Land Use Controls, Public Health Surveillance, and the Public's Peace of Mind at the United States Major Nuclear Weapons Legacy Sites

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Abstract

A survey of 1351 people at six U.S. Department of Energy nuclear weapon sites showed that the nuclear waste legacy was not the number one environmental concern. Most people who live within 50 miles of one of these six nuclear weapons sites were mildly to moderately concerned about the legacy. Other environmental issues, such as open space, water pollution, and local manufacturing and mining operations were considered slightly more worrisome by most of the respondents. The exceptions were Hanford and Savannah River where the nuclear legacy ranked second and third in priority. Yet residents want strong public health surveillance and land use controls, which at these sites means in perpetuity. Most trust DOE's science more than they do its communications. The findings are mostly, but not entirely, consistent with expectations drawn from the risk perception and organizational trust literatures. The challenge is how to establish a stewardship program that convinces state and local government, community advisory boards and the public that remediation can go on at the same time that some waste is interned either in perpetuity or until suitable new technologies can be safely deployed.

Key words: risk perception, nuclear waste, peace of mind, trust

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1. INTRODUCTION

During August 1945, the United States exploded nuclear weapons at Hiroshima and Nagasaki. The nuclear weapons manufactured during World War Two and the Cold War, in the words of Nobel Prize winning physicist Neils Bohr, turned the United States into "one huge factory." (OEM, 1995a, p 2). The nuclear factory left a legacy of hazardous nuclear and chemical waste in 34 states at over 100 locations. In 1989, the United States Department of Energy (DOE) created an environmental management (EM) program with an annual budget averaging $6-7 billion to address the legacy. Despite the expenditure of $70 billion, DOE estimates are that it will take decades and over $200 billion to manage the nuclear weapons waste legacy in the United States (range $170 to $375 billion, OEM 1995b). These costs are uncertain; but one certainty is that nuclear and chemical wastes will be left at some DOE site for decades, some in perpetuity, where they will slowly become less hazardous.

Closing a nuclear energy generating station is challenging (Kotval & Mullin, 1997). Leaving a contaminated nuclear legacy in perpetuity is daunting. The Ninth Circuit of the United States Court of Appeals said:

> "The management, storage and permanent disposal of nuclear waste, especially high level waste, is one of the gravest public health and safety problems facing our society. It is also the quintessential political 'hot' potato. While we, as a society, want to keep reaping benefits from nuclear science and the use of nuclear materials, nobody wants the resulting waste stored or disposed of anywhere close to himself" United States Court of Appeals for the Ninth Circuit, No 3-35711, Natural Resources Defense Council v. Abraham, (p.s.)

The nuclear waste legacy presents unprecedented science, engineering, public health, legal, economic, and political/organizational challenges. Without denying any of these challenges, an equal, if not greater, one is that the DOE as primary steward must

gain the trust of the residents who will live with this legacy, as well as their elected representatives. This requires listening to the collective voice of the population by being aware of what the public wants them to do to safeguard what is arguably the most dreaded environmental legacy that humans have created.

As a step in that direction, we asked people who live within 50 miles of the six DOE sites to prioritize a set of land use management, environmental health, and organizational policies that the Department can use to give residents some peace of mind about living the legacy in perpetuity. More specifically, we answered three questions:

1. How worried are residents about nuclear-weapon related wastes compared to other environmental issues in their area?
2. What are the public's peace of mind preferences?
3. What factors are associated with the public's preferences?

2. LITERATURE AND PLACE CONTEXTS

Worry is a state of the mind in which someone is frequently or perpetually restless and sometimes distressed about an existing or possible negative outcomes (MacGregor, 1991; Fischer et al., 1991; Sjoberg, 1998). Peace of mind in this research means allowing people to live without worrying a lot about nuclear waste left at sites. The concept has been applied to many concerns. For example, women at high risk for HIV/AIDS reported feeling "peace of mind" when their sexual partners used condoms (Juran, 1995). The concept has also been applied to living in earthquake prone areas, investment decisions, purchasing homes, safety devices for children, and numerous other decisions that are uncertain (Coolidge, 2004; Yanev, 1991).

The literature provides examples of how people achieve peace of mind. Thoreau moved to Walden Pond. Rajhans (2004) suggested forgetting and forgiving, not interfering with others' business, not being jealous, and enduring what cannot be cured. Parrish and Quinn (1999) suggested laughter. State and local officials, business owners and concerned citizens at DOE sites, however, cannot be expected to rely on laughter, or anything short of a stewardship plan supported by appropriate funding. The bulk of military nuclear waste is located at a small number of sites, six of which we chose for this study: Hanford (WA), Savannah River (SC), Idaho National Engineering Laboratory (ID), Oak Ridge (TN), Fernald (OH) and Rocky Flats (CO). In 1995, the DOE estimated that 72 percent of the $230 billion of its environmental legacy costs were at these sites (OEM, 1995a,b, see Appendix A for a brief description of each site). In essence, Hanford, Savannah River and INL are massive sites in rural settings. Fernald, Oak Ridge and especially Rocky Flats lie in more urbanized settings.

The literature provided theoretical grounding for the construction of the survey and the anticipated answers to the three research questions. The psychometric paradigm anchored our expectations. People's risk perceptions are the product of the integration of dread, uncertainty, controllability, potential for catastrophe, equity, and other attributes of the hazard (Bronfman & Cifuentes, 2003; Rohrmann & Chen, 1999; Slovic, 1987; Xie et al., 2003; Yong-Jin, 2000). The psychometric paradigm reduces these attributes to two or three, most commonly "dread" and the "unknown." Nuclear power is typically used to illustrate the dreaded and unknown hazard.

The psychometric paradigm implies fear of these sites, but many, if not all, respondents should have heard about the local site. Some probably have driven near it,

and some would have worked there or have a family member or friend who worked there. Research shows that familiarity leads to desensitization and acceptance (Halpern-Felsher et al., 2001; Lima, 2004). Our respondents might be less concerned about the nuclear weapons legacy than they were are other environmental problems, such as mining, manufacturing, sprawl and loss of open space.

With regard to the second research question (preference for peace of mind options), the planning, environmental management, organizational and risk communication literatures suggests hundreds of individual actions that a site steward can take that might increase peace of mind. One set of options would control site access and limit exposure by requiring the federal government to own the land in perpetuity, or until the risk was minimal. Second, public health surveillance options would require monitoring of the air/land/water, workers, the resident population, ecosystems, installation of an early warning system and frequent briefings to stakeholders. The third set of options are attempts to increase trust of the DOE and other responsible institutions, such as by increasing outreach, and by providing a trust fund to make sure that the vagaries of the annual federal budgeting process do not interrupt remediation and management,

People are much more likely to trust negative than positive risk information (Carlston, 1989; Koren & Klein, 1991; Siegrist & Cvetkovich, 2001; Slovic, 1993). This implies that the clear majority of respondents would select multiple public health and land use control policies because of their dread of nuclear materials, and might be hesitant about trust-building efforts that do not directly address their discomfort. For example, one option was to allow no visitors; an alternative is to try to build trust by

taking people on site tours. If the majority are afraid of exposure, then will chose limiting access and no guided tours. Not allowing future nuclear-related missions is an option, but it will mean less employment and gross regional product. Again because negative information clearly trumps positive information, we expected a general preference for no nuclear missions, except where there has been an ongoing effort to support them, such as INL (Alm et al., 2001; Blankenship et al., 2005).

With regard to the third research question (correlates of peace of mind priorities), the psychometric paradigm led us to assume that worries about the consequences of on-site activities would dominate the regressions, such as, fires, explosions, groundwater pollution, and ecological destruction. Yet specific worries typically are grounded in larger concerns about the environment and health (Baxter, 1990; Gillespie, 1999; Greenberg, 2005; Wulfhorst, 2003). We expected that concern about DOE's on-site activities would be part of overall worry about regional environmental health issues, such as natural hazards, mining and manufacturing, loss of open space, and concerns about the future.

We also anticipated the relationship between peace of mind preferences and environmental health concerns to be confounded by trust, site differences, and respondent demographic characteristics. With regard to trust, research shows that people distrust authority when they feel that it is incompetent, unfair, not acting in good faith, and does not shares their values (Earle & Cvetkovich, 1995; Nye, 1997; Pew, 1998; Poortinga & Pidgeon, 2003; Pew, 1998; Slovic, 1993). Worried and distrusting respondents should chose strict land use and access controls, and insist on frequent monitoring, surveillance, and reporting.

We expected site-related confounding. Some have more hazardous materials and dangerous conditions than others. However, there is not a linear relationship between hazard and risk perception. Sjoberg et al. (1998), for example, observed a U-shaped relationship, that is, mild to moderate threats lead to higher perceived risk. This means that Rocky Flats and Fernald, which have less hazardous materials at this time might have more perceived risk than Hanford and Savannah River that have nearly all the high level nuclear waste. Site differences are likely to be strongly influenced by recent media coverage. People tend to focus on hazards that are reported as risky, but they perceive more risk because of more coverage even when media stories do not assert risk (Kasperson, et al., 1988; MacGregor et al., 1994).

Demographic characteristics were expected to be the final confounders of dread-driven relationships. Research shows differences in risk perception by race/ethnicity, socioeconomic status, gender, age and other common characteristics (Bord & O'Connor, 1997; Finucane et al., 2000; Flynn et al., 1994; Greenberg, 2005; Vaughan & Nordenstam, 1991). Consistent with this literature, we expected more worrying about and desire for more peace of mind options by African and Indian Americans, women and the relatively poor. A stronger expectation was that those who had worked on the site, had a relative who had worked on the site, and/or in other ways were familiar with the site would be less likely to demand rigid land use controls and health-related surveillance because of desensitization (Gonzalez, 2002; Halpern-Felsher et al., 2001; Liu & Hammitt, 1999).

3. DATA AND METHODS

In order to answer the three research questions, we designed a survey instrument with 26 main questions and 77 queries. With regard to question 1 (DOE and other environmental concerns), we asked how worried respondents were about environmental problems in their area, such as natural disasters, hazardous waste from non-DOE related manufacturing and mining, traffic congestion, terrorism, agricultural activities, and loss of open space. A four-point scale was used: 1=very worried, 2=somewhat worried, 3=not too worried, 4=not at all worried (Table III). Seventeen peace of mind options were offered to answer the second research question. These were derived from larger list that we prepared and circulated among colleagues and students for review. To be as clear as possible about the intent of the survey we said: "in addition to removing materials from the site, some radioactive hazards are being left to decay in place so they will be less dangerous in the future. Some of these materials may remain at the site for many years." We asked what steps the DOE could take that would bring the greatest peace of mind about what is left on the site. A 10-point scale was used: 1= very low priority, 10 very high priority.

Five of the 17 choices probed public responses to restricting land use and activities (Table IV). A second set of options asked about monitoring air, land, water, workers, nearby residents and ecological systems, providing early warning alarm systems and training and equipment to local government responders. The last six peace of mind options asked for reactions to organizational policies that might build trust, such as a trust fund, requiring site managers to live near the site, providing information via the web and visits by site personnel (Table IV).

With regard to the third question (correlates of peace of mind), eight questions examined DOE-site specific concerns regarding cleanup and management of the legacy, including how much they worried about worker, resident, ecological risk, and destruction of cultural/archeological attributes. Another seven asked about off-site externalities, such as seepage of contaminants off-site into drinking water, transportation accidents, terrorist attacks on DOE off-site activities, animals carrying contamination off site, and job losses if the site reduces cleanup activities (See tables V-VII).

General environmental concerns should confound these choices. That is, people who want strong protective actions by the DOE, we assumed would be most concerned about the non-DOE environmental issues, such as non-DOE manufacturing and mining, loss of open space and other regional issues. The last general environmental question asked how the respondent would rate his/her area as a place to live: excellent, good, fair, or poor. This question also is widely used by the American Housing Survey to measure personal satisfaction with area.

Eight questions examined trust. Three were general, asking if the federal, state and local governments were doing "too much," "too little," or just "about the right amount" to protect the environment of the area. Five asked if respondents "strongly agreed," "agreed," "disagreed" or "strongly disagreed" that the DOE will make sure that the air, water and land are not polluted outside of the site's boundaries, that the DOE will be able to cleanup using new and safe technology, that the Department can effectively manage legacy and new waste. The last asked if the DOE communicates honestly with the public.

The six study sites have been owned and operated by the DOE, or its predecessor the Atomic Energy Commission and contractors for more than a half century. Hence it was essential that we include indicator of site-specific differences. The most obvious was to create a simple dummy variable for each of the six sites. Newspaper coverage might be influential, so we reviewed coverage in the major local newspapers for each site during the last two years (July 1, 2003 to June 30, 2005) for amount of coverage, and extent to which the tone of the coverage emphasized risk or was reassuring. All articles about waste management, waste shipment, new mission-related projects, development, or accidents were read. We did not include editorials, letter to the editor, or articles that were about legal, economic, employment and contractual issues or primarily about national or DOE complex-wide issues. An article the mentioned risks or hazards often and/or early in the article was considered one that emphasized hazard/risk.

The final set of questions asked for demographic information and about familiarity with the site. The demographic question included age, race/ethnicity, educational achievement, gender, length of residence in the area, age, income, and civic engagement during the last two years (voted, attended a local government meeting, volunteered for a civic activity). Familiarity questions asked if the respondent had ever heard of the site, how familiar they were with it, had they visited, driven by or through the site, and had they or a family member ever worked there.

The survey was administered over the phone using random digit dialing (RDD) using American Association for Public Opinion Research standards with a minimum target of 200 at each of six sites, 1200 overall. With respect to methods, we used simple and multivariate statistics, as described in more detail in the results section.

4. RESULTS

During the period July 14 to August 2, 2005, 1351 surveys were collected: 225 at five sites and 226 at one. Table I presents demographic data for the six sites. With regard to site differences, the most obvious were the larger proportion of college-educated respondents in the Rocky Flats sample than in the Savannah River and Hanford ones, and the relatively large proportion of African American respondents in the Savannah River sample. These differences mirror differences among these six areas.

Table I. Respondent Demographic Characteristics

Variable	Fernald	Hanford	Idaho Nat. Lab	Oak Ridge	Rocky Flats	Savannah River	Total
Age:							
18-29	11.8	15.2	13.8	10.3	7.6	10.7	11.6
30-49	36.2	37.2	38.7	35.5	40.7	37.6	37.6
50-64	33.0	30.5	27.1	31.9	34.0	36.7	32.1
65+	19.0	17.0	20.4	22.4	17.7	15.7	18.7
Education: College graduate	20.2	19.3	21.5	20.1	27.4	14.7	20.6
Race/ethnicity:							
Latino	0.5	7.2	3.6	0.4	8.1	1.8	3.6
White	86.5	87.2	94.6	91.9	83.3	68.9	85.4
Black	10.7	1.8	0.0	3.1	5.0	27.4	8.0
Asian	0.9	0.5	0.0	0.9	0.5	0.5	0.5
Indian	1.9	3.7	1.8	3.6	3.6	1.8	2.7
Family income, 2005, $, 1000s:							
<25	18.6	19.8	20.0	25.9	16.8	18.3	19.9
25-49.9	33.7	22.2	38.6	31.1	24.5	32.2	30.4
50-74.9	20.6	22.7	23.8	24.1	22.1	25.5	23.2
75-100	9.0	17.9	10.5	8.0	18.8	10.6	12.5
100+	16.1	14.5	5.2	9.9	16.3	10.6	12.1
No answer	2.0	2.9	1.9	0.9	1.4	2.9	2.0
Sex: male	47.6	48.0	48.0	48.0	48.2	48.0	48.0

4.1. Question 1. Worry about nuclear weapons-related waste

Table II shows that 22% of respondents worried "a great deal" and 28% "some" about the legacy. Yet half were not worried. The aggregate data obscure site differences. Fifty-seven percent of Oak Ridge and 56% of Hanford respondents worried "a great deal." This compared to less than 38% at Fernald, 46% at INL, and 47% at Rocky Flats. These findings are consistent with the reality that the first two sites have a great deal of the remaining legacy and Fernald and Rocky Flats do not. But INL also has a good deal of legacy waste and their worried proportion was 10% less than Hanford's or Oak Ridge's. These results are not easily attributable to the presence of hazards and risk.

A more plausible explanation is recent media coverage. During the last two years, Hanford (123) and Oak Ridge (92) had many more articles in the local newspaper about the waste management activities, waste shipment, new mission-related projects, and accidents than the other four sites combined. Fernald had only 35 stories, Rocky Flats 46, and INL 64 stories. There was no obvious relationship with emphasis on risk and danger in the coverage. Overall, the finding about a relationship between total coverage and greater worry is consistent with expectations. But only a detailed review of all mass media sources can clearly demonstrate a link between coverage and amplified risk.

Table II. Public Concern about Nuclear Weapon-Related Waste by Site*

Numbers are percent by site

Site	Great deal	Some	Not much	Not at all	Don't know/refused	Average value
Six sites (n=1330)	22.1	27.5	20.4	28.4	1.6	2.56
Fernald (n=222)	16.9	20.8	26.2	34.7	1.3	2.80**
Hanford (n=220)	25.3	31.1	17.3	24.0	2.2	2.41**
Idaho National Laboratory (n=223)	16.9	29.3	24.4	28.4	0.9	2.65
Oak Ridge (n=223)	28.9	28.8	19.6	21.8	0.9	2.35**
Rocky Flats (n=220)	18.7	28.0	17.8	33.3	2.7	2.67
Savannah River (n=222)	26.2	26.7	17.3	28.4	1.3	2.49

*Chi-square value to test the differences among the six sites was 41.7, $p<0.01$.
**Average values for Fernald are significantly lower than averages for Oak Ridge and Hanford.

Table III places table II in context. Compared to seven other environmental issues in these regions, worry about nuclear weapon-related waste ranks fifth in the proportion of respondents who reported worrying "a great deal." Respondents, as a whole, were more concerned about traffic congestion and development, and about losing open space for hunting, fishing, and other recreation. These observations are consistent with a growing national concern about the affects of sprawl. Residents were also slightly more concerned about drinking polluted water and the disposal of toxic wastes for manufacturing and mining in the area, which have been national concerns for three

decades (Baxter, 1990; Gillespie, 1999; Saad, 2004). Traffic congestion/loss of open space was a significantly higher worry than the on-site nuclear weapons legacy ($p<0.05$).

Table III. Comparison of Nuclear Weapons-Related and Seven Other Environmental Issues

Environmental issue	% worried a great deal	Average value* (1-4)
Traffic congestion and development of area	25.3	2.39**
Losing open space for hunting, fishing, hiking, and other recreation	24.8	2.50
Drinking water is polluted	24.1	2.52
Disposal of toxic wastes from manufacturing and mining	22.3	2.51
Cleanup of nuclear-weapons related waste	22.1	2.56
Agricultural chemical, fertilizer use, dust generation, and open-burning	16.1	2.57
Terrorism will hit your area	13.2	2.78**
Natural disaster, such as fire, flood, tornado, hurricane, and earthquake	9.3	2.88**

*Lower value means more worry: (1=a great deal; 2=some; 3=not much; 4=not at all).
**Cleanup of nuclear-related waste is significantly different from other worry at $p<0.05$.

Not surprisingly, there was variation among the six sites. At Hanford, Savannah River, and Oak Ridge, nuclear weapon-related waste ranked 2, 3, and 4, respectively among the 8 environmental concerns. At Rocky Flats, and Fernald, the nuclear legacy ranked 7 and 8, respectively. Summarizing, respondents at Hanford, Oak Ridge, and Savannah River demonstrated relatively more concern about the site legacy than Fernald, INL, and Rocky Flats.

4.2. Question 2: Peace of mind priorities

Land-use and activity controls, along with monitoring and surveillance were strong preferences (Table IV), as expected. Requiring the federal government to own the site until all hazards are removed had a mean value of 8.8 (range of 1 to 10). It was the

third highest priority, and the highest proportion (65%) rated it as 10, the highest possible number. There was more ambivalence about the other land use-related choices. For example, asking the federal government to own the land "forever" had an average value of 7.6 and 45% rated this option as 10. The seventh highest priority was keeping visitors off the site (mean 8.3, 54% rated 10).

Table IV. Preference for Peace of Mind Options

Option	Average value (SDV) [range is 1 (low priority to 10 (high priority]	% selected the maximum value
PH-1: Continuously sample the quality of the air and water at the site	9.0 (1.9)	64
PH-2: Regularly monitor health of site workers	8.9 (2.0)	64
LU-1: Make sure that federal government owns site until all hazards are removed	8.8 (2.2)	65
PH-3: Provide specialized training and equipment to emergency response personnel from surrounding areas	8.6 (2.4)	58
PH-4: Install an early warning system to alert residents to any problems	8.5 (2.4)	60
ORG-1: Require government report information about site to community representatives on a regularly scheduled basis	8.4 (2.3)	53
LU-2: Maintain security around site by keeping visitors and recreational users off the site	8.3 (2.5)	54
PH-5: Regularly monitor the health of bird, fish, animals and plants at the site	8.2 (2.3)	47
PH-6: Regularly monitor the health of people who live near the sites	8.2 (2.4)	49
ORG-2: Create a trust fund to make sure that long-term cleanup activities continue and can be done promptly	8.0 (2.5)	45
ORG-3: Maintain role of Citizen Advisory Boards that currently represent the community interests at the site	7.7 (2.5)	35
LU-3: Make sure remains owned by the federal government forever	7.6 (2.9)	45
ORG-4: Provide information about what is happening at site using web sites and visits by site personnel to schools and community groups	7.5 (2.7)	34
ORG-5: Require government to appoint and fund an independent watchdog group that includes local people and scientists to monitor site activities and report results to the community	7.5 (2.8)	38
LU-4: Do not allow any new nuclear-related activity on the site	6.8 (3.5)	42
ORG-6: Require that site managers live near the site	6.3 (3.1)	22
LU-5: Provide access to public via guided site visits	5.3 (3.1)	14

Two other land-use related options were more controversial. Forty-two percent gave no new nuclear-related activities on the site a score of 10. But this was only the 15th highest priority because many respondents did not like the policy. The lowest rated priority was providing guided visits to the public, which would be an organizational tool to build trust through openness.

There was little ambivalence about public health measures. Overwhelmingly, respondents wanted monitoring of the air, land, water, workers and nearby residents, the installation of early warning alarm systems and the provision of equipment and training for government responders. The average priority for the six health-related options was 8.6 and an average of 57% rated them as a 10.

The most ambivalence was for the five organizational options, that is, options that do not directly reduce exposure or monitor it. Providing information to the community advisory panel and creating a trust fund had average values of $\geq$8. Providing information via the web and via visits by site personnel to schools and community facilities had average values of 7.5. And requiring site management to live near the facility (average 6.3) and offering site visits (average 5.3) were the least selected peace of mind priorities.

Public preferences for each of the 17 options are important. We also need to understand associations among the 17 because we had anticipated that there would be a plurality of high nuclear dread respondents who would rate many land use control and public health surveillance policies as the highest priority. We measured this association across the 17 options in two ways. Cronbach's Alpha tests the viability of a set of measures as a single scale. A Cronbach's of >0.8 is normally considered evidence of an excellent scale. Cronbach's for the 17 measures was 0.906. This result was confirmed by

a factor analysis. The first statistical factor accounted for 44% of the variance, and 16 of the 17 peace of mind options had a correlation of >0.55 with this many peace of mind options factor. The exception was allowing new nuclear-related missions on the site. This policy option, therefore, will be treated in more detail in the next section.

Given consistency in response to peace of mind options, we created a single peace of mind scale by adding the 17 scores of each respondent. The average score of this scale was 133.3, and the median was 140 (range 17 to 170). In other words, as expected, we found a large number of people who wanted many of the policy options implemented. Relatively few wanted few of them.

4.3. Question 3. Correlates of Peace of Mind Priorities

Approximately three dozen ordinary least squares and ordinal regression analyses were run with each of the 17 peace of mind options and the overall peace of mind scale as the dependent variables. The results are too extensive to present in detail for every dependent variable. Instead, we highlight the results and discuss several in depth.

With regard to the 17-item peace of mind scale, 42 of the 59 correlations between the scale and the independent variables were significant ($p<0.01$). Less than one significant correlation would have been expected by chance (.01 x 59 = 0.59). All 28 environmental concern variables were significantly correlated with the scale, and the multiple-r value of these 28 was 0.556 with the peace of mind scale. Fourteen of the remaining 31 trust, site, and demographic indicators were significantly correlated with the scale. Among these, trust (multiple r= 0.347) and demographic (r=0.336) had stronger relationships than the site variables (multiple r=0.168). In short, as expected, the

environmental variables were the strongest and most consistent correlates of peace of mind choices.

Table V presents the stepwise analysis for the peace of mind scale. Three of the eight strongest correlates were worrying about transportation accidents, cleanup of the site will expose residents, and fires and explosions. Another was concern about toxic and mining wastes in the area (non-DOE). Three were trust-related. Those who wanted more peace of mind options thought that state government was not doing enough to protect the environment, that DOE would not be able to make sure that underground contaminants would not escape the site environment, and yet that the DOE will be able to cleanup contamination using new and safe technology. The eighth was poorer respondents tended to want more peace of mind options implemented.

Table V. Stepwise Regression of Peace of Mind Index

Correlate	B-value	Standard Error	Beta	t-value	p-value
Constant	165.8	9.31	---	17.83	<.01
Worried about transportation accidents (1=worried a great deal, … 4=not at all worried)	-5.27	1.54	-.222	-3.42	<.01
Worried that disturbing corroding or leaking containers will cause more damage than leaving them in place (1=worried a great deal, … 4=not at all worried)	-4.25	1.51	-.180	-2.82	<.01
Worried about disposal of toxic and mining wastes in area (1=worried a great deal, … 4=not at all worried)	-2.89	1.23	-.131	-2.36	.02
Respondent income, $ (1=less than $25,000, … 5=$100,000 or more)	-2.10	0.94	-.105	-2.23	.03
State government's effort to protect local environment (1=too much, 2=too little, 3=just right)	5.13	2.35	-.118	2.18	.03
DOE will be able to cleanup radioactive and chemical contamination at the sites using new and safe technology (1=strongly agree, … 4=strongly disagree)	-6.24	2.08	-.164	-3.00	<.01
Worried that there is a high risk of explosions and fires related to the cleanup. (1=worried a great deal, … 4=not at all worried)	-3.47	1.45	-.148	-2.39	.02
DOE will make sure that underground radioactive and chemical materials at the site do not pollute the air, land, and water outside of the site's boundaries (1=strongly agree, …4=strongly disagree)	3.61	1.82	.111	1.98	.05

*Multiple r was 0.643, adjusted r-squared 0.396.

To facilitate understanding of this regression result, we compared the 10% of respondents who wanted more of peace of mind options (average score per question of 9.5) to the 10% who were least interested (average score on the 17 options was 5.8). Among the first group, 73% were worried a great deal about transportation accidents, 60% were worried about fires and explosions, and 72% were worried about disturbing existing waste containers. In comparison, the proportions for their much less worried counterparts who wanted far fewer peace of mind options were only 10%, 4%, and 9%, respectively. Also, 42% of the many option group worried a great deal about toxic wastes from non-DOE activities compared to only 6% of their counterparts. These are strong perceptual differences.

With regard to income, 70% who were in the decile that wanted many peace of mind options implemented had family income under $50,000 a year compared to 41% of those in the decile that wanted fewer options implemented. The latter disproportionately earned >$100,000. With regard to the three trust indicators, the decile who wanted many peace of mind options consisted of 75% who feel that their state government was doing the right amount to protect the environment of their area, 21% who disagree that the DOE will prevent underground contaminants from escaping the site, and 18% who disagree that the DOE will be able to use new and safe technology. The numbers for the counterpart group that did not want as many options chosen were 30%, 25%, and 25%, respectively.

Two of three trust-related results were unexpected. We had expected the desire for more peace of mind options to be associated with the perception that state government and the DOE were less competent. Additional analyses were done to learn more about

these unexpected findings. These showed confounding by site familiarity. Specifically, those who reported working at the DOE site were less satisfied that the state was doing about the right amount to protect the area environment. Only 34% of self-acknowledged DOE workers thought that the state was doing the right amount to protect the area. The proportion that felt that the state was doing the right amount increased as familiarity with the DOE site decreased. For example, 55% who said that they never heard of the site believed the state was doing the right amount to protect the environment of the area.

With regard to the unexpected finding about DOE's capabilities to use new and safe technology, 16% of respondents who claimed that they were very familiar with the site disagreed that the DOE would be effective at using new technology. This compared to only 12% of those who said that they were not familiar with the site. In other words, self-identified familiarity was associated with slightly less confidence in the DOE's ability to use new and safe technology.

Table VI summarizes the three most significant correlates of each peace of mind option from the stepwise runs. The listing follows the order of preference (Table IV) from continuously sampling the air and water at the site (mean 9.0 of 10) to provide access to public via site visits (mean 5.3 of 10). The first column lists the option, the multiple correlation calculated, and the second column lists up to three significant correlates in the order they were selected. The six public health options show that those that wanted monitoring, surveillance, and alarm systems were worried about transportation accidents, non-DOE mining and manufacturing toxins, and they had concerns about their state and local governments current efforts to protect the environment.

Table VI. Statistically Significant Results for Seventeen Peace of Mind Options

Option (stepwise multipler)	Three most statistically significant correlates in stepwise regression, $p<0.05$
PH-1: Continuously sample the quality of the air and water at the site (mult-r=0.475)	Worried about transportation accidents (+) Local govt does too little to protect the env in area (+) Worried about disposal of toxic and mining wastes in area (non-DOE) (+)
PH-2: Regularly monitor health of site workers (mult-r=0.385)	Worried about transportation accidents (+) State govt does too little to protect the env in area (+) DOE will be able to clean up contamination at sites using new and safe technology (+)
LU-1: Make sure that federal government owns site until all hazards are removed (mult-r=0.326)	Resident income (-) Local govt does too little to protect the env in area (+) Respondent familiar with the site (-)
PH-3: Provide specialized training and equipment to emergency response personnel from surrounding areas (mult-=0.450)	Worried opening site to public could expose people (+) Worried about transportation accidents (+) DOE will be able to clean up contamination at sites using new and safe technology (+)
PH-4: Install an early warning system to alert residents to any problems (mult-r=0.583)	Worried that cleanup of site will cause expose residents (+) Worried about transportation accidents (+) Worried site may be target for terrorist attack (+)
ORG-1: Require government report information about site to community representatives on a regularly scheduled basis (mult-r=0.422)	Worried about transportation accidents (+) Resident of Oak Ridge site (-) Worried about disposal of toxic and mining wastes in area (non-DOE) (+)
LU-2: Maintain security around site by keeping visitors and recreational users off the site (mult-r=0.457)	Worried opening site to public could expose people (+) Worried site may be target for terrorist attack (+)
PH-5: Regularly monitor the health of bird, fish, animals and plants at the site (mult-r=0.516)	State govt does too little to protect the env in area (+) Worried about transportation accidents (+) Worried about disposal of toxic and mining wastes in area (non-DOE) (+)
PH-6: Regularly monitor the health of people who live near the sites (mult-r=0.532)	Worried that disturbing corroding or leaking containers will cause more damage than leaving them in place (+) Worried people may get sick from eating fish and wildlife from the site (+); Worked at DOE site (-)

Table VI. (Continued)

ORG-2: Create a trust fund to make sure that long-term cleanup activities continue and can be done promptly (mult-r=0.448)	Local govt does too little to protect the env in area (+) Area environment will be better in 25 years (-) Worry that the cleanup of the weapons sites will cause contamination in the area (+)
ORG-3: Maintain role of Citizen Advisory Boards that currently represent the community interests at the site (mult-r=0.572)	Worried about transportation accidents (+) Worried about disposal of toxic and mining wastes in area (non-DOE) (+) Worried that disturbing corroding or leaking containers will cause more damage than leaving them in place (+)
LU-3: Make sure remains owned by the federal government forever (mult-r=0.499)	Worried that cleanup of site will cause expose residents (+) Resident income (-) Worried about worker exposure (+)
ORG-4: DOE provide information about what is happening at site using web sites and visits by site personnel to schools and community groups (mult-r=0.420)	Worried some archeological sites will be destroyed by cleanup (+) Respondent is Indian/Native American (+) Female respondent (+)
ORG-5: Require government to appoint and fund an independent watchdog group that includes local people and scientists to monitor site activities and report results to the community (mult-r=0.583)	Worried cleanup at site will expose residents (+) Worried about fact that some waste materials will need to be remain buried or contained on site (+) Attended local govt meeting during the last two years (-)
LU-4: Do not allow any new nuclear-related activity on the site (mult-r=0.684)	Worried about new activities at site that involve use of nuclear materials (+) Worried people may get sick as a result of eating fish and wild life from the site (+) Resident lives in Rocky Flats area (+)
ORG-6: Require that site managers live near the site (mult-r=0.402)	Worried about high risk of fire and explosions related to the cleanup (+) DOE communicates honestly with people in the area (-) Volunteered for a civic function during the last two years (-)
LU-5: Provide access to public via guided site visits (mult-r=0.427)	Worried archeological sites may be destroyed by cleanup (+) Worried opening site to public access could expose people (-); Respondent is from the Fernald site (-)

The strongest correlates of the five land use options varied. For example, the overwhelming majority who wanted the DOE to own the site until all hazards are removed tended to be relatively poor, not familiar with the site, and did not think that the local government was doing enough to protect the local environment. The smaller number who were less interested in this option were more affluent, familiar with the site (many were site workers or related to one), and think their local government was doing a lot to protect the environment. In essence, they did not see the need for owning the entire site until all the wastes were cleaned up and they probably realized that waiting until the wastes were cleaned up means in perpetuity at some sites. Those who did not want visitors and recreational users on the site were worried about exposing people by opening the site and about a terrorist attack on the site. Those who supported allowing the public to visit the sites were not worried about exposing people, they were worried about disturbing archeological or buried site (hence guided visits), and they tended to be disproportionately not from the Fernald area, which has been seeking to redevelop part of the site. But more support for this policy was from the Savannah River Site, and we have found that residents have a great deal of interest in using large portions of the site for recreation (Joanna please add cite or two here).

Responses to the six organizational trust building options were quite variable. For example, the option to provide a trust fund to assure timely and uninterrupted cleanup was associated with responses that the local government has not done enough about protecting the environment and the area is likely to be worse in 25 years. Hence, a federal trust fund provides some long term support for the DOE-related environmental issues. Requiring that site managers live near the site was the 16th priority out of 17. But

those who wanted it tended to worry about fire and explosions at the site, and did not think that DOE communicates with the public. Having DOE management living near the site appears to be an insurance policy for these respondents.

We think the most interesting regression for a specific option was the choice of not allowing new nuclear missions (Table VII). The average score was 6.8 on a 10 point scale. Forty-two percent of respondents said it was a 10, that it, was a high priority option. But 15% said it was a 1, and 40% had it rated 5 or less. The regression helped us understand the variation. People who worried about new activities involving the use of nuclear materials worried about the impact of these activities, many worried about transportation accidents and about leaving materials on site. These respondents do not trust DOE to effectively manage any new waste on site. They tended to be relatively poor, African American and female. They lived near the Rocky Flats and Fernald site but not the Idaho site. The site-related findings were not surprising. Rocky Flats and Fernald are completing cleanups and the plans are for non-nuclear uses of the site. INL has received funding to develop a new nuclear reactor, and surveys show that the area closest to the site supports the idea of this new nuclear mission (Blankenship et al., 2005; Gonzalez, 2002).

Table VII. Stepwise Regression of Not Allowing New Nuclear-Related Activities on the Site

Correlate	B-value	Standard Error	Beta	t-value	p-value
Constant	9.25	0.87	---	10.63	<.01
Worried about new activities on the site that involve use of nuclear materials (1=worried a great deal, … 4=not at all worried)	-0.66	0.20	-.201	-3.29	<.01
Respondent near Rocky Flats site (1=yes, 0=no)	3.40	0.61	.232	5.59	<.01
Worried about transportation accidents (1=worried a great deal, … 4=not at all worried)	-0.39	0.18	-.118	-2.12	.03
Annual family income in 2005 (1=under $25,000, … 5=$100,000 or more)	-0.37	0.13	-.129	-2.95	<.01
Respondent near Idaho site (1=yes, 0=no)	-0.93	0.36	-.114	-2.58	.01
Respondent Sex (1=female, 0=male)	1.04	0.31	.143	3.37	<.01
Worried that some waste materials will need to remain buried or contained on site (1=worried a great deal, … 4=not at all worried)	-0.41	0.19	-.130	-2.21	.03
Respondent was African American (1=yes, 0=no)	1.66	0.61	.116	2.73	<.01
Trust DOE to effectively manage any new waste on the site (1=strongly agree, … 4=strongly disagree)	0.56	0.23	.108	2.45	.02
Respondent voted in election during the last two years (1=yes, 0=no)	-1.14	0.51	-.094	-2.24	.03
Respondent near Fernald site (1=yes, 0=no)	1.43	0.72	-.081	-1.97	.05

*Multiple r was 0.674, adjusted r-squared 0.437.

5. DISCUSSION

Before summarizing the results and discussing their public policy implications, we repeat two key limitations of the survey. Both are common to every survey because of budget constraints. One is that we would feel more confident if we had 400 to 800 samples at each site instead of 225. Totals of 800 and 400 provide sampling errors of 3.5% and 5 %, respectively, compared to 6.7% percent for a sample size of 225. Also, a national random sample with the same questions would have provided a comparison population. A second limitation is that we had to reduce the number of peace of mind options to 17. This was because the initial draft of the survey took 27 minutes compared to the 15 that was part of the design. We also had to eliminate questions that would have helped us better understand the sources people trust for credible information about sites. We had only one question that probed respondents' optimum-pessimism about the future. We would have used efficacy and optimism-pessimism scales to get a more precise perspective about respondent's personality characteristics that underlie these results.

These limitations should be addressed in future research. Also, while these are the major sites of concern, similar surveys at other DOE sites that may have residual waste for more than a decade would be valuable additions. There has been increasing discussion in the United States of electricity generation using nuclear fuel. Inevitably, the public will connect nuclear power and the nuclear waste legacy at these sites because some of these sites could host generating facilities and/or be the repository for more waste and technology development. We suggest adding questions to future surveys in order to probe the intersection of nuclear-based energy and nuclear waste management.

Given these caveats and suggestions, the study showed that most people who live within 50 miles of one of these six nuclear weapons sites were mildly to moderately concerned about the legacy. Other environmental issues, such as open space, water pollution, and local manufacturing and mining operations were considered slightly more worrisome by most of the respondents. The exceptions were Hanford and Savannah River where the nuclear legacy ranked second and third in priority.

While nuclear-related waste management was not the most worrisome environmental problem in any of the six regions, respondents clearly have high expectations of the DOE. Public health surveillance and land use controls were strongly favored by the vast majority. Ambivalence was evident about organizational trust-building options, including requiring site management to live near the site, allowing other nuclear-related missions on the site, and offering guided site visits.

In some ways, the correlates of peace of mind choices were as interesting as the options themselves. Worry about transportation accidents was a significant correlate in 9 of the 17 peace of mind stepwise regressions and the first selected in the peace of mind scale regression. Transportation accidents may be less risky than other on-site activities, but the public clearly does not feel that way. Concern about non-DOE related hazards from manufacturing and mining appeared in 6 of the 17, concern about DOE's ability to use new and safe technology was in 6, concern about public exposure by granting access was in 5, and fear that cleanup of the hazards will expose residents in 4. In fact, these five correlates accounted for 30 of 101 incorporated into the 17 stepwise regressions. Probing the underlying psychological triggers associated with these five variables should be done using focus groups and individual interviews.

With regard to theory, much, but not all, of what we observed had been expected based on the psychometric paradigm, theories about trust and habituation, and demographic correlates of risk. The most interesting theoretical challenge is to try to extract from these findings what appears to be mental models, or heuristics of how people perceive these DOE sites and their nuclear waste legacy. We know that people build simplified mental models of reality that help them cope with risks and stresses. These models are an integration of their personal experiences. They reuse these models and change them as new experiences occur (Chaiken, 1980; Eagly & Chaiken, 1992). This survey suggests that there are at least two mental models. The most common one perceives the DOE site as a mild to moderate threat, is not convinced that the Department can protect them against on-site problems and transportation accidents. These respondents, who are disproportionately poor, women, and Black and Indian Americans want monitoring, surveillance and early warning and are reluctant to let anyone on the site who does not have an official role, and almost every one of them wants the federal government to own the site until the contaminants are cleaned up. Their counterparts, or close to opposites, are a minority of respondents many of who are relatively affluent non-Hispanic Whites who work at the site or are otherwise familiar with it. Their mental model of their site is that it is not a threat, and they are not interested in many of the peace of mind options. Their highest priorities were for federal ownership of until the hazards are removed, monitor the health of site workers and the quality of the air and water. There is no unanimity among them regarding the DOE's capacity to implement these or other peace of mind options. A goal is to try to more clearly define the two main groups, identify others, and tie them back to underlying theoretical concepts about mental

models. What is missing from the current study, as noted earlier, are personality measures.

The research has clear implications for the DOE, other federal departments that are currently or will be involved on these sites, state and local government, community advisory boards, and other stakeholders. The responsible parties can take some comfort in the recognition that the nuclear weapons legacy is not the number one environmental concern at any of these sites. Yet the residents have high expectations, especially with regard to monitoring and reporting information, early warning systems, and tight control on the site at least until cleanup is achieved, which at some of these sites will take many generations. They also want early warning systems and training and equipment for likely outside first responders. It was most interesting that there was much less support for organizational-trust building options such as guided tours, requiring management to live near the site, web site and personal contacts, and even, surprisingly, a trust fund. Some respondents may perceive these as gimmicks rather as genuine risk reduction efforts.

The challenge faced by responsible parties is how to establish a stewardship program that responsibly manages financial resources in a way that convinces state and local government, community advisory boards and the public that remediation can go on at the same time that some waste is interned until suitable technologies can be safely deployed. Solid science and engineering are essential. But communicating the science and having the communications be trusted may be an equal or greater challenge. With regard to communications, the data we collected are both encouraging and discouraging. The encouraging information is that 74% of respondents believe that DOE will prevent underground contamination from migrating off site, 83% agree that the Department will

use new and safe technology, and 76% agree that it can manage waste left on the site and new waste. The discouraging information is that 33% disagree that the DOE communicates "honestly" and only 14% strongly agreed that they communicate honestly. These observations do not literally mean that the public feels that the DOE is deliberately not being honest. It may be that the public perceives that it is not getting the information in a timely fashion, or that it is not getting all the information. For example, 36% of respondents worried a great deal about transportation accidents. Among these respondents, 42% felt that the DOE does not communicate honestly with the public. In contrast, among those who were not worried about transportation accidents, only 2% felt the DOE did not honestly communicate. The DOE clearly has a credibility problem with some people.

Stewardship cannot succeed with a serious credibility problem (Lowrie et al., 2003). Gaining public trust in the main steward's organization and processes is essential. We know that it will not be easy to increase credibility because of the demonstrated difficulty of engaging people (Laurian, 2004). Yet more members of the public near these sites should have a greater peace of mind about the sites and the organizations responsible for them. The current situation at these sites is in fact an opportunity that few planners and risk analysts have a chance to engage in, which is to produce a stewardship plan that builds and ties a flexible sustainably protective risk management system (Greenberg et al., 2005) to a broad based risk communication program and paid for primarily by the federal government. This opportunity is rarely given to those who live near landfills, abandoned refineries, mines, and other non-government hazards. Cole (2001) argued that planners must "dare to dream," even if the work is idealistic and not

always realistic. At these DOE sites, part of the future has been determined by contamination, and it is incumbent upon the site planners and risk analysts, other responsible parties, and the Community Advisory Boards to invite stakeholders to "dare to dream" about how these sites can and should be used, managed, and connected to them in perpetuity.

Appendix A – Brief site descriptions

These are sites at which major parts of nuclear weapons were manufactured, tested, assembled, and where high-level waste resides. Much of the waste will remain at the sites in perpetuity, while the Department of Energy tries to develop safe and affordable remediation options. Briefly, Hanford is a 560 square miles of arid land located in southeast Washington along the Columbia River on agricultural land, which had been occupied by Indian Americans and farmers. The site was used for fabrication, irradiation, and chemical separation, and for component manufacturing. Hanford has the most of the weapons-related high-level nuclear waste, and thousands of nuclear and chemical waste sites. The Savannah River site (SRS), 360 square miles of former agricultural land, is located along the Savannah River on the border between Georgia and South Carolina near Augusta. Tritium was produced at SRS, and fuel was fabricated, irradiated, and separated. It contains most of the high level radioactive waste that is not at Hanford. The Idaho National Laboratory Site (INL) is 890 square miles of rangeland in southeast Idaho, 29 miles from Idaho Falls. The site was used for chemical separation, and some high level waste is buried there. Other non-nuclear missions were carried out, such as testing 16" battleship ammunition, and there are ongoing nuclear missions including a new era nuclear reactor under development. These first three sites in our study were chosen by the federal government for nuclear weapons development because of their remoteness from population centers and other specific characteristics, such as access to water. Fernald is a comparatively small site (less than two squares miles) where uranium refining, metal fabrication and machining were done. The site lies about 20 miles northwest of Cincinnati. Oak Ridge is a 55 square mile aggregate of three DOE

facilities where components of highly enriched uranium, depleted uranium and other elements were enriched. The City of Oak Ridge was built around the site. Lastly, Rocky Flats is a 10 square mile site that overlooks the Denver metropolitan region below. Plutonium triggers for nuclear weapons were manufactured at the site.

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