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The Benefits and Costs of Regulatory Reforms for Superfund

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United States v. Ottati & Goss [arose] out of a ten-year effort

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to force cleanup of a toxic waste dump in southern New Hampshire. The site was mostly cleaned up. All but one of the private parties had settled. The remaining private party litigated the cost of cleaning up the last little bit, a cost of about \$9.3 million to remove a small amount of highly diluted PCBs and "volatile organic compounds" (benzene and gasoline components) by incinerating the dirt. How much extra safety did this \$9.3 million buy? The forty-thousand-page record of this ten-year effort indicated (and all the parties seemed to agree) that, without the extra expenditure, the waste dump was clean enough for children playing on the site to eat small amounts of dirt daily for 70 days each year without significant harm. Burning the soil would have made it clean enough for the children to eat small amounts daily for 245 days per year without significant harm. But there were no dirt-eating children playing in the area, for it was a swamp. Nor were dirt-eating children likely to appear there, for future building seemed unlikely. The parties also agreed that at least half of the volatile organic chemicals would likely evaporate by the year 2000.¹

I. INTRODUCTION

A number of bills designed to increase the role of risk assessment and benefit-cost analysis in regulatory decision making were introduced by the 104th Congress. Many of the proposals would have greatly altered regulatory agencies' current practices. Some risk reform proposals would have required federal regulatory agencies to use central tendency estimates—instead of the conservative assumptions they often use today—to estimate levels of exposure in risk analyses, and to clearly articulate the assumptions embedded in risk assessments and benefit-cost analysis, so they can be analyzed and debated by the regulatory community.² With respect to benefit-cost analysis, some bills included a supermandate provision which would have required benefit-cost analysis in all circumstances. The supermandate provision would have trumped both existing statutes which prohibit balancing of benefits and costs,³ as well as the executive order which exempts agencies from using a benefit-cost test when such a test conflicts with the agency's legislative mandate.⁴ Another, more limited, proposal would have required Environmental Protection Agency (EPA) analysts to

1. STEPHEN BREYER, *BREAKING THE VICIOUS CIRCLE* 11-12 (1993).

2. H.R. 1022, 104th Cong. § 105(2) (1995).

3. *Risk Assessment: House Considering Broad Mandate to Apply Cost-Benefit Provision to All Laws*, 18 Chem. Reg. Rep. (BNA) 1478 (Jan. 13, 1995).

4. Exec. Order No. 12,866, 3 C.F.R. 638 (1993), *reprinted in* 5 U.S.C. § 601 (1994).

undertake an explicit benefit-cost analysis for those Superfund site cleanups which cost more than \$5 million.⁵

The congressional battle over these and other regulatory reforms ignited a debate about how such procedural reforms would affect regulatory policy. Proponents of the reform bills argued that the reforms would enhance efficiency. Many of the proposed reforms reflect economists' views that regulation would be more efficient if federal agencies based regulatory decisions on analyses that consider a range of assumptions, explained the risks their regulations address in terms of risks assumed to exist in other areas of our lives, and explicitly balanced the benefits and costs of the rules they proposed.⁶ Scholars such as Cass Sunstein make the case that benefit-cost analysis can systematically produce information on the impacts of regulatory decisions, focus attention on such decisions' intended and unintended effects, and assist agencies in taking into account both the quantifiable and unquantifiable effects of regulatory decisions.⁷

In contrast, many opponents of regulatory reform saw the proposed changes as a thinly veiled attempt to reduce rather than improve regulation, noting that regulatory reform coincided with the first election of a Republican House in forty years. Reform opponents have offered a number of critiques of the reform bills: benefit-cost analysis would weaken regulatory protection if the costs of regulation are more easily quantified than the benefits;⁸ the lack of knowledge in areas such as epidemiology and toxicology may cause risks to human health to be underestimated;⁹ and the divergence of public perceptions and expert analyses may result in the assessments of risk experts overriding the "preferences" of those affected by a regulation.¹⁰

Reform opponents also argued that the bills presented many procedural problems. Some bills explicitly provided for judicial challenges to the economic analyses, which would lead to increased litigation and unnecessary involvement of the courts in

5. H.R. 1022, 104th Cong. § 204 (1995).

6. *Id.* §§ 105(3), 201(a)(4) (1995).

7. See Cass R. Sunstein, *Legislative Foreword: Congress, Constitutional Moments, and the Cost-Benefit State*, 48 STAN. L. REV. 247 (1996).

8. *GOP Contract Would Undermine Enforcement of Environmental Regulations, Groups Say*, 25 ENV'T REP. (BNA) 1691 (Jan. 6, 1995).

9. *See generally Regulatory Reform Bill Poses Threat to Environmental Justice, Activists Say*, 25 ENV'T REP. (BNA) 2119 (Mar. 3, 1995).

10. See Sunstein, *supra* note 7, at 265 tbl. 3.

regulatory decision making.¹¹ The establishment of peer review panels to evaluate the scientific bases of regulatory proposals would add additional delays. The increase in reporting requirements for regulators spurred by the detailed retrospective regulatory assessments and other reports to Congress required by some bills, coupled with proposed cuts in agency budgets, would lead to regulatory gridlock.¹²

The conflicting views of the regulatory reforms, as either efficiency-enhancing or strategically burdensome, reflect a broader controversy over the general role of the administrative procedures that govern regulatory action. Traditional legal theories hold that legislation such as the Administrative Procedures Act establishes a framework to ensure openness, fairness, and public participation in rulemaking. Under this view, the rulemaking process itself is a normative good, since people value the democratic method of decision making embodied in the open and participatory process, and the information exchange generated by mechanisms such as notice and comment rulemaking generally improves the rulemaking outcomes.¹³

More recent literature describes administrative procedures as an instrument of political control. This theory, associated most strongly with the trio Mathew McCubbins, Roger Noll and Barry Weingast,¹⁴ details how members of Congress attempt to use administrative procedures, such as the design of the regulatory decision-making environment, to achieve political ends. Legislated administrative procedures help reelection-oriented Congress mem-

11. *Unintended Consequences for Business Predicted if Existing Legislation Enacted*, 19 Chem. Reg. Rep. (BNA) 201 (May 19, 1995); *House Bill's Risk Provisions Called "Prescription for Gridlock"* by Chafee, 25 Env't Rep. (BNA) 2037 (Feb. 24, 1995).

12. See *Id.*

13. See Peter H. Aranson et al., *A Theory of Legislative Delegation*, 68 CORNELL L. REV. 1 (1982); Cynthia R. Farina, *Statutory Interpretation and the Balance of Power in the Administrative State*, 89 COLUM. L. REV. 452 (1989); Jerry L. Mashaw, *Prodelegation: Why Administrators Should Make Political Decisions*, 1 J.L. ECON. & ORG. 81 (1985); Richard B. Stewart, *The Reformation of American Administrative Law*, 88 HARV. L. REV. 1669 (1975); John S. Wiley, Jr., *A Capture Theory of Antitrust Federalism*, 99 HARV. L. REV. 713 (1986).

14. See Mathew D. McCubbins et al., *Administrative Procedures as Instruments of Political Control*, 3 J.L. ECON. & ORG. 243 (1987) [hereinafter McCubbins et al., *Administrative Procedures*]; Mathew McCubbins et al., *Structure and Process, Politics and Policy: Administrative Arrangements and the Political Control of Agencies*, 75 VA. L. REV. 499 (1989); McNollgast, *Positive Canons: The Role of Legislative Bargains in Statutory Interpretation*, 80 GEO. L.J. 705 (1992). See also Murray J. Horn & Kenneth A. Shepsle, *Commentary on "Administrative Arrangements and the Political Control of Agencies:" Administrative Process and Organizational Form as Legislative Responses to Agency Costs*, 75 VA. L. REV. 499 (1989); Jonathan R. Macey, *Organizational Design and Political Control of Administrative Agencies*, 8 J.L. ECON. & ORG. 93 (1992).

bers serve the interests of their constituents, including voters and campaign donors. Examples of the strategic use of administrative procedures to reward interest groups include laws requiring a particular burden of proof,¹⁵ mandating that agencies consider the environmental impacts of their actions,¹⁶ and providing avenues for public participation in federal agency decision making.¹⁷

In this article we explore the issues raised in the debate over regulatory reform by examining the potential effects of implementing a mix of the proposed reforms within a highly visible and controversial environmental program, the U.S. Environmental Protection Agency's remediation of hazardous waste sites under the Superfund program. In Part II we describe EPA's current risk assessment procedures and other practices relating to Superfund implementation. In Part III we offer a qualitative description of how various proposed benefit-cost and risk assessment changes would have affected EPA's analyses and decisions under the Superfund program. In Part IV we provide quantitative data revealing the effects that different proposed policy reforms would have had on the Superfund program, had they been implemented. For a nationwide sample of 150 sites for which EPA made cleanup decisions in 1991-92, we examine how the sites selected for remediation would have been evaluated and how remediation decisions would have differed if various benefit-cost and risk assessment reforms had been in place. This examination demonstrates the potential gains in efficiency which could be achieved within the Superfund program through regulatory reform and indicates the degree to which implementation of such reform is feasible. In Part V, we conclude that the application of benefit-cost principles in the Superfund program could provide greater protection of human health and the environment through a program focused on the

15. For example, under the federal Food, Drug and Cosmetic Act a company must prove that a drug is safe before bringing it to market, while under the Toxic Substances Control Act, EPA must prove that a chemical is harmful to prevent its marketing. See McCubbins et al., *Administrative Procedures*, *supra* note 14.

16. For example, the National Environmental Policy Act requires that regulators at least develop information on the environmental impacts of their decisions. 42 U.S.C. §§ 4321-4370 (1994).

17. For example, the Emergency Planning and Community Right-To-Know Act (EPCRA) allows interested parties to petition EPA to remove chemicals from the list which governs industry pollutant discharge and release reporting under the Toxics Release Inventory program. In one instance, EPA removed the reporting requirement under EPCRA for the chemical di-n-octyl phthalate (DnOP) after the Vista Chemical Company petitioned for its removal. See *Facilities No Longer Required to Report DnOP on EPCRA's Toxic Release Inventory*, 17 Chem. Reg. Rep. (BNA) 1238 (Oct. 8, 1993).

balancing of real risks against cleanup costs. The calculations we present in Part V document the extent to which EPA can reduce cleanup expenditures without jeopardizing the objective of reducing risks.

II. HOW EPA IMPLEMENTS SUPERFUND TODAY

A. *Assessment of Health Risks*

EPA currently bases its hazardous waste site remediation decisions—such as which sites to clean up first, and how clean to make those sites—in part on its evaluation of the health risks associated with each particular waste site. Since estimates of risk levels can trigger certain actions in the Superfund program, it is useful to analyze first the general nature of risk assessment and its particular implementation in the Superfund program. The National Research Council (NRC) defines risk assessment as a four-step process involving (1) hazard identification (examining whether exposure to a substance generates adverse health outcomes), (2) dose-response assessment (exploring the relationship between the dose of a substance and the probability of the adverse health outcome), (3) exposure assessment (identifying the intensity, frequency, and duration of an individual's exposure to the substance), and (4) risk characterization (estimating the magnitude and/or probability that an adverse health reaction will occur from exposure to a substance).¹⁸ NRC's definition distinguishes *risk assessment*—the quantitative calculation of the probability of cancer or likelihood of noncancer health effects such as kidney disease or birth defects, from *risk management*—decisions about what levels of risk are acceptable and how risks might be remediated.¹⁹

Each step of the risk assessment and management procedures has been the topic of significant debate. For hazard identification, questions arise about using animal data or fragmentary evidence from small epidemiology studies as a basis for identifying which substances may be hazardous to humans.²⁰ Within dose-response models, analysts face the problem of extrapolating the probability of an adverse reaction at low doses of exposure from data on high

18. NAT'L RES. COUNCIL, NAT'L ACAD. OF SCI., *RISK ASSESSMENT IN THE FEDERAL GOVERNMENT: MANAGING THE PROCESS* 20-33 (1983).

19. *See id.* at 18-19.

20. *See* Robert B. Kuehn, *The Environmental Justice Implications of Quantitative Risk Assessment*, 1996 U. ILL. L. REV. 103, 113; Howard Latin, *Good Science, Bad Regulation, and Toxic Risk Assessment*, 5 YALE J. ON REG. 89, 98-100 (1988); Mark Eliot Shere, *The Myth of Meaningful Environmental Risk Assessment*, 19 HARV. ENVTL. L. REV. 409, 432-36 (1995).

doses of exposure, and deciding whether a threshold exists below which no harm is expected.²¹ Most models of cancer incidence assume there is no "safe" dose of a carcinogen, or no exposure level below which no harm is expected. On the other hand, many models of noncancer health effects do offer concentration levels where there is no observable adverse effect (NOAEL), and concentration levels indicating the lowest observed adverse effect level (LOAEL).²² With exposure assessment, variability across individuals and different demographic groups may not be reflected in assessment assumptions, and there often is substantial uncertainty about the distribution for many parameters.²³ The final stage of risk characterization generates critiques based on the degree to which underlying assumptions are not explicitly stated, the likelihood that assumed scenarios will occur, and the extent to which estimates are reported as a range of probabilities rather than a single estimate of risk.²⁴

EPA conducts an individual risk assessment for each site on the National Priorities List (NPL), the set of sites that qualify for remediation funds. EPA analysts assess chemical concentrations at the site and then estimate the corresponding health risks associated with the site.²⁵ The health risk estimate is comprised of both

21. See Kuehn, *supra* note 20, at 116; see also Latin, *supra* note 20, at 98-100; Shere, *supra* note 20, at 436-38.

22. See OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE, U.S. ENVTL. PROTECTION AGENCY, DIRECTIVE NO. 9285.701A, RISK ASSESSMENT GUIDANCE FOR SUPERFUND, VOLUME 1: HUMAN HEALTH EVALUATION MANUAL PART A (INTERIM FINAL) 7-7, 8-11 (1989) [hereinafter HUMAN HEALTH EVALUATION MANUAL].

23. See Kuehn, *supra* note 20, at 114; see also Shere, *supra* note 20, at 438-39.

24. See Kuehn, *supra* note 20, at 114; see also Shere, *supra* note 20, at 467-68.

25. See OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE, U.S. ENVTL. PROTECTION AGENCY, DIRECTIVE NO. 9355.0-30, ROLE OF THE BASELINE RISK ASSESSMENT IN SUPERFUND REMEDY SELECTION DECISIONS 1 (1991) [hereinafter OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE DIRECTIVE].

The most precisely quantified risks are the excess cancer risks for carcinogens, which are expressed in terms of a lifetime incremental cancer probability. The noncancer risk from a given chemical is expressed as a hazard quotient, defined as the calculated exposure intake divided by the chemical's reference dose (e.g., its highest no-observed-adverse-effect level). Within a particular exposure pathway, the noncancer hazard quotients for different chemicals are added to yield an overall pathway hazard index. While the hazard index "sums" information on noncancer exposures, the fact that the severity of health consequences (e.g., skin rashes or birth defects) differs for each chemical makes aggregation of non-cancer risks difficult. Moreover, the existence of a nonzero risk does not indicate the magnitude of the risk, so the *degree* of hazard in terms of the probability of risk is not clear for non-cancer exposures. For a further description of the Superfund risk assessment process, see James T. Hamilton & W. Kip Viscusi, *Human Health Risk Assessments for Superfund*, 21 *ECOLOGY L.Q.* 573, 583-84 (1994).

calculations of individual lifetime excess cancer risks (LECRs) as well as health risks due to exposure to chemicals associated with other adverse health effects.

It is important to note that EPA's assessments of risk in the Superfund program are based upon the calculated risk levels to a potentially exposed individual. The agency does not consider the *number* of potentially exposed individuals in its calculations of cancer risks. In addition, while EPA does not explicitly state the degree of conservatism represented by its risk estimates, an examination of the agency's assumptions reveals that it often uses very conservative parameter values in its risk assessments.²⁶ For example, in an analysis of health risks associated with groundwater contaminants at Superfund sites where future residential development is feasible, EPA analysts will simply assume such development will take place, without considering the *likelihood* of such development. Such use of conservative assumptions prompted Justice Breyer's concerns with the wisdom of the Superfund approach, quoted above.

B. *Determination of Cleanup Standards*

During the early implementation of the Superfund program, some critics noted that EPA officials used the latitude provided by the legislation to reach cleanup agreements that were highly favorable to polluters.²⁷ In response to the agency's implementation of the program, Congress passed the Superfund Amendments and Reauthorization Act (SARA).²⁸ This bill directs EPA to pursue

26. The degree of conservatism adopted in risk assessment in Superfund reflects agency choices, since legislation does not require EPA to focus on "reasonable maximum exposures," or on risks to a hypothetical or actual exposed individual rather than risks to the entire population. In fact, the risk management goals established by Congress for the Superfund program are extremely vague. The legislation calls for actions "as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or the environment." Pub. L. No. 96-510, 94 Stat. 2767 § 104(a) (1980) (codified as amended at 42 U.S.C. §§ 9601-9675 (1988 & Supp. IV 1992)).

27. Joseph A. Davis, *House Subcommittees Begin Reviewing EPA Documents; Two More Officials Are Fired*, 41 CONG. Q. WKLY. 411, 412 (1983). See also James T. Hamilton, *Going by the (Informal) Book: The EPA's Use of Informal Rules in Enforcing Hazardous Waste Laws*, 7 ADVANCES IN THE STUDY OF ENTREPRENEURSHIP, INNOVATION, AND GROWTH 109 (1996); James T. Hamilton & Christopher H. Schroeder, *Strategic Regulators and The Choice of Rulemaking Procedures: The Selection of Formal vs. Informal Rules in Regulating Hazardous Waste*, 57 LAW & CONTEMP. PROBS. 111 (1994) (providing evidence on how EPA has used discretion in enunciating and enforcing hazardous waste laws).

28. Superfund Amendments and Reauthorization Act (SARA), Pub. L. No. 99-499, 100 Stat. 1613 § 9621(b)(1) (1986) (amending 42 U.S.C. §§ 9601-9675 (1988 and Supp. IV 1992)) [hereinafter SARA].

remedies that “permanently and significantly [reduce] the volume, toxicity, or mobility of hazardous substances,”²⁹ thus discouraging the selection of less costly remedies such as institutional controls, containment, or removal. SARA also requires EPA to adopt as Superfund site cleanup standards those federal environmental standards from other programs that are “applicable” or “relevant and appropriate” (ARARs), and any state environmental standards that are more stringent than the federal standards.³⁰

The latitude of EPA site managers in making cleanup decisions is further restricted by a 1991 EPA guidance memo which states that if the cumulative lifetime excess cancer risk for an individual is less than 10^{-4} and the hazard quotient is less than one (meaning the chemical exposure level for noncancer risks is below the “no risk” threshold), then cleanup is “generally not warranted unless there are adverse environmental impacts.”³¹ While the directive provides that EPA regional officials may choose to clean up sites where cancer risks are between 10^{-4} and 10^{-6} , it requires site managers to explain why action is necessary if they choose to clean up.³² Site managers’ cleanup decisions are guided also by EPA’s National Oil and Hazardous Substances Pollution Contingency Plan,³³ which offers criteria for the site managers to use in selecting cleanup remedies. Site managers may consider long-term effectiveness and permanence, reduction of toxicity, mobility or volume, short-term effectiveness, implementability, cost, state acceptance, and community acceptance in developing a remediation plan, as long as the plan protects human health and the environment and complies with applicable environmental standards from other environmental programs.³⁴

III. HOW THE SUPERFUND PROGRAM WOULD CHANGE UNDER THE PROPOSED REFORMS

If the benefit-cost analysis and risk assessment reforms debated in Congress were implemented within EPA’s Superfund program, the nature of EPA’s analyses and resulting decisions would change

29. *See id.*

30. *See id.* § 9621(d)(2)(A).

31. *See* OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE DIRECTIVE, *supra* note 25, at 1.

32. *See id.* at 4.

33. 40 C.F.R. § 300 (1995).

34. 40 C.F.R. § 300.430(e)(9) (1995).

substantially.³⁵ To illustrate how EPA's assessment of risks could change under the proposed reforms, we consider EPA's calculation of lifetime excess cancer risks for an adult Superfund site resident exposed to groundwater contaminated with the chemical trichloroethylene (TCE).³⁶ The current EPA risk assessment guidelines, outlined in the Human Health Evaluation Manual, encourage risk analysts to estimate the "reasonable maximum exposure" at a site.³⁷ In assessing the chemical concentration of TCE at the site, the analyst would use the 95th percentile of the mean concentration, or the maximum concentration detected, whichever is lower. The analyst would then make assumptions, in accordance with the "reasonable maximum exposure" guidelines, regarding parameters such as frequency of exposure (typically 350 - 365 days per year, an upper bound assumption), daily ingestion of groundwater (2.0 liters per day for adults, approximately the 90th percentile), and number of years exposed to the contamination (thirty years, approximately the 95th percentile).³⁸

Conservative assumptions are also embedded in EPA's assessment of how likely it is that a chemical will cause cancer. To assess this propensity EPA analysts use a figure called the chemical's "slope factor," which is an upper bound estimate of the probability of development of cancer per unit intake of the chemical over a lifetime. This number, obtained from an EPA database representing the agency's assessment of the research literature on chemical toxicity, may include built-in safety factors of 10 or 100 due to low dose extrapolation or the assumption that animal data correlates closely with human reactions.³⁹ EPA analysts combine all of these

35. In our analysis, we combine a mix of individual proposals from the array of proposed bills in order to examine the potential impacts of regulatory reform.

36. In an analysis of risk assessments at a sample of 78 Superfund sites, we found that TCE was the third most frequently occurring carcinogen at these sites. TCE accounted for 5% of the total chemical cancer pathways at these sites. Hamilton & Viscusi, *supra* note 25, at 637. For an example of Superfund site remediation involving TCE groundwater contamination, see *Parties Agree to Pay over \$1 Million to Contain TCE Plume in Municipal Wells*, 19 Env't Rep. (BNA) 2267 (Feb. 17, 1989).

37. See HUMAN HEALTH EVALUATION MANUAL, *supra* note 22, at 6-4. The degree of conservatism this exposure level embodies is not specified. Default assumptions for risk assessment parameters reflect different degrees of conservatism depending on the parameter.

38. Mean values for these parameter values include 1.4 liters for daily ingestion of water and nine years for exposure duration. For a discussion of the impact of conservatism on the magnitude of Superfund risk assessment, see W. Kip Viscusi et al., *The Consequences of Conservatism in Superfund Risk Assessment* (1996) (working paper, on file with the *Stanford Environmental Law Journal*).

39. See Human Health Evaluation Manual *supra* note 22, at 7-11 to 7-13.

assumptions to yield an estimate of the probability the on-site resident will contract cancer from drinking groundwater contaminated with TCE.

In contrast, in a risk assessment conducted under the proposed reforms, EPA would use a range of estimates regarding any one parameter and would produce as a result a range of estimates of cancer risk from TCE. One proposed bill, acknowledging that parameters comprising cancer risk estimates are better conveyed as distributions, would require agencies to present risk estimates based on central tendency. For example, EPA analysts would be required to calculate risk estimates using mean or median parameter values, even if analysts also choose to use more conservative assumptions in calculations.⁴⁰

Since EPA's current guidelines encourage analysts to use differing degrees of conservatism on different parameters, the degree of conservatism represented in the ultimate risk assessment is unclear. Under the reform proposals, one could actually quantify the degree of conservatism embedded in a risk estimate. This could be done by applying Monte Carlo analysis to the approach described above. In a Monte Carlo analysis, an analyst randomly picks a point on the distribution of each parameter, estimates the lifetime excess cancer risk based on these points, and then repeats the process over and over to develop an estimate of the distribution of the lifetime excess cancer risk from TCE.⁴¹ Such an approach would enable analysts to identify the degree of conservatism embodied in different points on the overall risk distribution in Superfund site analyses.

Under other proposed risk assessment reforms, EPA's exposure characterization would change dramatically. For example, where future residential development on a Superfund site is feasible, the reforms could require EPA analysts to incorporate the likelihood of different exposure scenarios in their estimates of individual risk levels, rather than automatically assuming that such development will take place.⁴² These estimates of individual risk could then be combined with U.S. census data on surrounding populations living

40. H.R. 1022, 104th Cong. § 110 (1995).

41. See James T. Hamilton & Kip Viscusi, *Agency Discretion, Coalition Drift, and Social Welfare: Did the EPA Successfully Implement Superfund Legislation?* (1996) (working paper, on file with the *Stanford Environmental Law Journal*).

42. Cancer and noncancer risks at Superfund sites arise from several sources: dermal exposure, ingestion, or inhalation of contaminated soil and water as people use a site as residents, workers, recreational users, and trespassers.

on and near a contaminated site, yielding a distribution of estimates for the number of cancer cases arising from site contamination and the number of individuals likely to be exposed to "nonsafe" levels of noncancer risks.⁴³ These calculations of population risks would provide more information than the EPA's current practice of estimating risks to a potentially exposed individual.

Risk management in Superfund—the process of determining what remedy will be selected at a site—would also radically change under the proposed reforms. For example, one proposal would require EPA to choose site remedies based on benefit-cost analysis of site cleanups.⁴⁴ EPA would explicitly consider and balance remediation costs with cancer and noncancer risks, calculating indicators such as the cost per cancer case averted in their analysis.⁴⁵ The benefit-cost analysis would indicate the additional cost of meeting more stringent cleanup targets and establish the tradeoffs embodied in the selection of permanent remedies such as treatment of contamination instead of the use of institutional controls (such as deed restrictions that prohibit future residential use), containment, or removal of wastes. Cleanup standards would change even more dramatically if the supermandate provision, described in Part I, were implemented, allowing this benefit-cost framework to supersede the requirement that EPA use ARARs as cleanup

43. Estimating the expected number of cancer cases would involve assumptions about contaminant plume size, groundwater use, and the dispersion of contaminants as one gets farther from the site.

44. The use of benefit-cost analysis would automatically alter EPA's focus from individual risks to population risks; the agency would implicitly be concerned about both the magnitude of individual risks as well as the number of individuals exposed.

45. The evaluations of reductions in noncancer risks, since these range from skin rashes to reproductive effects, will be particularly difficult. In addition, these risks are stated as ratios of exposure rather than probabilities of experiencing the adverse effect. See Human Health Evaluation Manual, *supra* note 22, at 8-15.

An ideal benefit-cost analysis of a proposed Superfund remediation would go beyond mere calculation of the cost per cancer case averted. It would also quantify natural resource damages and, to the extent possible (perhaps through contingent valuation), monetization of them. The analysis would explore synergistic effects of exposure to multiple chemicals, though there currently are few data on the toxicity of combinations of chemicals arising at Superfund sites, and would explore differences in the efficacy of cleanup alternatives. For example, what is the probability that institutional controls will not succeed in restricting access to a site? What is the chance that a landfill containment will leak over 30 years, or the likelihood that a removal action will result in contamination as the waste is being transported offsite? Differences in the contribution of the site to a community's economic output, such as the loss that would occur if institutional controls caused land to lie fallow or the gain realized from future site use if the land were made suitable for residential development, would also be part of the analysis.

goals.⁴⁶

While many analysts have speculated about the impacts of regulatory reform on environmental policy, to date no one has estimated quantitatively how these proposals would affect the implementation of the Superfund program. In the following section we use extensive risk and cost data from a sample of Superfund sites to explore how regulatory decision making would change under various benefit-cost and risk assessment reforms.

IV. EMPIRICAL ANALYSIS OF THE EFFECT OF REFORMS ON THE SUPERFUND PROGRAM

A. *Structure of Analysis*⁴⁷

In this section we examine three different scenarios representing variations on EPA regulatory policy regarding which Superfund sites qualify for remediation; two of the scenarios reflect implementation of the proposed regulatory reform measures. The first scenario—the “current policy” scenario—is the structure under existing risk assessment guidelines, and provides the baseline for discussion. The second scenario—the “no ARARs” scenario—assumes risk managers make decisions regarding which sites to remediate based on risk considerations alone, rather than on the basis of existing ARARs. Environmental standards from other state and federal programs are thus no longer binding constraints. In this scenario, we assume EPA remediates sites with cumulative individual risk of at least 10^{-4} , which represents a risk cut-off based on current EPA guidelines.⁴⁸ The third scenario—the “no future on-site residents” scenario—assumes everything in the “no ARARs”

46. Both Senate Bill 343 and House Bill 9 at one time contained or considered benefit-cost provisions that would supersede any existing laws. See *House Considering Broad Mandate to Apply Cost-Benefit Provision to All Laws*, 18 Chem. Reg. Rep. (BNA) 1478 (Jan. 13, 1995); see also *Compromise to Address “Supermandate” Adopted by Senate in Regulatory Bill*, 26 Env’t Rep. (BNA) 566 (July 14, 1995).

47. Our analysis focuses on remediation actions at Superfund sites on the National Priorities List (NPL), the set of sites that qualify for federal remediation funds. Any hazardous waste site representing an immediate threat may qualify for short-term removal actions. EPA has conducted over 3,000 removal actions at NPL and non-NPL sites since 1980, with an average cost of approximately \$500,000. These removal actions are aimed at addressing imminent health dangers. See OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE, U.S. ENVTL. PROTECTION AGENCY, EPA/540/8-90/017, *PROGRESS TOWARD IMPLEMENTING SUPERFUND, FISCAL YEAR 1989: REPORT TO CONGRESS* (1990).

48. The 10^{-4} risk figure would not be pertinent if benefit-cost analysis were our sole guide. It may, for example, be worthwhile to eliminate risks smaller than 10^{-4} if the exposed population is large and the costs of risk reduction are low. In our analysis we use a risk cutoff to demonstrate how remediations might change if attention were focused on a

scenario and imposes the additional assumption that risk assessment reforms require EPA analysts to perform risk assessments that assume no new residents will move onto the Superfund site. This scenario thus precludes EPA from including hypothetical, future on-site resident risks in their risk assessments.⁴⁹

We then cross the three scenarios with an additional element of regulatory reform: the requirement that EPA analysts undertake an explicit benefit-cost analysis for site cleanups exceeding \$5 million, and not remediate sites for which the costs of remediation exceed the benefits.⁵⁰ The \$5 million threshold itself is an implicit benefit-cost decision, for it suggests that the transaction costs associated with benefit-cost analysis are more likely to yield higher net benefits at sites with large resource expenditures than at those with lower costs of remediation. We examine this assumption and the relative benefit-cost performance of sites above and below the \$5 million cost cutoff.

In analyzing this matrix of risk reform scenarios crossed with benefit-cost reform, we consider several dimensions. First, we examine what percentage of sites have remediation costs exceeding \$5 million. Second, we consider the cleanup costs and health risks associated with each Superfund site, and determine which sites would pass a benefit-cost test (meaning which site cleanups would have costs per cancer case averted lower than specific levels). Related questions under this second dimension are: is there a difference, above or below the \$5 million cleanup cost threshold, in terms of the desirability of the remediation decisions? Are the cleanups which cost less than \$5 million (and thus would not be subject to benefit-cost analysis) more or less cost-effective? In other words, are the cleanups which cost less than \$5 million cleaning up at a lower or higher cost per cancer avoided than those cleanups

given level of risk. We then add in benefit-cost considerations explicitly by calculating the cost per cancer case averted at sites.

49. Zoning restrictions could, for example, prevent development of hazardous waste sites for residential use. An alternative approach would be to estimate the probability of future, on-site residents at sites that currently do not have on-site residents.

50. While EPA may have considered options with different costs in determining cleanup remedies, the cost of cleanup at each site in our analysis is based on the actual remedy EPA selected for the site. Costs are expressed in 1993 dollars.

Although the decisions regarding which sites to remediate are based on risk levels rather than ARARs in our "no ARARs" and "no future on-site residents" scenarios, ARARs may still have an impact on the costs of remediations examined at these sites. This result is reached because current remediation expenditures may be influenced by the requirement to meet state or federal ARARs.

which cost more than \$5 million? Third, we examine how these policy analysis concerns interact with issues pertaining to environmental equity. For example, will hazardous waste sites with higher minority populations be disproportionately affected by a policy based on benefit-cost concerns? Finally, we consider what general policy prescriptions can be offered regarding the effective targeting of resources to clean up hazardous waste sites.

B. *Benefit-Cost Analysis of Superfund Remediations in the Current Policy Scenario*

Our analysis, outlined below, demonstrates that there are few Superfund remediations for which the benefits of cleanup exceed the remediation costs. From a sample of 150 sites where remediation decisions were made in 1991-92,⁵¹ we collected extensive data on individual risk levels, cleanup costs, and remediation cleanup targets. We then used the individual chemical concentration data collected by EPA to estimate the expected number of cancer cases arising at a site over the course of thirty years,⁵² and generated estimates of noncancer effects by calculating the number of individuals exposed to levels above the NOAEL or LOAEL (e.g., sites for which the chemical exposure exceeds the exposure threshold above which noncancer risks becomes a concern).

We employed two reference points to judge the cost-effectiveness of Superfund cleanups: \$5 million and \$100 million in cleanup costs per cancer case averted. The \$5 million figure represents the midpoint of the range of estimates for the implicit value of a statistical life using evidence from the labor market wage-risk tradeoffs.⁵³ The second reference point, \$100 million, is a useful threshold because the Office of Management and Budget has

51. We used a sample of nonfederal sites representative of the NPL as a whole in terms of previous site use, risk indicators, and regional distribution.

52. We used a thirty-year period because it is the time horizon used by EPA in its risk assessments.

Our estimates of cancer cases averted by remediation were derived by combining site level data on chemical concentration with information on contaminant plume size, data on groundwater use, and site population figures. For a description of our methodology, see Hamilton & Viscusi, *supra* note 41.

53. For instance, a worker who receives \$500 extra compensation to face an annual fatality risk of 10^{-4} would have an implicit value per statistical life of \$5 million, i.e., \$500 divided by the $1/10,000$ probability to yield a value per unit risk of \$5 million. This approach is recommended for conducting benefit-cost analysis by the U.S. Office of Management and Budget (OMB). See OMB, REGULATORY PROGRAM OF THE UNITED STATES GOVERNMENT (Apr. 1, 1992-Mar. 31, 1993) (App. V). For a review of this approach, see W. KIP VISCUSI, FATAL TRADEOFFS: PUBLIC AND PRIVATE RESPONSIBILITIES FOR RISK (1992).

never rejected a proposed regulation with a cost per life saved below \$100 million.⁵⁴ The \$100 million figure is also beyond the value at which there will be mortality costs associated with the regulation (due to diversion of resources from other health-enhancing uses) that exceed the direct risk reduction effects.⁵⁵

The individual lifetime excess cancer risks estimated by EPA at the 150 sites we examined are extremely high relative to risks regulated in other programs, though if one changes the assumptions about future land use, the risk estimates drop dramatically. By EPA's current calculations, among a set of 145 sites, 126 had individual lifetime excess cancer risks that were greater than or equal to 10^{-4} . If we match the chemical concentrations at these sites with information on populations that would be exposed under current land uses, the cancer risks from Superfund sites appear much different. At the 150 sites examined, over a thirty-year period, there would be 731 excess cancer cases estimated to arise from contamination. Of this amount, 652 are concentrated at one site, the Westinghouse site in Sunnyvale, California (notable for a high concentration of polychlorinated biphenyls (PCBs)). The median number of cancer cases per site averted by remediation is 0.017. Only ten of the 150 sites had one or more expected cancer cases estimated to arise over thirty years.

Our data also demonstrate that the cost-effectiveness of remediating the 150 sites sampled is quite low. If one matches cancers with remediation expenditures, the median cost per cancer case averted is \$384 million. Overall, only 44 out of the 145 sites had a cost per cancer case averted less than \$100 million. These costs are particularly dramatic considering that these numbers were calculated using the relatively conservative exposure parameters chosen by EPA, and also do not account for the time lag before the cancer cases occur. If one assumes mean chemical concentrations and a ten-year latency period for the onset of cancers, and discounts costs as well as benefits at a rate of 3%, the 150 sites' median cost per cancer case averted is \$6.4 billion. Viewed from the perspective of cost per cancer case averted in particular, there

54. See Viscusi, *supra* note 53.

55. See W. Kip Viscusi, *Mortality Effects of Regulatory Costs and Policy Evaluation Criteria*, 25 RAND J. ECON. 94, 107 (1994); see also Randall Lutter & John F. Morrall, III, *Health-Health Analysis: A New Way to Evaluate Health and Safety Regulations*, 8 J. RISK & UNCERTAINTY 34, 49-50 (1994); Cass Sunstein, *Health-Health Tradeoffs*, 63 U. CHI. L. REV. 1533, 1544-46 (1996); W. Kip Viscusi, *Risk-Risk Analysis*, 8 J. RISK & UNCERTAINTY 5, 12 (1994).

is substantial opportunity for regulatory reform to improve the implementation of the Superfund program.

C. *Benefit-Cost Analysis of Superfund Remediations Post Regulatory Reform*

We evaluate the consequences of various regulatory reforms (represented by the "no ARARs" scenario and the "no future on-site residents" scenario, outlined above) along the following dimensions: (1) the number of sites qualifying for remediation; (2) total remediation expenditures; (3) expected cancers averted by remediation; (4) populations protected from noncancer effects; and (5) environmental equity. Our results, which demonstrate that the adoption of the proposed regulatory reforms would save a great deal of money while sacrificing little in the way of mitigated health risks, are detailed in Tables 1-5 and explained below.

1. *Number of sites that would qualify for remediation.*

Table 1 details the number of sites that would qualify for remediation under the three different scenarios. The table demonstrates that altering risk assessment and benefit-cost practices would radically change the number of sites subject to remediation.

First, as outlined above, the table demonstrates that the cost-effectiveness of the remediation decisions chosen under EPA's current regulatory regime (i.e., the cost per cancer case averted for the alternative selected at the site) is quite low, particularly for sites with total cleanup costs exceeding \$5 million. Of the 150 sites in the sample, 145 had expected cancer cases over a thirty-year period greater than zero. We restrict our analysis to this group and assume that no policy action is warranted at the five sites with zero cancer risks. Of these 145 sites, 100 sites, or 69%, had total expected cleanup costs exceeding \$5 million and thus would be subject to benefit-cost analysis under the proposed regulatory reforms. Most of the remediations at the sites in this subset would not pass a benefit-cost test, so different remediation strategies would have to be considered if regulatory reforms were adopted. Only 5% of these 100 sites have a cost per cancer case averted under \$5 million. Twenty-six percent of the 100 sites have a cost per cancer case averted less than \$100 million.⁵⁶

56. Note that these estimates utilize EPA assumptions of conservative risk levels and do not discount deferred cases of cancer. Thus, even under procedures that overstate actual cost-effectiveness, few cleanups pass a benefit-cost test.

The results are somewhat better for the forty-five sites (see Table 1: Panel B) where total costs are sufficiently low that benefit-cost analysis would not be required by the proposed regulatory reforms. For this group, 40% (eighteen sites) had cleanups chosen with costs less than \$100 million per cancer case averted, and 18% (eight sites) had cleanups that cost less than \$5 million per cancer case averted. These numbers suggest that the sites that are exempted from benefit-cost analysis because of their lower cleanup costs have a greater likelihood of passing a benefit-cost test.

Current Superfund law requires the agency to use state or federal ARARs as cleanup goals. These cleanup standards, however, could be overridden by evidence derived from benefit-cost analysis if regulatory reform legislation trumped existing statutes. If current ARARs were ignored, and action were taken only at sites where cancer risks were at least 10^{-4} , the number of sites qualifying for remediation would drop from 145 to 126. Of the 126 sites that would be addressed if ARARs could be disregarded, ninety-one sites had costs sufficient to warrant conducting a benefit-cost analysis under the proposed reforms. Only twenty-four of these sites had cleanup remedies chosen that would pass a benefit-cost test based on the \$100 million cost per cancer case averted threshold.

Existing Superfund risk assessment guidelines encourage analysts to consider exposure pathways for on-site residents at Superfund sites, even if the area today is uninhabited or used as an industrial site. Table 1 indicates that if EPA analysts considered only actual risks based on current land use patterns,⁵⁷ rather than risks based on future, hypothetical on-site residents (as the case would be under the "no future on-site residents" scenario), a remediation policy of cleaning up only those sites with risks of at least 10^{-4} would yield a total of 86 sites subject to remediation out of 145. Of the sixty-eight sites where the costs would warrant benefit-cost analysis, just over a quarter have a cleanup cost under \$100 million per cancer case averted; only 6% would have a cleanup cost under \$5 million per case of cancer averted.

57. A more sophisticated application of risk assessment would estimate the probability that residents would move on site in the future, based on surrounding land uses and trends in residential growth in the area. This probability would then be multiplied by the future on-site resident risk to yield an expected risk for this population. The role of policy decisions such as zoning restrictions in influencing this probability would merit consideration as well.

2. *Total expenditures for remediation of Superfund sites.*

Implementing regulatory reforms requiring benefit-cost analysis would decrease the number of sites that would be remediated, substantially decreasing the total expenditures for the Superfund program. Table 2 examines the cost levels for the different policy scenarios considered in Table 1. A total of \$2.2 billion will be spent in cleanup costs at the 145 sites under current policy. If the remedies selected remain unchanged, but the number of sites remediated declined because decisions regarding which sites to clean up were made only on the basis of cancer risks rather than ARARs, as would be the case under the "no ARARs" scenario, \$2.0 billion would be spent on cleanup. Cleanup costs drop to \$1.6 billion if potential risks from future on-site residents do not trigger cleanups.

As one would expect, the total remediation costs are much greater at sites above the \$5 million total cleanup cost trigger: \$2.1 billion versus \$82.2 million, despite the fact that one-third of the sites falls below the \$5 million threshold. By focusing on the two-thirds of the sites with expenditures large enough to warrant a benefit-cost analysis, the EPA would examine 96% of expenditures. Within each scenario, a small percentage of the total expenditures is spent at sites where the currently selected remedy yields a cost per cancer case averted case that passes a benefit-cost test. For the larger sites with costs above \$5 million, a total of \$72 million is spent at sites with a cleanup cost per cancer case averted below \$5 million, and \$593 million is spent at sites with a cleanup cost per cancer case averted below \$100 million. More than \$1.4 billion in costs at these larger sites is spent to reduce cancers at a cleanup cost above \$100 million per cancer case averted. For the smaller sites with total cleanup costs less than \$5 million, \$3.5 million is spent at sites where a remediation cost per case of cancer averted is below \$5 million, and \$25 million is spent to reduce cancer cases at a cleanup cost below \$100 million per cancer case averted. The remaining \$57 million is spent on cancer prevention at a rate above \$100 million per cancer case averted.

More widespread use of benefit-cost analysis in determining which sites to remediate thus offers the potential for large savings in the Superfund program. If EPA remediation decisions were made based on actual risks (rather than ARARs), the number of sites remediated drops from 145 to 126 and expenditures drop by \$150 million. Ruling out hypothetical risks to future on-site resi-

dents reduces the number of sites to eighty-six, cutting cleanup costs by an additional \$420 million. If one recalculates the cleanup costs of those sites which do not pass the benefit-cost test, and assumes alternative remedies instead of the remedy actually implemented, costs would drop even further.

3. *Expected health problems averted by remediation.*

Under the reform scenarios, while both the number of sites that would qualify for remediation and the total amount of Superfund cleanup expenditures would dramatically decrease, the vast majority of cancer cases would still be averted since the sites that would qualify for remediation are the sites that pose greater cancer risks (see Table 3). Remediation of the full sample of 145 sites would avoid 731 estimated cancers arising over thirty years from site contamination. Basing decisions to remediate on risk levels of 10^{-4} or higher reduces the number of sites remediated to 126, but would still avert 713 cancers. Ruling out remediations based on risks to future on-site residents reduces the number of sites remediated to eighty-six, but does not significantly impact the number of cancer cases averted, which would shrink only to 710. Even when remediation decisions are generally based on current land uses rather than hypothetical future residential use, the cleanups avert the vast majority of cancers arising from the full sample of sites.

All but two of the total cancer cases averted are at sites with costs that would warrant a benefit-cost test. Perhaps most striking is that the requirement of benefit-cost tests for sites with total cleanup costs over \$5 million captures most of the cases of cancer that could be prevented. If EPA remediated only those sites subject to benefit-cost analysis which can be cleaned up for less than \$5 million per cancer case averted, 704 of the expected 731 cancer cases would be averted. With a \$100 million cost per cancer case cutoff, 726 out of the 731 expected cases would be prevented.

Implementation of a benefit-cost test would yield similar results for exposure to noncancer health risks, even though the test focuses on cancer effects. As Table 4 illustrates, regulatory reform would reduce expenditures while still protecting a significant number of residents from exposure to noncancer risks. For the sample of 145 sites, 113,000 residents living within one mile of a contaminated site face exposure to at least one chemical with a chemical exposure level above the no risk threshold. For the "no

ARARs" scenario, the number of those protected drops by only 3,000 people to 110,000. Remediation of sites under the "no future on-site resident scenario" would continue to protect 97,000 people (86% of the original number protected by remediation of 145 sites). Restricting site cleanups to those that passed a benefit-cost test would address most of these noncancer exposures. For example, remediating only those sites that can be cleaned up for less than \$5 million per cancer case averted would protect 70,500 (68,000 plus 2,500) people from noncancer risks; remediating only those sites that can be cleaned up for less than \$100 million per cancer case averted protects over 100,000 (97,000 plus 3,400) of the 113,000 people exposed to such health risks.

Because cancer and noncancer health risks exhibit a strong correlation, the vast majority of noncancer exposures can be averted by remediating sites that pass a benefit-cost analysis whereby the cost per cancer case averted is less than \$100 million. However, in a full benefit-cost analysis, EPA decisionmakers would collect more information on the magnitudes and harms of noncancer effects. This might lead to even more noncancer effects being addressed at the sample sites.

4. *Natural resource considerations.*

Proposed Superfund policies such as cleaning up sites on the basis of risk levels rather than ARARs, excluding hypothetical future risks, and applying benefit-cost tests to determine what sites to remediate all decrease remediation costs while preserving high levels of protection from cancer and noncancer risks. Two additional criteria are relevant in evaluating policy choices: the prevention of natural resource damage and the exposure of different demographic groups to different levels of health risks (i.e., environmental equity). According to EPA survey data, environmental concerns served as the basis for cleanup goals at only twenty-one of the 145 sample sites.⁵⁸ If potential on-site future residents did not drive remediation decisions, only eight of the twenty-one sites would still be protected. Of the twenty-one sites with assessed risks relating to natural resource damage, only four were cleaned up at a cost per cancer case averted of less than \$100 million. These numbers suggest that since natural resource damages may not be strongly correlated to cancer risks, adequate protection against nat-

58. Search of Remedial Project Managers Site Database, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. (1993).

ural resource damage would require that risk analysts explicitly incorporate measures of natural resource damages into remediation decisions.⁵⁹

5. *Environmental equity concerns.*

Risk assessment is frequently criticized for generating policies that have a negative impact on minority communities.⁶⁰ Such criticisms may be especially relevant to the Superfund effort since current Superfund guidelines do not incorporate synergistic effects of exposures to multiple chemicals (due to a lack of toxicity data).⁶¹ Risks to minorities, who are more likely to experience multiple exposures, may therefore be undercounted.⁶² And while some communities may benefit from hiring technical expertise to critique EPA's analysis, minority communities are typically less able to afford such consultation. Although Superfund has a technical assistance program that funds analysis for local communities, our research indicates that minority communities are much less likely to receive these grants than other communities.⁶³

The proposed risk reform legislation however, will not disproportionately harm minority populations. For the purpose of this assessment we define the minority population around a site as the total population minus non-Hispanic whites. Minorities would thus include African Americans, Hispanics, Asians, Native Americans, and those defined as other races in the census. Table 5

59. For a discussion of natural resource damages and Superfund, see Richard B. Stewart, *Liability for Natural Resource Injury: Beyond Tort*, in *ANALYZING SUPERFUND: ECONOMICS, SCIENCE, AND LAW* 219 (Richard L. Revesz & Richard B. Stewart eds., 1995).

60. Kuehn, *supra* note 20 at 106-07.

61. James T. Hamilton & W. Kip Viscusi, *Estimating Environmental Equity: Who Bears Risks at Superfund Sites?* (1996) (working paper, on file with the *Stanford Environmental Law Journal*) (indicating that for residents living within one mile of Superfund sites, the mean number of polluting facilities/sites tracked in five different EPA pollution databases within one mile of these Superfund sites was 11.4 for minority residents versus 6.3 for white residents. Minorities are thus more likely to bear a burden from synergistic effects from these multiple sources of pollution). For an additional discussion of environmental equity and Superfund, see JOHN A. HIRD, *SUPERFUND: THE POLITICAL ECONOMY OF ENVIRONMENTAL RISK* (1994) (finding that the number of sites in a county on the NPL increased with the nonwhite population percentage); Rae Zimmerman, *Social Equity and Environmental Risk*, 13 *RISK ANALYSIS* 649 (1993) (finding that the percentage of blacks and Hispanics of the aggregate populations of communities with NPL sites were higher than their national population percentage). See also Vicki Been, *Locally Undesirable Land Uses in Minority Neighborhoods: Disproportionate Siting or Market Dynamics?*, 103 *YALE L.J.* 1383 (1994); Richard J. Lazarus, *Pursuing "Environmental Justice": The Distributional Effects of Environmental Protection*, 87 *Nw. U. L. Rev.* 787 (1993).

62. See Hamilton & Viscusi, *supra* note 61.

63. *Id.* at 25-26.

reveals that for each policy scenario the minority population percentage is very similar. At the 146 sites that would be remediated under the current policy scenario, the mean minority population percentage is 17%.⁶⁴ The mean minority population is also 17% at the 126 sites remediated under the “no ARARs” scenario, and 16% for the policy scenario assuming “no future on-site residents.” The mean minority population percentage at sites subject to a benefit-cost test is also virtually identical to the overall minority percentages at these sites.

A different pattern emerges with respect to the mean minority percentage at sites that pass a benefit-cost test. At those sites with cleanup costs greater than \$5 million, which pass a benefit-cost test assuming a saved life is worth \$5 million, the mean minority percentage ranges from 32% to 39%. For smaller scale sites that are not subject to a benefit-cost analysis, but that would pass a benefit-cost test assuming a saved life is worth \$5 million, the mean minority population ranges from 17% to 34%. The departure from the overall mean minority population percentages is less dramatic for the larger set of sites which pass a benefit-cost test assuming a saved life is worth \$100 million. Nevertheless, even for this high cutoff, minorities are not disadvantaged by a regulatory scenario that requires benefit-cost analysis to determine which sites are remediated: the sites that pass the benefit-cost test, and therefore are remediated, have a higher mean minority population percentage than those sites with cleanups that do not pass a benefit-cost test.

Implementation of risk assessment and benefit-cost analysis requirements would also benefit minority populations by overriding some of the discretionary elements of the Superfund program which allow constituent pressures to trigger policy actions. Such discretionary elements can leave minority communities at a disadvantage if such communities are less likely to engage in collective action to pressure regulators or if their actions are met with less response.⁶⁵ We have found evidence that this is the case. The process by which sites are placed on the National Priorities List, the set of sites that qualify for remediation funds, is influenced by commu-

64. The mean minority population is the average of the population percentages in the given subsample of sites.

65. James T. Hamilton, *A Testing for Environmental Racism: Prejudice, Profits, Political Power?*, 14 J. POL'Y ANALYSIS & MGMT. 107, 129 (1995) (demonstrating that firms calculating where to expand hazardous waste processing capacity are more likely to target areas with lower levels of potential political activity).

nity pressure. Controlling for a measure of local levels of pollution, we found that hazardous sites in communities with higher percentages of minorities were less likely to be placed on the NPL; and that Superfund site residents in high minority, lower voter turnout sites are less likely to receive the technical assistance grants administered by the agency.⁶⁶

Table 5 indicates that if the regulatory playing field were leveled so that site remediation decision were based only on risks and costs rather than on community pressure or other factors, minority populations would not be harmed. The mean minority population percentage is actually much higher at the sites where remediations would be implemented based on benefit-cost analysis alone. Those smaller scale sites not subject to a benefit-cost test have slightly lower minority population percentages. In sum, risk assessment and benefit-cost analysis may help reduce environmental inequities by reducing the role for constituent pressure in remediations and by focusing attention on high health risks, which often occur in minority communities.

6. *Accounting for changes in risk assumptions.*

The first five subsections of Part IVC. generally treated the way that risks are calculated—hazard identification, exposure assessment and dose response—as a given and examined how changes in risk characterization and risk management rules altered site remedy decisions. This subsection quantifies how additional changes in EPA's risk assessment calculations would alter Superfund decision making.

As noted in Part III, if Congress adopted the risk reform provisions, EPA's calculation of risks would change in at least three ways. First, the reforms could require EPA to use population risks, rather than individual risks, as the basis of its risk assessments. Second, the requirement that agencies report risk estimates based on central tendencies would shift EPA's risk assessment analyses away from the use of "reasonable maximum exposure" scenarios to those based on mean assumptions. Third, the reforms would require EPA to assess risk not as a single point estimate, but as a probability distribution.

Our data demonstrate that the use of central tendency estimates in risk assessment greatly alters the ascertained magnitude of

66. Hamilton & Viscusi, *supra* note 61.

individual risks and population risks.⁶⁷ For 141 sites, we recalculated EPA estimates of soil and groundwater ingestion risks (which account for 40% of the exposure pathways at these Superfund sites). If one examines the maximum ingestion pathways at the sixty-seven sites where estimates of average chemical concentrations were available, the magnitude of the individual risks calculated are quite large (mean 0.038, median 0.0019). Classifying these sites on the basis of maximum ingestion risks, 94% would fall in EPA's current range requiring remediation (risk at least 10^{-4}), 5% would be in the discretionary range (10^{-4} to 10^{-6}), and 1% in the range where remediation is generally not pursued under current guidelines.⁶⁸ But if one uses mean estimates for the ingestion rates, exposure duration, and contaminant concentration parameters, the magnitude of the maximum ingestion risks drops substantially. The mean of the maximum ingestion risks using current EPA guidelines is twenty times larger than that derived from central tendency estimates (0.0019). The median risk calculated under EPA guidelines is also greater than that estimated with central tendency assumptions (0.00011). If EPA cleaned up sites based on maximum ingestion-risk levels calculated under central tendencies, 54% would fall into the remediation category of risks in excess of 10^{-4} , 43% would be in the discretionary zone of risks between 10^{-4} and 10^{-6} , and 3% would be in the category of risks below 10^{-6} where remediations are not generally pursued. A shift to central tendencies would thus place a substantial percentage of sites in the discretionary zone.

The number of cancer cases expected to arise also changes dramatically if one uses assumptions less conservative than those used by EPA. If exposure and intake parameters are set at conservative values, there are 731 cancer cases estimated to arise at the 145 sites over the next thirty years.⁶⁹ Under a different set of assumptions that the intake rate/body weight ratio and chemical contaminant values are at their means, that cancer occurs with a ten-year latency, and that cancer cases are discounted at 3% per year (since individuals value cancer cases differently depending on whether

67. See generally Viscusi et al., *supra* note 38 (discussing the use of central tendency estimates).

68. This sample of 67 sites excluded nine sites where the EPA chose to take "no action." If those "no action" sites were included, the mean risk for the 76 sites would be .034 and the median risk would be .0015.

69. See generally Hamilton & Viscusi, *supra* note 41 (describing the estimation methodology).

they are averted now or in the future), the estimated number of cancer cases changes from 699 to 204 cases at the ninety-nine sites where average concentrations were available.

Our data also demonstrate that the combination of conservative assumptions results in highly conservative estimates of the risks arising at Superfund sites. Monte Carlo analysis offers another way to quantify the degree of conservatism embedded in EPA's RME scenario. To explore this, we calculated a distribution of ingestion risks arising at eighty-six different sites using information on the distributions of exposure parameters and chemical concentrations. For the maximum ingestion pathways calculated under EPA guidelines, nearly two-thirds of the sites fell in the 99th percentile of the distributions calculated under Monte Carlo analysis.⁷⁰

7. *A note on remedy selections.*

The Superfund Amendments and Reauthorization Act directs EPA to select remedies that "permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances."⁷¹ This requirement constrains the agency to favor permanent treatment of contaminants at a site over potentially less costly remedies, such as institutional controls, containment, or removal of waste. Nevertheless, the diversity of remedies that have been selected, detailed in Table 6, demonstrates that site managers do enjoy some discretion over the selection of remedies.

Table 6 explores how remedy selection varies across different categories of sites. Specifically, institutional controls and removals were more likely at sites where cleanup costs were below \$5 million than at those where cleanup expenditures exceeded \$5 million.⁷² In terms of cost-effectiveness, sites that were cleaned up at less than \$100 million per cancer case avoided were much more likely to deal with soil contamination through institutional controls or removals than through treatment. The same holds true for ground-

70. Risk reform's emphasis on central tendencies and sensitivity analysis would help make clear the costs of conservatism. These costs are expressed in terms of both financial losses as well as expected lives lost. Resources may be diverted from cleaning up those sites with large expected risks, to those for which the risk is expected to be small but the conservative approach suggests that there is some chance that the risk could be large.

71. SARA, 42 U.S.C. § 9621(b)(1) (1994).

72. This pattern is especially pronounced for groundwater contaminants. At roughly half of the sites involving groundwater contamination where cleanup costs were less than \$5 million, EPA addressed contamination through institutional controls. Of the more expensive sites with groundwater contamination, EPA selected treatment remedies for 75% of the sites.

water remedies: sites which passed the rough benefit-cost test (with the assumption that a life is worth \$100 million) were more likely to deal with groundwater contamination through institutional controls. At some sites multiple remedies that use similar technologies but vary in price were proposed to deal with contamination. At sites with expenditures less than \$5 million, the less expensive soil proposal was chosen 52% of the time, while at more expensive sites the cheaper soil alternative was chosen only 33% on the time. There is thus some room for additional discretion to be used to reduce costs under current guidelines, despite the statutorily mandated preference for permanence which restricts the types of alternatives considered and chosen at sites.

Of the 145 sites in our sample, only forty-four had a cost per cancer case avoided which was less than \$100 million under current remedy selections. Of those 101 sites which did not meet this cutoff, fourteen had considered but not chosen remedies that, if chosen, would have resulted in a cost per cancer averted of less than \$100 million. At the remainder of the sites, none of the remedies proposed by EPA would result in a cost per cancer averted of less than \$100 million. To achieve greater efficiencies in cleanup at Superfund sites, regulatory reform would have to allow equal consideration of all possible remedies rather than strongly favoring permanent treatment.

V. CONCLUSION

The current policy approach used in the Superfund program is a peculiar halfway house. EPA devotes substantial effort to identifying chemicals at a site and ascertaining their potential risks. It also assesses the costs of a range of remedies in considerable detail. However, many key elements are missing in the agency's analyses. There is no explicit consideration of the size of the population at risk. Risks to a single individual have the same weight as risks to a large exposed population. Actual and hypothetical exposures to chemicals receive equal weight so that risks to a person who, in the future, may choose to live near a currently uninhabited Superfund site receive the same weight as risks to large populations that are currently involuntarily exposed.⁷³ EPA also reports the conservative risk assessment value for each site, without focusing its policy

73. We found that in setting cleanup target risk levels for chemicals at Superfund sites there is not a statistically significant difference in the treatment of current exposure pathways versus future, hypothetical exposure pathways. W. Kip Viscusi & James T. Hamil-

attention on the expected risk level or most likely risk scenarios. Finally, explicit tradeoffs that balance benefits and costs do not enter remediation decisions. These problems arise in part because of decision-making constraints in the Superfund legislation and in part because of the manner in which regulators have implemented the program.

Our data show that the core economic elements of the proposed regulatory reform bills would dramatically alter EPA's policy choices. Put simply, the reforms would require that agency regulations maximize the net gain to society (benefits less costs) using plausible risk assumptions. Sound risk assessment and benefit-cost analysis would force wiser spending and eliminate many of the problems that decrease the overall performance of those potentially desirable regulatory efforts such as hazardous waste cleanup.

Consider how benefit-cost analysis would help answer how effectively EPA has targeted its expenditures to reduce risks: for the most effective 5% of cleanup expenditures, through remediation EPA eliminates 99.46% of the cancer risks averted. All expenditures beyond that level will have cleanup costs per discounted case of cancer averted in excess of \$140 million. Potentially, EPA can generate virtually all the gains in reduced risk at a fraction of the cleanup costs. *At present, 95% of the expenditures at Superfund sites are devoted to eliminating only 0.5% of the cancer risk.*⁷⁴

Under risk assessment and risk management reforms, EPA would assess population risks, rather than simply individual risks, from contamination at Superfund sites. The agency would present central tendency estimates so that analysts could see the range of risks at a site.⁷⁵ More flexible remedy decisions based on risk levels rather than ARARs would reduce the costs associated with cleanup goals based on standards from other environmental programs, and costs based on the preference for permanent remedies.

Risk reform is inevitably vulnerable to becoming a vehicle for ignoring environmental hazards rather than remediating them more efficiently. As our analysis shows however, there is a wide zone within which risk reforms can improve efficiency without sacrificing human health considerations. In our analysis, the shift to-

ton, *Are Risk Regulators Rational? Evidence from Hazardous Waste Cleanup Decisions* (1996) (working paper, on file with the *Stanford Environmental Law Journal*).

74. These calculations assume a 3% discount rate for costs and cancers, a ten year latency period for the onset of cancers, and average exposure concentrations and intake parameters.

75. This is a process which Monte Carlo analysis would also further.

ward site cleanups based on risk levels alone—rather than ARARs and calculations that include on-site future residents—would reduce the number of sites remediated from 145 to eighty-six and site expenditures from \$2.2 billion to \$1.6 billion, but would reduce the number of cancer cases averted by only twenty-one (from 731 to 710) and the number of individuals protected from non-cancer exposures by 16,000 (from 113,000 to 97,000). Our analysis further indicates that calculation of risks based on central tendency should shift a substantial fraction of sites into the cleanup discretionary zone, where EPA site managers currently have the authority to decide whether or not to remediate a site. Removal of preference for permanence would also allow managers to consider more cost-effective alternatives.

The findings for minority populations are perhaps the most telling. Sites that pass a benefit-cost test have a much higher mean minority percentage than the average for the overall set of sites considered. These results help provide an efficiency rationale for the environmental equity movement. If current political pressures lead to neglect of environmental harms in minority communities, as the environmental justice critics note, such communities could benefit from decisions made on the merits of the risks. Our data support this: sites with large minority populations had stronger benefit-cost performance. By focusing on objective measures of risk, benefit-cost analysis will highlight the policy importance of addressing the real risks that minorities may face from hazardous waste sites.

To be more effective, current risk assessments must include more information—such as calculation of population risk—than they do now. EPA must better document any potentially important natural resource damage, noncancer effects, and synergistic influences. The transaction costs of these new calculations would be vastly offset by the savings afforded by an efficient implementation of the program. Our analysis shows that there is ample room for reforms to cut expenditures on cleanup with minimal sacrifice in terms of health risks.

TABLE 1: NUMBER OF SITES QUALIFYING FOR REMEDIATION UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel A: Sites with Cleanup Costs Over \$5 Million

	Total Number of Sites Qualifying for Remediation	Number of Sites with Total Cleanup Costs Over \$5 Million	Percentage of Sites with Total Cleanup Costs Over \$5 Million	Of Sites with Total Cleanup Costs Over \$5 Million, Number of those with Cost per Case of Cancer Averted Under \$5 Million	Of Sites with Total Cleanup Costs Over \$5 Million, Percentage of those with Cost per Case of Cancer Averted Under \$5 Million	Of Sites with Total Cleanup Costs Over \$5 Million, Number of Those with Cost per Case of Cancer Averted Under \$100 Million	Of Sites with Total Cleanup Costs Over \$5 Million, Percentage of Those with Cost per Case of Cancer Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	145	100	69	5	5	26	26
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	126	91	72	4	4	24	26
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	86	68	79	4	6	19	28

TABLE 1: NUMBER OF SITES QUALIFYING FOR REMEDIATION UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel B: Sites with Cleanup Costs Under \$5 Million

	Total Number of Sites Qualifying for Remediation	Number of Sites with Total Cleanup Costs Under \$5 Million	Percentage of Sites with Total Cleanup Costs Under \$5 Million	Of Sites with Total Cleanup Costs Under \$5 Million, Number of those with Cost per Case of Cancer Averted Under \$5 Million	Of Sites with Total Cleanup Costs Under \$5 Million, Percentage of those with Cost per Case of Cancer Averted Under \$5 Million	Of Sites with Total Cleanup Costs Under \$5 Million, Number of Those with Cost per Case of Cancer Averted Under \$100 Million	Of Sites with Total Cleanup Costs Under \$5 Million, Percentage of Those with Cost per Case of Cancer Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	145	45	31	8	18	18	40
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	126	35	28	5	14	15	43
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	86	18	21	3	17	8	44

TABLE 2: SUMMED CLEANUP COSTS OF SITES UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel A: Sites with Cleanup Costs Over \$5 Million

	Total Cost of Remediating All Sites in Simulation	Total Cost of Remediating All Sites with Individual Cleanup Costs Over \$5 Million	Total Cost of Remediating All Sites with Individual Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Total Cost of Remediating All Sites with Individual Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	\$2.16 Billion	\$2.08 Billion	\$71.6 Million	\$593 Million
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	\$2.01 Billion	\$1.94 Billion	\$52.6 Million	\$567 Million
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	\$1.59 Billion	\$1.55 Billion	\$52.6 Million	\$482 Million

TABLE 2: SUMMED CLEANUP COSTS OF SITES UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel B: Sites with Cleanup Costs Under \$5 Million

	Total Cost of Remediating All Sites in Simulation	Total Cost of Remediating All Sites with Individual Cleanup Costs Under \$5 Million	Total Cost of Remediating All Sites with Individual Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Total Cost of Remediating All Sites with Individual Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	\$2.16 Billion	\$82.2 Million	\$3.54 Million	\$25.0 Million
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	\$2.01 Billion	\$69.9 Million	\$3.54 Million	\$25.0 Million
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	\$1.59 Billion	\$41.8 Million	\$3.54 Million	\$17.4 Million

TABLE 3: EXPECTED CANCER CASES AVERTED UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel A: Sites with Cleanup Costs Over \$5 Million

	Total Cancer Cases Averted in All Sites in Simulation	Total Cancer Cases Averted in All Sites with Cleanup Costs Over \$5 Million	Total Cancer Cases Averted in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Total Cancer Cases Averted in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	731	728	704	726
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	713	710	686	708
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	710	708	686	706

TABLE 3: EXPECTED CANCER CASES AVERTED UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel B: Sites with Cleanup Costs Under \$5 Million

	Total Cancer Cases Averted in All Sites in Simulation	Total Cancer Cases Averted in All Sites with Cleanup Costs Under \$5 Million	Total Cancer Cases Averted in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Total Cancer Cases Averted in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	731	2	1	2
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	713	2	1	2
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	710	2	1	2

TABLE 4: EXPOSED POPULATIONS UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel A: Sites with Cleanup Costs Over \$5 Million

	Exposed Population in All Sites in Simulation	Total Exposed Population in All Sites with Cleanup Costs Over \$5 Million	Total Exposed Population in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Total Exposed Population in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	113,000	109,000	68,000	97,000
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	110,000	107,000	68,000	94,000
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	97,000	94,000	68,000	86,000

TABLE 4: EXPOSED POPULATIONS UNDER DIFFERENT POLICY ANALYSIS CRITERIA
 Panel B: Sites with Cleanup Costs Under \$5 Million

	Total Exposed Population in All Sites in Simulation	Total Exposed Population in All Sites with Cleanup Costs Under \$5 Million	Total Exposed Population in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$100 Million	Total Exposed Population in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	113,000	3,700	2,500	3,400
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	110,000	3,500	2,400	3,300
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	97,000	2,900	2,400	2,700

TABLE 5: INTERACTION BETWEEN MINORITY POPULATION AND DIFFERENT POLICY ANALYSIS CRITERIA
 Panel A: Sites with Cleanup Costs Over \$5 Million

	Mean Minority Population (as a percentage of site population) in All Sites in Simulation	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Over \$5 Million	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Over \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	17	18	32	26
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	17	17	39	25
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	16	17	39	22

TABLE 5: INTERACTION BETWEEN MINORITY POPULATION AND DIFFERENT POLICY ANALYSIS CRITERIA
 Panel B: Sites with Cleanup Costs Under \$5 Million

	Mean Minority Population (as a percentage of site population) in All Sites in Simulation	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Under \$5 Million	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$5 Million	Mean Minority Population (as a percentage of site population) in All Sites with Cleanup Costs Under \$5 Million and Cost per Cancer Case Averted Under \$100 Million
CURRENT POLICY: All Sites in Risk Sample	17	14	17	12
NO ARARS: Sites with Cumulative Risk of At Least 10 ⁻⁴	17	15	34	13
NO FUTURE ON-SITE RESIDENTS: Sites with Cumulative Risk of At Least 10 ⁻⁴ Assuming No Risks to Future On-site Residents	16	12	25	13

TABLE 6: SELECTION OF REMEDIATION ALTERNATIVES

Sites with Soil or Groundwater Contamination Addressed	Sites with Cleanup Costs Under \$5 Million	Sites with Cleanup Costs Over \$5 Million	Sites with Cost per Cancer Case Averted Under \$100 Million	Sites with Cost per Cancer Case Averted Over \$100 Million
<i>Soil:</i>				
Total Number	45	164	26	69
Percentage of total number:				
Institutional Controls	13%	4%	19%	3%
Containment	16%	22%	8%	24%
Removal	11%	4%	15%	5%
Treatment	56%	64%	50%	65%
Containment with Removal	4%	6%	8%	3%
<i>Groundwater:</i>				
Total Number	58	166	34	77
Percentage of total number:				
Institutional Controls	52%	25%	47%	22%
Treatment	48%	75%	53%	78%

Notes

