and conditioned personnel working 4-hour shifts. Since calculations in this document are based on 8-hour shifts, the coverage rate needs to be adjusted. Further adjustment is necessary for one hour per 8-hour shift for radiation control measures. With these adjustments and conversion to metric units, we get:

$$16{,}216 \text{ ft}^2/\text{hr} \times 0.80 \text{ fatigue adj.} \times 7/8 \text{ adj.} \times 0.093 \text{ m}^2/\text{ft}^2$$
$$= 1056 \text{ m}^2/\text{hr}$$

This figure is quite close to the adjusted rate calculated for Spokane Community College. The average of the two rates is 1017 sq meters per hour.

Table A.1.5.3.2 summarizes the rate and cost information for manual firehosing. Labor comprises 85 percent and equipment 15 percent of the operation.

Estimating the cost of high-pressure hosing of pavement using fire equipment such as pumpers and tankers is difficult because fire fighting equipment is used for emergencies, not continuous operation. Moreover, the personnel that use the equipment are specially trained for emergency operations. This sort of usage is much different from the relatively slow, methodical, and repetitive operation of hosing down streets as might be done following a nuclear reactor accident. The major differences as they would bear on costs

TABLE A.1.5.3.2. Summary of Manual Firehosing Information

Source	Water Applied (in.)	Rate (m^2/hr)	Cost (1982 \$/m^2) Total	Labor	Equipment
Spokane Com. Coll.	0.64	977	0.021	0.018	0.003
Owen et al.	0.35	1056	--	--	--

are apparent. Equipment and personnel would be in near-continual use. This would have the effect of lowering the average cost per hour of operation of both labor and equipment. Further, it would not be necessary to employ such highly trained and highly paid people as firefighters. For these reasons, the information provided by fire department sources occasionally needs to be adjusted by a significant amount.

Pump trucks commonly have the ability to pump 100 gallons per minute at 100 pounds per sq inch. However, the equipment can be adjusted to put out less water at higher pressures or more water at lower pressures. Pump trucks themselves generally have a 500-gallon tank capacity. At a pump rate of 100 gallons per minute, it is clear that pumpers require some additional water supply. The two alternatives for this are i) attachment to a hydrant or ii) use of a shuttle of tanker trucks. Tanker trucks normally have a capacity of 2000 to 3000 gallons. Larger capacity water transport vehicles do exist. A pumping rate of 100 gallons per minute would require a tanker-load of water, say, every 30 minutes of pumping. The number of tankers required to keep a pumper supplied will depend on the travel time to and from the water source, the time to refill a tanker, and the length of any interruptions in pumping by the pumper. Here we assume that three tankers per pumper are sufficient.

With respect to the labor requirements for high-pressure hosing of streets, sources associated with fire departments, not surprisingly, responded in terms of standard firefighting crews. Thus, both the Richland, Washington, Fire Chief and the Director of Finance of the Seattle Fire Department indicated that the crew for each pumper should consist of two firefighters and one officer and for each tanker there should be one firefighter. The Chairman of the International Fire Chiefs Association Hazardous Materials Committee recommended four people per pumper and three people per tanker.

Here we assume that with fire hydrants three people with one pumper are sufficient. The Richland Fire Chief provided labor and equipment costs that are standardized across Washington State. This standardization was done by the State Fire Chiefs Association for the purpose of interdepartmental billing when one department loans some of its equipment and personnel to a neighboring department for firefighting. At these rates a firefighter costs \$15 per hour, an officer \$20 per hour, a pumper \$85 per hour plus \$1.50 per mile, and a 1250-gallon tanker \$35 per hour plus \$1 per mile. The Seattle Fire Department

provided similar labor costs--$15 per hour for a firefighter and $18 per hour for an officer. Both sets of labor costs include salaries and benefits.

The lesser of these two sets of labor cost figures comes to $48 per hour for a three-man crew. As mentioned earlier, for decontamination work it would not be necessary for all workers to have the training, skills, and experience of firefighters. However, some specialized skill would be required for operation of the pumper. For the purposes at hand, we use $48 per hour for the three-man crew. The $85 charge per hour of use for the pumper may over estimate the average hourly cost with continuous operation. Nonetheless, that figure is used here since there is no basis for doing otherwise. Therefore, with hydrants available to supply water to the pumper, the total cost per hour is $133. Labor accounts for 36 percent of the total, and the remaining 64 percent goes for capital as well as operation and maintenance.

The estimates for the time required to adequately hose a paved surface vary greatly. The Chairman of the International Fire Chiefs Hazardous Materials Committee indicates that adequate hosing would require 500 gallons for 100 sq feet. This is a huge amount of water. It is equivalent to covering all paved surfaces with water to a depth of eight inches. If we assume 16 blocks per mile with streets 40 feet wide, there are 13,200 sq feet of street pavement per (linear) block. At a pumping rate of 100 gallons per minute, this coverage would require 11 hours per block.

In contrast, Nowell Patten, of the International Association of Fire Chiefs, estimates 15 to 20 minutes per block, excluding setup time. Close to this estimate is the one from the Seattle Fire Department Research and Development Section. They estimate half an hour for hosing one linear block and ten minutes for moving and setting up for the next block. The Richland, Washington Fire Department source feels that one to two hours per block would be required.

Of course, the length of time for hosing will be at least partially a function of the desired thoroughness, or level of decontamination, to be achieved. Unfortunately, except for Owen et al., the available references for the effectiveness of high-pressure hosing are not clear about the amount of water per surface area used. The coverages reported in Owen et al. range from 0.21 inches to 0.51 inches per pass. In fact, establishing a fixed water coverage per pass is arbitrary since one pass of, say, 1.00 inch of water should have about the same effectiveness as two passes of 0.50 inch of water. Lacking a more definitive standard, the coverage rate used here has been set equal to 0.50 inch. One reason for choosing this relatively heavy coverage is that because moving and setting up at a new location are costly, it is more economical to apply more water in fewer passes than less water in more passes.

Referring to Table 3.1 in Owen et al. (1967), we find that a coverage of 0.50 inch (0.31 gallon per sq foot) can be applied at an effective rate of 213 sq feet per minute. This allows 20 minutes for reconnecting to the next fire

hydrant. This rate is equivalent to 1189 sq meters per hour. With the final adjustment of one hour per shift for radiation protection measures, we get 1040 sq meters per hour.

The cost per sq meter is:

$$\frac{\$133/hr}{1040\ m^2/hr} = \$0.13/m^2$$

In the event that fire hydrants are not available, it would be necessary to add the cost of three tanker trucks and their drivers. We assume a cost of $17.45 per hour for the drivers. Recalling that the rental rate for a 1250-gallon fire department tanker in Washington is $35 per hour plus $1 per mile, we assume an average hourly cost of $50 per hour per tanker. This accounts for a larger tank capacity and about 10 miles driving each hour. With three tankers and three drivers, the cost of supplying one pumper with water is $202.35 per hour. The additional cost per sq meter is:

$$\frac{\$202.35/hr}{1040\ m^2/hr} = \$0.19/m^2$$

This brings the total cost per sq meter to $0.32. The share of the total cost comprised by labor is 26 percent, and that comprised by capital and operation and maintenance is 74 percent.

Standard fire department pump trucks are designed for stationary use. They are generally positioned at a convenient location for firefighting and kept there until the truck is no longer needed for that fire. In contrast, hosing pavement requires forward movement, even if the movement is slow. For this reason, other sorts of equipment were investigated.

Both the Forest Service and airport firefighting units have what is referred to as "pump and roll" equipment--equipment designed to pump water from a nozzle while the vehicle is moving. Unfortunately, for the purposes at hand, this equipment generally has a much too limited tank capacity, often less than 100 gallons.

When posed the question of how to efficiently accomplish a high-pressure hosing of very large areas of pavement, four different sources suggested essentially the same approach. These sources included contacts at the Portland, Oregon, and Wenatchee, Washington, offices of the U.S. Forest Service, at the U.S. Bureau of Land Management Interagency Fire Center in Boise, Idaho, and at Wajax Firefighting Equipment, Seattle, Washington. The method they suggested was to fit a 3000-gallon tank truck with a pump and a multi-orifice spray-bar. None of the sources indicated that there would be any problem in assembling such a rig. Further, the same basic equipment with some variation in pump size and the spray-bar could be used for low-pressure flushing,

high-pressure flushing, very high-pressure flushing, and other applications of liquids to roads. The major difference in equipment for these functions is pump size.

While a 20-horsepower pump can generate a flow rate of 100 gallons per minute at 100 pounds per sq inch, the flow rate drops sharply if the same pump is set for 400 pounds per sq inch. The result is that a substantially larger pump is required to generate both pressure and volume.

Besides the fact that the same basic equipment configuration can be used for low-, high-, and very high-pressure flushing, equipment of this sort may be immediately available. According to the Forest Service in Portland, heavy construction contractors use and rent this equipment. The Interagency Fire Center said that the military has a large surplus quantity of high-pressure, high-volume trucks for sale.

According to Wajax Firefighting Equipment, a new 3,000-gallon tank truck would cost about \$25,000 and the auxiliary equipment would add another \$6,000 \$8,000 to the cost, bringing the total to something like \$32,000. The source added that the General Services Administration estimates the charges for a 1000-gallon truck-sprayer at \$19.60 per hour for operation and maintenance plus \$500 per month for charges against capital. On this basis Wajax estimated the comparable charges at \$25.00 per hour and \$600 per month for a 3000-gallon rig. At a spray rate of 100 gallons per minute, the truck can spray for 30 minutes before refilling. Refilling time depends on the method. A gravity feed from an elevated tank would take only two to four minutes. A hydrant with a four-inch fitting could fill the tank in 10 minutes, while refilling from a pool with a booster pump would take 20 minutes. In addition, there would be travel time to and from the fill site. Assuming 20 minutes for filling and traveling plus one hour per shift for equipment and personnel radiation decontamination, there are 4.2 hours for spraying. This gives 8.4 loads of 3000 gallons each applied per shift, ignoring the problem of fractional tanker loads (shift length could be adjusted).

Assuming 43 shifts per month and 8 hours per shift, the hourly charge is figured as the sum of the monthly rental rate plus the hourly operation and maintenance charge plus the operator's salary:

$$\frac{\$600/\text{mo}}{43 \text{ shifts} \times 8 \text{ hr/shift}} + \$25/\text{hr} + \$17.45/\text{hr} = \$1.74 + \$25 + \$17.45 = \$44.19/\text{hr}$$

Using these cost figures, labor comprises about 39 percent, capital 4 percent, and operation and maintenance 57 percent.

Given the spray rate of 100 gallons per minute over a ten-foot width, the truck's speed is inversely related to the amount of water applied to the pavement. For an average of half an inch of water, the truck's speed would be 0.36 miles per hour. For twice as much water, an inch, the speed would be half that--0.18 miles per hour. On the other hand, looking at the coverage as

determined by the speed, a speed of one mile per hour gives a coverage of 0.18 inches of water. Using this one mile per hour speed, the total coverage per shift is:

$$1 \text{ mi/hr} \times 4.2 \text{ spraying hr} \times 5280 \text{ ft/mi} \times 10 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$

$$= 20{,}624 \text{ m}^2/\text{shift}$$

The average coverage per shift hour is, therefore, 2578 sq meters. Dividing this into the cost per hour yields a cost per sq meter of $0.017.

The Bureau of Land Management Interagency Fire Center provided information on a 9000-gallon capacity tractor-trailer rig. The cost of this equipment is shown in Table A.1.5.3.3. These figures are considerably higher than those supplied by Wajax for two reasons. The tank capacity is triple that represented by the Wajax data. Also, the pump in the BLM equipment is much larger. Note that the pump is mounted on a separate trailer. While it could be mounted on the truck frame itself, the BLM source said that this arrangement would facilitate using the truck's own pump to fill the tank if filling were to be done from a pond.

The price of the pump varies with the model selected. This source provided the following prices for various Hale brand pumps. The flow rates shown in Table A.1.5.3.4 are all given at 150 pounds per sq inch pressure. The price differences are due to valves and other fittings as well as flow rates. A precise evaluation of the proper choice of pump would involve weighing the values of the marginal products of the various inputs. Lacking the ability to do that, it can be noted that the last and most expensive pump on the list gives the highest pump rate per dollar. Also, the marginal cost for additional pump capacity generally declines for these models as capacity increases. As a result, further calculations are made based on the largest of the pumps shown on this list.

The source gave the hourly operation and maintenance cost at $20 per hour. This figure is not consistent with the higher figure for the smaller rig

TABLE A.1.5.3.3. Firehosing Equipment Costs, Bureau of Land Management Interagency Fire Center

Item	Price (1982 $)
Tractor	70,000
Trailer (9,000 Gal Brauhaus)	30,000
Spreader Bar, Installed	5,000
Pump	11,550-13,800
Add'l Trailer for Pump	4,340
Total	$120,890-$123,140

TABLE A.1.5.3.4. Flow Rates and Prices for Hale Pumps

Hale Pump Model	Rate (gal/min)	Price (1982 $)
FB50-F300	700	$11,550
FB50-C318	850	12,475
FB75-C318	850	12,750
FB75-F460	750	13,500
FB100-F460	1100	13,800

described by Wajax. It seems more likely that the BLM figure is too low rather than the Wajax figure too high. Arbitrarily, we assume an hourly operation and maintenance charge of $35. The monthly capital equipment charge will be more or less proportional to the total purchase price. Using the Wajax figures to estimate the monthly equipment charge on this basis, we get $2300.

As in the previous case, the cost per hour comes from summing the average capital cost, the operation and maintenance cost, and the operator's salary:

$$\frac{\$2300/\text{mo}}{43 \text{ shifts} \times 8 \text{ hr/shift}} + \$35/\text{hr} + \$17.45/\text{hr} = \$6.69 + \$35 + \$17.45 = \$59.14$$

Of this amount, labor comprises 30 percent, capital 11 percent, and maintenance and operation make up the remaining 59 percent.

At a pump rate of 1100 gallons per minute, the entire 9000-gallon tank capacity will be expelled in a little over 8 minutes. This would permit the truck to drive fas er while spraying. Here we assume 30 minutes total time for refilling, including travel to and from the fill site. This assumes a faster fill rate than for the 3000-gallon truck, which would be likely if this larger size equipment were used and higher-capacity pumps were purchased. Over a seven-hour period this equipment should average about 11 tank loads applied, with about 1.5 hours actual spraying time.

Again, the vehicle's speed and the amount of water sprayed per unit area are inversely related. Since the pump rate is 11 times that of the 100 gallon per minute equipment, the same coverage can be attained at a vehicle speed 11 times faster. Thus, for a coverage of half an inch, vehicle speed would be four miles per hour. This equipment would get the same coverage (0.18 inches) at 11 miles per hour that the 100 gallon per minute pump would produce at one mile per hour.

Assuming a vehicle speed of ten miles per hour (coverage of 0.20 inches), the area covered per shift is:

$$10 \text{ mi/hr} \times 1.5 \text{ hr spraying} \times 5280 \text{ ft/mi} \times 10 \text{ ft wide} \times 0.093 \text{ m}^2/\text{ft}^2$$

$$= 73{,}656 \text{ m}^2$$

The average coverage per shift hour would be one-eighth of this amount, or 9,207 sq meters. The cost per sq meter works out to:

$$\frac{\$59.14/\text{hr}}{9207 \text{ m}^2/\text{hr}} = \$0.006/\text{m}^2$$

The Portland office of the U.S. Forest Service advises that a 3,000-gallon capacity tank truck with pump and spray bar costs about $68,000 new. The performance specifications for this equipment are essentially the same as those described by Wajax Firefighting equipment. The only difference is the higher capital cost. This source is not able to provide additional cost data. Since there is no other new information from this source, apart from the purchase price, the same calculations as are done with the Wajax data are repeated. Only the capital cost figure is changed.

The monthly capital equipment cost is adjusted proportionately to the higher purchase price. This raises the hourly charge for capital to $3.71. Proceeding with exactly the same calculations as for the Wajax data, we get a total hourly cost of $46.16, of which labor comprises 38 percent, capital 8 percent, and operation and maintenance 54 percent. The cost per sq meter is $0.018 at the same rate of 2578 sq meters per hour.

Means' Building Construction Cost Data 1982 provides information that can give an indication of the cost of the operation. The lease and operating costs of a truck tractor and water tank trailer with engine-driven discharge are listed. A detailed description of this equipment is not available, so it is assumed that even if this equipment is not suitable for high-pressure pavement washing, the costs are not greatly different from the costs of proper equipment.

Four types of truck tractors are listed, differing in load capacity. The choice of tractor is therefore determined by the choice of trailer. Here there are two choices, one with a 5,000-gallon capacity and the other with a 10,000 gallon capacity. The truck tractors that appear to be appropriate for these trailers are, respectively, one with 195 horsepower and a 30-ton capacity, and one with 240 horsepower and a 45-ton capacity. The costs of these two rigs, as printed in Means, are shown in Table A.1.5.3.5. With two shifts per day, there are 336 hours per month. Dividing by this number gives an hourly rental cost

TABLE A.1.5.3.5. Means Cost Data for Firehosing Equipment

	Hourly Oper. Cost	Rent per Month
30-ton tractor	$ 8.10	$1675
5,000-gallon trailer	8.40	1975
Total	$16.50	$3650
45-ton tractor	$12.25	$2400
10,000-gallon trailer	9.95	2875
Total	$22.20	$5275

for the smaller equipment set-up of $10.86 and $15.70 for the larger one. Total hourly equipment cost is, then, $27.36 for the 5,000-gallon arrangement and $37.90 for the 10,000-gallon arrangement. Added to each of these is the $19.75 hourly labor cost for a heavy-truck driver.

The coverage rates for these two truck-trailer rigs are estimated in a manner similar to the previous estimates. At an assumed discharge rate of 100 gallons per minute, the 5,000-gallon tank would provide water for 50 minutes. If refilling takes 30 minutes and there are seven hours per eight-hour shift available for spraying, then 5.25 tank loads per shift could be applied. With 50 minutes spraying time per load, the total spraying time would be 4.375 hours per shift. Total surface coverage would be

$$1 \text{ mi/hr} \times 4.375 \text{ hr spraying/shift} \times 5280 \text{ ft/mi} \times 10 \text{ ft wide}$$

$$\times\ 0.093\ m^2/ft^2 = 21{,}483\ m^2/\text{shift}$$

Hourly coverage would be one-eighth of this amount, or 2685 sq meters.

For the 10,000-gallon truck-trailer setup, one tankload would provide 100 minutes of spraying at the 100 gallons per minute rate. If refilling takes 40 minutes, then a complete cycle of refilling and spraying will take two hours and 20 minutes. With seven production hours per shift, three tank loads will be sprayed, giving a total spraying time of five hours. Coverage in one shift will be

$$1 \text{ mi/hr} \times 5 \text{ hr} \times 5280 \times 10 \text{ ft wide} \times 0.093\ m^2/ft^2 = 24{,}552\ m^2$$

One-eighth of this amount, 3069 sq meters, is the average hourly coverage.

Having the coverage rate, it is easy to calculate the costs per sq meter. They are as shown in Table A.1.5.3.6.

TABLE A.1.5.3.6. Summary of Means Cost Data

Tank Capacity	Rate (m^2/hr)	Cost (1982 \$/m^2) Total	Labor	Equipment
5,000 gallon	2685	0.0176	0.0074	0.0102
10,000 gallon	3069	0.0187	0.0064	0.0123

Table A.1.5.3.7 summarizes the foregoing information regarding the high pressure hosing of pavement. One thing that is apparent is that the cost estimates cover a wide range. The highest cost estimates are those using fire department data. Using fire department pump trucks tends to be a slow method which also requires more equipment and more personnel per unit area. Of the methods presented, clearly the simplest one is to supply workers with hoses and little else. This method is quite practicable from a cost standpoint, too, as long as hydrants or high-pressure water mains are accessible. The BLM cost figure is significantly lower than all others. This low cost is primarily the consequence of utilizing a high output pump. Since Wajax, the Portland Forest Service office, and the Wenatchee Forest Service office all specified the same equipment and only the Bureau of Land Management Interagency Fire Center specified this high-volume equipment, there is a question as to whether the high-volume equipment is as common and as readily available. If this equipment is readily available, then it would be the preferred choice. If hydrants are available and the application of a high-volume of water is deemed desirable, then manual hosing would probably be the choice. In cases where neither high pressure hydrants nor the BLM-specified equipment is readily available, as may be likely, the Wajax-Forest Service figures become the preferred choice. All nonlabor costs are included under the equipment heading.

A representative cost would appear to be about \$0.018. Rates and cost shares are more widely dispersed. In general, the Wajax and the Means figures for the 5000-gallon equipment seem fairly reliable and not extreme; they were taken as representative.

A.1.5.4 Very High-Pressure Water Flushing

The porosity of asphalt and concrete will result in some radioactive particles being inaccessible to methods which otherwise have good removal efficiencies. One way to dislodge and remove particles which have become embedded in the pavement surface or have penetrated into crevices below the surface is to use a very high-pressure water wash. At pressures around 400 pounds per sq inch there is a good scouring action. However, in some cases water at this pressure may actually erode and break up some asphalt pavements.

According to Wajax Firefighting Equipment in Seattle, Washington, the most efficient way to accomplish a very high-pressure water scouring of pavement seems to be to use an equipment arrangement similar to that described previously in the discussion about high-pressure (100 pounds per sq inch) water

TABLE A.1.5.3.7. Summary of High-Pressure Water Cost Data

Method and Source	Vehicle Speed (mi/hr)	Amnt. Water Applied Applied (in.)	Rate (m^2/hr)	Cost (1982 \$/m^2)		
				Total	Labor	Equipment
Manual firehosing						
Spokane Comm. Col.	--	0.64	977	0.021	0.018	0.003
Owen et al.	--	0.35	1056	--	--	--
Pumper w/hydrant						
Var. fire depts.	--	0.50	1040	0.13	0.05	0.08
Pumper w/tanker						
Var. fire depts.	--	0.50	1040	0.32	0.08	0.24
Tanker w/pump						
Wajax	1	0.18	2578	0.017	0.007	0.010
BLM	10	0.20	9207	0.006	0.002	0.004
Forest Service	1	0.18	2578	0.018	0.007	0.011
Means - 5,000 gal.	1	0.18	2685	0.018	0.007	0.011
Means - 10,000 gal.	1	0.18	3069	0.018	0.006	0.012
Representative	1	0.18	2685	0.018	0.007	0.011

flushing. A tank truck with a capacity of, say, 3,000 gallons is fitted with a pump and a spray bar. With this setup, the truck can spray a ten-foot wide swath of pavement as it moves forward.

The major difference between the equipment required for the 100 pounds per sq inch wash and the equipment required for the 400 pounds per sq inch wash is the pump size. In order to maintain a flow rate of 100 gallons per minute at this higher pressure, a large pump driven with a V6 or V8 engine is necessary. Such a pump may be towed behind the truck on its own trailer or mounted on a larger truck frame. A 5-ton truck chassis would be required for the tank, pump, spray bar, and necessary auxiliary equipment.

The pump costs about $20,000 and the truck about $35,000, for a total of $55,000. Wajax suggests monthly lease payments of $600 for equipment costing $32,000. Using a proportional relationship, the monthly capital charge for this equipment is about $1030. With slightly less than an average of 22 working days per month and two shifts per day, this works out to:

$$\frac{\$1030/\text{mo}}{43 \text{ shifts} \times 9 \text{ hr/shift}} = \$3.00/\text{hr}$$

Wajax did not provide an hourly operation and maintenance cost for this equipment, but with the larger pump and pump engine we can assume it will cost more to run than equipment detailed in the section about high-pressure water flushing. Here we assume an hourly cost of $35.00. In addition, there are labor costs of $19.75 per hour for a heavy-truck driver.

Referring to Means' Building Construction Cost Data 1982, comparable cost figures can be derived. The basic equipment for very high-pressure water scrubbing of pavement includes the 5,000-gallon truck-trailer rig described in the previous section. To this would be added a high-pressure pump. On page 309, Means lists the costs of various diesel and electric firepumps, but it is not clear which, if any, of these would be appropriate. Perhaps the closest match between these pumps and the requirements for pavement washing would be met by modifying either the 85- or 118-horsepower pumps for higher-pressure and lower-volume output. These pumps cost about $30,000 each. On page 14, a 200-horsepower high-pressure pump is listed along with its hourly operating cost ($5.60) and the monthly lease rate. The lease rate is given as $1300 for the first month, $1180 for the second month, and $900 for the third month. Assuming that these costs are close to the costs for the proper pump for this application, the cost per sq meter can be calculated. We estimate the monthly rental charge for the pump with trailer and other incidental equipment at $1150. This comes to about $3.40 per hour. Adding the operating cost gives $9.00 per hour more for the equipment for very high-pressure (400 pounds per sq inch) water spraying compared with the high-pressure (100 pounds per sq inch) spraying. This brings the total hourly equipment cost to $36.36.

There is little information about how much water should be used. The Wajax source said that a vehicle speed of from four to six miles per hour

should result in good removal. This would result in a surface coverage of about .4 inches when the 100 gallons per minute is spread over a width of ten feet. Other sources on decontamination effectiveness are unclear about how much water should be applied to achieve any particular level of effectiveness. The coverage assumed here is 0.18 inches, the coverage resulting from a vehicle speed of one mile per hour. This is at the low end of the amounts of water reported in Owen et al.

With vehicle speed and refilling times about the same as for high-pressure spraying, we can calculate the costs on a sq-meter basis by straightforward division. This information is presented in Table A.1.5.4.1. Note, however, that because water at pressures as high as 400 pounds per sq inch may erode and break up asphalt pavement surfaces, it may be necessary for the spray truck to move faster than one mile per hour on asphalt.

A.1.5.5 Foam

Acid-based foams rely on maintaining a concentration gradient through the foam's thickness to pull the contamination out of the surface by reverse osmosis. Turco Products, a Division of Purex Corporation, in Carson, California, manufactures chemical bases for such foams. The method they prescribe is to mix the decontamination chemical such as Turco 4512A or Turco 4306D with water. The 4512A comes as a liquid costing $13.00 per gallon and is mixed to a ten-percent solution by volume. The 4306D comes as a powder, sold at $180 for 100 pounds. It is mixed 6 ounces per gallon of water.

The prepared solution is applied by pumping at about 20 to 40 pounds per sq inch pressure. The use of a foaming head such as a Dema Model 293 permits mixing with air and Turco 5865 to create a lather-like foam. The Turco 5865 is injected through the detergent supply connection on the foaming head. With the maximum quantity discount, this material costs $6.25 per gallon. It is mixed with the 4512A solution at something like one part foaming agent in ten.

TABLE A.1.5.4.1. Cost Data for Very High-Pressure Water Spraying

Source	Rate (m^2/hr)	Cost Basis	Cost (1982 $) Total	Labor	Equipment
Wajax	2685	$/hr	54.75	19.75	35.00
		$/$m^2$	0.0204	0.0074	0.0130
Means	2685	$/hr	56.11	19.75	36.36
		$/$m^2$	0.0209	0.0074	0.0135
Representative	2685	$/hr	55.43	19.75	35.68
		$/$m^2$	0.0206	0.0074	0.0132