8.11 Fish and Wildlife Monitoring

The following sections summarize wildlife-related monitoring activities conducted on and around the Hanford Site in 2004. Included is information on surveys and monitoring of Hanford Site animal populations, discussions of selected species that occur at Hanford and are protected by state and federal laws and regulations, results of activities to measure levels of Hanford-produced contaminants in fish and wildlife tissues, results of field studies to identify organisms that may be effective biological monitors of environmental contaminants (sentinel species), and activities to manage organisms that might affect workers or have become radiologically contaminated.

Wildlife populations at Hanford are monitored to assess the abundance, condition, and distribution of populations of selected species. Data collection and analyses are integrated with contaminant monitoring efforts, and analytical results may be used to help characterize potential risks or impacts to biota. They may also be used to support objectives for completing Hanford's waste management and environmental restoration missions. Information on threatened, endangered, and sensitive wildlife species is collected so DOE can determine site compliance with the requirements of applicable state and federal laws and regulations. Fish and wildlife that inhabit the Columbia River and the Hanford Site are monitored for contaminants because they could potentially be exposed to Hanford-produced materials and be adversely affected, and because contaminated animals could be harvested and consumed by members of the public. Sentinel species are being evaluated because some organisms may be useful for identifying changes in environmental conditions over time. When discovered, pest organisms are removed and disposed of to eliminate possible impact to worker safety and health and to control the spread of radioactive contamination. For further information about these monitoring and pest control efforts and the programs that support them, see Section 8.0 of this report or DOE/RL-91-50.

8.11.1 Ecological Monitoring of Hanford Site Wildlife Populations

This section provides current information on characterization, inventories, and monitoring of key fish and wildlife species and populations found on the Hanford Site and presents this information in the context of historical data and trend information. Wildlife populations of interest include wildlife potentially hunted offsite and used for food as well as special status species listed by Washington State or the U.S. Fish and Wildlife Service as threatened or endangered.

8.11.1.1 Chinook Salmon

R. P. Mueller

Chinook salmon (*Oncorhynchus tshawytscha*) are an important resource in the Pacific Northwest; they are caught commercially and for recreation and are also of cultural importance to Native Americans. Today, the most important natural spawning area in the mainstem Columbia River for fall Chinook salmon is the free-flowing Hanford Reach (Dauble and Watson 1997). In the first years of Hanford Site operations, monitoring identified only a few redds (spawning nests) in the Hanford Reach. Between 1943 and 1973, a number of dams were constructed on the Columbia River and the formation of reservoirs behind these dams eliminated many mainstem spawning areas. These changes resulted in increased numbers of salmon spawning in the Hanford Reach. Fisheries management strategies aimed at maintaining spawning populations in the mainstem Columbia River also have contributed to the increased number of redds found in the Hanford Reach.

The number of fall Chinook salmon redds in the Hanford Reach are estimated through aerial surveys. Aerial surveys do not yield absolute redd counts due to environmental conditions that affect detection (e.g., water depth, water turbidity, and sun angle) and difficulty associated with accurately counting individual redds in high density spawning areas. However, redd survey estimates are highly correlated with adult salmon escapement estimates obtained by state and federal agencies within the Columbia River Basin.

Survey results show the number of redds increased from the early 1960s through the 1980s until reaching a high in 1989 of nearly 8,800 (Figure 8.11.1). In the early 1990s, survey estimates indicated a decline in the number of redds to approximately one-third of the 1989 peak. The number of redds peaked again in 1996 and 1997 and then declined before rising again in 2001. This trend continued though 2002 and a count of 9,400 redds was estimated in 2003, which was the highest count since monitoring began in 1948.

During 2004, approximately 8,470 redds were observed, which is a slight decrease from the record count in 2003. The primary spawning areas in the Hanford Reach in 2004 (Figure 8.11.2) were similar to areas used in previous years with the majority of redds occurring near Vernita Bar (Area 10), Locke Island (Areas 4 and 5), and the areas upstream (Areas 6 and 7) and downstream (Areas 2 and 3) of Locke Island. The general locations of the spawning areas have not changed appreciably over the past few years.

8.11.1.2 Steelhead

R. P. Mueller and M. R. Sackschewsky

In February 2003, two steelhead (*Oncorhynchus mykiss*) redds were discovered near the Columbia River shoreline adjacent to the north end of the 300 Area. Steelhead at this location are considered part of the upper Columbia River Evolutionarily Significant Unit, listed as endangered under the *Endangered Species Act*.

To address the presence of spawning steelhead near the 300 Area, DOE prepared a biological evaluation of the potential impact of site characterization and cleanup efforts on steelhead in the Hanford Reach and came to the conclusion that the ongoing characterization and cleanup project activities may affect, but are not likely to adversely affect, upper Columbia River steelhead. This biological evaluation was sent to the National Oceanographic and Atmosphere Administration Fisheries in December 2003. The National Oceanographic and Atmosphere Administration Fisheries concurred with the DOE conclusion in January 2004. DOE committed to increase monitoring efforts for steelhead redds in the Hanford Reach during 2004 and to limit activities in the

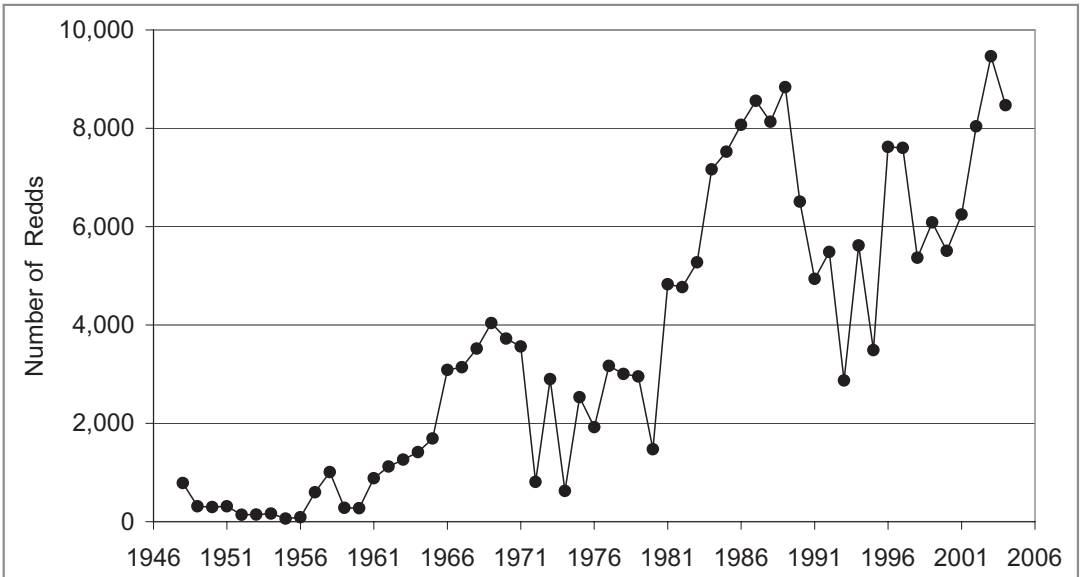

Figure 8.11.1. Number of Salmon Redds in the Hanford Reach of the Columbia River

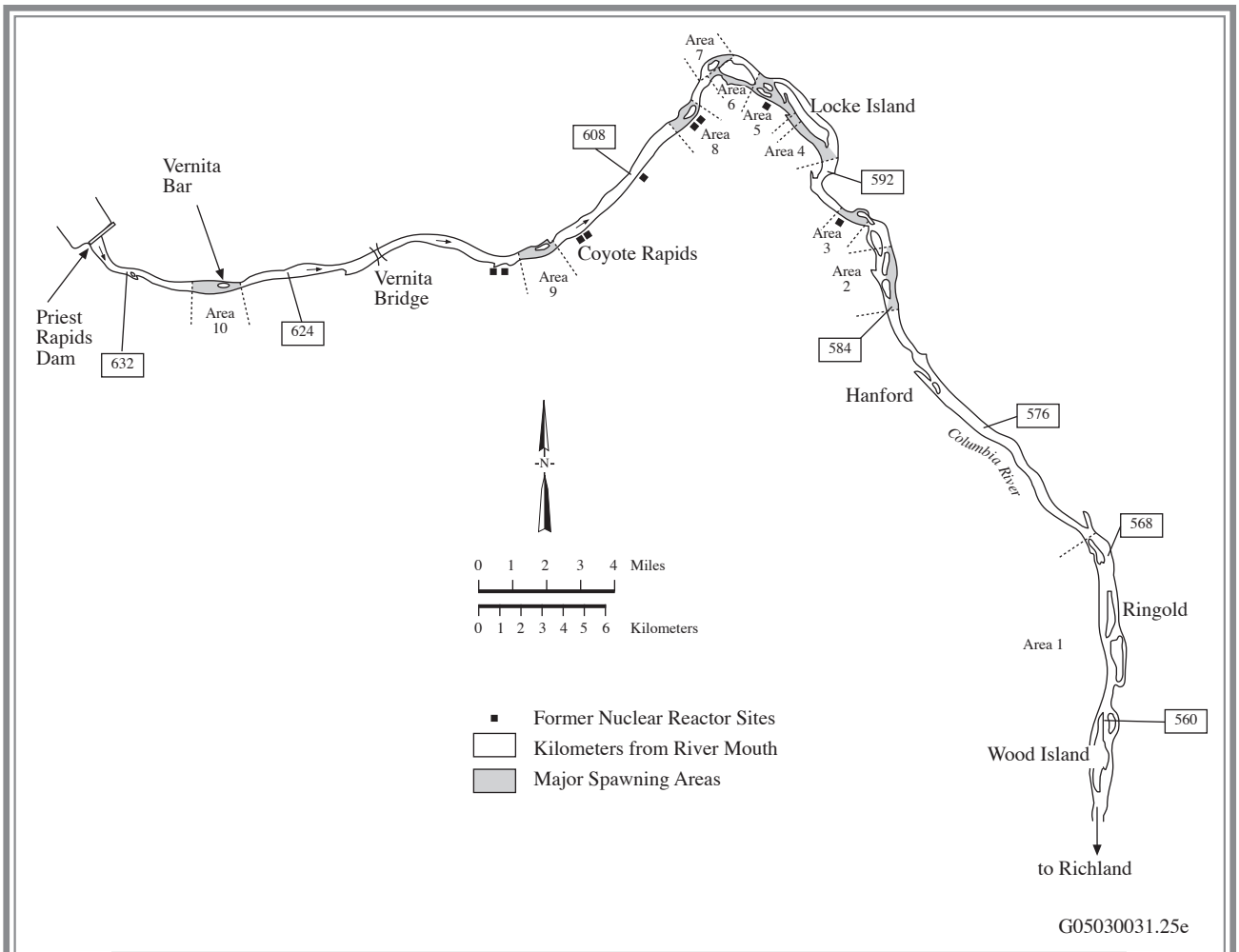

Figure 8.11.2. Major Fall Chinook Salmon Spawning Areas in the Hanford Reach of the Columbia River

vicinity of any redds that were discovered. Aerial surveys during March and April 2004 indicated that steelhead had not returned to the redd site at the 300 Area nor were steelhead redds observed elsewhere in the Hanford Reach. Surveys in 2005 documented a few steelhead redds along the Benton County shoreline in fall Chinook salmon spawning Area 1 (Figure 8.11.2).

8.11.1.3 Mule Deer

K. D. Hand and B. L. Tiller

Population characteristics of mule deer (*Odocoileus hemionus*) on the Hanford Site have been monitored since 1994. Roadside surveys are conducted from mid-November to mid-January to assess age and sex ratios and the frequency of testicular atrophy in males. The survey route extends from near the 300 Area in the south to the 100-B/C Area in the north and is divided at the Hanford town site into north and south regions. Tiller and Poston (2000) found that there is little overlap in the home ranges of deer occupying these two regions.

Seven surveys were conducted between mid-November 2004 and late-January 2005. A combined total of 448 deer observations were made over the seven repeated surveys, which included multiple observations of the same animals in some cases. An average of 64 deer were recorded on each survey. Individual animals were identified according to sex and age class (fawn or adult). For male deer, the presence of misshapen, velvet covered antlers was used as an indicator of testicular atrophy.

Trends in the ratios of fawns to does over time can be used to monitor changes in mule deer population size and

health. Data from the 2004-2005 surveys show a pattern of fawn to doe ratios that has been observed previously. In 2004, the north region fawn to doe mean estimate was 20 fawns per 100 does and the south region mean estimate was 24 fawns per 100 does (Figure 8.11.3). These estimates are lower than those seen in 2003 when the mean estimates were 47 and 56 fawns per 100 does for the north and south regions, respectively. For comparison, ratios reported by the Washington Department of Fish and Wildlife for Yakima and Benton Counties averaged 55 fawns per 100 does from 1996 to 2000 (Washington Department of Fish and Wildlife 2001). Hanford fawn to doe ratios for all survey years (1994-2004) are reported as weighted averages, using the total number of fawns and does seen per survey as the weighting factor.

In the early 1990s, testicular atrophy and sterility were observed in some male mule deer on the Hanford Site (Tiller et al. 1997; PNNL-11518). Further investigation found no clear cause for these conditions (Tiller et al. 1997). Testicular atrophy in male mule deer is associated with abnormal antler growth manifest as misshapen, velvet covered antlers, which can be easily noted in field surveys. The frequency of testicular atrophy in mule deer has varied (Figure 8.11.4) since surveys began in 1994. Since 1998, the frequency of apparent testicular atrophy decreased, with no abnormal antlers on bucks sighted in 2003. Note that no data were collected in 2002. However, data from 2004 and early 2005 show an apparent increase of this condition especially in the north region (12.5% in the north region and 5% in the south region). However, observations of affected deer and the resultant frequency estimates need to be interpreted with caution since small sample sizes may not fully reflect the population conditions. Table 8.11.1 shows the total number of bucks observed and the number with antler abnormalities observed during roadside surveys between 1994 and 2004.

8.11.1.4 Freshwater Mollusks

R. P. Mueller and B. L. Tiller

The Hanford Reach of the Columbia River has historically sustained a number of native freshwater mollusks. Mollusk species are declining globally and regionally (Frest and Johannes 1995), and native species are being

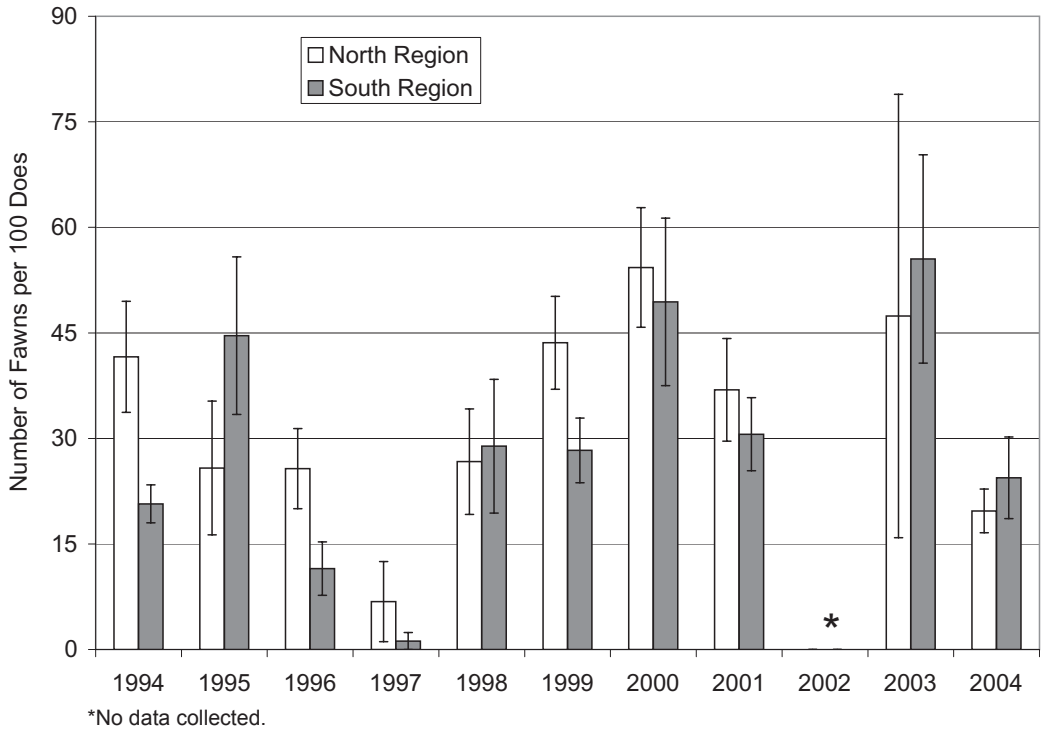

Figure 8.11.3. Estimates of the Number of Fawns per 100 Does in the Post-Hunting Period on the Hanford Site from 1994 through 2004 (mean ±1 standard error)

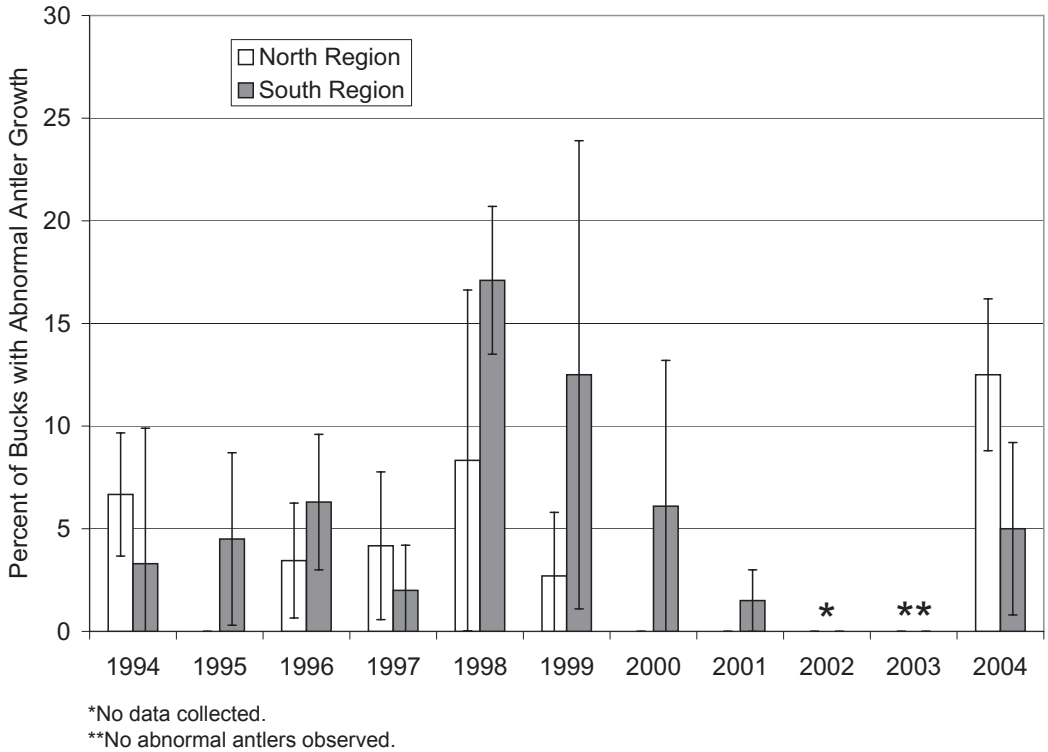

Figure 8.11.4. Percent of Male Mule Deer on the Hanford Site from 1994 through 2004 Showing Signs of Abnormal Antler Growth (mean ±1 standard error)

Table 8.11.1. Total Number of Bucks and Number of Bucks Showing Signs of Antler Abnormality Observed in Roadside Surveys from 1994 through 2004

	North Region		South Region	
Year	Total Number of Bucks	Number of Bucks with Antler Abnormality	Total Number of Bucks	Number of Bucks with Antler Abnormality
1994	30	2	90	3
1995	19	0	22	1
1996	29	1	16	1
1997	24	1	51	1
1998	12	1	70	12
1999	37	1	80	10
2000	37	0	33	2
2001	50	0	68	1
2002	ND	ND	ND	ND
2003	11	0	17	0
2004	64	8	40	2

ND = No data.

replaced by invasive aliens such as the Asiatic clam (*Corbicula fluminea*). These types of organisms are potential receptor species for Hanford contaminants because they are sedentary filter-feeders, which increases their potential for exposure to contaminated water and sediment. They are also food organisms and could transfer contaminants to aquatic and terrestrial predators that consume them. Surveys for mollusks along the Hanford Reach allows for an assessment of distribution and status of species and populations.

Mollusk surveys during 2003 and 2004 found 17 taxa (5 mussels and 12 snails) along the Hanford Reach; 3 taxa are considered to be special status species by federal or state agencies (Table 8.11.2). Survey results for mussels obtained by snorkeling during 2004 indicated that three *Anadonta* species were common in habitats dominated by sand and silt substrates. In addition, shells of the Western pearl mussel (*Margaritinopsis falcata*) were found in small numbers at two sites, but the species appears to be absent from its historic range.

Individuals of the Columbia springsnail (*Pyrgulopsis* sp.) were found in 2 of 17 surveys. This taxa has been collected elsewhere in the middle and lower Columbia River but has not been formally described. This species appears similar to the Idaho springsnail (*Pyrgulopsis idahoensis*), which is listed as a federal endangered species, but a recent taxonomic evaluation by the Smithsonian Institute indicated that the Columbia springsnail, Idaho springsnail, and two other *Pyrgulopsis* species should all be considered as a single species: the Jackson Lake springsnail (*Pyrgulopsis robusta*). Based on this taxonomic revision, the U.S. Fish and Wildlife Service initiated a re-evaluation of the federal status of the Idaho springsnail and is considering listing the Jackson Lake springsnail, including the Hanford Reach population, as threatened and endangered under the *Endangered Species Act*.

Table 8.11.2. Mussels and Freshwater Snails Observed in the Hanford Reach of the Columbia River in 2003 and 2004

Common Name	Scientific Name	Status
Mussels		
California floater	*Anadonta californiensis*	State Candidate/Federal Species of Concern
Kennerly floater	*Anadonta kennerlyi*	
Oregon floater	*Anadonta oregonensis*	
Asiatic clam	*Corbicula flumine*	
Western pearl mussel	*Margaritinopsis falcata*	
Freshwater Snails		
Creeping ancylid	*Ferrissia rivularis*	
Giant Columbia River limpet	*Fisherola (Lanx) nuttalli*	State Candidate
Giant Columbia River spire snail[(a)]	*Fluminicola (Lithoglyphus) columbiana*	State Candidate/Federal Species of Concern
Pebblesnail	*Fluminicola* sp.	
Olympia pebblesnail	*Fluminicola virens*	
Prairie fossaria	*Fossaria bulimoides*	
Golden fossaria	*Fossaria obrussa*	
Ash gyro	*Gyraulus parvus*	
Button sprite	*Menetus cvallioglyptus*	
Physa	*Physella* sp.	
Springsnail	*Pyrgulopsis* sp.	
Abbreviate pondsnail	*Stagnicola apicina*	
Artemesian rams-horn	*Vorticifex effusus effusus*	

(a) Not found during 2003-2004 surveys; found previously in the 1990s.

8.11.1.5 Amphibians

J. M. Becker and B. F. Miller

Amphibians may serve as key indicators of ecological health and as receptor species for use in ecological assessments. Relatively little information exists on amphibian distribution and breeding sites along the Columbia River shoreline (Soll et al. 1999). During 2004, Pacific Northwest National Laboratory personnel conducted surveys along the Benton County shoreline of the Hanford Reach to locate and characterize potential and actual breeding sites and the amphibian species that use them. Varying water discharges at Priest Rapids Dam upstream cause the river level to fluctuate and create shoreline pools that may be used by amphibians as breeding sites. Amphibian breeding sites may occur in slough and backwater areas that are continuously inundated or in temporary pools that lie within the main river channel and are flooded periodically. The highest exposure of amphibians to contaminants could occur during larval life stages at breeding sites where contaminants enter the Columbia River.

Pools along the Hanford Reach that could serve as amphibian breeding sites were identified by evaluating Washington Department of Fish and Wildlife video tapes of aerial reconnaissance flights along the Columbia River shoreline from Priest Rapids Dam to Richland. Fifteen permanent and temporary pools were identified and surveyed during the summer of 2004. These included eight shoreline pools and five pools in sloughs or backwater areas. Survey data were also collected from pools in two upland borrow pits adjacent to the 100-B/C Area. Larvae (egg masses and/or tadpoles) and adults of three species were found within or around eight of these pools. Two species are native to the Columbia Basin, the Great Basin spadefoot (*Spea intermontana*) and Woodhouse's toad (*Bufo woodhousii*), and one species, the bullfrog (*Rana catesbeiana*), is an introduced species (Table 8.11.3). Survey results indicate that Woodhouse's toads were most abundant along the Hanford Reach, followed by the bullfrog and Great Basin spadefoot. The pools that form along the Columbia River shoreline at the Hanford Site may be especially important for Woodhouse's toad, a Washington State monitor species thought to occur only within the Columbia Basin of the Pacific Northwest (Washington Herp Atlas 2002).

The distribution of the bullfrog in the Columbia Basin parallels that of Woodhouse's toad (Washington State GAP Analysis Project 1997). The bullfrog, native to the eastern United States and introduced in western Oregon around 1930 (Corkran and Thoms 1996; Nussbaum et al. 1983), is known to consume other amphibians and is suspected as having displaced native amphibian species in the Pacific Northwest (Corkran and Thoms 1996; Environmental News Network 2000). Native species such as Woodhouse's toad and the Great Basin spadefoot may find it difficult to compete with this top-level predator. Results from these initial surveys will be used to guide future efforts to monitor habitat use and relative abundance of amphibian species along the Hanford Reach of the Columbia River.

Table 8.11.3. Amphibian Species Observed in Pools Along the Shoreline of the Hanford Reach of the Columbia River in 2004

		Amphibian Species Observed (Adults)		Amphibian Species Observed (Larvae[a])	
Pool Type	Number of Pools Surveyed	Pools Occupied	Species	Pools Occupied	Species
Shoreline	8	3	WT, BF	3	WT, BF
Slough	5	4	WT, BF, GBS	4	WT, BF, GBS
Borrow pit	2	1	WT, GBS	1	WT, GBS

(a) Egg masses or tadpoles.
BF = Bullfrog.
GBS = Great Basin spadefoot.
WT = Woodhouse's toad.

8.11.1.6 Small Mammals

K. D. Hand and B. L. Tiller

Riparian (terrestrial shoreline) habitats along the Hanford Reach of the Columbia River, ranging from dense shrub to open cobble, are habitats for various species of small mammals (mostly rodents). Little is known about the habitat use, species diversity, and seasonal abundance of the small mammals that occupy these riparian areas. Small mammals are often key receptor species in ecological assessments. Those in riparian areas adjacent to Hanford reactor sites may be exposed to Hanford chemical or radiological contaminants. Surveys of Hanford Reach riparian habitats were undertaken in 2003 and 2004 to identify the species present and characterize their seasonal abundance.

Three species of small mammals were captured during the study (Table 8.11.4) in two riparian vegetation types (willow and low shrub-forb-cobble association) during four seasonal periods (early spring, late spring, late summer, and autumn). The most common species was the deer mouse (*Peromyscus maniculatus*), which was present in both vegetation types and was most abundant during the early spring period. The western harvest mouse (*Reithrodontomys megalotis*) was the second most abundant species and was also found in both vegetation types but was captured primarily during the early spring and autumn. The least abundant species found was the Great Basin pocket mouse (*Perognathus parvus*), which was captured only in the willow habitat during the late summer period. This information will be used for selecting species when planning Hanford Site ecological assessments.

8.11.1.7 Bald Eagles

R. E. Durham and M. R. Sackschewsky

Bald eagles (*Haliaeetus leucocephalus*) have wintered along the Hanford Reach for many years. In accordance with DOE's *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150), limited-access road closures within 800 meters (875 yards) of major perching and roost sites and within 400 meters (437 yards) of out of line-of-sight major perching and roost sites have been in force from November 15 through March 15 since 1994. While these dates generally encompass the arrival and departure times of wintering bald eagles, nest-tending activities and territorial displays in the late 1990s have been observed as early as October with nest occupancy continuing to as late as August. However, all nesting attempts documented along the Hanford Reach have so far been unsuccessful.

During 2004, a pair of adult bald eagles returned during November to occupy the historical nest site in the vicinity of the former White Bluffs town site. This was the only site occupied by an eagle pair during 2004. Visual surveys in late February through March 4, 2005, revealed the nest site was unoccupied.

Primary causes of eagle nest abandonment may include (1) adverse weather, (2) food availability, (3) human activity near the nest, and (4) avian predator interactions (hazing and harassment by magpies and ravens). The causes of eagle nest abandonment along the Hanford Reach have not been determined. Food resources do not appear to be limiting as a pair of eagles stayed through

Table 8.11.4. Capture Ratios (standardized per 100 traps) for Small Mammals by Season and Community Type

	Willow				Low Shrub-Forb-Cobble			
Species	Early Spring	Late Spring	Late Summer	Autumn	Early Spring	Late Spring	Late Summer	Autumn
Deer mouse	8.4	0.0	0.0	NS	10.7	2.4	0.3	4.5
Western harvest mouse	2.1	0.0	0.6	NS	2.5	0.2	0.6	3.0
Great Basin pocket mouse	0.0	0.0	1.1	NS	0.0	0.0	0.0	0.0

NS = No sampling attempt.

August in 1999 (PNNL-13230); thus, some other factor is likely responsible for nest desertion on the Hanford Site. A large buoy was placed in the Columbia River near the nesting site to help minimize disturbance from boating activities. During 2001 and 2002, traffic monitors (instruments to count passing vehicles) were placed at the entrance to the nesting area access road at a location approximately 400 meters (437 yards) from the nesting site used by the eagle pair. Vehicle counts were low between November and January and increased dramatically during late February and early March (PNNL-14295).

8.11.1.8 Sage Sparrow

C. A. Duberstein, M. A. Simmons, M. R. Sackschewsky, and J. M. Becker

Big sagebrush (*Artemisia tridentata*) communities found on the Hanford Site provide critical habitat for several sagebrush-obligate species, including the sage sparrow (*Amphispiza belli*). Sage sparrows are protected under the *Migratory Bird Treaty Act*. They were identified as an evaluation species for the development of Hanford-specific habitat-usage computer models (DOE/RL-96-88). A habitat-usage computer model, called the habitat-value index, is being developed to assign a value to habitats for nesting sage sparrows. The habitat-value index will be used to calculate the cost to restore or create habitat of similar value that may be lost during cleanup activities. The first step in developing the index is to quantify the relationships between the size of sage sparrow nesting territories and the characteristics of the associated sagebrush habitat.

To develop the index, 37 sage sparrow territories were mapped and the vegetation characteristics within the territories were measured. The variables most strongly associated with territory size included sagebrush cover, annual grass and forb cover, and the amount of bare ground. Analysis further indicated that two landscape-scale features are also associated with territory size: fire history and the patchiness of sagebrush cover. Areas that burned within the last 26 years have less sagebrush cover than areas that did not burn recently (Figure 8.11.5a), and the sage sparrow territories are larger in previously burned areas than in unburned areas (Figure 8.11.5b). Also, sagebrush cover is patchy in burned areas (Figure 8.11.5c). Sage sparrows may require larger territories in areas with lower, patchy sagebrush cover in order to obtain sufficient resources (e.g., food and hiding cover).

Four habitat types were identified for use by nesting sage sparrows: (1) mature sagebrush overstory with an undisturbed understory, (2) a mature sagebrush overstory with a disturbed understory, (3) a recovering sagebrush overstory with an undisturbed understory, and (4) a recovering sagebrush overstory with a disturbed understory. Mature overstory habitats are characterized by a higher, more contiguous sagebrush cover and increased time since the last fire compared to recovering habitats. Disturbed understory habitats are characterized by more annual grass and forb cover and less bare ground than can be found in undisturbed areas. Sage sparrow territories were found in all four habitat types, with 14 of the 37 in the mature-undisturbed habitat, 7 each in both mature-disturbed and recovering-undisturbed habitats, and 9 in the recovering-disturbed habitat. The habitat-value index is being tested during 2005 to examine the relationships between habitat variables and sage sparrow distribution and abundance as well as to determine the types of habitat that cannot support sage sparrow territories.

8.11.2 Monitoring of Fish and Wildlife for Hanford-Produced Contaminants

J. A. Stegen

In 2004, several types of wildlife and fish were collected at locations on and around the Hanford Site (Figure 8.11.6) as part of routine monitoring for Hanford-produced contaminants. Samples from these organisms were analyzed for selected radionuclides and metals that are suspected or known to be present on the Hanford Site (Table 8.11.5). Samples were also collected at locations that are distant from the site to obtain reference (background) contaminant measurements.

Most fish and wildlife samples collected on or near the Hanford Site for routine human-exposure pathway assessments are obtained annually, but specific species are only sampled every 2 or 3 years. Samples routinely obtained at locations believed to be unaffected by Hanford Site effluents and emissions are collected approximately every 5 years.

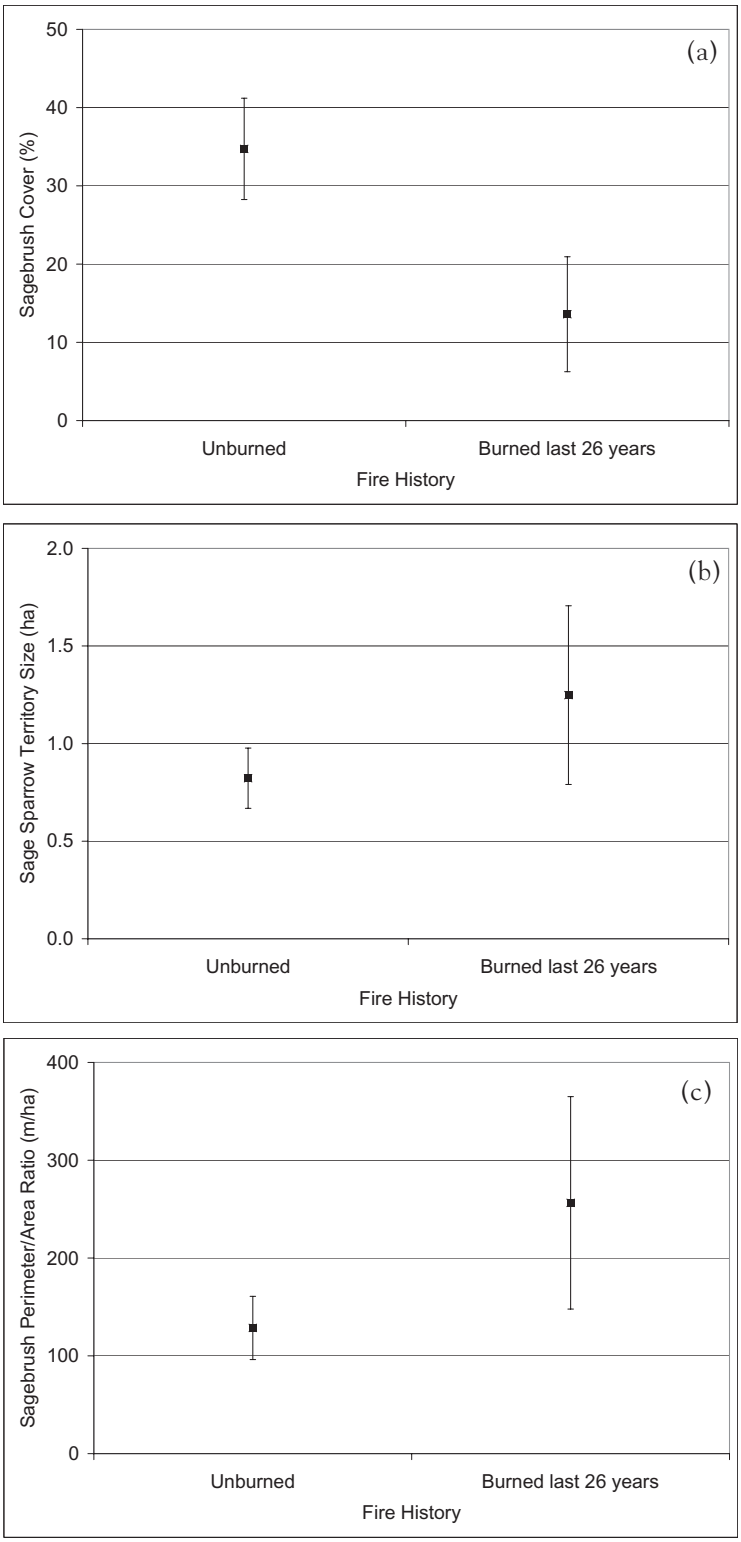

Figure 8.11.5. Mean (±95% confidence limits) Sagebrush Cover (a), Territory Size (b), and Sagebrush Patchiness (c) for Burned Versus Unburned Sage Sparrow Territories on the Hanford Site in 2003 and 2004

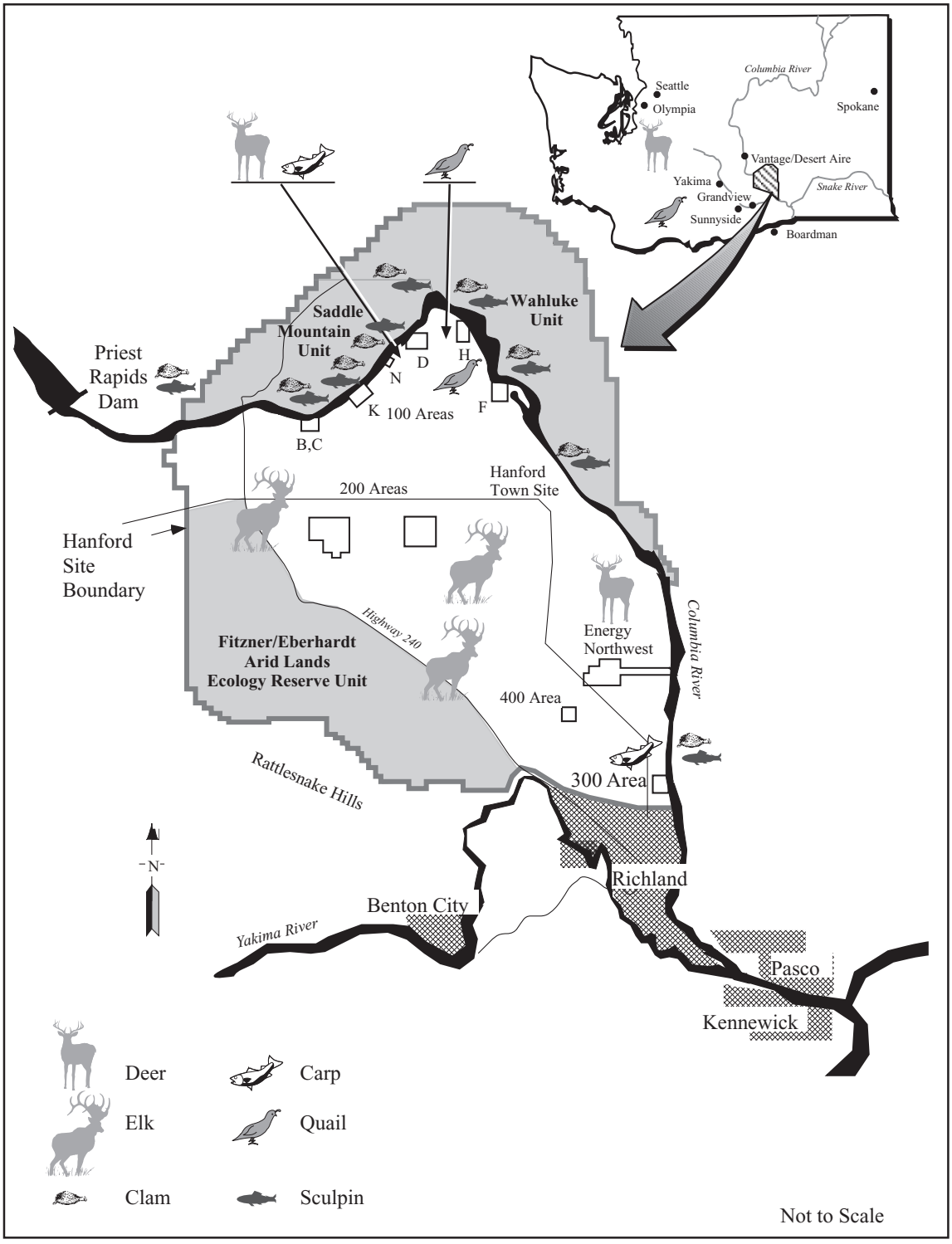

Figure 8.11.6. Fish and Wildlife Sampling Locations On and Around the Hanford Site, 2004

Table 8.11.5. Site-Wide and Offsite Fish, Wildlife, and Aquatic Sentinel Sampling Locations and Analyses, 2004

Biota	No. of Reference Locations	No. of Onsite Locations	No. of Analyses			
			Gamma	Strontium-90	Technetium-99	Trace Metals
Fish (carp)	0	2	10	10	0	10
(sculpin)	1[a]	22	0	17	16	29
Upland game (California quail and pheasant)	1[b]	2	12	12	0	12
Asiatic clams	3[a]	54	0	63	63	55
Big game (deer)	1[c]	2	10	10	0	3
(elk)	0	3	3	3	0	0

(a) Collected near the Vernita Bridge.
(b) Collected near Grandview, Washington.
(c) Black-tailed deer sample collected near Olympia, Washington.

In 2004, all fish and wildlife samples collected were monitored for strontium-90 contamination and were analyzed by gamma spectrometry to detect a number of gamma emitters (Appendix F) including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples.

Strontium-90 is chemically similar to calcium; consequently, it accumulates in hard tissues rich in calcium such as bone, antlers, and eggshells. Strontium-90 has a biological half-life in hard tissue of 14 to 600 days (PNL-9394). Hard-tissue concentrations may profile an organism's lifetime exposure to strontium-90. However, strontium-90 generally does not contribute much to human dose because it does not accumulate in edible portions of fish and wildlife. Strontium-90 is present in the Hanford environs as a result of past operating and waste disposal practices. Currently, contaminated groundwater entering the Columbia River via shoreline springs in the 100-N and 100-H Areas is the primary source of Hanford-produced strontium-90 measurable in the Hanford environment; however, the current contaminant contribution relative to historical fallout from atmospheric weapons testing is small (<2%) (PNL-8817).

Cesium-137 is particularly important to the human food chain because it is chemically similar to potassium and is found in the muscle tissues of fish and wildlife. Having a relatively short biological half-life (<200 days in muscle and <20 days in the gastrointestinal tract [PNL-9394]), cesium-137 is an indicator of recent exposure to radioactive materials. Cesium-137 is present in the environment as a result of past Hanford Site operating and waste disposal practices as well as from historical worldwide fallout resulting from nuclear weapons testing.

Gamma spectrometry results for most radionuclides are not discussed here because levels were too low to measure or measured concentrations were considered artifacts of low-background counts. Low-background counts occur at random intervals during sample counting and can produce occasional spurious false-positive results. For many radionuclides, concentrations were below levels that could be detected by the analytical laboratory. When this occurred for an entire group of samples, two times the total propagated analytical uncertainty was used as an estimate of the nominal detection level for that analyte and particular medium. Results, propagated analytical uncertainties, and minimum detection amounts for all results may be found in PNNL-15222, APP. 1.

Monitoring various biota for uptake and exposure to radionuclides both near and distant from Hanford Site operations continues to assure that consumption of fish and wildlife does not pose a threat to humans. Monitoring also provides long-term trends of contamination in selected components of the ecosystem. Wildlife and fish sampled and analyzed during 2004 for radioactive constituents included carp (*Eyprinus cyprinus*), upland game

(California quail [*Callipepla californica*] and ring-necked pheasant [*Phasianus colchicus*]), deer (mule deer [*Odocoileus hemionus*] and black-tailed deer [*Odocoileushemionus columbianus*]), and elk (*Cervus elaphus*).

A number of trace metals that have the potential to accumulate in certain fish and wildlife tissues have been identified in the Hanford Site environment as potential contaminants of concern (e.g., chromium, copper, lead, and mercury), particularly in areas of the site where contaminated groundwater enters the Columbia River along the shoreline (PNNL-14295). Historical operations at Hanford resulted in the production of both radiological and non-radiological wastes, including metals, in liquid, solid, and gaseous forms. These wastes were placed in various disposal sites at Hanford, including trenches, cribs, ditches, ponds, and underground storage tanks (PNNL-13487). Atmospheric releases included fly ash from coal-fired steam/power plants that were associated with each reactor. Fly ash contains trace metals and natural radionuclides that may have deposited on the soil around the reactor areas. In addition to waste associated with past Hanford operations, other sources of contamination have impacted the site. Heavy metals generated from upriver mining and smelting activities have been transported down the Columbia River (Johnson et al. 1990) and into the Hanford Reach. Also, contaminants associated with past and present agricultural practices have contributed to the contaminant inventory at the Hanford Site (Yokel and Delistraty 2003). For example, arsenic is likely associated with historical applications of lead arsenate on fruit orchards prior to World War II. Lead arsenate was once the most commonly used insecticide in fruit orchards and studies that examined the extent of arsenic contamination in pre-World War II orchard soil near the 100 Areas showed elevated levels of arsenic compared to levels in soil from reference locations (Yokel and Delistraty 2003).

Organisms can accumulate metals through incidental soil ingestion, by drinking contaminated water, and by consuming contaminated foods. The spatial variability of concentrations of metals in the environment is influenced by the contributions of both natural sources and industrial contaminants. Thus, concentrations of metals and organism exposures can vary between locations. This variability can produce some uncertainty in the source of the metals within the sampled organism. To determine the Hanford Site's contribution to levels of metals in biota collected on the Hanford Site or in the Hanford Reach, samples were also collected from the Columbia River both upstream and downstream of the site and from reference areas distant from the site. A comparison of concentrations of metals in upstream, downstream, and reference samples with concentrations in Hanford Reach or Hanford Site samples may provide information on increases in concentrations of metals potentially due to activities on the Hanford Site. Currently, there is not a large dataset for metals in wildlife and fish from the Hanford Reach, the Hanford Site, or from reference locations and the data that do exist show some degree of variability. Additional monitoring data may help to reduce the variability.

Trace metal concentrations were monitored in carp, deer, and upland game in 2004 and results are summarized in the following discussions. Individual results and the associated uncertainties may be found in PNNL-15222, APP. 1.

8.11.2.1 Analytical Results for Carp Samples

Fishing is a popular activity along the Hanford Reach of the Columbia River and fish, such as carp, are harvested for food and could potentially contribute to human exposure. Carp are nomadic and generally have large home ranges. These fish are likely moving up and down the Hanford Reach and may be exposed to metals and persistent radionuclides in the river environment. Monitoring fish for uptake and exposure to radionuclides and metals at locations both near to and distant from the Hanford Site continues to be important to track the extent and long-term trends of contamination in the Hanford Reach environment. During 2004, ten carp were collected from two locations in the Hanford Reach: five between the 100-N and 100-D Areas and five near the 300 Area (Figure 8.11.6). Fillets and the eviscerated remains (carcass) of carp were analyzed for a variety of radiological contaminants and liver samples were analyzed for metals in 2004.

Cesium-137 results were below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in all ten carp fillet samples collected from the Hanford Reach during 2004. These results are consistent with results reported throughout the past 10 years that indicated a gradual decline in cesium-137 levels in fish found both at background locations and near the Hanford Site.

Strontium-90 concentrations in carp carcass samples collected from near the 300 Area were all below the analytical detection limit (0.05 pCi/g [0.0019 Bq/g] wet weight). Strontium-90 was found in all the carp carcass samples collected between the 100-N and 100-D Areas during 2004. The median level of strontium-90 in carcass tissues collected from the region between the 100-N and 100-D Areas during 2004 was 0.33 pCi/g (0.012 Bq/g) wet weight (Figure 8.11.7). The strontium-90 concentration in one of the five carp samples collected between the 100-N and 100-D Areas (1.5 pCi/g [0.055 Bq/g] wet weight) was approximately two times greater than the highest value reported over the preceding 10-year period. Elevated amounts of strontium-90 have been consistently measured in carp and other bottom-feeding fishes (suckers and whitefish) collected near the 100-N Area in the past. The median- and maximum-result pattern near the 100-N Area may indicate some of the fish have consumed items containing elevated amounts of strontium-90 from Hanford sources and have incorporated some strontium into their tissues. Strontium-90 concentrations in carcass tissue would have to be around 600 pCi/g (22 Bq/g) wet weight (in the absence of other radionuclides and external exposure) to be near the DOE dose limit of 1.0 rad (10 mGy) per day established for aquatic organisms (Section 8.14.6).

Liver samples from 5 carp collected near the 300 Area and 5 carp collected between the 100-N and 100-D Areas were analyzed for 18 trace metals during 2004. Concentrations in the samples were compared to concentrations in carp samples collected at a reference location upstream of the site, near Desert Aire, Washington, in 2002 (PNNL-14295, APP. 1). The samples from the reference location were not analyzed for mercury and barium, and beryllium was the only trace metal not detected above analytical detection limits (0.02 µg/g dry weight) in samples from all locations (Appendix C, Table C.11; PNNL-14295, APP. 1). The median and maximum concentrations of cadmium, arsenic, silver, thallium, and zinc were elevated in the carp samples collected between the 100-N and 100-D Areas in 2004 compared to concentrations in samples collected near Desert Aire in 2002 (Appendix C, Table C.11; PNNL-14295, APP. 1). However, with the exception of cadmium, concentrations were similar to concentrations in liver samples collected from carp near the 100-N Area in 1997 and 2002 (PNNL-11795, APP. 1; PNNL-14295, APP. 1).

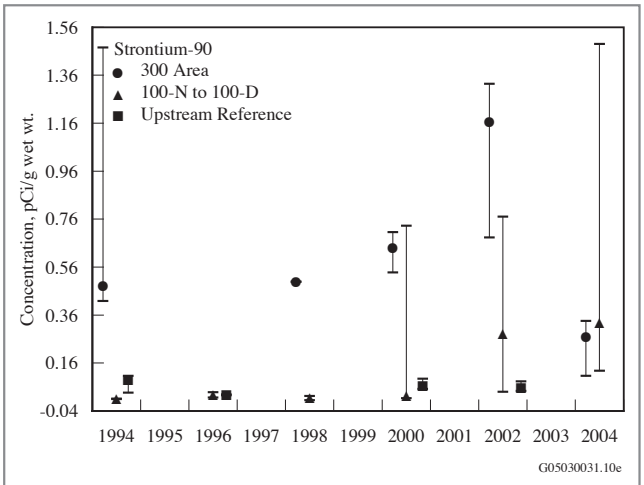

Figure 8.11.7. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Columbia River Carp Carcasses at the Hanford Site, 2004 Compared to Previous Years

The maximum concentration of cadmium in 2004 (209 µg/g dry weight) was more than two times greater in carp livers collected between the 100-N and 100-D Areas compared to the maximum concentration of cadmium in carp livers collected near Desert Aire (87 µg/g dry weight) and near the 100-N Area in 1997 (94 µg/g dry weight) and in 2002 (89 µg/g dry weight) (Appendix C, Table C.11; PNNL-14295, APP. 1; PNNL-11795, APP. 1). The median concentration of cadmium in carp sampled between the 100-N and 100-D Areas (36 µg/g dry weight) was over five times greater than the median concentration measured in Desert Aire carp (6.5 µg/g dry weight) but was similar to the median concentrations measured in carp collected near the 100-N Area in 1997 (41 µg/g dry weight) and 2002 (38 µg/g dry weight) (PNNL-11795, APP. 1; PNNL-14295, APP. 1). The median and maximum concentrations of cadmium in carp livers collected near the 300 Area in 2004 were elevated compared to concentrations measured in samples from Desert Aire in 2002 but were similar to concentrations measured in carp livers collected in 1997 and 2002 near the 300 Area (PNNL-11795, APP. 1; PNNL-14295, APP. 1).

The maximum uranium concentration in carp livers collected between the 100-N and 100-D Areas (0.24 µg/g dry weight) was elevated compared to the maximum uranium concentration in carp livers collected at Desert Aire (0.085 µg/g dry weight) (Appendix C, Table C.11;

PNNL-14295, APP. 1). However, the median uranium concentration in samples collected between the 100-N and 100-D Areas in 2004 (0.053 µg/g dry weight) was below the median concentrations measured in carp collected at Desert Aire (0.055 µg/g dry weight) and collected between the 100-N and 100-D Areas (0.11 µg/g dry weight) in 2002 (PNNL-14295, APP. 1). Carp livers were not analyzed for uranium in 1997. The maximum concentration of uranium in carp livers collected near the 300 Area (0.38 µg/g dry weight) was elevated compared to the maximum concentration in samples collected at Desert Aire (0.085 µg/g dry weight) and the maximum concentration previously reported for carp sampled near the 300 Area (0.29 µg/g dry weight) (PNNL-11795, APP. 1; PNNL-14295, APP. 1). The median concentration of uranium in carp liver collected near the 300 Area in 2004 (0.09 µg/g dry weight) was elevated compared to the median concentration in samples from Desert Aire in 2002 (0.055 µg/g dry weight) but was below the median concentration reported in carp liver samples collected near the 300 Area in 2002 (0.13 µg/g dry weight) (PNNL-14295, APP. 1). Elevated uranium concentrations in carp liver samples from near the 300 Area is consistent with the elevated uranium concentrations measured in 300 Area clam samples in 2004.

The maximum concentration of chromium in carp livers collected between the 100-N and 100-D Areas in 2004 (12 µg/g dry weight) was approximately seven times higher than the maximum concentration measured in carp livers collected at Desert Aire (1.6 µg/g dry weight) (PNNL-14295, APP. 1). However, the median concentration in samples collected between the 100-N and 100-D Areas (0.50 µg/g dry weight) was below the median concentrations measured in carp collected at Desert Aire (1.3 µg/g dry weight) and near the 100-N Area in 2002 (1.8 µg/g dry weight) (PNNL-14295, APP. 1).

The median concentrations of zinc, copper, and silver in liver samples from carp collected near the 300 Area during 2004 were elevated compared to concentrations in samples collected at Desert Aire (Appendix C, Table C.11; PNNL-14295, APP. 1) but were similar to concentrations measured in carp liver samples collected near the 300 Area in 1997 and 2002 (PNNL-11795, APP. 1; PNNL-14295, APP. 1). The median concentrations of arsenic and manganese were elevated in liver samples collected near the 300 Area in 2004 compared to concentrations measured in the 2002 Desert Aire samples and in liver samples collected in 1997 and 2002 near the 300 Area (PNNL-11795, APP. 1; PNNL-14295, APP. 1). However, maximum concentrations of arsenic and manganese in samples collected near the 300 Area in 2004 were below the maximum concentrations measured in Desert Aire samples in 2002 (PNNL-14295, APP. 1).

The dataset for metals in carp near the Hanford Site is relatively small and results are variable; therefore, it is difficult to draw conclusions. In addition, no state or federal benchmark criteria are available for tissue concentrations of metals in fish. However, Washington State has developed acute and chronic aquatic life criteria for ambient surface water. Both Columbia River and Columbia River shoreline spring water samples have been collected near Hanford operational facilities for many years and results for river and spring water samples collected during 2004 are presented in Sections 8.4 and 8.5. In general, concentrations of metals in river and spring water samples, including cadmium, were less than the Washington State ambient surface water quality acute and chronic criteria for the protection of aquatic life (Appendix C, Table C.5; Appendix D, Table D.3). Median concentrations of most metals, including cadmium, in Hanford Reach sediment samples collected during 2004 were lower than concentrations in sediment collected at the Priest Rapids Dam upstream of the Hanford Site (see Section 8.4.2 for discussion).

Currently, Washington State does not have a surface water quality criterion for uranium. There were elevated concentrations of uranium in near-shore Columbia River water samples, shoreline spring water samples, and Columbia River and shoreline springs sediment samples collected near the 300 Area in 2004. Uranium concentrations at the 300 Area were roughly two to four times the concentration measured in sediment collected near Priest Rapids Dam (see Sections 8.4.2 and 8.5.2 for discussion). However, median and maximum concentrations of uranium in river and riverbank spring sediment were at or below concentrations of uranium found in sediment collected at the Priest Rapids Dam in 2004.

8.11.2.2 Analytical Results for Upland Game Samples

California quail are one of the most prevalent upland game birds found on the Hanford Site. Most of the quail that reside onsite are found along the shoreline of the Columbia River where trees and shrubs provide shelter. Quail forage for seeds, other plant parts, and grit in grassy and weedy places not far from cover. Ordinarily, quail do not travel far from where they hatch. Individual birds on the Hanford Site may spend their entire lives near one of the retired plutonium reactors. Quail can be exposed to metals and persistent radionuclides when they forage on materials from plants that have roots in contact with contaminated groundwater or soil, drink contaminated water, or ingest contaminated grit. Seven California quail were collected in the region between the 100-H and 100-F Areas and in the region between the 100-D and 100-H Areas on the Hanford Site in the fall of 2004. Radionuclide levels found in muscle and bone samples analyzed during 2004 were compared to levels measured in upland game samples collected onsite during the previous 10-year period and were also compared to levels found in five upland game samples collected from a reference location near Grandview, Washington, in 2004.

Concentrations of cesium-137 were below the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in the three quail muscle samples collected between the 100-H and 100-F Areas, in the four samples collected between the 100-D and 100-H Areas, and in the five samples collected at the reference location. The number of samples with cesium-137 concentrations at or below the analytical detection limit from 1998 to 2004 (36 of 36 collectively) reflects the continued downward trend in worldwide levels of cesium-137 fallout from atmospheric weapons testing that took place from the 1950s through the 1970s.

One quail bone sample collected onsite between the 100-D and 100-H Areas, and one quail bone sample collected from the reference location in 2004 had strontium-90 concentrations above the analytical detection limit (0.04 pCi/g [0.001 Bq/g] wet weight). The maximum concentration found in quail bones collected in 2004 between the 100-D and 100-H Areas (0.11 pCi/g [0.004 Bq/g] wet weight) was similar to the maximum concentration reported in bones collected in 2004 from the reference location (0.10 pCi/g [0.004 Bq/g] wet weight). Results from all other bone samples collected onsite and at the reference location were below the analytical detection limit. These results are consistent with results obtained in past years and do not indicate elevated levels of strontium-90 in upland game (Figure 8.11.8).

Three liver samples from quail collected between the 100-H and 100-F Areas and 4 liver samples from quail collected between the 100-D and 100-H Areas on the Hanford Site were analyzed for 18 trace metals during 2004. Liver samples from 5 pheasants collected at a reference location near Grandview, Washington, were analyzed for 16 metals in 2004. The reference samples were not analyzed for barium and mercury. For most trace metals, concentrations in samples collected on the Hanford Site were the same as or below concentrations in samples collected at the reference location (Appendix C, Table C.12).

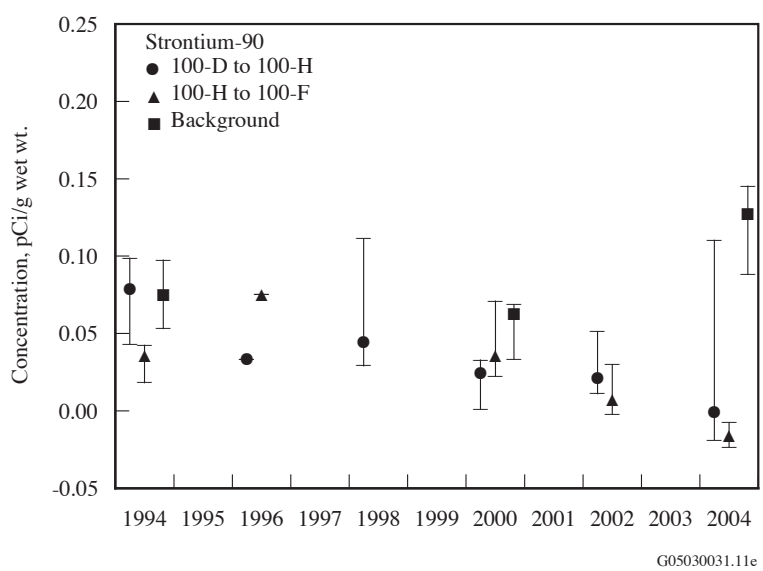

Figure 8.11.8. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Upland Game Bird Bone Samples, 2004 Compared to Previous Years

Beryllium, antimony, thorium, and uranium were not detected above analytical detection limits in any of the upland game bird liver samples collected on the Hanford Site in 2004. The median and maximum concentrations of aluminum, chromium, cadmium, selenium, and thallium were two to five times higher in liver samples collected between the 100-D and 100-H Areas compared to the median and maximum concentrations measured in liver samples from the reference location. Cadmium concentrations in three of the four samples collected in 2004 between the 100-D and 100-H Areas exceeded the maximum concentration measured in upland game bird samples from the same general area in 2002 (PNNL-14295). The maximum concentrations of aluminum, chromium, and selenium in liver samples collected in 2004 between the 100-N and 100-D Areas were below the minimum concentrations of aluminum (12 µg/g dry weight), chromium (1.9 µg/g dry weight), and selenium (7.1 µg/g dry weight) measured in upland game bird liver samples collected in the same general area in 2002 (PNNL-14295).

The maximum concentration of aluminum (9.5 µg/g dry weight) in upland game liver samples collected between the 100-H and 100-F Areas was more than five times higher than the maximum aluminum concentration measured in samples from the reference location (1.5 µg/g dry weight). However, the median concentration in the three samples collected between the 100-H and 100-F Areas was below the median concentration measured in samples collected at the reference location and two of the three samples had concentrations of aluminum below the minimum concentration measured at the reference location.

8.11.2.3 Analytical Results for Deer Samples

Studies of mule deer populations residing on the central portions of the Hanford Site indicate their division into three relatively distinct groups (Tiller and Poston 2000): (1) deer that live near the retired reactors in the 100 Areas are designated the north area population; (2) deer that reside from the Hanford town site south to the 300 Area are designated the south area population; and (3) by default, deer living around the 200 Areas, away from the river, are designated the central area population. The central area population has decreased significantly with the eliminations of Gable Mountain Pond and B Pond. Deer can be exposed to metals and persistent radionuclides when they forage on plants that grow in places where plant roots have access to contaminated groundwater or soil, drink contaminated water, or incidentally ingest contaminated soil. Deer hunting is not allowed above the high water mark on the Benton County side of the Columbia River (on the Hanford Site), but the river is not a barrier to deer movements. Deer captured and tagged on the Hanford Site have been legally killed by hunters on the Hanford Reach shoreline below the high water mark and across the river in Franklin County.

Radionuclide levels in muscle and bone samples harvested from nine deer collected onsite in 2004 were compared to levels in tissues from a deer collected distant from the site and to results measured in samples collected during the preceding 10-year period. Four deer were from the north population and five were from the south population. In 2004, reference tissue samples from a black-tailed deer collected near Olympia, Washington, were donated to DOE by the Washington State Department of Health. Additionally, reference samples were collected between 1992 and 1995 near Boardman, Oregon, and in Stevens County, Washington (see PNNL-11472, Section 4.5), and during 2000 from the lower Yakima Valley, near Sunnyside, Washington (see PNNL-13487, Section 4.5). Contaminant concentrations measured in a white-tailed deer that was co-sampled with the Washington State Department of Health during 1996 from Vail, Washington (see PNNL-12088, Section 4.5), were also used for comparisons. These comparisons with samples from distant locations are useful in evaluating Hanford's relative contribution of radionuclides in deer. The deer collected in Stevens County and Vail, Washington, inhabited mountain regions that received more rainfall (and more atmospheric fallout over a period of several decades) than Hanford, increasing background levels of fallout radionuclides there (Tiller and Poston 2000). The climate and precipitation of the Boardman, Oregon, and the Sunnyside, Washington, regions are similar to Hanford.

Cesium-137 was not detected (at or below the detection limit of 0.03 pCi/g [0.001 Bq/g] wet weight) in any of the nine deer muscle samples collected onsite in 2004 or in the muscle sample from the black-tailed deer collected near Olympia in 2004. These results are consistent with a decline in cesium-137 levels in all wildlife examined from 1983 through 1992 (PNL-10174) and with data obtained

over the preceding 10 years. During this period, the levels of cesium-137 in more than 60 Hanford Site deer muscle samples were less than levels measured in reference deer samples collected from 1991 through 1995 from Stevens County, Washington, and, during 1996, from Vail, Washington.

Strontium-90 was detected in all nine deer bone samples collected onsite and analyzed in 2004 and continues to demonstrate the utility of this organism to accumulate this radionuclide and to depict trends of strontium-90 contamination in the environment. Median levels of strontium-90 found in deer bone in 2004 were similar between the north and south sampling areas (Figure 8.11.9). The highest concentration of strontium-90 (1.24 ± 0.22 pCi/g [0.05 ± 0.008 Bq/g] wet weight) obtained onsite during 2004 was obtained from the north area near the 100-N Area. When compared to the bone samples from the south area, strontium-90 concentrations in bone samples from the north area were typically elevated in about one of three samples collected there throughout the preceding 10-year period, with the highest concentration (20.8 ± 5.2 pCi/g [0.77 ± 0.19 Bq/g] wet weight) reported during 1992 (see PNNL-13487, Section 4.5). The apparently higher concentrations reported in samples from the north area may indicate some exposure to localized contamination in the 100-N Area. Strontium-90 was detected in the 2004 reference sample from Olympia, Washington (1.29 ± 0.19 pCi/g [0.05 ± 0.007] wet weight). Previous reference samples of deer bone indicate strontium-90 concentrations can be as high as 2.06 ± 0.4 pCi/g (0.08 ± 0.01 Bq/g) wet weight.

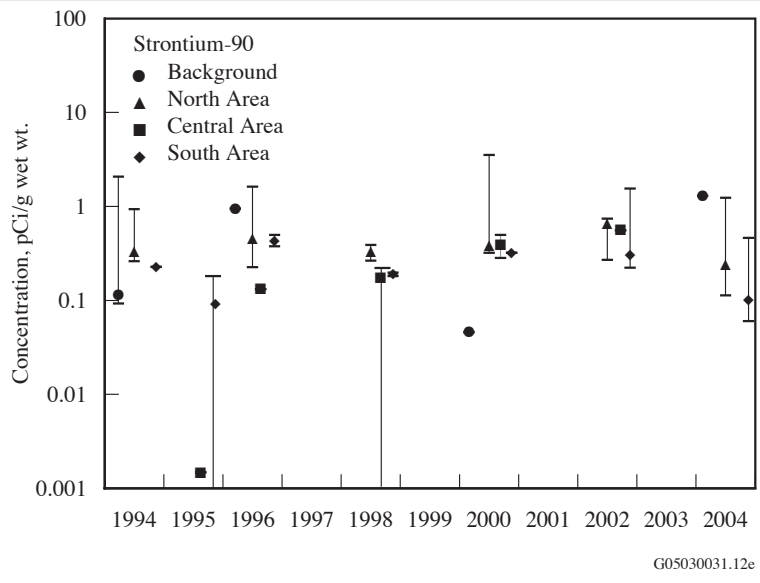

Figure 8.11.9. Median, Maximum, and Minimum Strontium-90 Concentrations (pCi/g wet wt.) in Hanford Site and Background Deer Bone Samples, 2004 Compared to Previous Years

Liver samples from two mule deer collected near the 100-N Area and the black-tailed deer from near Olympia, Washington, were analyzed for trace metals in 2004. Concentrations measured in Hanford Site deer were compared to concentrations in four mule deer samples obtained at a reference location near Boardman, Oregon, in 1994 (PNNL-11518) and to concentrations measured in samples from the black-tailed deer (Appendix C, Table C.13; PNNL-11518).

Most trace metal concentrations in liver samples collected from deer near the 100-N Area in 2004 were similar to or less than concentrations measured in samples from the reference locations (Appendix C, Table C.13). Uranium, nickel, beryllium, thorium, and antimony were not detected above analytical detection limits in samples collected on the Hanford Site in 2004. Concentrations of copper were elevated in samples collected onsite compared to the sample collected near Olympia, Washington, but were not elevated compared to concentrations in samples collected near Boardman, Oregon. Thallium concentrations were above the analytical detection limit in samples collected onsite. Thallium concentrations were below the analytical detection limits in samples collected near Olympia, Washington (0.004 µg/g dry weight), and Boardman, Oregon (0.04 µg/g dry weight). However, the detection limit for the samples collected near Boardman exceeded the maximum concentration found in samples collected on the Hanford Site (PNNL-11518).

Cadmium, selenium, and arsenic levels were elevated in samples collected onsite compared to concentrations in all reference samples. The median and maximum concentrations of cadmium measured in the samples collected onsite were approximately two times higher than the median and maximum concentrations measured in the samples from Boardman, Oregon (PNNL-11518), and six to

seven times higher than the concentration measured in the sample from Olympia, Washington. The median and maximum concentrations of selenium in samples collected onsite were slightly elevated compared to levels in samples collected near Boardman, Oregon, but were over four times higher than the concentration measured in the sample collected near Olympia, Washington. Arsenic concentrations measured in samples collected onsite were over 20 times higher than the concentration measured in the sample collected near Olympia, Washington, and concentrations measured in samples collected near Boardman, Oregon. The elevated arsenic seen in deer collected near the 100-N Area is likely associated with eating grass from fields that were fruit orchards prior to World War II. These orchards were commonly sprayed with lead arsenate to control insects. A 2002 study that examined the extent of arsenic contamination in pre-Hanford orchard soil near the 100 Areas showed elevated levels of arsenic compared to levels in soil from reference areas (Yokel and Delistraty 2003).

8.11.2.4 Analytical Results for Elk Samples

Radionuclide levels in elk samples collected on the Hanford Site in 2004 were compared to levels in elk samples previously collected onsite, along roads near the Hanford Site (killed by traffic), on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit of the Hanford Reach National Monument, and from a reference location in central Idaho. In 2004, samples of muscle and bone were collected from two animals killed by traffic on Highway 240 on the Hanford Site and one killed by traffic near the 200-East Area (Figure 8.11.6). Muscle samples were analyzed for gamma emitters, including cesium-137, and bone samples were analyzed for strontium-90.

Cesium-137 was not detected above the analytical detection limit (0.03 pCi/g [0.001 Bq/g] wet weight) in any of the elk muscle samples collected in 2004. Three muscle samples collected from central Idaho in 1999 were the only elk samples analyzed in the last 10 years with cesium-137 concentrations above analytical detection limits. These results were consistent with historical big game results and with the trends observed in a Hanford wildlife summary report (PNL-10174).

Strontium-90 was detected in all elk bone samples analyzed in 2004. The median concentration in the samples (0.272 pCi/g [0.01 Bq/g] wet weight) was consistent with levels previously observed on the Hanford Site and on the Fitzner/Eberhardt Arid Lands Ecology Reserve Unit (Figure 8.11.10). Interestingly, the highest concentration of strontium-90 observed in elk in recent years comes from reference samples collected in 1999 from central Idaho and is likely associated with the historical accumulation of fallout in the central Idaho area.

8.11.3 Sentinel Organisms

B. L. Tiller

For environmental monitoring purposes, organisms can be used to (1) detect and quantify contaminants in a given ecosystem (sentinel organisms) and (2) indicate risks to an ecosystem (indicator organisms). Organisms that are best suited for accumulating contaminants and serving as biological monitors of environmental contaminants are termed sentinel species, whereas organisms (or defined assemblages of organisms) that are sensitive to damage or injury from elevated levels of environmental contaminants are referred to as indicator species. In practice, the desirable features of both the sentinel and indicator species are often found only in a limited number of organisms. The organisms chosen for monitoring environmental health often have both sentinel and indicator species attributes.

8.11.3.1 Asiatic Clam Sample Results and Analytes of Interest

Asiatic clams (*Corbicula fluminea*) may be one of the best sentinel organisms along the Hanford Reach of the Columbia River to support DOE cleanup and monitoring objectives on the Hanford Site. This organism is relatively immobile its entire life (0 to 3 years), lives in shallow shoreline areas, is a filter-feeder that feeds on phytoplankton and microbes, and is common along the Hanford Reach shoreline. These habitat and food source preferences make this organism an ideal candidate for monitoring contaminants in groundwater seeping into the Columbia River.

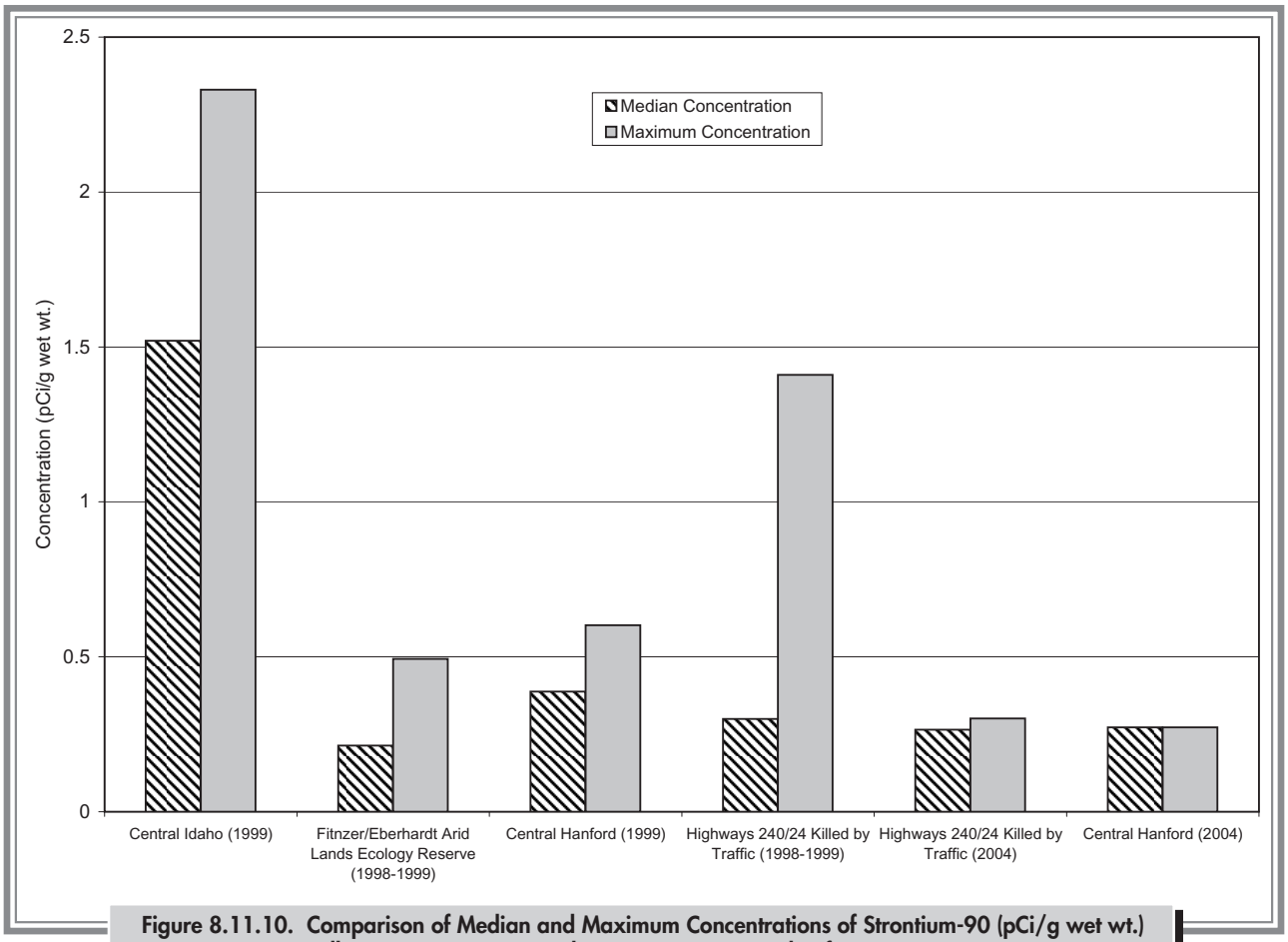

Figure 8.11.10. Comparison of Median and Maximum Concentrations of Strontium-90 (pCi/g wet wt.) in Elk Bone, 2004 Compared to Previous Years and Reference Locations

Asiatic clams were collected along the Hanford Reach during August 2004 through September 2004 to evaluate the spatial patterns of Hanford radiological and non-radiological contaminants entering the Columbia River. Clam tissue samples were collected near each of the six Hanford Site reactor areas (100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F Areas), the 300 Area, the Hanford town site, and from an area upstream of the Hanford Site near the Vernita Bridge that serves as a reference location (Figure 8.11.6). Sampling locations near each of the Hanford Site facilities were selected based on known or suspected elevated levels of legacy contaminants entering the Columbia River via shallow groundwater.

At each site, sampling points were selected near the river's low-water mark, which was visually identified by the presence of persistent periphyton colonies growing on the river bottom (during portions of the year, periphyton dries out and dies above the low-water mark). Clam samples were systematically collected from this point and at another point extending into the river perpendicular to the shoreline at a water depth of 2 meters (6 feet). Clam samples were flash-steamed for approximately 15 to 30 seconds using deionized water and the shells were separated from the soft tissues. Shells from 15 to 30 individual clams from each sampling site were composited for strontium-90 and technetium-99 analyses. Soft tissues were composited (from 2 to 50 organisms per sample) and analyzed for 18 trace metals, including chromium, mercury, and uranium (Table 8.11.5).

Strontium-90 was detected in 61 of 63 (96%) of the clam shell samples collected and analyzed during 2004. Levels measured in clam shells collected from the reference location near the Vernita Bridge during 2004 ranged from 0.19 to 0.228 pCi/g (0.007 to 0.009 Bq/g) wet weight. The maximum strontium-90 concentration measured near the 100-N Area during 2004 (10.1 pCi/g [0.4 Bq/g] wet weight) was 44 times higher than the maximum reference location level, and the level near the 100-H Area

(0.78 pCi/g [0.03Bq/g] wet weight) was 3.4 times higher than the maximum reference location level (Table 8.11.6). Strontium-90 was also detected in samples collected during a 2004 special study near the 100-N Area. The maximum concentration measured in clam shells as part of this study was 50.5 pCi/g (1.87 Bq/g) wet weight (DOE/RL-2005-22).

Technetium-99 was not found above analytical detection limits (ranging from 0.55 to 0.64 pCi/g [0.02 to 0.025Bq/g] wet weight) in any of the clam shell samples collected and analyzed during 2004. This was consistent with results reported during 2003 (PNNL-14687).

With the exception of beryllium, trace metals were consistently detected in soft tissue clam samples collected during 2004 (Table 8.11.6). Concentrations of most metals in Hanford Reach clam samples were equal to or below levels found in three samples collected upstream of the Hanford Site during 2004. Chromium concentrations in clam soft tissues were elevated near the 100-B/C, 100-K, 100-N, and 100-D Areas compared to concentrations measured near the Vernita Bridge (ranging from 2.34 to 5.75 µg/g dry weight). The highest concentration of chromium reported in clam tissue during 2004 (70.1 µg/g dry weight) was collected between the 100-K and 100-N Areas, a location that had not been previously sampled or noted to have active flowing spring water (Figure 8.11.11).

The tissue concentrations of chromium reported in clams generally indicated the highest exposures occurred in the shallowest areas and decreased as water depth increased (Figure 8.11.11). Elevated chromium concentrations in clam tissues collected during 2004 were generally consistent with results reported during 2002 (PNNL-14687). Chromium concentrations measured in 16 of 19 (84%) clam samples collected at 2 meters (6 feet) below the low-water line during 2004 were at or below the reference concentrations measured near the Vernita Bridge (ranging from 2.34 to 5.75 µg/g dry weight). Elevated chromium concentrations appeared to extend beyond the 2-meter (6-foot) water depth at two sampling points near the 100-D Area and one sampling point near the 100-K Area (Figure 8.11.11). The perpendicular distances corresponding to the 2-meter (6-foot) water depth varied according to the slope of the shoreline at each location sampled and ranged from 8 to 123 meters (25 to 381 feet).

No state or federal agency benchmark criteria are available to compare to tissue concentrations of chromium measured near the 100-B/C, 100-K, 100-N, and 100-D Areas. However, water samples collected at some of the sites where clam samples were collected indicated elevated exposure to Hanford sources of chromium (Table 8.11.7). Surface water quality criteria for aquatic life are found in WAC 173-201A-040, *Toxic Substances* (Appendix D, Table D.3). Water collected from springs near the 100-B/C,

Table 8.11.6. Trace Metals (µg/g dry wt.) and Radionuclides (pCi/g wet wt.) in Asiatic Clams,[a] Hanford Reach Samples Compared to Reference Area Samples Collected Upstream of the Vernita Bridge, 2004

Sample Locations	Trace Metals									Radionuclides	
	Silver	Aluminum	Arsenic	Barium	Beryllium	Cadmium	Copper	Chromium	Mercury	Strontium-90	Technetium-99
100-B/C Area					ND[b]						ND
100-K Area					ND						ND
100-N Area					ND						ND
100-D Area											ND
100-H Area					ND						ND
100-F Area					ND				ND		ND
Hanford town site					ND						ND
300 Area					ND				ND		ND
	Manganese	**Nickel**	**Lead**	**Antimony**	**Selenium**	**Thorium**	**Thallium**	**Uranium**	**Zinc**		
100-B/C Area											
100-K Area											
100-N Area											
100-D Area											
100-H Area											
100-F Area											
Hanford town site											
300 Area											

(a) Metals analyses on soft tissues and radiological analyses on shells.
(b) Not reported above analytical detection limit.

	Maximum concentrations in Hanford Reach samples equal to or below maximum concentrations reported from reference area samples.
	Maximum concentrations in Hanford Reach samples between 1 and 2 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples between 2 and 5 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples between 5 and 10 times the maximum concentrations reported in reference area samples.
	Maximum concentrations in Hanford Reach samples greater than 10 times the maximum concentrations reported in reference area samples.

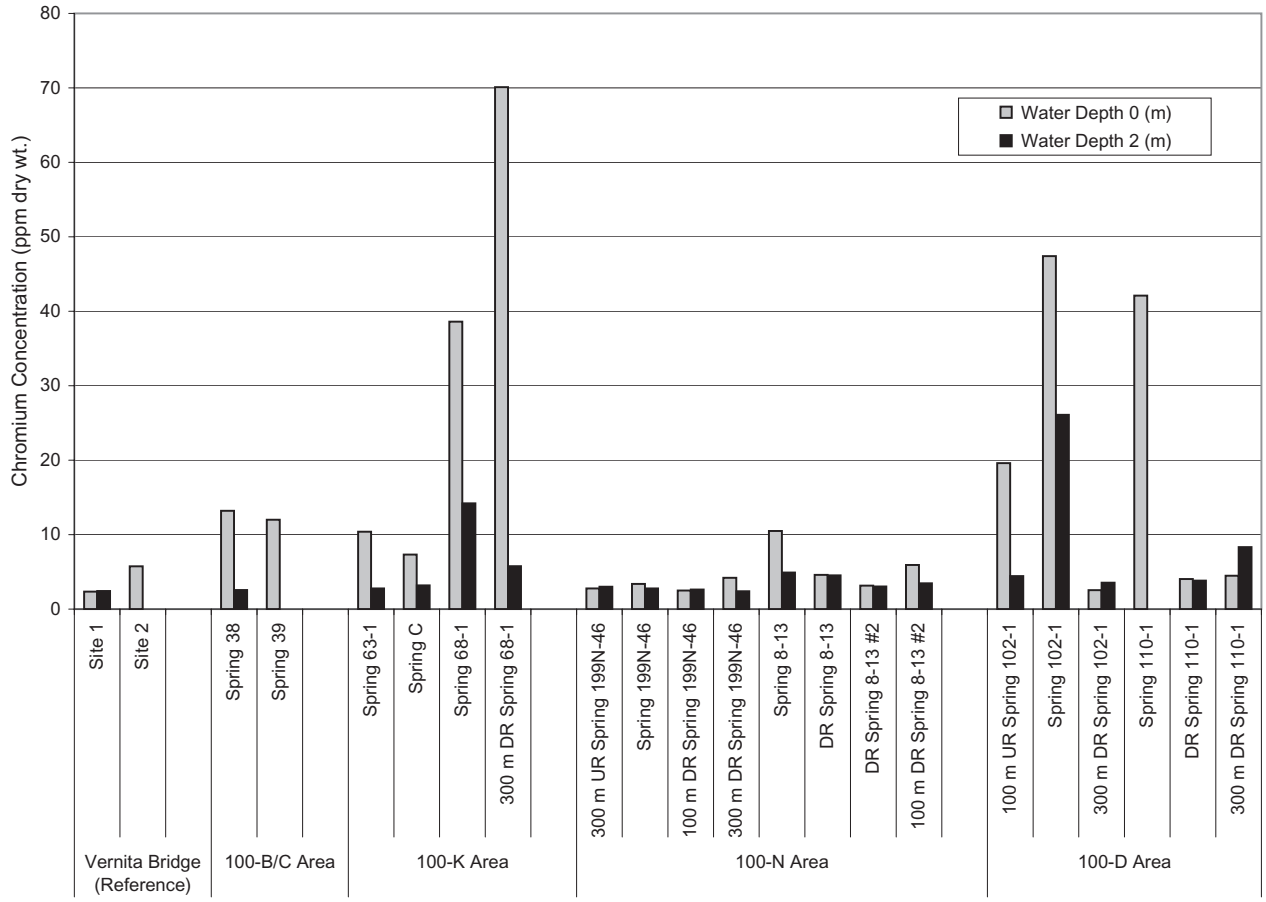

Figure 8.11.11. Chromium Levels (µg/g dry wt.) in Soft Tissues of Asiatic Clams Collected Near the Vernita Bridge and the 100-B/C, 100-K, 100-N, and 100-D Areas at the Low-Water Line and 2 Meters (6 feet) Below the Low-Water Line, 2004. DR = downriver; UR = upriver.

Table 8.11.7. Comparison of Chromium Levels in Clam Tissue (2004), Spring Water (2003), and Riverbank Spring Sediment (2003) Samples Collected Along the Benton County Shoreline of the Hanford Reach

General Region	2004 Clam Tissue[a] (µg/g dry wt.)	2003 Spring Water (µg/L)	2003 Sediment (µg/g dry wt.)
The Vernita Bridge (Reference)	2.34 - 5.75	No sample	92.1
100-B/C Area	12 - 13.2[b]	7.5 - 20	68.4 - 112
100-K Area	7.3 - 70.1[b]	0.97 - 82	110.0
100-N Area	10.5[c]	5.6 - 12	No sample
100-D Area	42.1 - 47.4[c]	12 - 150	No sample

(a) Not blank corrected.
(b) Blank contained 0.78 µg/g dry wt.
(c) Blank contained 0.8 µg/g dry wt.

100-K, 100-N, and 100-D Areas during 2003 contained chromium at concentrations exceeding WAC guideline levels that may produce chronic toxic effects (Table 8.11.7; Appendix D, Table D.3). Water concentrations of chromium at the 100-B/C, 100-K, and 100-D Areas also exceeded WAC guideline levels that may produce acute toxic effects (Table 8.11.7; Appendix D, Table D.3). In 2004, spring water was not collected at the site where the highest chromium levels (70.1 µg/g dry weight) were observed in clams, which were collected near the 100-K Area in 2004 (Table 8.11.7).

One clam sample collected near the 300 Area contained over 15 times the concentration of uranium (2.7 µg/g dry weight) compared to the maximum concentration measured near the Vernita Bridge during 2004 (0.18 µg/g dry weight, Table 8.11.6). Uranium was not appreciably elevated in the samples collected near the other Hanford Site reactor areas or near the Hanford town site. These results are consistent with results observed during 2003 and 2001 (PNNL-14687; PNNL-13692).

8.11.3.2 Sculpin Sample Results and Analytes of Interest

Sculpin probably best represent the ideal sentinel fish along the Hanford Reach of the Columbia River because they have relatively small home ranges, eat aquatic insects, dwell on the river bottom, and are relatively abundant. Prickly sculpin (*Cottus asper*) represent a different feeding guild than Asiatic clams because they are predators and have the potential to accumulate contaminants such as mercury, arsenic, and organic materials in their tissues that otherwise may go undetected in non-predator organisms, soil, sediment, or water.

Prickly sculpin samples were collected during 2004 near six of the Hanford Site reactor areas (100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F Areas), the 300 Area, the Hanford town site, and an area upstream of the Hanford Site near the Vernita Bridge that serves as a reference location (Figure 8.11.6). Sculpin tissues were analyzed for strontium-90, technetium-99, and trace metals (Table 8.11.5). Sculpin samples were not analyzed for gamma-emitting radionuclides in 2004. However, no gamma-emitting radionuclides were detected in sculpin samples (whole organisms) collected and analyzed in 2003.

During 2004, 17 whole body sculpin samples were analyzed for strontium-90 and 16 for technetium-99. Liver samples from 32 sculpin were analyzed for 18 trace metals (Appendix C, Table C.14). For the radionuclide and metals analyses, each sample consisted of a number of individual organisms or livers because the mass required for these analyses was larger than the weight of any individual organism or organ. The three reference samples collected in 2004 near the Vernita Bridge had concentrations of several metals including lead, aluminum, cadmium, chromium, and mercury that were elevated compared to concentrations in samples collected upstream of the Vernita Bridge in 2003 and near Hanford Site reactor areas in 2004. To be conservative, concentrations in samples collected near the Hanford reactor areas in 2004 were compared to concentrations in ten sculpin samples collected upstream of the Vernita Bridge in 2003.

For most trace metals and radionuclides, concentrations measured in sculpin samples collected near the Hanford reactor areas were generally equal to or less than concentrations measured in sculpins collected in 2003 and 2004 upstream of the Vernita Bridge (Appendix C, Table C.14). The median concentrations for chromium, aluminum, barium, and lead in sculpin collected near the Hanford reactor areas were two to three times greater than the median concentrations of these metals in sculpin collected upstream of the Vernita Bridge in 2003. The median concentrations of lead, manganese, and barium were approximately five times higher in sculpin samples collected near the 100-D Area than the median concentrations of these metals measured in the sculpin samples collected in 2003 upstream of the Vernita Bridge. The median concentrations of aluminum in sculpin samples collected near the 100-K Area and chromium in sculpin samples collected near the 100-B/C Area were approximately five times higher than the median concentrations of these metals in the sculpin samples collected in 2003 upstream of the Vernita Bridge.

Strontium-90 concentrations were only measured above analytical detection limits (0.03 to 0.12 pCi/g [0.001 to 0.005 Bq/g]) in 2 of 17 (11%) sculpin samples collected and analyzed during 2004 and did not appear to be appreciably elevated near the 100-N Area where high strontium-90 concentrations were observed in Asiatic clam samples (Table 8.11.6). Technetium-99 was measured above the analytical detection limits (0.25 to 0.28 pCi/g

[0.01 to 0.11 Bq/g]) in 5 of 16 (31%) sculpin samples collected and analyzed during 2004. The median technetium-99 concentration measured in sculpin samples collected near Hanford Site facilities (0.18 pCi/g [0.007 Bq/g]) was elevated compared to the median concentration observed in samples collected from the upstream reference area in 2003 (0.08 pCi/g [0.003 Bq/g]).

8.11.4 Investigations of Radioactive Contamination in Wildlife and Wildlife-Related Materials Near Hanford Site Facilities and Operations

S. M. McKinney and R. M. Mitchell

Investigative sampling is conducted in and near operational areas to monitor the presence or movement of radioactive materials around areas of known or suspected contamination and to verify radiological conditions at specific project sites. All investigative samples are field surveyed for alpha and beta/gamma radiation and some samples are analyzed at a laboratory to identify specific radionuclides. Generally, the predominant radionuclides in investigative samples from the 100 and 200 Areas are strontium-90, cesium-137, and plutonium-239/240. Uranium-234, uranium-235, and uranium-238 are usually found in 300 Area samples.

Twenty incidents of radiologically contaminated wildlife and wildlife-related materials were investigated during 2004 and from these, three samples were submitted for laboratory analyses. The analytical results obtained from each of these can be found in PNNL-15222, APP. 2. The number of samples submitted for analysis depended on opportunity (i.e., resulting from the pest control activities), the technical merits of having isotopic analyses results, and the analytical budget, rather than prescheduled sampling at established sampling points. Of the 20 cases of contaminated wildlife or wildlife-related samples investigated, 7 were found during routine environmental surveys and 13 were found during cleanup operations. These samples included mud dauber wasp nests; rabbit, bird, and mice feces; mice; and ant hills.

When wildlife was investigated, radiological surveys were performed to determine whether an animal was contaminated. If a live animal was found to be free of contamination, it was taken to an area of suitable habitat and released. If an animal was contaminated, a decision was made based on the level of contamination, collection location, and frequency of occurrence either to collect the animal as a sample or to dispose of the animal in a burial ground. The number of contaminated animals discovered during 2004 and their levels and ranges of radioactivity were within historical levels (WHC-MR-0418). A discussion of the efforts to control undesirable or contaminated biota at Hanford during 2004 is provided in Section 8.11.5.

The number and general locations of wildlife contamination incidents investigated during 2004 are summarized in Table 8.11.8. The numbers of contamination incidents investigated in 2004 and during the previous 10 years are provided in Table 8.11.9.

Table 8.11.8. Number of Wildlife or Wildlife-Related Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 2004

Location	Number of Incidents
200-East Area tank farms	4
200-West Area tank farms	2
200-East Area burial grounds	1
200-West Area burial grounds	0
200-East Area cribs, ponds, and ditches	1
200-West Area cribs, ponds, and ditches	0
200-East Area fence lines	0
200-West Area fence lines	0
200-East Area roads and railroads	0
200-West Area road and railroads	0
200-East Area unplanned release sites	0
200-West Area unplanned release sites	0
200-East Area underground pipelines	0
200-West Area underground pipelines	0
Cross-site transfer line	1
200-East Area miscellaneous	2
200-West Area miscellaneous	2
200-North Area	0
100 Areas	5
300 Area	2
400 Area	0
600 Area	0
former 1100 Area	0
Totals	**20**

Table 8.11.9. Annual Number of Wildlife or Wildlife-Related Contamination Incidents Investigated Near Hanford Site Facilities and Operations, 1994 through 2004

Year	Number of Incidents	Year	Number of Incidents
1994	27	2000	12
1995	25	2001	10
1996	41	2002	10
1997	30	2003	26
1998	55	2004	20
1999	16		

8.11.5 Control of Pests and Contaminated Biota

A. R. Johnson, J. G. Caudill, R. C. Roos, J. M. Rodriguez, R. A. Schieffer, and R. K. Woodford

Species of animals such as the domestic pigeon (*Columbia livia*), Northern pocket gopher (*Thomomus talpoides*), house mouse (*Mus musculus*), and deer mouse (*Peromyscus maniculatus*) must be controlled when they become a nuisance, health problem, or contaminated with radioactivity. Biological control personnel responded to 20,850 animal control requests from Hanford employees in 2004. Control responses ranged from requests to remove animals within radioactive waste facilities to eradicating insect invasions of work areas. Approximately 1,900 trap and bait stations were used to control populations of animals in and near facilities and offices. Increased vegetation control appears to have resulted in fewer locations for animals to hide and live in critical areas. There were 20 contaminated animals discovered during 2004. This is approximately 57% less than the peak number of 46 in 1999 and is a 23% decrease compared to the total for 2003 (26).

Flying insects and insect-related material collected during operations on the Hanford Site are monitored for radiological contaminants. In 2003, wasps were using contaminated mud from the 105-H Basin, as it was being decommissioned and demolished, to build nests (PNNL-14687). Because demolition of the 105-H Basin in the 100-H Area was completed in 2003, monitoring of mud dauber wasps in that area was terminated. Only seven of the contaminated animal samples collected in 2004 related to insects (five inactive wasp nests and two active ant mounds) in the operations areas (100-H, 100-N, 200-East, and 300 Areas).

There were no incidents of offsite contamination by animals during 2004, and all cases of new contamination reported onsite were cleaned up or scheduled for cleanup.