United States
Environmental Protection
Agency

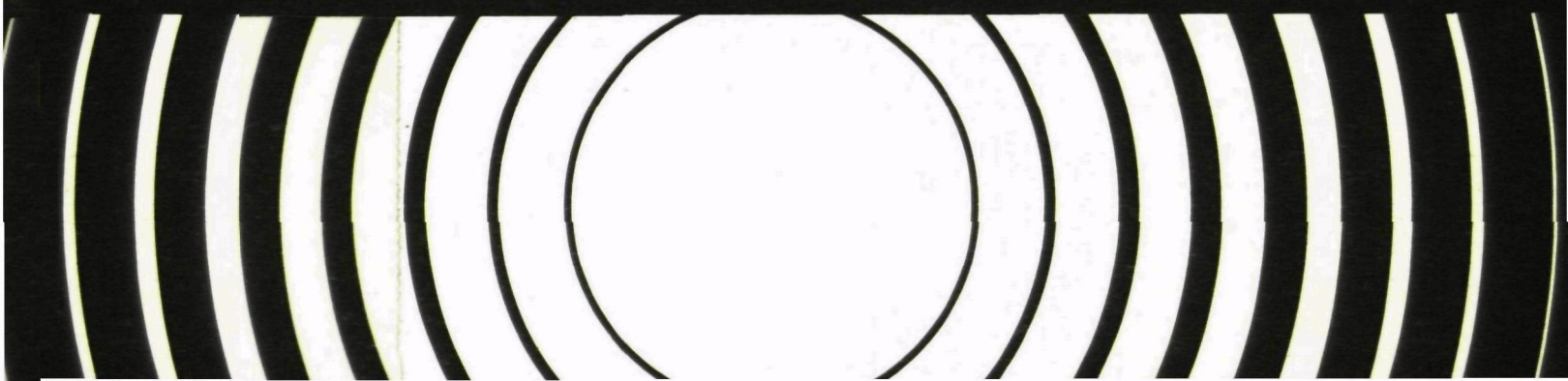
Office of
Radiation Programs
Washington, DC 20460

EPA 520/1-89-015
June 1989

Radiation

EPA

Economic Criteria for Relocation



Economic Criteria for Relocation

Dr. Byron M. Bunger

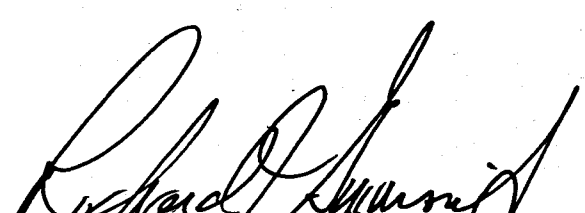
Office of Radiation Programs
U.S. Environmental Protection Agency
Washington, DC 20460

1989

FOREWORD

The Environmental Protection Agency is responsible for the development of criteria for protection of the public from radiation resulting from nuclear incidents and accidents. These criteria are referred to as protective action guides (PAGs). One consideration in the development of PAGs is the cost of implementing protective actions.

This report provides background information on the social cost of relocating households away from areas contaminated as a result of a release of radioactive particulate material to the atmosphere from an accident at a nuclear power plant. Results of the analyses presented herein were used in the development of PAGs for relocation.



Richard J. Guimond, Director
Office of Radiation Programs

Washington D.C.

CONTENTS

ECONOMIC CRITERIA FOR RELOCATION

1. Objective

The purpose of a Protective Action Guide (PAG) for relocation is to establish a restricted zone from which all residents will be relocated to protect them from exposure to radioactive contamination while their property is being decontaminated. The relocation PAG is expressed in terms of the projected dose from an accidental release of radioactive material. The PAG is used to establish the boundary of the area to be decontaminated.

EPA establishes the relocation PAGs using a method which incorporates both the risk of health effects and the cost of avoiding risk by relocation. Using this method, all residents receiving an exposure above a predetermined level are relocated regardless of cost, but residents receiving lower exposure would also be relocated if the benefits of relocation justify the cost.

The analysis performed here is to determine only the cost of relocation. This cost is used elsewhere to investigate the feasibility of relocation based on its costs and benefits (EP-89).

2. Conditions and Approach

Evacuation is the immediate and urgent removal of people from an area to avoid or reduce exposure, usually from the plume itself or from high levels of deposited radioactive material. Evacuation is expected to start soon after an accident at a nuclear power reactor (within hours) and to last no more than a few days. Relocation, on the other hand, is the removal or

continued exclusion of households from contaminated areas to avoid chronic radiation exposure. All households relocated are expected to be moved from their place of residence within a few days of the decision to relocate, and to be on relocation for a period of as much as a year. Many people evacuated immediately after an accident will be converted to relocation status while other people that were evacuated may be allowed to return to their homes. Others who were not evacuated may be relocated.

The following conditions are expected to be met when a population is on relocation:

1. An airborne plume has passed and left behind a deposit of radioactive material.

2. The movement of occupants and their possessions was carried out shortly after the decision to relocate and was completed within a few days. The area from which people were relocated was established as a restricted zone with controlled access.

3. Decontamination is to be carried out on property outside, as well as inside, the restricted zone. In particular, it is assumed that the extent of decontamination required will be the same on a property just outside the zone as on an adjacent identical property within it.

4. Relocation of the population from an area halts operation of all neighborhood retail and service businesses (e.g., service stations, repair shops, and other services based in fixed places of business) in the restricted zone. These neighborhood businesses are assumed to not be moved from the restricted zone. Other industries (e.g., manufacturing, utilities, and government) are assumed to continue to operate so long as the doses to employees do not exceed occupational

dose limits (i.e., independently of the Relocation PAG). Therefore, the cost of relocation borne by the commercial sector is assumed to accrue only from the interruption of neighborhood retail and service businesses.

The costs associated with the implementation of the PAG for relocation is evaluated through a comparison of the social costs of relocating an average household that is just inside the restricted zone with the social costs of not relocating an identical household that is just outside the restricted zone. The comparison is made between average households at the margin, immediately adjacent to the boundary of the restricted zone, i.e., figuratively, between the last household included in the restricted zone and the first house excluded from the restricted zone. At the boundary of this zone, the difference in monetary costs between relocating and not relocating is the monetary cost assigned to the radiation risk experienced by the household that is not relocated.

Specifically, consider the comparison of relocation of the occupants of two similar residences of equal value at the time of the accident that are on either side of a line established by the relocation PAG. (Conceptually the two residences need not be immediately adjacent to one another; they could be separated by intervening streets, crop lands, open lands, forests, or structures so long as the two houses being compared require the same amount of decontamination using the same methods of clean-up. However, the derivation is better conceptualized and the geographic location of the line demarking the restricted zone is more precisely determined if the two residences are thought to be immediately adjacent to each other.) The relevant costs associated with moving or not moving these households can be divided into three components. The most obvious is the cost of relocating or not relocating the households themselves. The

second component is the cost of closure of community-based retail and service businesses, and the third is the loss of public facilities such as use of streets, schools, libraries and parks, and public utilities such as electrical power, natural gas, and telephone service. Although we will enumerate a variety of costs for each of these three components, not all will have to be explicitly evaluated, since in some cases costs for the relocated household will be the same as those for one that is not, and will not contribute to the difference between the two. The objective is to determine the net difference in the costs for the relocated and unrelocated households.

3. Costs of Relocating Household

3.1 Identification of Household Costs

The cost of relocating the households themselves is considered first. Assume that residence A is located just inside the boundary of the restricted zone and residence B is adjacent to residence A, but is just outside the boundary of the zone. The occupants of residence A (household A) are relocated and the occupants of residence B (household B) are not relocated. Consider the costs associated with the relocation of household A. It is reasonable to assume that residence A is to be decontaminated and restored to use because it is at the boundary of the restricted zone and, therefore, not severely contaminated. The costs associated with the relocation of household A and the decontamination of residence A are:

A1. The costs of moving occupants A and their possessions (excluding large furniture and appliances) to temporary living quarters outside the restricted zone, and back to their residence after its decontamination. This includes the monetary value placed on the risk of accidental injury or fatality during the moves.

A2. The loss of the use of residence A during the time household A is on relocation.

A3. The loss in the monetary value of residence A as a result of having been contaminated. This loss is caused by the perception of risk from residual levels of contamination still present after decontamination. It is a permanent loss.

A4. Any extra cost on the part of household A in maintaining the standard of living formerly provided by residence A. This cost derives from the fact that residence A can be assumed to have provided the services desired by its occupants at the lowest possible cost.

A5. Extra cost of maintenance and security for residence A. Extra maintenance is anything above the normal upkeep needed to maintain the residence. This stems from the extended length of the vacancy of residence A. Extra security is everything above the normal level of police services and protective measures needed to protect residence A against fire, theft, and vandalism while it is unoccupied.

A6. The cost of decontaminating residence A, including all associated monitoring costs.

A7. Any emotional pain and suffering experienced by household A resulting from having been relocated.

A8. All extra travel costs imposed on household A due to having been relocated.

A9. All extra travel costs imposed on those residing in the region surrounding the restricted zone as a result of adding residence A to the restricted zone.

A10. The true health risk due to the levels of contamination on the property from the time of return of the occupants to their residence through the remaining useful life of residence A. This health risk is based on the true level of contamination rather than the perception of risk by occupants of residence A.

Although the occupants of residence B are not relocated, there are costs associated with the decontamination and cleanup of this residence. Most of these costs are equal to or comparable to a cost incurred by household A. The equal, or comparable cost is identified where appropriate. They are:

B1. The loss in the monetary value of residence B as a result of having been contaminated (even though at a low enough level that the household is not relocated). This permanent loss in value is caused by the perception of risk from residual levels of contamination still present after decontamination (as discussed below, this cost is judged to be equal to cost A3).

B2. The cost of decontaminating residence B, including all associated monitoring costs (offset by cost A6).

B3. Any emotional pain and suffering resulting from the fear of radioactive contamination experienced by household B as a result of not having been relocated (similar to cost A7).

B4. The true health risk to household B due to the radioactive contamination for the period of time from the beginning of relocation (for household A) through decontamination of residence B and on to the end of relocation (for household A). It is assumed that residences A and B are both decontaminated before the end of relocation for household A.

B5. The true health risk to household B due to the contamination for the period of time from the end of relocation

(for household A) through the remaining useful lifetime of residence B. This health risk is based on the true levels of contamination rather than the perception of risk by occupants B (offset by cost A10).

The costs described above are summarized in Table 1.

3.2 Discussion of Household Costs

The risk of accidental injury or death as a result of the two moves caused by relocation is very small and the associated monetized value can be neglected (part of cost A1). Other costs of moving household A are related primarily to transportation of household members and their possessions (except for large furniture and appliances which are assumed to remain at the residence).

Cost A2 cannot be evaluated independently of costs A3 and A6. In estimating the loss of use of residence A (cost A2), the dollar value of the loss accounted for should be based on the market value of the property after the accident, but prior to decontamination. This may be evaluated as the value of the residence after decontamination has taken place, less the cost of decontamination. Due to the perception of risk from any residual contamination that will remain after decontamination, the market value of residence A after decontamination must be adjusted downward.

The loss of use of residence A also includes the loss in consumer surplus derived from the property. There is reason to believe that some of the amenities and externalities derived from the neighborhood and environment that contribute to the consumer surplus may be temporarily (or even permanently) lost after the accident. (This loss would be due to such things as the disruption of the neighborhood due to the accident, possible loss of continuity of the neighborhood caused by condemnation

Table 1: Relocation Cost Categories

Cost category	Applicability: Residence A (Relocated)	Applicability: Residence B (Not Relocated)
Move the household	Cost A1. Round trip for family and most possessions	No cost
Loss of use of residence until decontaminated	Cost A2. True cost but basis to be adjusted to account for costs A3 and A6	No cost
Depreciation due to accident and resulting contamination	Cost A3 which is the same as cost B1	Cost B1
Extra costs due to higher cost of services at new residence	Cost A4	No cost
Extra cost of maintenance and security for vacant property	Cost A5	No cost
Decontamination of residence	Cost A6 which is the same as cost B2	Cost B2
Emotional stress	Cost A7 from relocation	Cost B3 from exposure to radiation
Travel costs due to having been relocated	Cost A8	No cost
Travel costs due to an increase in the size of the restricted zone	Cost A9.	No cost
Health risk to households from radiation exposure		
(a) During relocation	No cost	Cost B4
(b) Following relocation	Cost A10 which is the same as cost B5	Cost B5

and withdrawal from use of some property within the restricted zone, and lingering fears resulting from the fact an accident actually has occurred.) Although some consumer surplus would be restored to household A after their residence is decontaminated, it is doubtful that there would be any consumer surplus derivable from residence A during the period of relocation if household A were to remain in it rather than relocate. This is because it may be argued that household B, which does not relocate, probably derives little or no consumer surplus from its residence during the period of relocation. The neighborhood of residence B is severely disrupted due to the relocation of neighbors and friends, and the closure of local streets and businesses. In addition, there is general anxiety caused by living in a radioactively contaminated area which reduces any remaining consumer surplus. We conclude that household B probably experiences a complete loss in consumer surplus during the relocation period. Since residences A and B are side by side, they could be expected to experience similar losses in consumer surplus. Therefore, the loss in consumer surplus to household A during relocation is assumed to be zero.

The result is that cost A2 is determined by subtracting the estimated loss in value due to residual contamination (cost A3) and the cost of decontamination (cost A6) from the before market price for residence A. This cost continues for the duration of relocation.

Costs A3 and B1 are the losses in the values of the houses resulting from the perception of risk from residual contamination. These are assumed to be identical. Even though the true levels of risk are expected to be quite low, it is anticipated that these risks will be perceived to be much larger than they really are, and will, therefore, result in substantial loss in the value of each residence. Although it may appear that the inclusion of both these property losses and the true risks from residual contamination (costs A8 and B5) is

double counting, it is appropriate that they both be included since the loss in property values probably has little relationship to the true levels of risks and is believed to be much greater than it would be if the true risks were the determining factor.

It can be assumed that (at least within a few years) after completion of decontamination residences A and B will be of equal value. (Note that they are assumed to be of equal value at the time of the accident.) Therefore, depreciation of property values due to contamination (costs A3 and B1) are equal. Since these costs associated with residences A and B are equal, they are not needed for the comparison of costs for residences A and B. (Note that this does not negate the need to evaluate cost A3 in order to evaluate cost A2, as previously discussed).

It is probably impossible to estimate the loss due to residual contamination without empirical evidence based on an actual accident. We have arbitrarily assumed a value in the evaluations presented in the appendix.

The extra expense that would be required to maintain the standard of living formerly provided by residence A (Cost A4) is a social cost. It is primarily related to price increases in housing due to increased occupancy in areas outside the relocation zone and to the inability to find a replacement residence, while on relocation, that fits the household's needs as well as residence A.

The extra costs of maintenance and security (cost A5) are estimated separately. The annual maintenance cost of a vacant property is arbitrarily assumed to be twice the annual cost of routine repairs. Cost of extra security is estimated to be equal to the additional premium charged for insuring vacant property. (Note that we are only interested in the cost of

maintaining security at residences with low levels of contamination. Costs for basic security for the heavily contaminated areas are not a component of relocating household A.)

Decontamination costs (costs A6 and B2) are assumed to be equal, and consequently are not needed for the comparison except for determining the reduced value of residence A (Cost A2) as discussed previously.

The costs of pain and suffering (costs A7 and B3) cannot be evaluated in dollars, but are likely to be similar in value for households A and B. Therefore no analyses of these costs are carried out.

Overall travel costs for former occupants of the restricted zone are increased (Cost A8). Persons relocated from the restricted zone are probably forced to travel further to their places of work, school, and other activities, while on relocation. Therefore, increased travel costs are included in the cost of relocation for household A. These costs were estimated on the basis of the predicted size of the restriction zone for an SST-2 type accident with average meteorology and population distribution typical of nuclear power plant environments.

Persons not relocated, but residing in the region of the restricted zone are forced to travel longer distances when going about their daily routine because of the closure of roads and streets traversing the restricted zone (Cost A9). Any marginal increase in the area encompassed in the restricted zone marginally increases travel distances for those residing outside the restricted zone.

The health risk imposed on the occupants of residence B during the period that household A is relocated (Cost B4) is not estimated here, but must be estimated in the process of

establishing the PAG. It is assumed that both residence A and residence B are decontaminated before household A is returned to its residence.

After household A returns to residence A, both households A and B are subjected to the low levels of risk from the residual levels of contamination remaining after these residences have been decontaminated. The residual contamination level at the two residences is assumed to be the same. Therefore, the true health risk imposed by residual contamination (costs A9 and B5) is assumed to be equal for the two residences and are not evaluated.

The result is that the sum of costs A1, A2 (as adjusted by costs A3 and A6), A4, A5, A8 and A9 is the net monetary cost directly related to relocating household A. Cost B4 (a health risk) is the net detriment incurred by household B. These costs and health risk are to be evaluated for a residence characteristic of the U.S. population of single family dwellings located in urbanized areas. Both residences are assumed to be of average size and value, and to be located on average sized residential lots. These residences are assumed to house families of average size for the U.S. population with average levels of family income. This sum is the first component of the cost needed for establishing the relocation PAG. It must be summed to the two other major components of cost discussed below.

4. Cost of Business Closures

The second major component of costs to be used in establishing the relocation PAG is the social cost of the closure of neighborhood-based retail and service businesses. These businesses derive most of their revenue from the communities they serve. All such neighborhood businesses are assumed to be closed since the absence of a population would result in little or no demand for their products or services.

Note that closure of all types of businesses other than retail trade and services is not included in relocation costs. Any closure of manufacturers or farms would be based on occupational exposure regulations or the inability to sell contaminated products. These costs would not be a result of relocation of the public.

The social value of the contribution of neighborhood businesses to their communities is the "value added" to the products or services they provide, which is the return to the factors of production used by these businesses. This is the wages paid employees, profits to owners, interest payments to cover the return on capital invested in buildings, equipment and inventory, and the rent on land. This value added is lost when these businesses are closed, and the loss continues until these factors of production are reemployed. Since it is to be expected that these businesses will reopen when they, and the neighborhoods they serve, are recovered and restored to use, the length of their unemployment is the length of the relocation period. This cost is to be expressed as a cost per household.

Another cost associated with the closure of these businesses is the loss of any inventories held at the time of their closure that cannot be sold or used after recovery.

These two business-related costs are calculated based on the aggregate of these types of businesses nationwide. This sum, expressed as a cost per household, represents the estimated social cost of the closure of these businesses.

5. Cost of Idle Governmental Facilities and Public Utilities

The third major component of costs needed to establish the relocation PAG is the loss of the use of public facilities provided by local government and the plant capacity and distribution system for public utilities. Examples of

governmentally provided facilities and services likely to be affected are streets, schools, libraries, parks, playgrounds, recreational facilities, and sanitation and water services. The public utilities lost are primarily electrical power, natural gas and telephone service.

6. Total Cost of Relocation

The net total monetary cost of the relocation of household A, exclusive of the health risk imposed on household B during the period of relocation is the sum of three components: the direct cost of relocating household A; the cost of business closures, expressed on a per household basis; and the cost of the loss of public facilities and services, and public utilities, also expressed on a per household basis. This sum represents the total monetary cost of the closure of residence A.

Some components of total monetary cost are proportional to the duration of relocation; others are fixed and independent of the duration of relocation.

The length of time of relocation must be established in order to estimate total costs. Since the property near the boundary of the restricted zone is not severely contaminated, it is assumed for this assessment that it will be possible to decontaminate it within one year. A one-year period of relocation is used.

Table 2 shows that the estimated average net cost of relocating a household from the boundary of the restricted zone is about $71 per day. Based on an average of 2.66 residents per household, the average cost per individual is about $27 per day. Analyses supporting the values in Table 2 are in the Appendix.

As stated at the beginning of this report, the projected dose limit (the PAG) which would be established by evaluating the costs and benefits of relocation is determined in the PAG Manual (EP-89). There the net cost of relocation, $27/person/day, is compared to the net increase in health risk experienced by persons not relocated, which is Cost B4 in Table 1.

Table 2: Cost of Relocating a Household at the Boundary of the Relocation Zone

Operation or cause	Cost per day	Cost per accident
A1 Moving costs (two moves)		$1641/accident
A2 Loss of use of residence	$ 7.89/day	
A4 Household's extra living costs	$ 3.41/day	
A5 Extra maintenance and security costs for vacant property	$ 1.98/day	
A8 Extra travel cost to household	$ 9.94/day	
A9 Extra travel cost to others in region of household	$ 1.96/day	
Value of lost business		
lost business activity	$37.39/day	
lost inventory		$ 52.00/accident
Idle government facilities and public utilities	$ 3.44/day	
Totals	$66.01/day	$1693/accident[a]

[a] If relocation lasts one year, the daily cost equivalent to the fixed cost of $1693 is 1693/365 = $4.64/day. The resulting total daily cost is therefore estimated to be about $71/day/household.

REFERENCE

EP-89 U.S. ENVIRONMENTAL PROTECTION AGENCY. Manual of Protective Action Guides and Protective Actions for Nuclear Incidents. EPA/520/1-75-001. March 1989.

APPENDIX

A.1 Derivation of the Cost of Relocation

This Appendix presents the derivation of the costs of relocation shown in Table 2 of the main text. It also discusses the reasoning behind the methodology used for the cases where the methodology is not straight forward. Cost numbers used in identifying costs conform to those used in the body of this report.

A.2 Moving Costs (Cost A1)

Moving cost is the only cost shown in Table 2 of this report that is sensitive to the total size of the relocation zone. This is because, as explained below, the distance the household residing just inside the boundary must move is a function of the total number of persons moved, as well as other parameters.

It is assumed that the households inside the boundary of the relocation zone are moved to areas outside the relocation zone as the boundary line is moved outwards from the center of the most highly contaminated area, and it is further assumed that the vacant houses nearest the relocation zone are always the ones chosen to house those relocated. Those households located just inside the final boundary of the relocation zone will be moved to vacant houses on the outer perimeter of the area used to house those relocated. Reflection will confirm that this correctly determines the marginal cost of moving the households at the boundary of the relocation zone, because, if the boundary had been established just one residence's width inside its final location, these households would not have had to be moved.

For the purpose of the evaluation performed here, the size of the relocation zone used is determined by a 2-rem PAG based on an SST-2 type accident (SN-82). This PAG level is chosen because it is the dose justified solely on the basis of health risk. If it had been determined that cost considerations justified a lower PAG, a larger relocation zone would have been analyzed.

The relocation zone is assumed to be elliptical with major and minor axes equal to 45 km and 15 km respectively (or 28 mi and 9.3 mi respectively). These dimensions are calculated based on an SST-2 accident with average meteorological conditions and a one-year dose commitment equal to 2 rems (SN-82). The area of this ellipse is:

Area of ellipse = 3.14 x 14 x 4.7 = 204 mi^2.

The population density within this ellipse is assumed to be 105 persons/mi^2. This value is based on the average population density within 30 miles of 91 reactor sites for all NRC administrative regions (NU-82, Fig. D.1-13). The number of persons relocated is:

Total persons relocated = 105 x 204 = 21,420.

The population density outside the relocation zone, but within 100 miles of the reactor sites is assumed to be 95 persons/mi^2 (NU-82, Fig. D.1-15). The persons relocated are assumed to move to the nearest available housing in the area surrounding the relocation zone. They are assumed to occupy only that housing in the surrounding region that is for rent or for sale. Based on the 1980 Census of Housing, this vacancy rate is 3.8 percent (BC-80). Therefore, the potential density outside the relocation zone, assuming all housing for rent or for sale is occupied by relocated households is:

(Potential density)(1-0.038) = 95.

Therefore, potential density = 98.75 persons/mi^2.

Thus the area outside the relocation zone is able to absorb 98.75 - 95 = 3.75 persons/mi^2. The area needed to absorb 21,420 persons is:

Area = 21,420/3.75 = 5708 mi^2.

Assume that the perimeter of the area needed to house those relocated is an ellipse with major and minor axes equal to (r + 14) mi and (r + 4.7) mi respectively where r is the distance from the boundary of the relocation zone to the perimeter of the relocation area needed to house those relocated. The value of r is determined from the following equation:

$3.14(r + 14)(r + 4.7) = 5708 + 204 = 5912,$

$r = 34.3$ mi.

The average length of move is, therefore, assumed to be 34.3 miles.

It is assumed that most households would not move their heavy appliances and bulky furniture. The least expensive means of moving household goods a relatively short distance is by use of a rental truck, where temporary workers are hired to do the packing, loading and unloading. Employing a moving firm to complete the entire job is substantially (about 3 to 5 times) more expensive. To move the belongings of an average 1500-1700 sq. ft. home with three bedrooms requires a 22-24-foot truck. According to Ryder Truck Rental, the one-way mileage cost for a 22-ft truck ranges from \$0.30 - \$0.50. The cost of gasoline is estimated based on a cost of \$1 per gallon, using an 8-mile per gallon estimate, provided by Ryder, for fuel efficiency. This translates into \$0.125 per mile. Combining this with \$0.40 as an average mileage cost for truck rental gives approximately \$0.55 for the value of the total cost per mile. The fixed cost for the truck is \$50.00 per day. It is estimated that each move would take a maximum of two days. The estimated fixed cost of the boxes for packing household belongings for the situation described above is \$250.00 (CO-88).

Total labor requirements for the move are based on estimates provided by local movers. To move the contents of the house described above would require a supervisor and driver, and two additional people to pack, load, and unload the personal belongings of the household. While it is assumed that, in most cases, the head of the household would drive the truck and supervise the move, the opportunity cost of this labor should be included in the calculation. A wage rate of $15 per hour, which approximates the wage of a union truck driver is used. Most moving companies employ unemployed local workers to assist in moving and pay them about $5 to $10 per hour, depending on local wages for common labor. A rate of $8 per hour is used in this calculation. The estimated total time for each move, obtained from a local moving company, is 14 hours, not including driving time. Driving time is assumed to be two hours. The fixed cost of one move is (CO-88):

Truck Rental	$100
Boxes	250
Supervisor and Driver (16 hrs at $15/hr)	240
Two laborers (2x14 hrs at $8/hr)	224
	$814

Therefore, the cost of the move to temporary housing is:

(814 + 34(0.55)) = $833

The cost of the return, one year later, is discounted one year at 3% to account for the one-year delay in expenditure where the discount factor is 0.9709:

0.9709 (814) = $808.

Therefore, the cost of the two moves is $1641.

A.3 Loss of the Use of Residence (Cost A2)

The loss of the use of residence A for the one-year time period of relocation is calculated for the average value of detached houses for the U.S. The average value for detached

houses for the U.S. for 1980 was $47,200 in 1980 dollars (BC-88, Table 1222). The adjustment to 1988 dollars, based on the consumer price index (CPI) for shelter (CE-89, Table B-58) is:

$$\frac{129.1}{81.0} = 1.59.$$

Thus the 1988 price for the average detached house is:

$47,200 (1.59) = $75,229.

Consumer surplus represents whatever extra value a household may put on their place of residence over and above its market price. This value derives from such things as access to the places of work and school, established friendships with neighbors, familiarity with the neighborhood and other non-tangible benefits received from the residence and its location. This consumer surplus is probably largely lost to household A as a result of the accident. It is also substantially lost to household B during the period of relocation due to the severe disruption of the neighborhood, the relocation of neighbors, and the closure of local shopping, as well as to the general fear of radiation contamination. It is assumed here that the consumer surplus is entirely lost to household B during the period of relocation. Since residences A and B are side be side, household A could derive no consumer surplus from residence A during the period of relocation, so loss of consumer surplus does not contribute to the loss of use of residence A during relocation.

Assume a 20% loss in value of the residence due to the perception of risk from residual contamination. As mentioned in the body of this report, the choice of 20% is arbitrary because this value can be determined only in the event of an actual accident at a nuclear power reactor that causes sufficient contamination that households are relocated. It is further assumed that the cost of decontaminating residence A is 5% of its value. Thus, it is assumed that the value of the residence before being decontaminated is 75% of its value before the

accident. The value of the residence before decontamination is, therefore:

0.75 ($75,229) = $56,421.

Assume the useful future life of the residence is 30 years and that the long run annual rate of interest (independent of inflation) is 3%. The amortization factor is 0.051019. Therefore the annual cost is:

0.051019 ($56,421) = $2,879,

and the daily cost is:

$2.879/365 = $7.89/day.

A.4 Households Extra Living Costs (Cost A4)

The forced relocation of household A imposes a loss in the overall quality of life. This loss stems from such things as differences in the size and layout of the replacement residence, an inconvenient or undesirable set of amenities provided by the residence, and lack of knowledge of the local community and shopping locations. All of these are aside from the qualities included in consumer surplus, as discussed above. We assume this loss could be compensated for by increased income. It is assumed that it would require a 5% increase in after tax income to restore this quality of life. Annual after tax income for 1985 was $22,646 per household (BC-88, Table 695). The adjustment to 1988 dollars based on the CPI for all items is 118.3/107.6 = 1.10 (CE-89, Table B-58). Thus, after tax income for 1988 was 1.1 (22,646) = 24,898. Therefore, extra living costs are:

0.05 (24,898)/365 = $3.41/day.

A.5 Extra Maintenance and Security Costs for Vacant Property (Cost A5)

It is assumed that the maintenance requirements for residence A during the time it is vacated is double the

requirements when it is occupied. Therefore, the extra costs of maintenance can be calculated based on the normal cost of maintenance. Total costs of residential maintenance in 1983 were $\$18{,}128 \times 10^6$ (BC-88, Table 1229). The total number of housing units in 1983 were $93{,}519 \times 10^3$ (BC-88, Table 1221). Assuming the maintenance cost for 1-unit structures is the same as for other types of housing, the average maintenance cost for 1-unit structures in 1983 was:

$$\frac{\$18{,}128 \times 10^6}{93{,}519 \times 10^3} = \$193/\text{structure}.$$

The adjustment factor for 1988 dollars based on the CPI for home maintenance and repairs (CE-89, Table B-59) is:

$$114.7/99.9 = 1.148,$$

and the cost in 1988 dollars is:

$$1.148(\$193) = \$223/\text{year or } \$0.61/\text{day}.$$

Local insurers in Richland, Washington; Chicago, Illinois; and Portland, Oregon, were contacted to obtain estimates of the premium required to insure a 1500-sq. ft., vacant, single-family detached home against ordinary risks under ordinary conditions (CO-88). The estimates varied widely from carrier to carrier at each location as well as from location to location. The premium cost of insuring a vacated house in Richland is approximately $30 to $250 per year, depending on the carrier. In Chicago, that cost ranges from $500 to $1500 per year with the qualification that some residences would be considered uninsurable. In Portland, the premium is about $300 to $700 per year. We used a cost of $500 per year as an estimate that falls within the range of these costs. Therefore, security costs are estimated to be $1.37/day.

Extra maintenance and security costs sum to $1.98/day.

A.6 Extra Travel Costs to Household (Cost A8)

It is assumed that major arterial highways will be reopened for use soon after the accident and that their use will be unaffected by the choice of the boundary of the restricted zone.

Travel to work, school, church, and to visit friends and relatives is assumed to be the only travel that is increased as a result of relocation. The yearly trips and the number of miles traveled in 1983 (BC-88, Table 1005) were:

	Trips (x 10^6)	Miles (x 10^6)	Av. Miles
To Work	35,375	302,185	8.5
To School and Church	7,444	40,990	5.5
To Visit Friends and Relatives	12,543	135,801	10.8
Totals	55,362	478,976	8.65

The number of households in the U.S. in 1983 was 83,918 x 10^3 (BC-88, Table 56). The average trips per day per household were:

$$\frac{55{,}362 \times 10^6}{83{,}918 \times 10^3 \times 365} = 1.81 \text{ trips/household/day.}$$

Assume that one-half of these trips are replaced by equal length trips from the new location (note that the household was on the edge of the restricted zone, so it may be reasonable to expect that about one-half of these activities will be relocated outside the restricted zone or shut down, in which case a substitute activity may be found). Therefore, assume that 1.81/2 = 0.9 trips per day per household are still undertaken, to the old locations, and that the round-trip mileage to these locations is increased by 40 miles (note that the household is assumed to have moved 34 miles, so the 40-mile round trip seems reasonable). Travel costs by automobile were $0.272 per mile in

1985 (BC-88, Table 1010). This cost can be adjusted to 1988 dollars by the CPI for private transportation (CE-89, Table B-59):

$$\frac{107.6}{106.2}\ (0.272) = \$.276.$$

Therefore additional travel cost to the relocated household is estimated to be:

$$0.9\ (\$.276)(40) = \$9.94.$$

A.7 Extra Travel by Others in the Region of the Household (Cost A9)

The presence of the restricted zone forces changes in the patterns of automobile travel in the region surrounding the restricted zone. Households not relocated can be expected to experience increased travel because streets and roads in the restricted zone are closed. The problem is to estimate the increased travel resulting from the addition of a single residence to the restricted zone.

This estimate is based on an urban area where streets are laid out on a rectangular grid. Assume there are 12 block lengths per mile in one direction and 14 block lengths per mile in the other, so that the average block length is about 13 per mile. Assume there are 10 residences on each full block.

As the boundary of the restricted zone is moved outwards, the addition of the first residence on the first block across the street from the restricted zone forces the closure of the street between that residence and the restricted zone. Assume that all traffic using that street is diverted two block lengths (a one-block length deviation outwards from the restricted zone and a one-block return). The average total deviation is 2/13 miles. The addition of the other residences on that same block to the restricted zone causes no further increase in travel distances. If a residence on another block on the same street is added to

the restricted zone, no additional travel is imposed. However, if a residence on a block further out from the restricted zone is added, another 2/13 miles of extra travel is imposed. For the purpose of this estimation, it is assumed that the average additional travel imposed by the addition of a block of houses to the restricted zone is 1/13 miles. Since it is assumed that there are 10 residences on each block, the average increase in travel distance for each residence added to the restricted zone is (1/10)(1/13) = 0.0077 miles.

The average vehicle miles traveled on local, urban streets for 1985 was 924 miles per day per mile of street (BC-88, Table 1000). There are two primary considerations in evaluating whether this is an appropriate estimate for this case. First, all residents in the neighborhood that resided in the restricted zone are relocated, so their contribution to this local travel is removed. Since the street under discussion is immediately adjacent to the restricted zone, relocation can be expected to remove upwards of one-half of the traffic on the local street. Secondly, those people still residing in the area, and traveling to points across the relocation zone are forced to divert their route of travel around the restricted zone increasing the travel on local streets immediately adjacent to the restricted zone. It is assumed here that these two influences, which counteract each other, will leave this estimate unchanged. Therefore, the extra travel caused by adding a residence to the restricted zone is estimated to be (0.0077)(924) = 7.1 miles per day. The cost to operate an automobile is $0.276 per mile in 1988 dollars, as used above. Therefore, the extra travel cost to others in the region from adding one residence to the restricted zone is estimated to be 7.1(0.276) = $1.96 per day.

A.8 Cost of Lost Business Activity

The relocation of the large number of households from the restricted zone will force the closure of all retail and service

businesses located in the restricted zone. For the purpose of this estimate it is assumed that these businesses are distributed within the restricted zone in the same proportion as in the entire country. Therefore, the cost of this loss in business can be calculated on a per household basis. It is assumed that the goods and services provided by these businesses will be replaced by similar goods and services provided by other business establishments in the vicinity of the relocated households. Since the relocated households will be thinly dispersed over the entire area absorbing the relocated households it is assumed that the closed businesses are unable to relocate. This is because they have no assurance they will be able to retain any significant proportion of their former business in competition with the businesses already established in the region surrounding the relocation zone. Therefore, it is assumed that all inputs to businesses (i.e., all labor and the capital investment) are unemployed for the duration of the relocation.

As stated in the body of this report, the appropriate measure of the loss of these business activities is the value they add to the gross national product. The gross product contributed by retail trade and by services in 1986 were $\$407.7 \times 10^9$ and $\$700.2 \times 10^9$ respectively. The value of retail trade can be adjusted to 1988 dollars by use of the CPI for all commodities (CE-89, Table B-60):

$$\frac{111.5}{104.4} (407.9 \times 10^9) = \$436.5 \times 10^9.$$

Similarly , the value of services can be adjusted to 1988 dollars by use of the CPI for all services (CE-89, Table B-60):

$$\frac{125.7}{115.4} (\$700.2 \times 10^9) = \$762.7 \times 10^9$$

The value of retail trade and services is then summed to give $\$1198 \times 10^9$ in 1988 dollars. This value can be adjusted for population growth, where it is assumed that the per capita

consumption of retail goods and services remained constant from 1986 to 1988 (CE-89,Table B-31):

$$\frac{243{,}915 \times 10^3}{241{,}613 \times 10^3} (\$1198 \times 10^9) = \$1221 \times 10^9$$

There are 89,479,000 households in the U.S., therefore, the business loss per household per day is (BC-88, Table 56):

$$\frac{1221 \times 10^9}{89{,}479{,}000 \times 365} = \$37.39/\text{household/day}$$

A.9 Cost of Lost Business Inventory

Food inventories at any one time are estimated to be $18.6 billion (BC-88, Table 1307). As cited above, the number of households in 1987 was 89,479,000. Therefore, the inventory per household is:

$$\frac{18.6 \times 10^9}{89{,}479{,}000} = \$208/\text{household}$$

Assume that 25% of food inventories are lost as a result of the accident. Therefore, the loss in inventories is:

$0.25(\$208) = \$52.00$/household.

A.10 Loss of Use of Local Government Facilities and Public Utilities

The relocation of the large number of households from the restricted zone will idle or reduce the use of government facilities and services, and public utilities. Examples of the publicly provided facilities and services likely to be affected are streets, traffic control systems, schools, libraries, parks, playgrounds, recreational facilities, and sanitation and water service. Electrical power, natural gas and telephone service are the primary public utilities affected.

Although the facilities and services lost to the households that relocate will be replaced by similar facilities and services at their place of relocation, the plants and equipment serving their old residences are idle during the period of relocation. The fact that the facilities and services at the pre-relocation residences are replaced by similar facilities and services at the replacement residences does not necessarily imply that idle capacity at one location is simply being traded for idle capacity at another location. It is normal that there be vacant housing, both for rent and for sale, in any area. This means that there is slack in the system which, in a sense, is planned for in the provision of these facilities and services. The national average vacancy rate (housing for rent and for sale) was 3.8 percent in 1980 as used in deriving the cost of moving. In the large scale relocation investigated here it is to be expected that the provision of the facilities and services at the new location overstresses the system because the normal vacancy rate is reduced. This is the justification for considering the idling or under utilization of these facilities and services in the relocation zone to be a cost of relocation.

These estimates are based on the capital invested in state and local government, and in domestic telephones, electric utilities and privately owned gas utilities.

Gross stock in equipment and structures owned by state and local government was estimated to be $\$2643 \times 10^9$ in 1986 (BC-88, Table 722). This is adjusted to 1988 dollars by use of the gross national product (GNP) deflator for state and local government purchases of goods and services (CE-89, Table B-3):

$$\frac{130.2}{115.3} (\$2643 \times 10^9) = \$2985 \times 10^9.$$

Since there are 89,479,000 households in the U.S. gross stock per household is:

$$\frac{2985 \times 10^9}{89,479,000} = \$33,350/\text{household}.$$

A problem is to estimate how much of this total is affected by relocation. Many services provided by state and local governments are unlikely to be affected by relocation. Examples are: administration of state and local governments, administration of the court system, operation and maintenance of major highways, operation of the national guard, colleges and universities, and state police. It is assumed here that the use of one-half of the total capital investment by state and local governments is lost to each household that relocates. Therefore, the gross stock and equipment owned by state and local government that is idled during relocation is estimated to be $16,675 per household.

The gross book cost of plants owned by domestic telephones was $\$195 \times 10^9$ in 1985 (BC-88, Table 881). Investment in electric utility plants was $\$397 \times 10^9$, and investment in gas utility plants was $\$88 \times 10^9$ in 1985 (BC-88, Tables 936 and 941). Since all of these costs are expressed in 1985 dollars, they can be summed and then converted to 1988 dollars. The estimated gross investment in stock and equipment in telephones, electric and gas service was $\$680 \times 10^9$ in 1985. This is converted to 1988 dollars by the GNP deflator for gross domestic investment (CE-89, Table B-3):

$$\frac{105.2}{100.6} (\$680 \times 10^9) = \$711 \times 10^9.$$

This can than be expressed as a gross stock per household:

$$\frac{\$711 \times 10^9}{89,564,000} = \$7,945/\text{household}.$$

This can now be summed to the gross stock and equipment owned by State and local government calculated above:

$16,675 + 7,945 = \$24,620/\text{household}.$

Assume the useful future life of this capital equipment is 30 years and that the long run annual rate of interest,

independent of inflation, is 3 percent. The amortization factor is 0.051019. The annual cost is:

.051019($24,620) = $1256/household.

Therefore, the loss of these services, on a per day basis is:

$1256/365 = $3.44/household/day.

REFERENCES

BC-80 BUREAU OF THE CENSUS. 1980. Census of Housing, Vol. 1, Chapter 1, Part 1, United States Summary.

BC-88 BUREAU OF THE CENSUS. Statistical Abstract of the U.S., December 1988.

CE 89 COUNCIL OF ECONOMIC ADVISORS. Economic Report of the President, January 1989.

CO-88 Private Telephone Conversations Undertaken by EPA Contractor, June 1988.

NU-82 U.S. NUCLEAR REGULATORY COMMISSION. Technical Guidance for Siting Criteria Development, NUREG/CR-2239, December 1982.

SN-82 SANDIA NATIONAL LABORATORIES. Technical Guidance for Siting Criteria Development. NUREG-CR 2239. U.S. Nuclear Regulatory Commission, Washington, DC 20555, December 1982.

☆U.S. Government Printing Office : 1989 - 617-003/04905