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Regional economic benefits of environmental management at the US Department of Energy's major nuclear weapons sites

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The five major US Department of Energy nuclear weapons sites located in the states of Colorado, Idaho, South Carolina, Tennessee and Washington have changed functions. Environmental management of 50 years of on-site contamination is now the primary function of the sites. The cost of this cleanup is estimated at over $200 billion. A regional economic simulation model was built to estimate the economic impact of changing environmental management expenditures on the surrounding regional economies. These simulations show wide variability among the host regions in dependence on the DOE site and differences in the likelihood of producing jobs and adding to personal income from environmental management investments at the sites. Urban regions, such as Oak Ridge, are more able to convert environmental management dollars into local jobs and income than rural regions, such as the Idaho National Environmental Engineering Laboratory.

Keywords: economic impact, nuclear weapons sites, remediation, cleanup, US Department of Energy.

Introduction

What US Government agency supervises the largest hazardous waste management budget? If, like most people, you answered the US Environmental Protection Agency (EPA), then your answer is almost right. The EPA has a massive program, including more than 1300 so-called 'Superfund' or National Priority List sites. Russell *et al.* (1991) estimated that the EPA would spend $151 billion during the years 1990–2020, or an average of about $5 billion a year to manage these sites.

But the EPA does not manage the most expensive hazardous waste management program. That distinction belongs to the US Department of Energy (DOE). Russell *et al.* (1991) gave a best estimate for the DOE over the same 30 year period of $240 billion, or $8 billion a year. The DOE's own estimates are that $230 billion will be spent for environmental management during the period 1995–2070, with a range of $200–350 billion (Office of Environmental Management, 1995a). The DOE environmental management legacy is the second largest economic mortgage left to future American generations. Only the national debt is larger.

From the perspective of regional economics, the distribution of environmental management expenditures by the EPA and DOE is markedly different. The EPA's hazardous waste site remediation money is spent on 1300 sites and in every state. In contrast, over 70% of the DOE environmental management (EM) budget is spent at only five sites in Colorado, Idaho, South Carolina, Tennessee and Washington. Environmental management budgets of $400 million to over $1 billion a year concentrated in relatively isolated regions should constitute a significant part of a regional economy. In other words, the five major DOE environmental management, or EM, sites should be excellent places to study the local economic impact of massive environmental management funding. The purpose of this research was to answer two questions about impacts of DOE

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environmental management expenditures on areas immediately surrounding the five sites where it spends the vast majority of its EM funds: (1) What proportion of gross regional product (GRP) is directly accounted for by DOE funds, and more specifically DOE environmental management funds?; and (2) What is the estimated economic impact of changing the DOE environmental management budgets on the surrounding regions? Answering these questions explicitly provides information needed by DOE policymakers, local officials and other stakeholders in the regions surrounding these facilities. In fact, regional interest groups have requested answers to these questions.

Before proceeding, it is important that three contexts are provided. One is historical. The nuclear weapons complex of over 100 sites across the United States grew out of the Manhattan project during the Second World War. The initial facilities were constructed on the outskirts of Chicago (IL), and in three completely new towns: Oak Ridge (TN), Los Alamos (NM) and Richland (WA, Hanford site). Many of the other sites were planned and built during the initial phases of the cold war in the late 1940s and early 1950s. The large sites in Idaho (Idaho National Environmental Engineering Laboratory, or INEEL), Colorado (Rocky Flats), and South Carolina (Savannah River, or SRS) were planned and constructed during this period and expanded during the cold-war buildup that lasted from the mid-1970s through the late 1980s. While some of these sites also include large energy research labs, the history of contamination mostly stems from weapons development and nuclear material production (Office of Environmental Management, 1995a,b, 1996; US Department of Energy 1995, 1996, 1997).

All of the facilities were originally located in rural areas. Over the years, urbanisation has moved from the nearest cities toward each of the sites. Oak Ridge and Rocky Flats are now part of the major metropolitan regions—Knoxville with a population of over 600 000 and Denver with a population of over 2 million. Smaller metropolitan regions exist at the other sites. The small relative size of these areas has made the areas surrounding the Hanford, INEEL and Savannah River sites more dependent on the DOE and more vulnerable than their counterparts at Rocky Flats and Oak Ridge to changes in DOE spending patterns (Gerber, 1992; Greenberg *et al.*, 1997; Lancaster, 1984; Schill, 1996).

The second context is situational. Substantial economic change is occurring in these regions. The regions surrounding these five weapons sites enjoyed substantial increases in jobs and income during the military buildup that occurred in the administrations of Presidents Carter and Reagan (Greenberg *et al.*, 1997). However, in 1989 the cold war ended, the major weapons buildup ended, the DOE began to dismantle its nuclear weapons complex and jobs in these regions declined. At the Savannah River Site (SRS), for example, DOE site-related jobs decreased from 24 000 in 1994 to 16 000 in 1997 (Greenberg *et al.*, 1997). Further cuts are expected to perhaps as low as 8000 jobs. While the nuclear weapons mission was scaling down, an environmental management mission began. The DOE organised an Environmental Management Program aimed at addressing contamination across its complex of more than 130 sites. Funding for this program at the five sites grew from $1·7 billion in 1990 to $3·7 billion in 1996 (in constant 1992$). The DOE's environmental management dollars are used for a variety of activities, such as controlling dangerous high-level radioactive wastes stored in massive tanks; converting the liquid high-level wastes to solids by mixing with molten glass; monitoring ground, and surface water, and ecological systems; and cleaning up contaminated hot spots. The DOE has also begun a land use planning process that is directly tied to the environmental management activities (Office of Environmental Management, 1996).

As 'state anchored' districts (Markusen, 1996), the residents of these regions are extremely concerned about the anchor being removed (Lowrie and Greenberg, 1997a,b). There is also a concern that the DOE and its predecessor, the Atomic Energy Commission, have paid such high wages and provided such flexible working hours that private industry will not locate in these regions (Lowrie and Greenberg, 1997a). In addition, researchers have argued that the mere presence of a nuclear weapons site has discouraged private industry from locating near these sites (Brauer, 1995; Hooks and Getz, 1996; Weida, 1993). In short, environmental management is perceived in these regions as a substitute

Table 2. Department of Energy (DOE) expenditures at sites as a contribution to gross regional product: five site-regions, 1994[a]

Site-region (1)	DOE final demand (million $) (2)	DOE EM final demand (million $) (3)	(3)/(2)	REMI estimate of GRP (million $) (4)	1994 DOE as % of GRP (5)	1994 DOE EM as % of GRP (6)
Hanford	1754	1535	0·88	11 008	16·0	13·9
INEEL	607	535	0·88	3199	19·0	16·7
Oak Ridge	2270	629	0·28	16 031	14·2	3·9
Rocky Flats	907	489	0·54	18 720	4·8	2·6
Savannah River	1509	764	0·51	9454	16·0	8.1
All five sites	7047	3952	0·56	58 412	12·1	6·8

[a]The table expresses gross regional product in terms of final demand. The year 1994 had relatively high DOE environmental management (EM) budgets. See text and Table 4 for other values.

of GRP for each site-region produced by REMI is shown in column 4. The Rocky Flats and Oak Ridge regional GRPs are more than five times the INEEL one. The Savannah River and Hanford GRPs fall between these three.

The fifth and sixth columns are the DOE final demand as a proportion of the total regional economy. As a context, in 1994, federal spending (in terms of consumption and investment) accounted for 7·4% of the gross domestic product of the United States. The DOE accounted for an average of 1·1% of federal spending. Therefore, DOE accounted for 0·08% of federal spending. So any region where DOE spending accounts for more than 0·08% should be considered to have a large concentration of DOE expenditures. All five regions far exceed the average. Therefore, these regions are characterised as dependent upon DOE EM expenditures. Yet, the regions vary in terms of the degree of dependence from 32 to more than 200 times the average level of DOE EM spending. INEEL (16·7%) and Hanford (13·9%), by far, are most dependent on DOE's environmental management expenditures followed by SRS (8·1%). The DOE's EM budget plays a much smaller role in the Oak Ridge (3·9%) and Rocky Flats (2·6%) regions. While Table 2 puts the DOE's environmental management program in perspective for a single year, it is noted that the year 1994 was one in which DOE expenditures were relatively high in the regions. The simulated DOE expenditure patterns, which will be presented in Table 4, are based on a baseline that averages the period 1990–1996, and hence the DOE part of the regional GRP is slightly inflated in 1994 compared to the entire recent past.

Table 3 shows DOE EM expenditures by site for selected years during the period 1990–2010. Briefly, the sites with the largest EM budgets produced nuclear materials, built components and assembled weapons. They are the places where the most dangerous wastes are found. The top five are responsible for about 70% of the total EM budget throughout the period. Hanford and Savannah River have received the largest shares of the DOE EM budget in every year.

Table 3 also shows that the 13 other major DOE sites receive in aggregate about the same amount as the Hanford or Savannah River sites. The rest of the DOE includes over 100 sites located across the United States. The aggregate EM budget of this rest of the DOE ranges from 8 to 17% of DOE's total EM. Summarising, the DOE's EM budget is a large component of the economies of the five regions, especially Hanford, INEEL and Savannah River.

Question 2: regional economic impacts of changes in environmental management investments

In the baseline forecast, the model implicitly continues current DOE funding patterns levels into the future. It was estimated what would happen if the DOE raised or lowered

Table 3. Department of Energy (DOE) environmental management (EM) expenditures at major sites, 1990–2010 Millions of 1992 (% of total DOE EM)

Site-region	1990	1992	1994	1996	1998	2000	Annual 2001–2005	Annual 2006–2010
Hanford	501	1060	1471	1195	1379	1202	1212	1098
	(21·1)	(24·8)	(24·8)	(20·8)	(21·4)	(19·3)	(19·6)	(21·5)
INEEL	241	325	513	417	430	467	510	496
	(10·2)	(7·6)	(8·6)	(7·3)	(6·7)	(7·5)	(8·9)	(9·7)
Oak Ridge	300	499	603	443	852	844	764	539
	(12·7)	(11·7)	(10·2)	(7·7)	(13·2)	(13·5)	(13·4)	(10·5)
Rocky Flats	149	182	469	522	497	411	374	369
	(6·3)	(4·3)	(7·9)	(9·1)	(7·7)	(6·6)	(6·6)	(7·2)
Savannah River	501	551	732	1120	1185	1236	1161	1075
	(21·1)	(12·9)	(12·3)	(19·5)	(18·4)	(19·8)	(20·4)	(21·0)
Other major DOE ($n=13$ sites)	479	1003	1283	1067	1077	1083	935	854
	(20·3)	(23·5)	(21·7)	(18·5)	(16·8)	(17·4)	(16·4)	(16·7)
Rest DOE US ($n>100$ sites)	199	650	872	982	1027	987	841	682
	(8·4)	(15·2)	(14·7)	(17·1)	(15·9)	(15·8)	(14·7)	(13·3)
Total DOE	2370	4269	5943	5748	6447	6230	5706	5113

Source: Office of Environmental Management, 1985a, Office of Environmental Management 1995b, 1996.
[a]Numbers may not add to totals because of rounding.

Table 4. Department of Energy (DOE) environmental management (EM) site budgets as a proportion of gross regional product (GRP), 1997–2010

Time period and change in DOE final demand 1992$ millions	Hanford	INEEL	Oak Ridge	Rocky Flats	Savannah River
REMI estimate of regional GRP,					
1997	11 069	3200	16 242	18 843	9729
2010	13 870	4097	21 039	24 834	12 332
DOE final demand, baseline annual avg, 1990–96	1141	402	487	337	712
1997 % of Region GRP	10·3	12·6	3·0	1·8	7·3
2010 % of Region GRP	8·2	9·8	2·3	1·4	5·8
DOE final demand, baseline +10%	1225	442	536	370	783
1997 % of Region GRP	11·3	13·8	3·2	2·0	8·1
2010 % of region	9·1	10·8	2·5	1·5	6·4
DOE final demand, baseline +50%	1711	603	703	505	1068
1997 % of Region GRP	15·5	18·8	4·5	2·7	11·0
2010 % of region	12·3	14·7	3·5	2·0	8·7
DOE final demand, baseline −10%	1027	362	438	303	641
1997 % of Region GRP	9·3	11·3	2·7	1·6	6·6
2010 % of region	7·4	8·8	2·1	1·2	5·2
DOE final demand, −50%	570	201	244	168	356
1997 % of Region GRP	5·1	6·3	1·5	0·9	3·7
2010 % of region	4·1	4·9	1·2	0·7	2·9

REMI, Regional Economic Models Inc.

its EM budgets at the five sites. A variety of increases and decreases were simulated for the period 1997–2010.

Table 4 shows what was entered into the model for each simulation. Specifically, Table 4 presents baseline and simulated EM expenditures in the context of the growing GRPs of the five regions. Changes in EM expenditures were modeled to occur between 1996 and 1997 and then to continue through-

for building bombs, in other words, butter replacing guns.

A third point of context is that the reader should know that this research was funded by the US DOE under a co-operative grant to explore issues of importance to stakeholders. For the record, the DOE did not request this study nor, did it in any other way influence the research questions, design or interpretations of the results. It is the concern of the residents of the regions, rather than the DOE, which prompted this study.

Methods and their limitations

A multi-regional economic simulation model built by Regional Economic Models Inc. (REMI) was selected. The builders of this model estimate regional forecasts based upon econometric estimation of key variables within the context of the national economic forecast as developed by the Department of Labor (Saunders, 1993). These variables include regional purchase coefficients, migration rates, wage rates and inter-industry trade as detailed in the model handbook and in the regional economics literature (Treyz, 1993; Treyz *et al.*, 1980).

Economic forecasting is not an exact science. Such models should be used to explore small changes in key variables. Specification error within the model may be multiplied with each iteration. The model has performed well in tests that simulated recent economic history. Treyz estimates that the mean average percent error for US employment estimates to be between 1·4 and 1·8% in the 1st year and 5·0 and 7·6% in the 8th year. Treyz also notes that errors will be higher for an individual industry or region (Treyz, 1993). However, compared to other regional economic forecasting techniques the REMI model performs well (Grimes *et al.* 1992).

Six decisions made about the design and application of the model strongly influence the results. Each of these is discussed. First, the regions of interest were defined. US counties are the basic geographical building blocks. Three methods were considered for building the multi-county regions. Regions could have been defined by the extent of environmental impact. Such a definition would provide a context for compensatory claims as well as economic redevelopment. However, a great deal of uncertainty exists about the extent of off-site environmental impact and the transport of hazards at the sites (see for example Farris *et al.*, 1996). Another possibility was to determine the extent of economic linkage of each county to the nearby weapons site by measuring the residential location of DOE site workers (for example, see Halliburton NUS, 1992). Unfortunately, residential location data were not available for all the sites. Therefore, the economic regions were defined as any county within 10 miles (16·1 km) of the perimeter of a DOE site. In some of the rural sites this definition means that some counties with relatively little linkage to a DOE facility were included. For example, Burke County (GA) lies directly across the Savannah River from the Savannah River site. However, because there is no bridge crossing the river at that point, Burke has benefitted much less than one would normally expect based on direct distance from the facility. An advantage of using 10 miles as a distance is that it provides a consistent definition and allows us to measure how off-site effects vary by region over a fixed distance. Additionally, this definition includes many of the off-site areas whose environment may have been adversely impacted by DOE facilities.

One exception to the 16·1 km zone was made. Adams and Denver Counties (CO) were not included in the Rocky Flats site-region even though they are between 15 and 17 km away. Adams and Denver are the center of the Denver metropolitan region of over 2 million people. Preliminary analyses showed that these two counties would have obfuscated any impacts of adding even $100 million into the regional economy through the Rocky Flats site. The disadvantage of this decision is that more of the DOE investment escapes the local region than would be the case if the larger Denver region had been defined as the local region.

Conversations with staff at the Savannah River site implied that there are formal transactions between the site-regions. In other words, when the DOE builds or remediates at the Savannah River site some flow of dollars occurs at the other sites. A model is needed, capable of capturing transactions between the Savannah River site and Hanford, INEEL Oak Ridge and Rocky Flats. In addition, the

Table 1. Definition of nuclear weapons site regions used in the study[a]

Region	State	Counties
1. Hanford	Washington (WA)	Adams, Benton, Franklin, Grant, Yakima
2. Idaho National Environmental Environmental Engineering Laboratory (INEEL)	Idaho (ID)	Bingham, Bonneville, Butte, Clark, Jefferson
3. Oak Ridge	Tennessee (TN)	Anderson, Blount, Knox, Loudon, Morgan, Roane
4. Rocky Flats	Colorado (CO)	Boulder, Gilpin, Jefferson
5. Savannah River (SRS)	Georgia (GA) South Carolina (SC)	Burke, Richmond Aiken, Allendale, Barnwell
6. Other major DOE sites: Burlington, Fernald, Kansas City, Lawrence Livermore, Los Alamos, Mound, Nevada Test Site, Paducah, Pinellas, Portsmouth, Sandia, Waste Isolation Plant, Weldon Spring	Iowa (IA), Ohio (OH), Missouri (MO), California (CA), New Mexico (NM), Ohio (OH), Nevada (NV), Kentucky (KY), Florida (FL), Ohio (OH), New Mexico (NM), New Mexico (NM), Missouri (MO)	Includes 40 counties near these sites
7. Rest of US	All 50 States	Includes almost 3000 counties

[a]The Department of Energy (DOE) has over 100 sites. Facilities in over 100 of these 3000 counties receive some DOE funding. This proportion is provided in Table 3 for context.

DOE has 13 other weapons sites that also have received considerable EM funding from the DOE (Office of Environmental Management, 1995a,b). It was expected that some of these sites, which include Los Alamos and Sandia (NM), Lawrence Livermore (CA), and 10 others might also interact with the five major sites. Consequently, the third design decision was to build a model that contains the five regions, an aggregate for these 13 other DOE-site regions, and the rest of the United States. Table 1 shows the final set of regions and counties included in the analysis. The location of these five regions is also shown in Figure 1.

Selection of the forecasting period was a second design issue. Regional Economic Models Inc. provides a baseline forecast from 1995 to 2035. Since social and economic conditions are changing so rapidly in the world, long-term forecasts with REMI or any simulation model are problematic. Consequently, this forecasting period was ended at the year 2010.

The extent of inter-industry detail was a third design decision. The model chosen uses 14 economic sectors: durable products manufacturing; non-durable products manufacturing; mining; construction; transport and public utilities; finance, insurance and real estate; retail trade; wholesale trade; services; agricultural services; state and local Government; federal civilian; federal military; and farm.

The US Bureau of Economic Analysis, which prepared the data used in REMI, characterises employment at these DOE sites by the business of the site contractor. Thus, when DuPont was operating contractor for the Savannah River site, employment at the site was assigned to the inorganic chemical industry, or in the case of the authors' model to non-durable manufacturing. When Rockwell International was the contractor at Rocky Flats, workers were assigned to the 'other transportation equipment industry' in the durable manufacturing sector. In the authors' model, non-durable manufacturing is where nearly all of the DOE jobs have been located at the Hanford, INEEL, Oak Ridge and Savannah River sites. The limitation of the classification used in this model is that there is some non-durable manufacturing unrelated to the DOE site in these regions, and the equations in the models are doubtless somewhat distorted by mixing the transactions of the DOE in with them. The only way of avoiding this problem is to develop a model with much greater business sector detail. In the case of REMI, a 53-sector and 172 (or is it 174)-sector model could have been developed. The 172-sector multi-regional model would have reduced some of the distortion. However, cost was prohibitive.

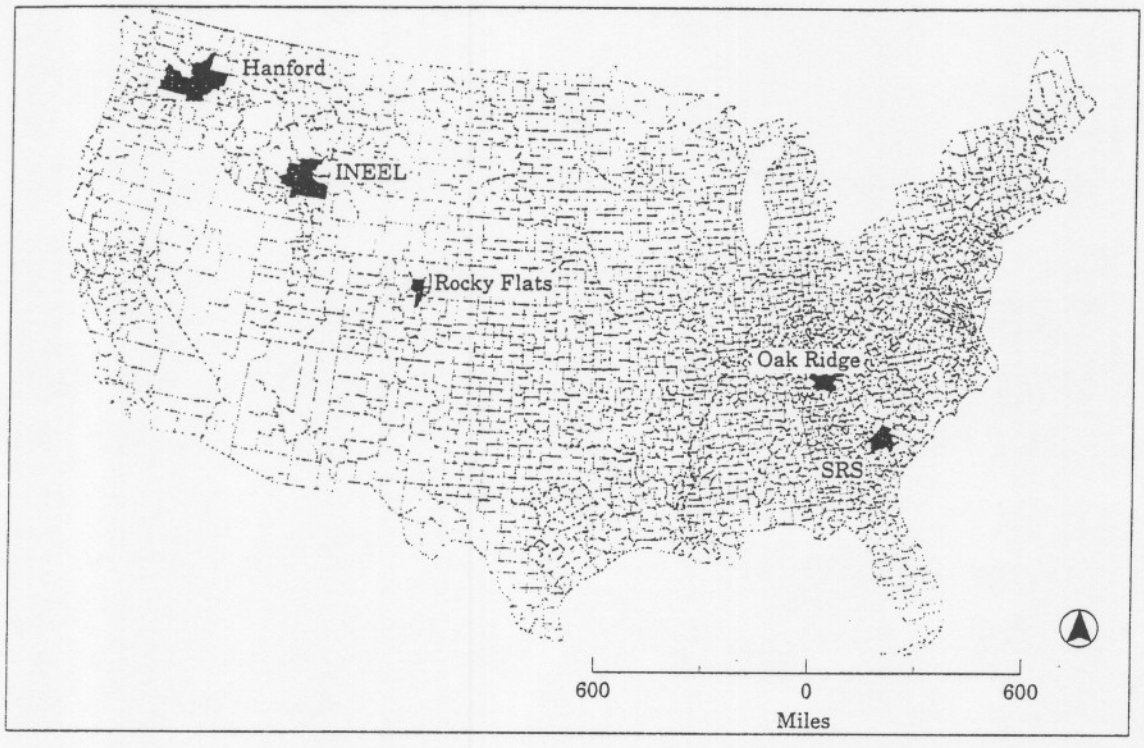

Figure 1. Large Department of Energy Facilities and surrounding regions.

Specifically, the model we used costs about $20 000. The 172-sector model costs about seven times as much.

A fourth decision was to run the simulations without compensation. Since the DOE EM budget is a tiny part of the overall United States budget, it was assumed for the purposes of the analyses that the additional funds added to budget did not come from another federal source. However, in these tight budgetary times, new federal spending is typically offset by cuts in spending some place else. Therefore, a second set of runs was also carried out in which the rest of federal spending as expressed in terms of final demand was cut across the board to pay for the increased EM expenditures. In regions that have a military base, for example, a measurable, albeit small difference between the compensated and uncompensated runs was expected. The compensated runs show that the rest of the United States loses economic activity in order to pay for environmental management of the weapons complex.

The fifth decision was to rely on published DOE reports to distribute EM funds for the period 1997–2010 (US Department of Energy, 1995, 1996, 1997). As the historical data for the period 1990–1996 to be discussed below will show, some changes occur in EM allocations. However, lacking an alternative source or rationale for allocations, the authors relied on the DOE's internal documents.

The sixth, and perhaps most critical decision, was to build a simulation process that recognised the reality that economies do not grow and decline in precisely the same way. Using published DOE data, the ratio of site jobs associated with site budgets (US Department of Energy, 1995, 1996) was estimated. Hypothetically, for example, assume that 100 million dollars is associated with 1000 site jobs. The ratio would be 10 jobs per million. A wage bill for the model was created by multiplying the estimated number of new employees by the average wage at each site. For example, if the average wage package is $55 000, then $55 million of the $100 million is allocated to the wage bill of the model. The

remaining $45 million is spent on purchases. After studying DOE records, 1989–1990 was picked to represent the year when the DOE budget was expanding the most and 1991–1992 as the year when it was growing the least. Allocations for the increases in DOE budgets were based on the average distribution of changes in the economy by the business sectors at the Hanford, INEEL and Savannah River DOE sites recorded in 1989–1990. These three regions were picked because, as will be shown below, they are much more dependent on DOE expenditures than are the Rocky Flats and Oak Ridge regions. That is, the impact of DOE budget shifts is more likely to be accurately captured and not obfuscated in the historical economic records of the first three regions than the last two far less dependent ones. Allocations for decreases in DOE budgets were generated from the average distribution of funds in 1991–1992 in the same way. The result of using this method of allocating the purchases is that the magnitude of impact increases in site budgets are not the same as decreases. In short, it was assumed that the sectoral impacts of economic growth are different than the impact of decline.

Initial tests of interregional effects and compensated impacts

Before presenting the answers to the two research questions, the results of two preliminary tests are briefly presented. The field work had implied that there are interregional transactions among the DOE sites. In order to test this hypothesis and prior to running the simulations for this paper, this assumption was tested in reality by building a hypothetical factory with a capital cost of $1 billion at the Savannah River site. The plant was assumed to be built during the period 1997–1999. Construction was distributed to the various sectors in the model. The results supported the expectation that flows occur among the major DOE site-regions. Over 4000 construction jobs were estimated to be created at SRS in 1997. In addition, several hundred jobs were created at each of the four other sites and the other DOE sites. Since the cost of the new facility was compensated by cuts in the rest of the United States economy, the rest of the US lost over 7000 jobs. In other words, the assumption that interregional effects among these major weapons sites occur is supported by the model simulations.

Simulations were done with and without compensation from other federal programs. The uncompensated runs assume that the additional budgetary resources come from another source outside the model. The compensated runs assume that every dollar added to the DOE EM program comes out of another Federal Government program. As expected, there were only small differences between the compensated and uncompensated analyses in the five regions of interest. During the period 1997–2000, change in employment decreased an average of less than 10%. The difference between the compensated and uncompensated results decline to less than 5% by the end of the simulation period. Since the compensated and uncompensated runs are strongly correlated, it is unnecessary to present both sets of results. The uncompensated ones are presented and it is noted that the compensated runs produce fewer jobs and less increases in personal income.

Question 1: environmental management as a component of the regional economies

Gross regional product (GRP) is a measure of the net economic activity in a regional economy. Gross regional product may be measured in terms of either income or final demand. Final demand was used to measure GRP in this study. Final demand is a measure of the goods and services consumed by the public and Government. Table 2 shows the final demand of the DOE at the five weapons regions in 1994. Department of Energy consumption at the five regions was $7 billion (column 2). Final demand was highest in the Oak Ridge region, almost four times higher than what it was at the Idaho site (INEEL). Environmental Management budgets, however, were highest at the Hanford and Savannah River sites (column 3). The estimate

Table 5. Estimated impact of Department of Energy (DOE) environmental management (EM) site budgets on five site-regions, 1997–2010

	Hanford	INEEL	Oak Ridge	Rocky Flats	Savannah River	Total of five sites
Employment baseline, 1997	263 086	81 071	378 503	459 299	236 022	1 417 981
Personal income baseline, 1997, $ millions	10 213	2771	14 657	21 469	8510	57 620
Gross regional product, baseline, 1997, $ millions	11 069	3200	16 242	18 843	9729	59 083
Employment, baseline +50%						
1997	16 872	5833	10 432	5727	11 794	50 658
2007	14 827	4525	8798	4719	9829	42 698
2010	14 961	4467	9173	4727	9938	43 266
Personal income, baseline +50%						
1997, $ millions	535	172	351	149	324	1531
2010	942	251	571	250	519	2533
Gross regional product, baseline +50%						
1997, $ millions	890	288	515	280	603	2576
2010	1069	332	604	284	727	3016
Employment, baseline −50%						
1997	−19 490	−6597	−11 036	−6847	−13 259	−57 229
2007	−17 579	−504	−9482	−5799	−11 474	−49 738
2010	−17 854	−5398	−9854	−5848	−11 669	−50 623
Personal income, baseline −50%						
1997, $ millions	−597	−186	−362	−165	−342	−1652
2010	−1106	−293	−602	−296	−581	−2878
Gross regional product, baseline −50%						
1997, $ millions	−937	−300	−524	−293	−620	−2674
2010	−1119	−346	−615	−294	−746	−3120

out the study period. Therefore, the biggest economic impacts are in 1997, the first year of the simulations, and these impacts decrease. For example, the GRP of the Hanford region is estimated to increase from $11·1 billion in the year 1997 to $13·9 billion in the year 2010. The average annual DOE EM budget for the period 1990–96 at the site was $1·1 billion. The baseline scenario continued $1·1 billion as the budget for the entire study period. Hence, the DOE proportion of the regional GRP decreased from 10% in 1997 to 8% in the year 2010.

The GRP estimates in Table 4 do not tell the economic impact tale because not all the money allocated to a site creates jobs and personal income in the local region. Some funds purchase goods and services outside the regions. In addition, when some of the money is spent locally, it pays the salaries of local employees. This, in turn, further stimulates purchases of goods and services both locally and outside the region. Table 5 presents the net increases in jobs in the years 1997, 2007 and 2010; personal income in 1997 and 2010; and gross regional product in 1997 and 2010. These increases would have a major impact on the local economies. The 50% increase is estimated to produce more than 50 000 jobs and $1·53 billion in personal income in the five site-regions, including 28 000 jobs and $850 million in the Hanford and Savannah River regions. In the year 2010, the model estimates 43 000 jobs and $2·53 billion in personal income in the five site-regions. The 10% simulation produces about one-fifth of the 50% simulation, or about 10 000 jobs and $300 million in personal income in 1997. Given this almost linear relationship presentation of results in Table 5 is limited to the 50% scenarios.

Changes in EM spending affect the relationship between jobs and personal income in the regions. Note that while the number of jobs produced falls between 1997 and 2010 in a given scenario, EM spending increases personal income in the region. For example, in the 50% scenario, the net increase in jobs in 2010 for the five sites is 86% of the job impact in 1997, while the net increase in

personal income is 166% of the 1997 impact. This increase in personal income reflects the relatively high salaries of DOE facility personnel. Increases in DOE spending lead to more of these high-paying jobs which in turn leads to increased wages in other parts of the local economies in these regions.

To place these estimates in perspective, the ratios of local expenditures across all regions per job created in 1997 were calculated using the 50% increase in EM funding increment. It costs $23 390 in EM dollars to produce an additional job in the Oak Ridge region, whereas it costs $34 500 to create one at INEEL. The costs per job at Savannah River, Rocky Flats and Hanford were $30 200, 29 300 and 33 800, respectively. Note that these results are consistent with the nature of the surrounding regions. The regions that produce the most jobs per dollar of investment (Oak Ridge and Rocky Flats) have larger regional populations and are more urbanised. Hanford and Savannah River received the most EM funds, but they are less urbanised, so slightly more of the EM investments are not available to induce new jobs within the region. INEEL's site-region barely has 100 000 people and the site receives only about one-half of the investment of Hanford and Savannah River. Consequently, INEEL has the lowest job creation per dollar of EM investment.

Further evidence of the urban and total investment effects is found in the time-series of estimated impacts. The ratio of impact in the region was plotted against changes in EM expenditures to show these results over time. In Figure 2 the ratio of jobs created per million by year is shown. The maximum impact at every site occurs in the year 1997. Thereafter, the DOE investment becomes a smaller share of the regional economy. But in the more urbanised regions, the local economy captures a sufficient share of the investment to generate indirect and induced impacts that are apparent before the year 2010. Table 5 shows a piece of this evidence as the year 2007 estimated employment impacts. Oak Ridge, the most urbanised study region, had a job impact of 10 432 in the year 1997 in the 50% increase scenario. This drops to a low of 8750 in the year 2005. However. thereafter it rises again as a result of the indirect and induced effects of the DOE investments and reaches 9173 in 2010. In contrast, INEEL had a job impact of 5833 in the year 1997. This continued to drop throughout the study period. Too much of INEEL's initial investment is not captured locally.

While the job impact is highest in the early years, the impact on personal income keeps rising during the study period. Increased DOE spending leads to increased personal income and eventually leads to increased population growth and increased economic growth. Once again, Oak Ridge is the best performing region. Figure 3 shows that by 2010, the increased DOE spending has almost twice the impact on personal income in Oak Ridge than it has in INEEL.

Finally, the impact on Gross Regional Product over time is shown in Figure 4. These results show once again the dynamic nature of the Oak Ridge economy. The more rural regions produce significantly less economic activity per dollar of EM expenditure. These results also show the sensitivity of region definition on the forecasted impacts. The decline in the GRP ratio (relative to the other DOE regions) in the Rocky Flats region results from increasing economic activity in portions of the Denver Metropolitan Area not included in the region of impact.

The net impact of a budget cut is greater than an equivalent increase in the DOE EM budget. This reflects the downsizing trend of the present economy: companies do not fully make up for job losses during boom periods. For example, the 50% decrease in EM spending is associated with a loss of 57 229 jobs in 1997. Decreasing the budget leads to a 13% higher job impact ratio than increasing the budget. This effect is more pronounced in INEEL, a more dependent region, than in Oak Ridge as seen in Figure 5. Decreases in DOE spending produce a 14% higher job impact ratio in INEEL. Decreases in DOE spending at Oak Ridge only produce a 5·8% higher job impact ratio.

Findings and implications

Two important findings emerge from these analyses. First, over 8% of the gross regional product of the Hanford, INEEL and Savannah River site-regions are due to DOE environmental management expenditures. Oak Ridge and Rocky Flats are located in

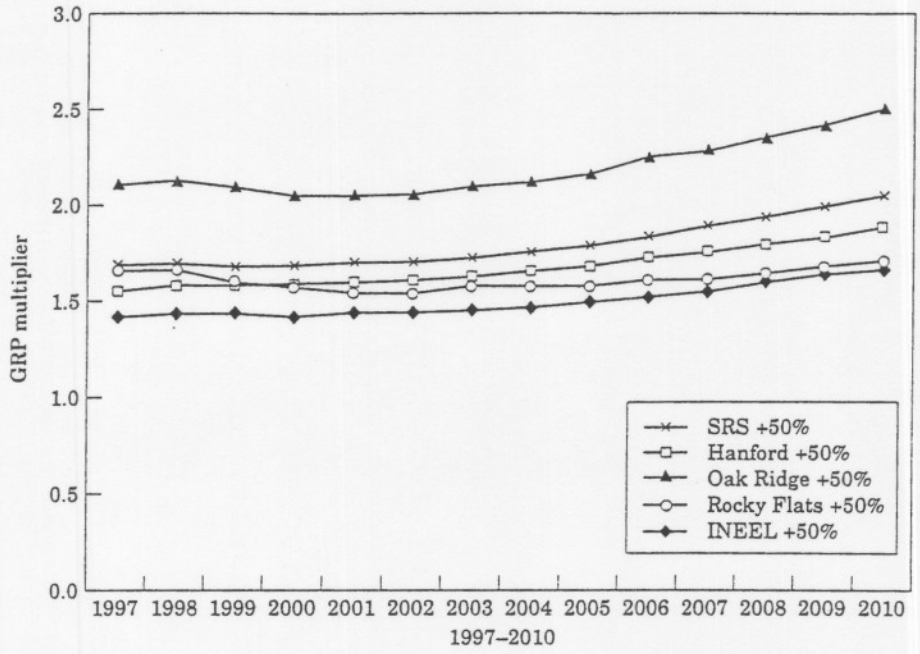

Figure 4. Ratio of net changes in gross regional product (GRP) to changes in environmental management spending by region.

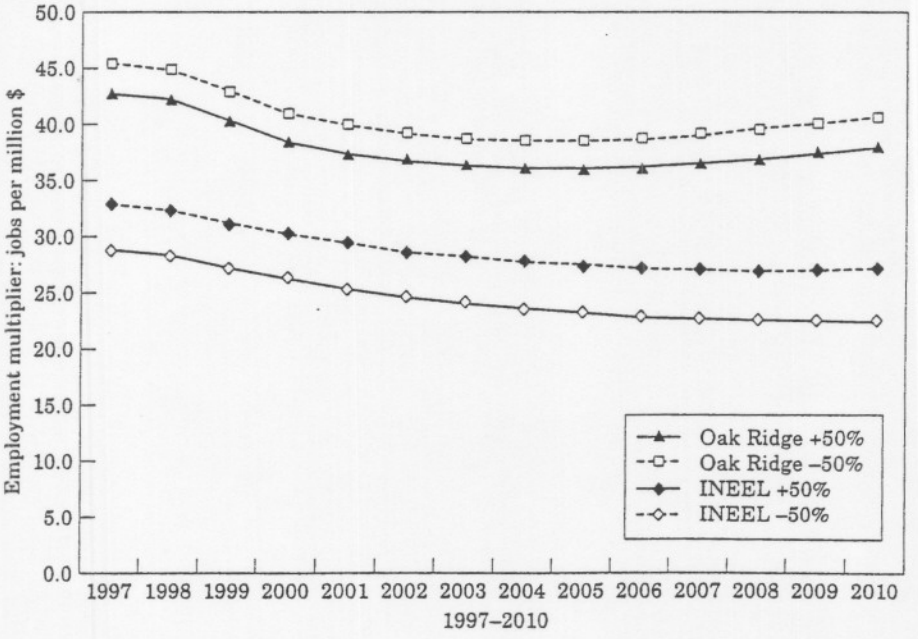

Figure 5. Comparison of job impacts with equivalent environmental management budget increases and decreases Oak Ridge vs. INEEL.

Savannah River and especially INEEL to turn environmental management investments into jobs and personal income because of their larger population, employment and infrastructure. In other words, the site regions that most badly need the investment because of their dependency lose more of it to other regions.

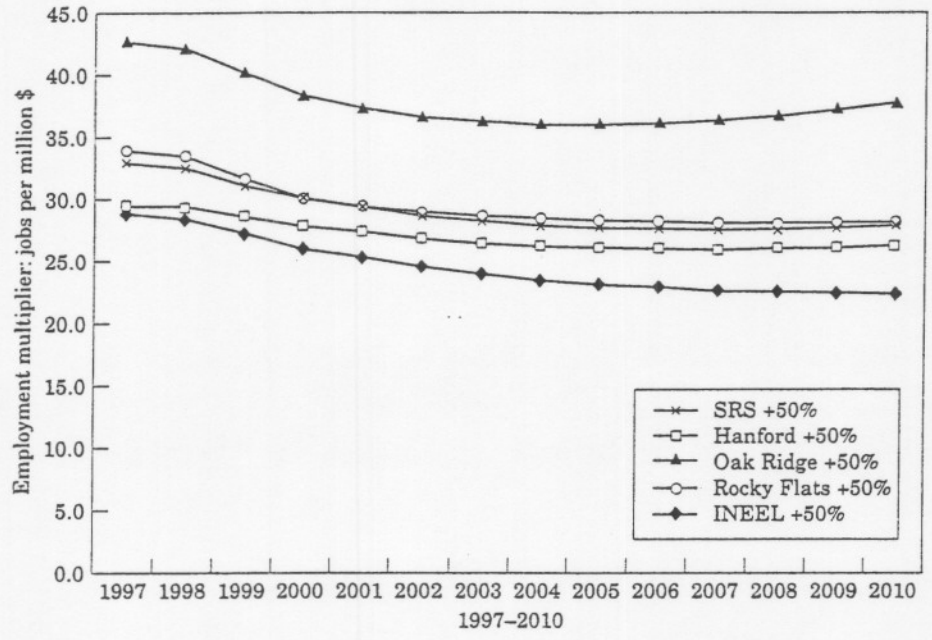

Figure 2. Ratio of net change in jobs per million dollars of environmental management spending by region.

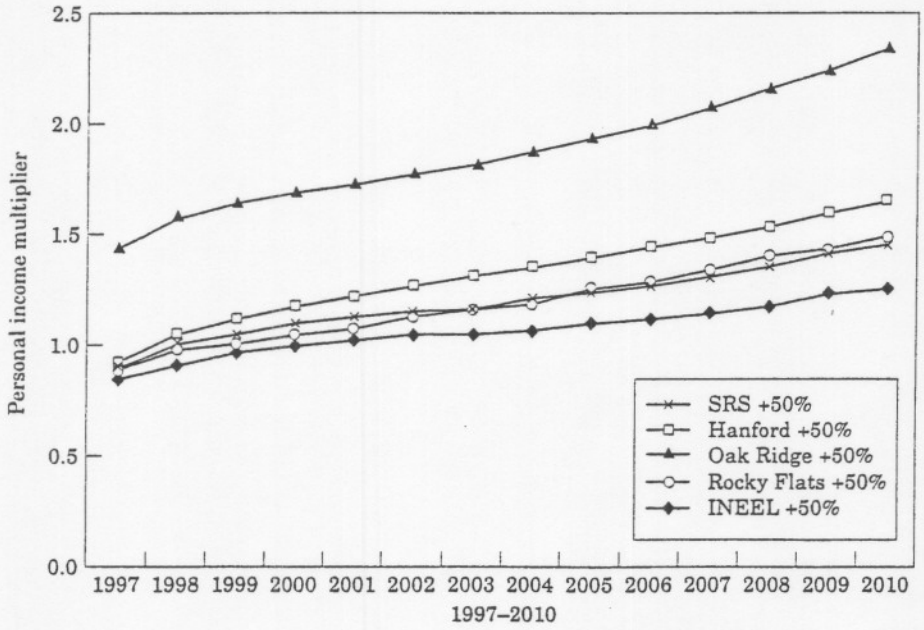

Figure 3. Ratio of net change in personal income to changes in environmental management spending by region.

large metropolitan regions, and consequently the hundreds of millions of dollars spent at those sites are relatively less important in the regions as a whole.

Second, all five of the regional economies would clearly benefit by increases in the DOE environmental management budgets of 10% or more, and conversely they would be hurt by decreases in the budget. Notably, Rocky Flats and Oak Ridge, the two sites that least depend on DOE environmental management funds, are more likely than Hanford,

improving the economic health of these regions, including some like environmental management that emphasise DOE on-site investments and others like investing in education and infrastructure off-site that call upon Government and other private parties to co-operate. This study is a step in that direction.

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It is important that some caveats are reiterated about the information underlying these results before proceeding. In this analysis, because of budget constraints, the authors have relied on a model that has somewhat limited abilities to capture inter-industry differences. The authors think a model with many more business sectors would probably give more accurate estimates. In addition, in order to have a comparable definition of region, some counties have been included that are not well integrated to the weapons sites along with some that are. Finally, every model clearly relies on historical relationships to simulate the future.

The first two of these three information-based constraints can be alleviated with additional resources. For example, a model for the Savannah River site is currently being built that will have 53 inter-industry sectors. One of the tests to be made is to determine how more industry sector detail changes the results produced for Savannah River. Even though the 53-sector-model is expected to be more reliable than the 14-sector one used in this case, it is debatable that the data collected by the United States Government is readily convertible to business sectors that comfortably conform to studies of the economic impact of environmental management investments. Indeed, one of the goals of this project is to recommend how information collection can be improved so that forecasting can be more accurate. Options for definition of site-regions were severely constrained by data. Through consultation with stakeholders in the surrounding areas, regions that are more valuable to the area planners should be obtainable.

Some may question the fact that the DOE EM budgets were arbitrarily increased and decreased for the simulations. In reality, as the historical data show, substantial budget increases and decreases have happened at these site-regions. A 50% increase of EM budgets is certainly possible, as is a 50% decrease. The DOE has considered aggressively pursuing cleanup during the next decade to lower the overall mortgage for cleaning up the sites. Consequently, the authors feel that the simulations presented in this paper are plausible.

The authors hope to extend the analyses in the near future. This initial study focused on environmental management expenditures and impacts of these investments. The authors are designing analyses in which the regional economic impacts of off-site activities, such as, building roads, bridges, sewers and potable water systems, and adding teachers and buildings to educate people in the regions will be examined. The authors also plan to examine the economic impact of expanding recreation and educational programs on the DOE sites. In addition, DOE has requested the authors' assistance in examining the off-site impacts of land use options they are considering for some of the sites. Finally, one of the goals of environmental management for these regions is to make regions more attractive to businesses that might be avoiding them because of the nuclear weapons stigma. In other words, the authors would expect economic benefits external to the model from environmental management investments, as well as the internal benefits examined here. The authors are engaged in field studies to measure the external benefits of environmental management. Once identified, they may be added to this modeling framework.

The point of all these simulations is not to make a case that the DOE and the Federal Government is morally obligated to spend money in these regions. A large literature already exists that makes the case for and against spending and specific kinds of spending in these regions (Anderson, Bischak and Oden, 1991; Brauer, 1995; Employment Research Associates, Inc., 1988; Gerber, 1992; Gertcher and Weida, 1990; Hooks and Bloomquist, 1992; Lancaster, 1984; Oden and Markusen, 1995; Office of Environmental Management 1995a,b; Russell, 1997; Schill, 1996; Schwartz, 1995; Weida, 1993). The authors have no theoretical elegance to add to the literature. Nor is it the authors' claim that complete or perfect information is needed because it is known that models produce imperfect forecasts. Rather, the point is to provide those that live in the site-regions, the DOE, and the US Congress with plausible and reasonable estimates of what is likely to happen if the DOE makes major investments or disinvestments in these regions. A necessary step toward building a consensual policy about the economic future of these nuclear weapons regions requires upgrading our knowledge about them. The authors need to objectively examine a variety of options for

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