Published in final edited form as:

J Environ Manage. 2010 December ; 91(12): 2707–2716. doi:10.1016/j.jenvman.2010.07.028.

Regulatory requirements and tools for environmental assessment of hazardous wastes: Understanding tribal and stakeholder concerns using Department of Energy sites

Joanna Burger^{a,b,c,*}, Charles Powers^{b,d}, and Michael Gochfeld^{b,c,e}

^aDivision of Life Sciences, Rutgers University, 604 Allison Road, Piscataway, NJ 08854-8082, USA

^bConsortium for Risk Evaluation with Stakeholder Participation (CRESP), Rutgers University and Vanderbilt University, USA

^cEnvironmental and Occupational Health Sciences Institute (EOHSI), Piscataway, NJ, 08854, USA

^dCivil and Environmental Engineering, Vanderbilt University, 400 24th Avenue, Nashville, TN, 37235, USA

^eEnvironmental and Occupational Medicine, UMDNJ-Robert Wood Johnson Medical School, Piscataway, NJ 08854, USA

Abstract

Many US governmental and Tribal Nation agencies, as well as state and local entities, deal with hazardous wastes within regulatory frameworks that require specific environmental assessments. In this paper we use Department of Energy (DOE) sites as examples to examine the relationship between regulatory requirements and environmental assessments for hazardous waste sites and give special attention to how assessment tools differ. We consider federal laws associated with environmental protection include the National Environmental Policy Act (NEPA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), as well as regulations promulgated by the Nuclear Regulatory Commission, Tribal Nations and state agencies. These regulatory regimes require different types of environmental assessments and remedial investigations, dose assessments and contaminant pathways. The DOE case studies illustrate the following points: 1) there is often understandable confusion about what regulatory requirements apply to the site resources, and what environmental assessments are required by each, 2) the messages sent on site safety issued by different regulatory agencies are sometimes contradictory or confusing (e.g. Oak Ridge Reservation), 3) the regulatory frameworks being used to examine the same question can be different, leading to different conclusions (e.g. Brookhaven National Laboratory), 4) computer models used in support of groundwater models or risk assessments are not necessarily successful in convincing Native Americans and others that there is no possibility of risk from contaminants

(e.g. Amchitka Island), 5) when given the opportunity to choose between relying on a screening risk assessments or waiting for a full site-specific analysis of contaminants in biota, the screening risk assessment option is rarely selected (e.g. Amchitka, Hanford Site), and finally, 6) there needs to be agreement on whether there has been adequate characterization to support the risk assessment (e.g. Hanford). The assessments need to be transparent and to accommodate different opinions about the relationship between characterizations and risk assessments. This paper illustrates how many of the problems at DOE sites, and potentially at other sites in the U.S. and elsewhere, derive from a lack of either understanding of, or consensus about, the regulatory process, including the timing and types of required characterizations and data in support of site characterizations and risk assessments.

Keywords

Department of Energy sites; Laws and regulations; Natural resources; Tribal nations; Environmental justice

1. Introduction

Clean up and restoration of contaminated sites is one of the most pressing environmental problems that the US and the World face (Lubbert and Chu, 2001; Crowley and Ahearne, 2002; Burger, 2007a). Ecosystem evaluation and the improvement of ecosystem health are no longer concerns only of ecology. The issues raised now attract a broad range of stakeholders and governmental agencies (including Tribal governments). Further, the integration of ecological paradigms and evaluation methods and tools is improving as it is better linked with environmental management of contaminated sites (Cairns, 1980, 1994; NRC, 1986, 1993; Bartell et al., 1992; Cairns and Niederlehner, 1992, 1995; Cairns and Niederlehner, 1992; Barnhouse, 1991, 1994; Suter, 2001; Burger, 1997a,b, 2002, 2007a; Burger et al., 2007a,b; NRC, 2007).

At a time when global changes include climate change, sea level rise, development and destruction of habitats and biomes, increasing human populations, and concentrations of people along coasts, it is even more critical for risk managers, public policy makers and the public to understand the range of regulatory regimes used to manage hazardous sites. Indeed, it is particularly critical to integrate the various methods and protocols for hazardous waste management and natural resource protection into environmental assessments and decision-making, which include Tribal, federal and state governmental agencies, and other stakeholders. Functioning ecosystems should provide the goods and services that human populations require, which include not only clean air and water, food and fiber, medicines, other products, and protection from storms and inclement weather, but also recreational opportunities, aesthetic pleasures, cultural and religious experiences, and existence values (Harris and Harper, 2000; Zender et al., 2004; Bridgen, 2005; Stumpff, 2006; Burger et al., 2008a,b; Harper and Harris, 2008). The pragmatic task of combining protection of ecosystem functions with environmental assessment and management increasingly requires involvement from Tribal governments and stakeholders (Goldstein et al., 2000). Stakeholder

refers to all parties involved, including regulators and other government agencies, conservation organizations, scientists, and the public.

With increased Native American and stakeholder involvement comes a need for clearer definition of terms, and delineation of the relationships between laws/regulations and assessment tools, so that it is possible to achieve agreement on both the assessment tools and the temporal relationships among them. While regulators, and those that are regulated, are often aware of the myriad of laws and regulations that apply to environmental protection, a range of other stakeholders may not be well informed. The appropriate laws and regulations that give regulatory direction to the activities to be carried out in specific sub-areas within a large site may not be clear to Tribal Nations and/or to other governmental agencies (local, state and federal) that have partial oversight of waste sites. A lack of information and understanding may be particularly problematic for low-income, minority and Tribal populations who are sometimes not included early or prepared adequately to allow their informed and meaningful public participation. Failure to include such groups is a matter of environmental justice, an issue increasingly recognized by the DOE in its environmental justice program (DOE, 2008a).

In this paper we examine the relationship between regulatory requirements and environmental assessments for hazardous waste sites, and discuss temporal relationships among assessment tools, using Department of Energy (DOE) sites as case studies for contentious stakeholder concerns and issues. Faced with a massive remediation and restoration work that involves special challenges associated with the containment and storage of nuclear material and decommissioning of nuclear facilities, DOE currently acts within a regulatory framework that is often complicated at best, and confusing and contradictory at worst. Given that most DOE sites are under state and federal regulations, as well as some formal or informal regulation or consultation by the Nuclear Regulatory Commission, it is especially difficult for stakeholders to understand the regulatory frameworks being addressed, and the constraints imposed on DOE from state and federal regulations.

The inclusion of Native Americans, governmental agencies other than regulators, and other stakeholders in decisions involving hazardous waste sites is becoming more important to solving these contentious environmental problems. This is particularly true for DOE sites that may cover hundreds of square miles, often contain unique and valuable habitats, and endangered/threatened species, often are located on geography where tribes have some treaty claims and/or are sometimes are located close to heavily populated areas (Rocky Flats near Denver, Brookhaven on Long Island, Fernald in Ohio, Kansas City plant, Oak Ridge Reservation in Tennessee). For Native Tribes and a full range of stakeholders to be involved in designing and overseeing environmental assessment, all involved parties should use the same terminology and understand the same laws, regulations and procedures.

The information and ideas presented in this paper are based on 15 years experience on DOE sites by each author at over a dozen DOE sites, including the Savannah River Site, Oak Ridge, Hanford, Los Alamos, Idaho National Laboratory, Brookhaven, and some of the small DOE sites (e.g. Burger et al., 1999, 2003, 2004a,b, 2005, 2006a,b, 2007a,b; Solitare et

al., 2000; Snodgrass et al., 2000; Salazar et al., 2003; Gochfeld et al., 2006; Gochfeld and Mohr, 2007; see also www.CRESP.org), on the work of others at DOE sites (e.g. Malone, 1990; Kunreuther et al., 1990; Brown, 1998; Dale and Parr, 1997; Crowley and Ahearne, 2002; Greenberg et al., 2003a,b, 2005a,b; Whicker et al., 2004; Macfarlane and Ewing, 2006), and on DOE documents (e.g. DOE, 1991, 1993a,b, 1994a,b, 1995, 2001). The references for our work at the case study sites can be found in the individual case studies.

1.1. Background on the Department of Energy

We use the DOE as a case study because it has the largest cleanup and remediation task in the United States, has facilities in well over half of the states, and decisions are currently being made at several sites that greatly impact local communities, ecological health, and human health. During and after World War II, the DOE obtained land in several states for developing nuclear weapons. When the Cold War and weapons production ended in 1989, the mission and priorities of DOE changed, and the Office of Environmental Management (EM) was created to deal with remediation (Sink and Frank, 1996; Daisey, 1998). DOE currently manages over a 100 sites in 34 states, ranging in size from less than a city block to areas exceeding 1000 square miles (2560 sq. km) (Crowley and Ahearne, 2002). In the past five years a number of sites for which the DOE was responsible have been remediated and the sites turned over to other public ownership.

Most DOE sites are contaminated with highly toxic, typically long-lived radiological wastes that are found in storage facilities, and as soil, surface, and groundwater contamination (DOE, 1991, 1987; Crowley and Ahearne, 2002). DOE is engaged in public discourse about the ecological, political, and societal issues concerning remediation, restoration, natural resource damage assessment, and long-term stewardship of their sites, including those where radiological waste will be maintained or stored (Sharples et al., 1993; DOE, 2001; Greenberg et al., 2007). The DOE faces a number of unique temporal and spatial issues where the appropriate inclusion of Tribal governments and stakeholders in their decision-making is important (Burger et al., 2001a, 2005, 2007b; Harper and Harris, 2008), and many of the DOE sites have valuable resources (DOE, 1994a,b,c, 1996a; Brown, 1998; Dale and Parr, 1997; Burger et al., 2003, 2004b, 2008b; Whicker et al., 2004). While we use DOE sites as case studies, the problems of nuclear and other hazardous wastes remaining from the Cold War legacy are faced also by agencies in many countries in Europe and Asia.

2. DOE's regulatory framework

Environmental protection in the United States involves a number of different regulatory frameworks, including the National Environmental Policy Act (NEPA), the Comprehensive Environmental Response Compensation Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA; controlled through the states), and regulations imposed by the Nuclear Regulatory Commission for those sites with an NRC license (Table 1). In addition, the states where DOE sites still require major cleanup have promulgated state laws and regulations that sometimes complicate the application of federal environmental laws. Beginning in 1989, the major mechanism for regulatory planning and implementation at DOE sites are Tri-part agreements between DOE, the Environmental Protection Agency (EPA), and relevant state agencies. Since then these have become

complex contractual agreements that sometimes chart a path through the required steps of cleanup, but which are also reflective of diverse trade-offs concerning which activities are to be undertaken or completed. In some cases, parts of sites are under the regulatory authority of several state and federal agencies (Table 2 for DOE). Part of a DOE site may be on the EPA's National Priorities List (NPL), while others are free of any radiological or chemical contamination. All of these regulations and laws are aimed at environmental assessment in support of protecting human health and the environment, and the intent of having both state and federal regulatory authority is to ensure this protection.

From a Tribal Nation or stakeholder perspective, and even sometimes from the regulator's perspective, it is often difficult to determine and understand the regulatory framework for specific parts of a site, let alone for the entire site. Whenever multiple agencies and multiple regulations/laws are involved, the complexity increases. Since Native Americans and non-regulator stakeholders often are not part of the negotiations between DOE and state agencies, confusion results from a lack of transparency.

3. Environmental assessment controversies

Several environmental evaluation and risk assessment tools are available in support of the regulations and environmental protection (Table 3), but all of these require extensive and well-organized data on contaminant or radiological levels in media (air, water, soil, sediment) or in biota, or impairment (or death) in biota and the food chain. Data gathered over many years that has never been synthesized loses temporal and spatial understandability and becomes a source of confusion rather than a source of information to guide risk management decision-making. And as the information simply proliferates, it serves to create differences of factual interpretation and opinion regarding its proper use in the required environmental assessments among DOE, its regulators, Tribal Nations, and stakeholders. While the regulators hold the final authority for cleanup standards, the perspectives of Tribal Nations cannot be ignored because of Treaties with the US government (Nez Perce Tribe, 2003). The views of other stakeholders must also be taken into consideration. For example, at Hanford in eastern Washington, Oregon is not a signatory to the Tri-Party Agreement but needs to be considered because the Columbia River that flows past the Hanford Site continues on through Oregon to the Pacific Ocean, potentially carrying with it any radionuclides or other contaminants from Hanford (Gephart, 2003).

Tribal rights are important components of environmental assessment and environmental protection at DOE sites (Table 4). For example, at Hanford, the Yakama Indian Nation, Confederated Tribes of the Umatilla Indian Reservation, and Nez Perce Tribe ceded land near the Columbia River in their treaties of 1855, but the tribes retained rights to hunt and fish, gather roots and berries, and to pasture horses and cattle in their usual and accustomed places which includes the land and river portion at Hanford (Schuster, 1998; Stern, 1998; Gephart, 2003). Other large DOE sites were also built on lands that were traditional American Indian hunting and fishing grounds, including the Shoshone-Bannock on Idaho National Laboratory, and the San Ildefonso Pueblo, Jemez Pueblo, Santa Clara Pueblo, and Cochiti Pueblo on what is now Los Alamos National Laboratory (Arnon and Hill, 1979;

Edelman, 1979; Lange, 1979; Sando, 1979; Burger, 1999). Because Native Americans are sovereign Nations within the US by treaty, they are not considered stakeholders, as the US courts have ruled that they are governments, and they are understood to be such in this paper.

4. Case studies: points of confusion for tribal nations, government agencies and others

The cases described below are meant to indicate some of the areas where there is confusion about the relevant and required regulatory and assessment framework, which leads to different conclusions by diverse groups of people.

4.1. Oak Ridge

In Tennessee, East Fork Poplar Creek and the Clinch River flow by the DOE's Oak Ridge Reservation, and there has been controversy about potential PCB and mercury exposure to fish in these waterways (DOE 1996b). The Oak Ridge Reservation, which has a continuing DOEmission, contains three main facilities: Y-12 Plant, K-25 Site, and Oak Ridge National Laboratory. Runoff and effluent discharges from all three facilities enter the Clinch River arm via either White Oak Creek or Poplar Creek. Released contaminants include radionuclides, metals, and organic compounds originating from all three sites (DOE 1996b).

The Clinch River is under fish consumption advisories for PCBs, and DOE is concerned about contamination from radionuclides and mercury, particularly in Poplar Creek, and whether additional cleanup of sediment from Poplar Creek is warranted. Mercury levels in some fish from East Fork Poplar Creek were sufficiently high to pose a risk to human consumers (Campbell et al., 2002; Burger and Campbell, 2004). For local people, confusion results from the differences in advisories posted in adjacent waters by the State of Tennessee for Clinch River and DOE for Oak Creek, and for PCBs and mercury. From a health and environmental protection standpoint, this case study illustrates the confusion that results when conflicting messages are given. Since the rivers and creeks are connected, the public is understandably concerned about potential differences in mercury contamination in fish.

4.2. Brookhaven National Laboratory

The Peconic River flows through Brookhaven National Laboratory (BNL) on Long Island, New York, and people fish along the river. BNL has a continuing mission for the DOE. During remedial investigations, elevated levels of pesticides, organic chemicals, heavy metals, and radionuclides were detected in the sediments of the Peconic River (DOE 2002a,b,c). Mercury, the main contaminant of concern, came from the release of treated wastewater from the site.

Public controversy occurred because there was a difference in assessments of the risk from mercury in fish (Burger and Gochfeld, 2005). The State of New York stated that no new fish consumption advisories were warranted for the Peconic River, while Suffolk County and DOE's risk assessments determined that some remediation was needed because of mercury contamination of the river. The public was confused because all entities used "risk

assessments” to arrive at their differing conclusions, and used the same contaminant data in fish (Burger and Gochfeld, 2005).

The discrepancies at the BNL were due to the different *kinds* of risk assessments that were conducted (Burger and Gochfeld, 2005; Fig. 1). DOE conducted a baseline risk assessment using the EPA’s guidelines and default assumptions (DOE 2002a). The baseline risk assessment was done under the CERCLA process and used exposure scenarios that assumed site neighbor fish consumption, as well as other activities (e.g. recreation), and the Department’s assessors used several routes of human exposure (fish ingestion, exposure to soil and water). Further, they used conservative assumptions, such as that anglers and their families might eat fish from the Peconic River all year, and that fish were of the legal size (DOE 2002a). DOE concluded that some remediation was essential to reduce the potential uptake of contaminants that would create risk to anglers, now and in the future.

The New York Department of Health had the responsibility for evaluating mercury in fish and determining whether additional consumption advisories were warranted. It did not consider other sources of mercury exposure. It concluded that no additional fish consumption advisories were required, which seemed in conflict with DOE’s conclusion. The two evaluations, however, are not contradictory because DOE’s risk assessment was for the purposes of determining total risk over an individual’s lifetime from all mercury contamination from Brookhaven, whereas the State of New York was interested in the current potential risk to fish consumers.

This case illustrates two key points: 1) the regulatory framework employed can differ even when it is being used to examine the same question (e.g. risk to anglers), and 2) the same methodology (EPAs) can be used for risk assessments, but if the risk management questions are different (risk from fish consumption from Peconic River fish vs total risk from mercury at a DOE site), then the conclusions will differ. In this case, the “is there a risk” question asked by DOE was broader than that asked by the State. This example suggests that both the questions and the assumptions of risk assessments need to be clear to all parties, including health agencies, regulators, DOE and the public.

4.3. Amchitka

Amchitka Island (Aleutian Chain, Alaska) was the site of three underground nuclear tests (1965–1971) by DOE. There was considerable controversy at the time about nuclear testing, and controversy continued for decades (Kohlhoff, 2002). Although there was testing of radionuclide levels in marine organisms immediately following the last detonations, there was no testing of radionuclide levels in organisms thereafter (DOE, 2000). The local marine resources are of high cultural, commercial, and ecological value (NRC, 1996a), and the region (but not Amchitka Island) is inhabited by Aleuts. There is commercial fishing by Aleut and others in the waters surrounding Amchitka Island (Burger et al., 2007d).

When the DOE decided to close Amchitka, there was considerable concern on the part of the U.S. Fish & Wildlife Service, State of Alaska, Aleut/Pribilof Island Association, and others because it did not consider the development of a groundwater model and a human health risk assessment (DOE, 2002a,b) to be sufficient for closure (Burger et al., 2005; Fig. 2). Partly

the problem resulted from two factors: 1) a difference of opinion about what assumptions and data were used for the human health risk assessment, and 2) no agreement on whether the biota and food chain were free of radionuclides derived from the underground nuclear tests. The human health risk assessment had a number of flaws, including a lack of a resident scenario, and lack of data on the food chain, radionuclide levels in subsistence/commercial fish or any other subsistence foods (algae, birds and eggs), and consumption patterns. The risk assessment had only default assumptions, which are not correct for Native Americans (Harris and Harper, 1997; Patrick, 2002; Burger et al., 2007d).

The Aleuts and stakeholders (USFWS, State of Alaska, others) believed that biota should be collected for analysis, rather than relying on a human health risk assessment model that was based on no site-specific data on contaminants or consumption patterns. The controversy raged for decades. The dispute was resolved by bringing in an outside consortium of scientists (Consortium for Risk Evaluation with Stakeholder Participation [CRESP]) to design a Science Plan to develop the missing data to determine whether the food chain was safe (CRESP, 2003; Burger et al., 2005), and to conduct a research expedition to collect biota for radionuclide analysis (Powers et al., 2004). The results of the scientific studies indicated that the subsistence foods and commercial fish were free of radionuclides from the nuclear test, but could provide no assurance that the foods would continue to be safe (Burger et al., 2007e,f,g). The data were used to develop a biomonitoring plan that included subsistence foods and commercial fish (Burger, 2007a,b,c; Burger et al., 2007c) that was incorporated into the DOE long-term stewardship plan for Amchitka (DOE, 2008b).

The Amchitka case illustrates 4 key points 1) Computer models are not necessarily successful in convincing Native Americans and others that there is no risk from contaminants, especially when there is already a level of distrust of the entity providing the assurance, 2) Screening human health risk assessments that are based on no site-specific data on radionuclide levels or consumption pattern are not persuasive, 3) When faced with a screening risk assessment or conducting site-specific analysis of radionuclides in biota of interest, the screening risk assessment is not sufficient, and 4) The federal waste law processes (both RCRA and CERCLA) provide for site-specific feasibility or characterization work, which was not performed before DOE completed its human health risk assessment. In the case of Amchitka, the Aleuts, State of Alaska and USF&WS required site-specific information on radionuclide levels before they could agree to transfer the site to the Office of Legacy Management. Once the data showed that biota are not contaminated, formal risk assessments were no longer required. The inclusion of the full range of stakeholders (not just DOE and the State of Alaska) was necessary to reach a consensus solution. Further, the inclusion of Aleuts on the research vessel to collect biota in their subsistence manner increased acceptance of the science, and led to closure.

4.4. Hanford site

The Hanford Site (586 Sq miles), located in Washington, adjacent to the Columbia River, was the major site in the Manhattan Project aimed at producing the first nuclear bomb (GAO, 2005). Nine nuclear reactors and four reprocessing plants at Hanford produced about two-thirds of the plutonium used in the United States for defense purposes; the last reactor

shut down in 1987, and the processing plant closed in 1990 (Zorpette, 1996; Gephart, 2003). More than 1.7 trillion gallons of liquid waste, radionuclides and hazardous chemicals were released to the ground at Hanford; some are in the soil above the water table (the vadose zone), some have reached the groundwater, and others have reached the Columbia River (DOE, 2008c). 60% of the Nation's defense nuclear wastes are located at Hanford, mostly in underground tanks that have leaked or could leak (French, 1999).

Since its inception Hanford has been controversial because of the potential for contamination of the Columbia River, because these lands used were traditional Tribal lands of several sovereign Indian Tribes (Harris and Harper, 2000, 2008; Nez Perce Tribe, 2003), and the end of the government mission made the future use of the site of interest to the tribes. A Tri-Party Agreement was negotiated in 1989 (Ecology, EPA, DOE, 1987), long before the extent of the contamination and the difficulty of addressing it were understood. The resulting cleanup milestones and projected schedule to which the three parties agreed, based on almost no site real characterization, have proven to be unrealistic. Considering the technical difficulties of dealing with massive radiological and chemical wastes, the concerns of stakeholders, combined with the growing recognition of how difficult it is to address the massive amounts of high level waste on site, resulted in a growing cleanup price-tag (DOE, 1987; NRC, 1996a,b, 1998, 1999, 2001; Gephart and Lundgren, 1998). At the same time, DOE, the Hanford Advisory Board (HAB), Tribes, and others have recognized the importance of cultural and ecological riches of Hanford and the Columbia River (DOE, 1994a, 1996c,d; Geist, 1995; Burger et al., 2003; Nez Perce Tribe, 2003).

Tribal governments are interested in integrating cleanup and future land use, decreasing effects on human health and the environment, and understanding effects of contamination and cleanup on their usual and accustomed treaty rights (Tano et al., 1996; Harris and Harper, 1997, 2008; Goldstein et al., 2000; Nez Perce Tribe, 2003; Drew et al., 2003; Harper et al., 2008). DOE and others recognized the importance of building consensus (NRC 1994), and of turning extensive and diverse opinions about future use of the site into a comprehensive future land-use plan that was developed as an Environmental Impact Statement under the guidelines of the National Environmental Policy Act (NEPA) (DOE, 1999, revised 2008). The role of risk in cleanup and future land use decisions came to the fore (NRC, 1983, 1993; DOE, 1999, 1996c,d).

Because of Hanford's overwhelming size, complexity, massive stockpiles of waste, and tanks and facilities, the job of remediation is difficult in terms of the regulatory framework, scheduling of feasibility/characterization studies, and risk assessments. There was controversy over whether Hanford should conduct a baseline risk assessment for the Columbia River, or a screening risk assessment. In either case, there was insufficient characterization to conduct an assessment of current risk to humans and the environment. Comments from Native Tribes, the State of Oregon, HAB, and the Tri-Parties (Washington, US EPA, DOE) resulted in the realization that a feasibility study that provided more characterization of the contaminants in the Columbia River was needed (DOE, 2007, 2008c). DOE and the other Tri-Party members recognized that to be successful, the characterization of the river needed to include sufficient input from Native American Tribes, Oregon, and others (Fig. 3). This same group of entities reiterated the need for a site-wide

model that examined risk on the whole Hanford Site (Department of Ecology, 2008), a task that is made difficult by its sheer size and complexity.

The Hanford case study illustrates several points: 1) There has to be agreement about the meanings of different risk assessments, and the assessment to be conducted (e.g. screening or baseline), 2) There has to be agreement on whether adequate characterization has been completed, and whether that characterization satisfies RCRA or CERCLA requirements, and 3) Different viewpoints about the relationship between characterizations and risk assessments need to be clarified early in the process, and that clarification needs to occur among all relevant parties, not just the Tri-Party signatories (e.g. for Hanford, it must include the Tribes and State of Oregon).

4.5. Savannah River Site

The Savannah River passes along the Savannah River Site (SRS, South Carolina), and separates the site from Georgia. The different regulatory regimes involve state and federal agencies. The problem initially arose because the two states had different advisories for fish consumption as a result of mercury; mercury levels in the Savannah River were partly due to activities on SRS. The mercury presented a risk, particularly to black fishermen who have higher consumption rates than the white population (Burger et al., 2001a,b). The differences in risk assessments were addressed by producing a fish fact sheet that explained the risk from mercury that satisfied both states, DOE, and EPA.

5. Discussion and conclusions

The case studies examined above illustrate some general principles that require further consideration by federal agencies and their regulators, as well as Native Americans and others interested in solving complicated, contentious environmental problems (Table 5). Several themes are common to the case studies, as well as to other DOE sites, and are necessary for moving forward toward cleanup and closure, including: 1) Agreement among the responsible agency, regulators, Native Americans and others about both the regulatory requirements that apply, and the environmental assessments that are required by each regulation, 2) Open and transparent communication about the regulatory requirements and nature and extent of environmental assessments is essential to moving forward with remediation, restoration and closure, 3) The nature, extent and types of site-specific data necessary (on exposure routes, contaminants in media and biota), and 4) The types and timing of risk assessments and site characterization. Without overall agreement or consensus, DOE and other agencies will be unable to move forward toward remediation and restoration at their sites, and will be unable to close those sites.

Other issues seem to be unique to particular sites, such as 1) Confusion about the regulatory authority or jurisdictions, 2) The nature of the risk assessment methodology and basic assumptions of different methods, and 3) The efficacy of computer models to predict potential human and ecological risk. Many of these derive from the large size and complexity of sites, and a changing history. That is, DOE sites were shrouded in secrecy for several decades, and only with the ending of the Cold War and the establishment of EM (Environmental Management) did DOE increase communication and the involvement of

Native Americans and stakeholders in the cleanup process. Thus, the failure on DOE's part to involve Native Americans and stakeholders early and often in their decision-making process contributed to the current problems.

It should be noted that the case study approach has certain limitations: 1) the results and conclusions cannot be replicated elsewhere, although they form the basis for similar examinations at other sites in the U.S. and in countries with nuclear facilities, 2) the conclusions rely on the expertise of the authors, and 3) the cases provide lessons learned, but not experimental evidence of conclusions. Nonetheless, we based our conclusions on multiple years of study at multiple sites by a multi-disciplinary team.

Finally, these cases illustrate that for many of the sites, the people most interested and affected by a lack of information about the regulatory framework are minorities (SRS), low income (SRS), or Native Americans (Hanford Site, Amchitka, Los Alamos, Idaho National Laboratory). It is thus an environmental justice issue that has been recognized by DOE (DOE, 2008a). DOE established its environmental justice program in accordance with Executive Order 12,898 (DOE, 2008a) to develop effective goals and strategies, engage public participation and trust, and ensure accountability through performance metrics. Words used to describe their goals and objectives include identify, develop, conduct, recruit, and support or fund various activities, and to serve on advisory boards (DOE, 2008a). While these are important aspects of participation, the case studies identified the need for greater involvement and collaboration in research and decisions involving the site, rather than just communication. We suggest that collaboration is important to move the environmental cleanup and long-term stewardship program at DOE forward over the next 25–50 years.

Acknowledgments

We particularly thank M. Gilbertson, J. Clarke, M. Greenberg, J. Alchowiak, M. Duchesne, and J. Stewart and R. B. Stewart for helpful discussions about the complexities of dealing with environmental problems within a framework of regulatory constraints. We thank S. Shukla and C. Jeitner for help with graphics. This research was funded by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) through DOE (DE-FC01-06EW07053), NIEHS (P30ES005022), and EOHSI. The conclusions and interpretations reported herein are the sole responsibility of the authors, and should not in any way be interpreted as representing the views of the funding agencies.

References

- Arnon, NS.; Hill, WW. Santa Clara Pueblo. In: Ortiz, A., editor. Handbook of North American Indians. Vol. 9. Washington, DC, USA: Smithsonian Institution Press; 1979. p. 296-307.
- Barnhouse LW. The role of models in ecological risk assessment: a 1990s perspective. *Environmental Toxicology and Chemistry*. 1991; 11:1751–1760.
- Barnhouse LW. Issues in ecological risk assessment: the CREAM perspective. *Risk Analysis*. 1994; 14:251–256. [PubMed: 8029496]
- Bartell, SM.; Gardner, RH.; O'Neill, RV. *Ecological Risk Estimation*. Boca Raton, FL: Lewis Press; 1992.
- Bridgen P. Protecting native Americans through the risk assessment process: a commentary on An examination of U.S. EPA risk assessment principles and practices. *Integrated Environmental Assessment and Management*. 2005; 1:83–85. [PubMed: 16637152]
- Brown KS. The great DOE land rush. *Science*. 1998; 282:616–617.
- Burger J. Method for and approaches to evaluating susceptibility of ecological systems to hazardous chemicals. *Environmental Health Perspectives*. 1997a; 105:843–848. [PubMed: 9255570]

- Burger J. The Historical Basis for Ecological Risk Assessment. in Preventive Strategies for Living in a Chemical World. New York Academy of Sciences, New York. 1997b:360–371.
- Burger J. American Indians, hunting and fishing rates, risk and the Idaho National Engineering and environmental Laboratory. Environ. Res. 1999; 80:317–329. [PubMed: 10330305]
- Burger J. Incorporating ecology and ecological risk into long-term stewardship on contaminated lands. Remediation. 2002; 18:107–120.
- Burger J. A model for selecting bioindicators to monitor radionuclide concentrations using Amchitka Island in the Aleutians as a case study. Environmental Research. 2007a; 105:316–323. [PubMed: 17698056]
- Burger J. The effect on ecological systems of remediation to protect human health. American Journal of Public Health. 2007b; 97:1572–1578. [PubMed: 17666693]
- Burger J. Protective sustainability of ecosystems using Department of Energy buffer lands as a case study. Journal of Toxicology and Environmental Health. 2007c; 70:1815–1823. [PubMed: 17934954]
- Burger J, Campbell KR. Species differences in contaminants in fish on and adjacent to the oak Ridge Reservation, Tennessee. Environmental Research. 2004; 96:145–155. [PubMed: 15325875]
- Burger J, Gochfeld M. The Peconic River: concerns associated with different risk evaluations for fish consumption. Journal of Environmental Planning and Management. 2005; 48:789–808.
- Burger J, Sanchez J, Gibbons JW, Benson T, Ondrof J, Ramos R, et al. Attitudes and perceptions about ecological resources and hazards of people living around the Savannah River Site. Environmental Monitoring and Assessment. 1999; 57:195–211.
- Burger J, Gochfeld M, Powers CW, Waishwell L, Warren C, Goldstein BD. Science, policy, stakeholders, and fish consumption advisories: developing a fish fact sheet for the Savannah River. Environmental Management. 2001a; 27:501–514. [PubMed: 11289450]
- Burger J, Gaines KF, Gochfeld M. Ethnic differences in risk from mercury among Savannah River fishermen. Risk Analysis. 2001b; 21:533–544. [PubMed: 11572431]
- Burger J, Leschine TM, Greenberg M, Karr J, Gochfeld M, Powers CW. Shifting priorities at the Department of Energy's Bomb factories: protecting human and ecological health. Environmental Management. 2003; 31:157–167. [PubMed: 12520373]
- Burger J, Carletta MA, Lowrie K, Miller KT, Greenberg M. Assessing ecological resources for remediation and future land uses on contaminated lands. Environmental Management. 2004a; 34:1–10. [PubMed: 15383872]
- Burger J, Powers CW, Greenberg M, Gochfeld M. The role of risk and future land use in cleanup decisions at the Department of Energy. Risk Analysis. 2004b; 24:1539–1549. [PubMed: 15660610]
- Burger J, Gochfeld M, Kosson DS, Powers CW, Friedlander B, Eichelberger J, et al. Science, policy, and stakeholders: developing a consensus science plan for Amchitka Island, Aleutians, Alaska. Environmental Management. 2005; 35:557–568. [PubMed: 15886955]
- Burger J, Mayer H, Greenberg M, Powers CW, Volz CD, Gochfeld M. Conceptual site models as a tool in evaluating ecological health: the case of the Department of Energy's Amchitka Island nuclear test site. Journal of Toxicology and Environmental Health. 2006a; 69:1217–1238. [PubMed: 16754537]
- Burger, J.; Gochfeld, M.; Kosson, DS.; Powers, CW. CRESP. New Jersey: Piscataway; 2006b. Biomonitoring for Ecosystem and Human Health Protection at Amchitka Island.
- Burger J, Gochfeld M, Powers CW. Integrating long-term stewardship goals into the remediation process: natural resource damages and the Department of Energy. Journal of Environmental Management. 2007a; 82:189–199. [PubMed: 16554118]
- Burger J, Gochfeld M, Powers CW, Kosson DS, Halverson J, Siekaniec G, Morkill A, Patrick R, Duffy LK, Barnes L. Scientific research, stakeholders, and policy: continuing dialogue during research on radionuclides on Amchitka Island, Alaska. Journal of Environmental Management. 2007b; 85:232–244. [PubMed: 17175094]
- Burger J, Gochfeld M, Kosson DS, Powers CW. A biomonitoring plan for assessing potential radionuclide exposure using Amchitka Island in the Aleutian Chain of Alaska as a case study. Journal of Environmental Radioactivity. 2007c; 98:315–328. [PubMed: 17683832]

- Burger J, Gochfeld M, Jeitner C, Burke S, Stamm T, Snigaroff R, et al. Mercury levels and potential risk from subsistence foods from the Aleutians. *Science of the Total Environment*. 2007d; 384:93–105. [PubMed: 17590413]
- Burger J, Gochfeld M, Jewett SC. Radionuclide levels in invertebrates from Amchitka and Kiska Islands in the Aleutian Chain, Alaska. *Environmental Monitoring and Assessment*. 2007; 128:329–341. [PubMed: 17057992]
- Burger J, Gochfeld M, Kosson DS, Powers CW, Jewett S, Friedlander B, et al. Radionuclides in marine macroalgae from Amchitka and Kiska Islands in the Aleutians: establishing a baseline for future biomonitoring. *Journal of Environmental Radioactivity*. 2007f; 91:27–40. [PubMed: 17029666]
- Burger J, Gochfeld M, Kosson DS, Powers CW, Friedlander B, Stabin M, et al. Radionuclides in marine fishes and birds from Amchitka and Kiska Islands in the Aleutians: establishing a baseline. *Health Physics*. 2007g; 92:265–279. [PubMed: 17293699]
- Burger J, Gochfeld M, Pletnikoff K, Snigaroff R, Snigaroff D, Stamm T. Ecocultural attributes: evaluating ecological degradation: ecological goods and services vs subsistence and tribal values. *Risk Analysis*. 2008a; 1261–1271. [PubMed: 18657067]
- Burger J, Gochfeld M, Greenberg M. Natural resource protection of buffer lands: integrating resource evaluation and economics. *Environmental Monitoring and Assessment*. 2008b; 142:1–9. [PubMed: 17899418]
- Cairns, J., Jr, editor. *The Recovery Process in Damaged Ecosystems*. Ann Arbor, Michigan: Ann Arbor Service; 1980.
- Cairns, J., Jr, editor. *Rehabilitating Damaged Ecosystems*. Boca Raton, FL: CRC Press; 1994.
- Cairns, J., Jr; Niederlehner, BR. Predicting ecosystem risk: genesis and future needs. In: Cairns, J., Jr; Niederlehner, BR.; Orvos, DR., editors. *Predicting Ecosystem Risk*. Princeton, NJ: Princeton Scient. Publ. Co.; 1992. p. 327–344.
- Cairns J Jr, Niederlehner BR. Developing a field of landscape ecotoxicology. *Ecological Applications*. 1995; 6:780–796.
- Campbell KR, Dickey RJ, Sexton R, Burger J. Fishing along the Clinch River arm of Watt Bar Reservoir adjacent to the Oak Ridge Reservation, Tennessee: behavior, knowledge and risk perception. *Science of the Total Environment*. 2002; 299:145–161.
- Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Amchitka Independent Assessment Science Plan. Piscataway, NJ: CRESP; 2003. <http://www.cresp.org>
- Crowley KD, Ahearn JF. Managing the environmental legacy of U.S. nuclear-weapons production. *American Scientist*. 2002; 90:514–523.
- Daisey JM. A report on the workshop on improving exposure analysis for DOE sites, September 1996, San Francisco, CA. *Journal of Exposure Analysis and Environmental Epidemiology*. 1998; 8:3–8. [PubMed: 9470100]
- Dale VH, Parr PD. Preserving DOE's research parks. *Issues in Science and Technology*. 1997; 282:616–617.
- Department of Ecology, Washington State. *Cleaning Hanford's Groundwater*. Olympia, WA: Department of Ecology; 2008.
- Department of Energy (DOE). Natural resource damage assessment: pre-assessment screening and integration with CERCLA ecological evaluations. WashingtonDC: USDOE; 1991. available at www.eh.doe.gov/oepa/guidance/cercla/nrda2.pdf [accessed Jan 2008]
- Department of Energy (DOE). Final Environmental Impact Statement: Disposal of Hanford Defense High-level, Transuranic and Tank Waste, Hanford Site, Richland, Washington. Washington, DC: USDOE; 1987. (DOE/EIS-0113)
- Department of Energy (DOE). Integrating natural resource damage assessment and environmental restoration activities at DOE facilities. *Federal Facilities Environmental Journal*. 1993a; 4:295–317.
- Department of Energy (DOE). Natural Resource Damages under CERCLA. Washington DC: USDOE; 1993b. EH-231–017/0693
- Department of Energy (DOE). Department of Energy (US DOE/EM-0266). Washington DC: 1994a. Closing the circle on the splitting of the atom.

- Department of Energy (DOE). Department of Energy (DOE/FM-0002). Washington DC: 1994b. Stewards of National Resources.
- Department of Energy (DOE). Department of Energy, Office of Energy Research. Washington DC: 1994c. National Environmental Research Parks.
- Department of Energy (DOE). USDOE, DOE/EH-0510. Washington DC: 1995. Natural Resource Damage Assessment Implementation Project: Savannah River Site.
- Department of Energy (DOE). Department of Energy Sites. 1997. Washington, DC: 1996a. Estimate of Potential Natural Resource Damage Liabilities at U.S. (Report to Congress).
- Department of Energy (DOE). DOE/OR/01-1393/V1&D3. Oak Ridge, TN: Oak Ridge Nat. Lab.; 1996b. Remedial Investigation/feasibility Study of the Clinch River/Poplar Creek Operable Unit.
- Department of Energy (DOE). USDOE, DOE/EM-0283. Washington DC: 1996c. Hanford Site: Comprehensive Facility and Land Use Plan.
- Department of Energy (DOE). DOE-RL 96-87. Richland, WA: 1996d. Programmatic Guidance for Biological Resources Management on the Hanford Site.
- Department of Energy (DOE). Record of Decision: Hanford Comprehensive Land-use Plan, Environmental Impact Statement. 1999. also available at. DOE, Washington DC. <http://www.hanford.gov/doe/eis/hraeis/rod/hcprod.html> Revised in September 2008
- Department of Energy (DOE). National Defense Authorization Act (NDAA). Washington, DC: 2001. Long-term Stewardship Report to Congress. Prepared to fulfill a requirement in the FY 2000
- Department of Energy (DOE). United States Nuclear Tests July 1945 through September 1992. Las Vegas, Nevada: Nevada Operations Office; 2000. DOE/NV-209
- Department of Energy (DOE). Baseline Human Health Risk Assessment (Operable Unit V. Peconic River). Upton, New York: Brookhaven National Laboratory; 2002a.
- Department of Energy (DOE). DOE/NV-11508-51. Las Vegas, Nevada: Nevada Operations Office; 2002b. Modeling Groundwater Flow and Transport of Radionuclides at Amchitka Island's Underground Nuclear Tests: Milrow, Long Shot, and Cannikan.
- Department of Energy (DOE). DOE/NV-857. Las Vegas, Nevada: Nevada Operations Office; 2002c. Screening Risk Assessment for Possible Radionuclides in the Amchitka Marine Environment.
- Department of Energy (DOE). Columbia River Risk Assessment (Draft Document). Richland, Washington: 2007.
- Department of Energy (DOE). Environmental Justice: Five-year Implementation Plan DOE/LM-1462. Grand Junction, Colorado: 2008a.
- Department of Energy (DOE). Draft Long-term Surveillance and Maintenance Plan for the U.S DOE Amchitka AK, Site (DOE-LM/1131-2008). Grand Junction, Colorado: 2008b.
- Department of Energy (DOE). Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River (Revised Draft A) DOE/RL-2008-11. Richland, WA: 2008c.
- Drew CH, Deirdre A, Grace SM, Silbernagel ES, Hemmings AS, Griffith WC, et al. Nuclear waste transportation: case studies of identifying stakeholder risk information needs. *Environmental Health Perspectives*. 2003; 111:263–272. [PubMed: 12611653]
- Edelman, SA. San Ildefonso Pueblo. Southwest. In: Ortiz, A., editor. *Handbook of North American Indians*. Vol. 9. Washington, DC, USA: Smithsonian Institution Press; 1979. p. 308-316.
- French, RT. Health of the Hanford Site. Seattle, WA: U. Wash; 1999. Comments at Proceedings: An Informal Collection of Papers from the Conference.
- GAO. Department of Energy: Preliminary Information on the Potential for Columbia River Contamination from the Hanford Site. GAO: Washington, DC; 2005.
- Geist DR. The Hanford Reach: what do we stand to lose. *Illahee*. 1995; 11:130–141.
- Gephart, RE. Hanford: a conversation about nuclear waste and cleanup. Richland, Washington: Batelle Press; 2003.
- Gephart, RE.; Lundgren, RE. PHNL-10773. Richland, WA: Pacific Northwest Laboratory; 1998. Hanford Tank Clean up: a Guide to Understanding the Technical Issues.
- Gochfeld M, Mohr S. Protecting contract workers: case study of the US Department of Energy's nuclear and chemical waste management. *American Journal of Public Health*. 2007; 9:1607–1613. [PubMed: 17666686]

- Gochfeld M, Volz CD, Burger J, Jewett S, Powers CW, Friedlander B. Developing a health and safety plan for hazardous field work in remote areas. *Journal of Occupational and Environmental Hygiene*. 2006; 12:671–683. [PubMed: 17050349]
- Goldstein BD, Erda S, Burger J, Faustman EM, Friedlander BR, Greenberg M, et al. Stakeholder participation: experience from the CRESPP program. *Environmental Epidemiology and Toxicology*. 2000; 2:103–111.
- Greenberg M, Miller KT, Lowrie K, Carletta MA, Burger J. An ecologically oriented database to guide remediation and reuse of contaminated sites. *Remediation*. 2003a; 14:69–83.
- Greenberg M, Lowrie K, Frisch M, Lewis D. National government policy options for contributing to regional economic stability: the U.S. Department of Energy's major nuclear weapons sites. *Review of Policy Research*. 2003b; 20:647–670.
- Greenberg M, Burger J, Gochfeld M, Kosson D, Lowrie K, Mayer H, et al. Endstate land uses, sustainably protective systems, and risk management: a challenge for remediation and multi-generational stewardship. *Remediation*. 2005a; 16:91–105.
- Greenberg M, Hollander J, Mayer H. Sustainable urban redevelopment and shrinking the federal government's footprint. *Federal Facilities Environmental Journal*. 2005b; 16:33–43.
- Greenberg M, Lowrie K, Burger J, Powers C, Gochfeld M, Mayer H. Preferences for alternative risk management policies at the United States major nuclear weapons sites. *Journal of Environmental Planning and Management*. 2007; 50:187–209.
- Harper BL, Harris SG. A possible approach for setting a mercury risk-based action level based on tribal fish ingestion rates. *Environmental Research*. 2008; 107:60–68. [PubMed: 17631290]
- Harper, BL.; Harding, AK.; Waterhous, T.; Harris, SG. EPA-Star-J1–R831046. Richland, WA: 2008. Traditional Tribal Subsistence Exposure Scenario and Risk Assessment Guidance Manual. www.hhs.oregonstate.edu/ph/tribal-grant Available at.
- Harris SG, Harper BL. A native American exposure scenario. *Risk Analysis*. 1997; 17:789–795. [PubMed: 9463932]
- Harris SG, Harper BL. Using eco-cultural dependency webs in risk assessment and characterization of risks to tribal health and cultures. *Environmental Science and Pollution Research*. 2000; 2:91–100.
- Harris, SG.; Harper, BL. Confederated Tribes of the Umatilla Indian Reservation. Pendleton, OR: 2008. How Incorporating Tribal Information Will Enhance Waste Management Decisions.
- Kohlhoff, DW. Amchitka and the Bomb: Nuclear Testing in Alaska. University of Washington Press: Seattle, Washington; 2002.
- Kunreuther H, Easterling D, Desvousges W, Slovic P. Public attitudes toward siting a high-level nuclear waste repository in Nevada. *Risk Analysis*. 1990; 10:469–484.
- Lange, CH. Cochiti Pueblo. Southwest. In: Ortiz, A., editor. *Handbook of North American Indians*, vol. 9. Washington DC, USA: Smithsonian Institution Press; 1979. p. 366–372.
- Lubbert RF, Chu TJ. Challenges to cleaning up formerly used defense sites in the twenty-first century. *Remediation*. 2001; 11:19–31.
- Macfarlane, M.; Ewing, R. *Uncertainty Underground: Yucca Mountain and the Nations High-level Nuclear Waste*. Cambridge, MA: MIT Press; 2006.
- Malone CR. Performance assessment and long-term environmental problems. *Project Appraisal*. 1990; 5:134–138.
- National Research Council (NRC). *Risk Assessment in the Federal Government: Managing the Process*. Washington DC: National Research Council, National Academy Press; 1983.
- National Research Council (NRC). *Ecological Knowledge and Environmental Problem-solving*. Washington DC: National Academy Press; 1986.
- National Research Council (NRC). *Issues in Risk Assessment*. Washington DC: National Academy Press; 1993.
- National Research Council (NRC). *Building Consensus through Risk Assessment and Management of the Department of Energy's Environmental Remediation Program*. Washington DC: National Academy Press; 1994.
- National Research Council (NRC). *The Bering Sea Ecosystem*. Washington DC: National Academy Press; 1996a.

- National Research Council (NRC). The Hanford Tanks: Environmental Impacts and Policy Choices. Washington DC: National Academy Press; 1996b.
- National Research Council (NRC). Systems Analysis and Systems Engineering in Environmental Restoration Programs at the Department of Energy's Hanford Site. Washington DC: National Academy Press; 1998.
- National Research Council (NRC). An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks. Washington DC: National Academy Press; 1999.
- National Research Council (NRC). Science and Technology for Environmental Cleanup at Hanford. Washington DC: National Academy Press; 2001.
- National Research Council (NRC). Models in Environmental Regulatory Decision Making. Washington DC: National Academy Press; 2007.
- Nez Perce Tribe. Treaties: Nez Perce Perspectives. US DOE and Confluence Press; 2003.
- Patrick, R. Proceedings of the Amchitka Long-term Stewardship Workshop. Fairbanks, AL: CRESPP/ Univ. of Alaska; 2002. How local Alaska native communities view the Amchitka issue.
- Powers, CW.; Burger, J.; Kosson, DS.; Gochfeld, M.; Barnes, D., editors. Biological and Geophysical Aspects of Potential Radionuclide Exposure in the Amchitka Marine Environment. Piscataway, NJ: CRESPP; 2005.
- Salazar MK, Takaro TK, Gochfeld M, Barnhart S. Occupational health services at ten U.S. Department of Energy weapons sites. *American Journal of Industrial Medicine*. 2003; 43:418–428. [PubMed: 12645097]
- Sando, JS. Jemez Pueblo. Southwest. In: Ortiz, A., editor. Handbook of North American Indians. Vol. 9. Washington, DC: Smithsonian Institution Press; 1979. p. 418-424.
- Schuster, HH. Yakima and neighboring groups. Southwest. In: Walker, JE., editor. Handbook of North American Indians. Vol. 9. Washington, DC: Smithsonian Institution Press; 1998. p. 327-351.
- Sharples FE, Dunford RW, Bascietto JJ, Sutter GW II. Integrating natural resource damage assessment and environmental restoration at federal facilities. *Federal Facilities Environmental Journal*. 1993; 4:295–318.
- Sink CH, Frank CW. DOE forges partnerships for environmental cleanup. *Forum for Applied Research and Public Policy*. 1996; 11:65–69.
- Snodgrass JW, Komoroski MJ, Bryan AL Jr, Burger J. Relationships among isolated wetland size, hydroperiod, and amphibian richness: implications for wetland regulation. *Conservation Biology*. 2000; 14:414–419.
- Solitare L, Lowrie K, Frisch M, Greenberg M, Noah JC, Burger J. Enhanced recreational opportunities at U.S. DOE sites: economic evaluation of an alternative land use scenario at Savannah River Site. *Federal Facilities Environmental Journal Winter*. 2000:51–71.
- Stern, T. Cayuse, Umatilla, and Walla Walla. Southwest. In: Walker, JE., editor. Handbook of North American Indians. Vol. 9. Washington DC, USA: Smithsonian Institution Press; 1998. p. 395-419.
- Stumpff LM. Reweaving the earth: an indigenous perspective on restoration planning and the National Environmental Policy Act. *Environmental Practice*. 2006; 8:93–103.
- Suter GW II. Applicability of indicator monitoring to ecological risk assessment. *Ecological Indicators*. 2001; 1:101–112.
- Tano ML, Reuben JH, Powaukee D, Lester AD. An Indian tribal view of the back end of the nuclear fuel cycle: historical and cultural lessons. *Radwaste March*. 1996:44–47.
- Whicker FW, Hinton TG, MacDonell MM, Pinder JE III, Habberger LJ. Avoiding destructive remediation at DOE sites. *Science*. 2004; 303:1615–1616. [PubMed: 15016982]
- Zender, LS.; Gilbreath, S.; Sebalo, S.; Leeman, W.; Erbeck, A. How much does tradition matter: comparison of tribal versus non-tribal values in the context of waste site pollution. 2004. www.zender-engr.net (accessed 05.09.07).
- Zorpette G. Hanford's nuclear wasteland. *Scientific American May*. 1996:88–97.

BROOKHAVEN

Figure 1.
Schematic of the risk assessment differences at Brookhaven National Laboratory (after Burger and Gochfeld, 2005).

AMCHITKA

Figure 2.

Schematic of involvement of Native Americans and stakeholders in arriving at a solution for risk evaluations at Amchitka.

HANFORD

Protect the Columbia River: An Evolving Process

The Elephant in the Room- NRDA

Figure 3.

Schematic of differences in involvement of the Tri-Parties compared to Native Americans and others at Hanford Site.

Table 1

Regulatory requirements for environmental assessment, the federal agency associated with the assessments, and the types of assessments required.

Federal/state agency	Law and associated regulations	Types of assessments
Council on Environmental Quality	National Environmental Policy Act (NEPA)	Assessments of existing environment and potential impacts of the project; assessment areas include air and water quality, noise, aesthetics, land use, and socio-economic and cultural impacts as well as other potential project-specific impacts
Environmental Protection Agency	Resource Conservation and Recovery Act (RCRA)	RCRA Facility Investigations (RFI) to provide information needed to investigate potential corrective actions at operating hazardous waste management facilities, as well as corrective measures studies.
Environmental Protection Agency	Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (as amended)	Remedial investigations to provide information to evaluate remediation technologies and approaches; human health and ecological risk assessments
Department of Energy	DOE Orders (435.1)	Orders that include performance assessments and other measure to evaluate work performed
Nuclear Regulatory Commission	Regulations for land disposal, geologic disposal of HLW, siting of new facilities and license terminations for existing facilities	Environmental investigations of existing site conditions and human health dose assessments for proposed actions; site surveys for all contaminations and all pathways under the license termination rule (only for sites with NRC licenses)
State agencies	Relevant state laws, regulations and permits	Requirements and permits depend upon the state, but states usually act jointly with EPA and DOE in Tri-Party Agreements

Table 2

Regulatory regimes for major DOE sites, with closure dates (modified from Burger et al., 2004a and DOE websites).

LTS site	State	Regulating law	EM mission completion date	Continuing mission
Amchitka Island	Alaska	AEA, RCRA	2007 (completed)	No
Argonne National Laboratory East	Illinois	RCRA	2009	Yes
Argonne National Laboratory West	Idaho	CERCLA	2009	Yes
Ashtabula	Ohio	AEA/RCRA		No
Brookhaven National Laboratory	New York	AEA, CERCLA, RCRA	2020	Yes
Central Nevada Test Area	Nevada	AEA, RCRA	2012	No
Columbus-Battelle	Ohio	AEA		No
Energy Technology Center	California	AEA	2018	No
Fernald	Ohio	CERCLA/RCRA	2006 (completed)	No
Gasbuggy Site	New Mexico	AEA, RCRA	2014	No
General Electric Vallecitos		AEA	2014	No
Gnome-Coach Site	New Mexico	AEA	2014	No
Hanford Site	Washington	CERCLA, RCRA (TRIPARTY) AEA	2050–2062	No
Idaho National Laboratory	Idaho	CERCLA, AEA, RCRA	2037	Yes
Kansas City Plant	Missouri	AEA, CERCLA, RCRA	2006(completed)	Yes
Laboratory for Energy Related Health Research	California	CERCLA	2005	No
Lawrence Berkeley National Laboratory	California	AEA, CERCLA	2006	Yes
Lawrence Livermore National Laboratory – Main Site	California	AEA, CERCLA	2009	Yes
Lawrence Livermore National Laboratory – Site 300	California	AEA, CERCLA	2008	No
Los Alamos National Laboratory	New Mexico	AEA, RCRA	2015	Yes
Moab	Utah	AEA/CERCLA	2028	No
Mound (Miamisburg)	Ohio	CERCLA	2006 (completed)	No
Nevada Test Site	Nevada	AEA, RCRA	2038	Yes
Oak Ridge Reservation	Tennessee	CERCLA, RCRA, AEA,	2021	Yes
Paducah Gaseous Diffusion Plant	Kentucky	CERCLA, RCRA	2040	Yes
Pantex Plant	Texas	CERCLA, RCRA	2009	Yes
Portsmouth Gaseous Diffusion Plant	Ohio	RCRA, CERCLA, AEA	2044	Yes
Project Shoal Area	Nevada	AEA	2008	No
Rio Blanco Site	Colorado	AEA/RCRA	2009	No
Rocky Flats	Colorado	CERCLA (FFA) RCRA, AEA	2006 (completed)	No
Rulison Site	Colorado	AEA/RCRA	2011	No
Salmon Site	MS	AEA/RCRA	2010	No
Sandia National Laboratories – NM	New Mexico	RCRA	2009	Yes
Savannah River Site	South Carolina	CERCLA, RCRA (FFCA) and AEA	2039–2040	Yes

LTS site	State	Regulating law	EM mission completion date	Continuing mission
Separation Process Research Unit	New York	AEA/RCRA	2014	No
Stanford Linear Accelerator (SLAC)	California	CERCLA	2011	Yes
Weldon	Missouri	CERCLA		No
West Valley	New York	AEA	2112	No

Table 3

Definitions of key terms of interest to stakeholder in the remediation and restoration process.

Environmental evaluation	An evaluation of any aspect of the environment, including abiotic and biotic features (species, population, community, ecosystem, landscape level).
Environmental assessment	Similar to environmental evaluation, but it implies greater quantification
Risk assessment	Assigning a probability of an adverse effect from a stressor
Ecological risk assessment	Assigning a probability of adverse effect to ecosystems or their component parts.
Human health risk assessment	Assigning a probability of an adverse effect on humans; usually involving population effects (disease rates, tumor rates, death rates) or biomarkers of effects.
Environmental risk assessment	Refers to human health risk assessment, but sounds like it refers to ecological risk assessment
Baseline risk assessment	An ecological (or human health) risk assessment of conditions at the current state; determined for the purposes of setting cleanup levels or remediation, or of future evaluation of the efficacy of cleanup or restoration ¹ . Also an ecological (or human health) risk assessment of conditions at some pre-defined base time (e.g. before the chemical or radiological release, physical disruption, or disease)

Table 4

Major steps to achieve Tribal and stakeholder-driven decisions on contaminated sites that are science-based.

• Define the problem spatially and temporally.• Identify Tribal Nations, US governmental agencies, local and state government agencies, non-governmental agencies, and the public.• Re-define the problem with collaboration of Tribal Nations, U.S. government agencies, local and state agencies, non-governmental agencies, and all interested and affected parties.• Construct a dynamic, conceptual site model that can be tied to specific environmental assessment tools and methods.• Construct an overall assessment plan that integrates among units or habitats within a large site (including all necessary characterization, risk evaluations, and assessments), as well as temporal plan for characterizations and assessments.

Table 5

Examples of conflicting views of necessary assessment tools, where adding additional assessment tools led to solutions.

Location	Problem	DOE tools initially proposed	Stakeholder with other view	Desired tools
Oak Ridge	High mercury levels in fish in Poplar Creek	Mercury levels in fish and Human health risk assessment	* Recreational fishermen * DOE scientists	Trophic level analysis and pathways of exposure
Savannah River Site	High mercury in fish	Human health risk assessment	* fishermen * DOE * States	Exposure assessment, mercury in fish
Brookhaven National Laboratory	Potential human health risk from mercury in fish	Human health risk assessment for all exposure pathways	* State of New York * Public	Human health risk assessment for exposure from fish consumption
Amchitka	Closure with assurance of protection of human health and the environment	Groundwater models and Human health risk assessment	* State of Alaska * Aleutian Pribilof Island Association * US Fish & Wildlife Service	Additional characterization: Sampling and radionuclide analysis of marine biota at all levels of the food chain
Hanford Site	Protection of the Columbia River	Groundwater models and Human health risk assessment and Ecological risk assessment based on present data set	* Native Tribes * States of Oregon and Washington * Public	Additional characterization: sampling of sediment, water and fish.
Hanford Site	Risk from contaminants in the river: Defining a baseline	Baseline risk assessment that defines current conditions as base	*Native Tribes *States of Oregon and Washington	Baseline defined as condition prior to DOE occupation, or additional current sampling