Industrialization aides wildlife: the irony of two D.O.E sites, the Hanford Reservation and Pantex Plant

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Abstract

The U.S. Department of Energy's Hanford site was established in southeastern Washington during the 1940s to produce plutonium during World War II. The Pantex Plant in the Texas Panhandle was originally used by the U.S. Army for loading conventional ammunition shells and bombs, but was rehabilitated and enhanced in the 1950s to assemble nuclear weapons using the plutonium produced at Hanford. Environmental monitoring has been ongoing at both locations for several decades to detect and assess potential impacts of facility operations on air, surface and ground waters; foodstuffs, wildlife, fish, soils, and vegetation; and to determine population status of key species.

Ironically, by virtue of its size (1,450 km^2 [560 mi^2]), restricted public access, and conservative use of undeveloped land, the Hanford Site has provided a sanctuary for plant and animal populations that have been eliminated, or greatly reduced from, surrounding agricultural and range lands. Preliminary evaluations suggest that this is also true at the Pantex Plant, parts of which are still farmed and grazed. Analytical results support population studies showing little, if any impacts to the environment.

Currently, measured concentrations of airborne radionuclides around the perimeters of both sites are below applicable guidelines. Concentrations of radionuclides and nonradiological water quality in the Columbia River at Hanford are in compliance with existing standards. Radiological and non-radiological water quality in the Ogallala Aquifer beneath the Pantex Plant is also in compliance with applicable standards. Foodstuffs irrigated with river water downstream from the Hanford Site show levels of radionuclides that are similar to those found in foodstuffs from control areas. The low levels of ^{137}Cs and ^{90}Sr in a few onsite Hanford wildlife samples, and concentrations of radionuclides in soils and vegetation from onsite and offsite at both locations are typical of those attributable to naturally occurring radioactivity and to worldwide fallout.

The Hanford Reach of the Columbia River and its islands, and the Pantex Plant with its playas, both serve as refuges for raptorial birds and migratory waterfowl. In addition, the Hanford Reach serves as a migration route for several species of salmon. Chinook salmon and steelhead trout spawn there. Bald eagles congregate along the Hanford Reach in the fall and winter to feed on the spawned-out carcasses of salmon and on wintering waterfowl. Other raptorial birds, coyotes, mule deer, and many other species abound. An elk population founded in the early 1970s now exceeds 600 animals. The low radiological doses and stable or growing populations of key biotic species are remaining consistent. This suggests beneficial effects from Hanford's 50 years of protection from public intrusion, and demonstrates the value of long-term population studies.

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INTRODUCTION

The U.S. Department of Energy (DOE) Hanford Site occupies a land area of about 1,450 km^2 in semiarid southeastern Washington (Figure 1). The Columbia River (Hanford Reach) flows through the Site and forms part of its eastern boundary. The Reach (about 82 km) is the last unimpounded stretch of the Columbia River in the United States, except for the portion between Bonneville Dam and the river's mouth. Because public access to the Hanford Site has been restricted and the Site has been free from agriculture for over 50 years, it has conserved the habitats of, and now serves as a refuge for, various plants and animals.

Nuclear and non-nuclear industrial and research activities have been conducted at Hanford since 1943. The most significant activities environmentally, involved the production of nuclear materials and the chemical processing and waste management associated with the major product, plutonium. By-products included gamma, beta, and alpha-emitting radionuclides and various non-radioactive chemicals in gaseous, liquid, and solid forms. Buildings are confined to a few widely spaced clusters along the Columbia River and near the Site's interior. Road, railroads, and electrical transmission lines that together occupy about six percent of the land area connect these clusters. The current mission of the Hanford Site is environmental restoration.

The DOE Pantex Plant occupies a land area of about 65 km^2 in the middle of the Texas Panhandle (Figure 1). This includes about 24 km^2 that are leased from Texas Tech University for use as a safety and security zone. The topography is relatively flat, characterized by rolling grassy plains and numerous natural playas (ephemeral lakes). There are over 17,000 playas on the Texas High Plains, most less than 1 km in diameter, that receive water runoff from the surrounding area. The region is semiarid and the Plant is surrounded by agricultural and range lands.

The Pantex Plant was used during World War II (1942-1945) by the U.S. Army to load conventional ammunition shells and bombs. In 1951, the Atomic Energy Commission began rehabilitating portions of the original Plant and constructing new facilities for nuclear weapons operations. The primary mission of the Pantex Plant is currently the disassembly of nuclear weapons. Pantex is also responsible for assembly of nuclear weapons; surveillance, storage, maintenance, modification, repairs and non-explosive testing of nuclear weapons components; and the manufacturer of chemical explosive components. Current operations involve short-term handling (but not processing) of encapsulated uranium, plutonium, and tritium, as well as a variety of industrial chemicals. Environmental restoration and waste management activities are also part of the Plant's mission.

Environmental monitoring has been conducted for over 50 years at Hanford (Gray 1993), and for over 25 years at Pantex (Gray and McGrath 1995) to assess potential impacts to individuals and populations that may have been exposed to radionuclides, ionizing radiation, and hazardous chemicals. Environmental media sampled have included air, surface and ground waters, foodstuffs (fruits, vegetables, milk, etc.), fish, wildlife, soils, and vegetation. The population status of key fish and wildlife species is also determined at Hanford and similar efforts are being initiated at Pantex Plant.

RADIOLOGICAL MONITORING

Air.

At Hanford, air is sampled continuously for airborne particulates and analyzed for radionuclides at 40 onsite and offsite locations, including 11 in nearby and distant communities (Dirkes and Hanf 1997). Nine of the stations are operated by local teachers as part of the Community-Operated Environmental Surveillance Program (Hanf et al. 1997). At selected locations, gases and vapors are also collected and analyzed. The potential radiation dose from various point source emissions to air on the maximally exposed individual (a hypothetical person who receives the worst-case dose) was 0.01 mrem/yr (effective dose equivalent) in 1996 (Dirkes and Hanf 1997). This is well below both the DOE radiation limit of 100 mrem/yr to the public and the 10 mrem limit for the air pathway specified by the Clean Air Act.

At Pantex, air is sampled continuously for airborne particulates and gaseous tritium at 27 onsite and offsite locations (DOE 1997). Seventeen of the stations were established around the Plant perimeter during 1994 and 1995 (DOE 1996). Samples are analyzed for radionuclides (^{3}H, $^{234,238}U$, $^{239/240}Pu$). The potential radiation dose to the maximally exposed individual was 0.000088 mrem in 1996 (DOE 1997), well below the average Texas Panhandle external background dose (93 mrem/yr), the DOE radiation limit of 100 mrem/yr to the public, and 10 mrem/yr limit for the air pathway specified by the Clean Air Act.

Surface Water

Columbia River water is used for drinking at cities downstream of Hanford, and for crop irrigation and recreational activities (fishing, hunting, boating, waterskiing, and swimming). Thus, it constitutes a potential environmental pathway to people for radioactivity in liquid effluents. Although radionuclides occur in small but measurable quantities in the Columbia River, concentration are below Washington State and U.S. Environmental Protection Agency (EPA) drinking water standards (Dirkes and Hanf 1997).

The Pantex Plant does not include or border any rivers or streams. However, storm-water runoff from the Plant and lands leased from Texas Tech University flows through ditches to onsite playas and offsite. Thus, playas are ideal surface locations for assessing Plant release. Radionuclide concentrations in 1996 were less than DOE's Derived Concentration Guide (DCG) for ingested water and the levels established in the Safe Drinking Water Act (SDWA). Gross alpha/beta levels observed in 1996 were comparable to historical and offsite control levels (DOE 1997).

Ground Water

At Hanford, ground water, primarily from an unconfined aquifer, is sampled from about 800 wells and analyzed (Dirkes and Hanf 1997). Tritium (^{3}H), which occurs at relatively high levels in the unconfined aquifer, is one of the most mobile radionuclides, and thus its distribution reflects the extent of ground-water contamination from onsite operations. Ground water from the unconfined aquifer enters the Columbia River through subsurface flow and springs that emanate from the riverbank (McCormack and Carlile 1984). Tritium concentrations in wells near the springs ranged from 19,000 to 250,000 pCi/L and averaged 176,000 pCi/L in 1985 (Price 1986). Although the concentrations of ^{3}H and other radionuclides in springs generally reflected those in nearby ground-water wells, they were lower in springs due to the mixing of ground and surface water. Tritium concentrations in the river were generally less than those in springs and were less than half of the regulatory limit for drinking water (20,000 pCi/L) (EPA 1976). From 1983 through 1989, annual average ^{3}H concentrations in the river (<20,000 pCi/L) were at least a factor of 100 below the drinking water limit (Dirkes 1990). Other radiological constituents found above detection limits in the river have been ^{129}I, $^{239/240}Pu$, ^{90} Sr, ^{99}TC, ^{234,} ^{238}U, and ^{235}U (Dirkes 1990; Jaquish and Bryce 1990).

At Pantex, ground water is sampled from 67 wells (63 onsite, 4 offsite). Eighteen wells are in the Ogallala aquifer, and 49 are in perched ground water (DOE 1997). Eighteen onsite drinking water taps were also sampled in 1996. One offsite location each was sampled for ground water and drinking water as a control. Although naturally occurring radionuclides were present in the Ogallala aquifer in 1996, concentrations were less than the DOE DCG and the levels established in the SDWA. There was no indication of contamination from Pantex activities in the Ogallala water supply wells or a well field operated by the City of Amarillo northeast of the Plant.

Foodstuffs

Samples of alfalfa and several foodstuffs, including milk, vegetables, fruit, beef, chickens, eggs, and wheat, are routinely collected from several locations, primarily downwind (south and east) of the Hanford Site (Jaquish and Bryce 1980; Price 1986; Gray 1993; Dirkes et al. 1994; Dirkes and Hanf 1995, 1997). Samples are also collected from upwind and somewhat distant locations to obtain information on background radiation levels and those attributable to worldwide fallout. Foodstuffs from the Riverview Area (across the river and southeast) are irrigated with Columbia River water withdrawn downstream of the Site. Although low levels of ^{137}Cs, ^{3}H, ^{129}I and ^{90}Sr, have been found in some foodstuffs, concentrations in samples collected near Hanford are similar to those in samples collected away from the Site. Concentrations in samples collected upwind are similar to those in samples collected downwind of the Site. Although human foodstuffs have not been routinely sampled at Pantex, analysis of winter wheat and grain sorghum that are eaten by cattle showed radionuclide concentrations similar to those expected to occur naturally (DOE 1996, 1997).

Fish and Wildlife

Fish are collected at various locations along the Columbia River, and boneless fillets are analyzed for ^{60}Co, ^{137}Cs and ^{90}Sr. Carcasses are analyzed to estimate ^{90}Sr in bone. Short-lived radionuclides, including the biologically important ^{32}P and ^{65}Zn, have essentially disappeared from the river (Cushing et al. 1981) through radioactive decay. Radionuclide concentrations in fish collected from the Hanford Reach of the Columbia River are similar to those in fish from upstream locations (Dirkes et al. 1994; Dirkes and Hanf 1995, 1997).

Historically, deer (*Odocoileus* sp.), ring-necked pheasant (*Phasianus colchicus*), mallard ducks (*Anas platyrhynchos*), Nuttal cottontail rabbits (*Sylvilagus nuttallii*), and black-tailed jack rabbits (*Lepus californicus*) have been collected at Hanford and tissues analyzed for ^{60}Co and ^{137}Cs (muscle), $^{239/240}Pu$ (liver), and ^{90}Sr (bone). The doses that could be received by consuming wildlife at the maximum radionuclide concentrations measured in 1985 through 1994 were below applicable DOE standards (Price 1986; Jaquish and Bryce 1990; Woodruff et al. 1991, 1992; Dirkes et al. 1994; Dirkes and Hanf 1995). Routine wildlife sampling of prairie dogs (*Cynomys ludivicianus*) was initiated at Pantex in 1995 (DOE 1996). Radionuclide concentrations in prairie dogs are similar to or less than those in other environmental media (DOE 1997).

Soils and Vegetation

At Hanford, samples of surface soil and rangeland vegetation, such as sagebrush (*Artemesia sp.*) have been historically collected at onsite and offsite locations. Sampling and analyses from 1985 through 1994 showed no radionuclide buildup offsite that could be attributed to Hanford operations (Price 1986; Jaquish and Bryce 1990; Woodruff et al. 1991, 1992; Dirkes et al. 1994; Dirkes and Hanf 1995).

At Pantex, samples of surface soil were collected at 50 onsite and 22 offsite locations during 1996. Plutonium, uranium, and tritium levels were comparable to historical levels (Honea and Gabocey 1991) and to those at control sites (DOE 1997). Vegetation samples (native, exotic, and domestic grasses) were collected from 5 onsite and 18 offsite locations during 1996. No indication of radionuclide contamination from Pantex Plant was found.

Overall Radiological Impact from Hanford and Pantex Operations

The maximally exposed individual is a hypothetical person who would receive the maximum calculated radioactive dose when worst-case assumptions are used concerning location, inhalation of radioactive emissions, consumption of contaminated food and water, and direct exposure to contaminants. Expressed as effective dose equivalents, the calculated dose received by a maximally exposed individual at Hanford was 0.01 to 0.1 mrem annually from 1985 through 1996. The average per capita effective dose for 1985 through 1996 based on the human population of 330,000 to 380,000 people living within 80 km of the Site, was <0.001 to 0.05 mrem annually (Price 1986; Jaquish and Bryce 1990; Woodruff et al. 1991, 1992; Dirkes et al. 1994; Dirkes and Hanf 1995, 1996, 1997). The calculated dose received by a maximally exposed individual at Pantex Plan was £0.000088 mrem from 1993 through 1996 (DOE 1994, 1995, 1996, 1997). These estimates and the measured background radiation at Hanford and Pantex Plant can be compared to other routinely encountered radiation sources, such as natural terrestrial and cosmic radiation, medical treatments including x-rays, natural internal body radioactivity, worldwide fallout, and radiation from consumer products (Figure 2). Radiation doses to the public from the Hanford Site and Pantex Plant have been consistently below applicable standards and substantially less than doses from other routinely encountered sources of radiation not associated with either facility.

CHEMICAL MONITORING

Air

At one time, nitrogen oxides (NO_x) were released at Hanford from fossil-fueled steam and chemical processing facilities, most notably the Plutonium Uranium Extraction (PUREX) Plant. Nitrogen dioxide samples were collected until the PUREX Plant ceased operations in 1990. Nitrogen dioxide concentrations measured from 1984 through 1990 were well below federal and state ambient air quality standards (Woodruff et al. 1992; DOE 1997).

The Pantex Plant is not a major source of air emissions. Although only limited (1 station) non-radiological air monitoring is required, 3 non-radiological air monitoring stations were actually constructed in 1995, and became part of the Plant's routine monitoring program in 1996 (DOE 1997). Additionally, the Texas Natural Resource Conservation Commission (TNRCC) has monitored for volatile organic compounds (VOC), particulates and fluorides at 5 onsite and 1 offsite locations over the last several years. No significant contaminant levels have been reported.

Surface Water

Non-radioactive wastewater from the Hanford Site is discharged at several locations along the Columbia River. Discharges consist of backwash from water intake screens, cooling water, water storage tank overflow, a building drain, and fish-laboratory wastewater. Effluents from each outfall are monitored under a National Pollutant Discharge Elimination System (NPDES) permit. The Columbia River is also monitored by the U.S. Geological Survey (USGS) upstream and downstream of the Site, to verify compliance with Washington State water-quality requirements.

Columbia River water has also been sampled in transects both upstream and downstream of the Site (Dirkes et al. 1993). The samples were analyzed for VOCs, metals, and anions based on their known presence in ground water near the river and studies documenting their entry into the river. Although VOCs were not routinely detected, several metals and some anions were detected at levels comparable to those reported by the USGS as part of their national water quality-monitoring program (McGavok et al. 1988). There were not measurable differences between upstream and downstream concentrations of metals and anions in river water.

Becker and Gray (1992) evaluated several water quality variables in the Columbia River, upstream and downstream of Hanford reactors, for the periods 1951 to 1953 and 1986 to 1988. Five reactors were operational during the 1951 to 1953 period, and all were shut down during the 1986 to 1988 period. Despite the operational differences, ammonia nitrogen, pH, and coliform bacteria in river water did not differ significantly between the two periods. Phosphate in the Hanford Reach had decreased significantly over the 33-year interval, while biochemical oxygen demand, dissolved oxygen, and nitrate nitrogen had increased. These changes, while detectable statistically, were relatively small and not related to present-day activities at the Site. Today, the quality of water in the Hanford Reach remains well within Washington State standards for Class A waters (WSDOE 1977). Occasional low pH values, which appear to originate upriver, violate these standards.

At Pantex, selected onsite and offsite surface water locations are sampled, and the samples are analyzed for VOCs, semi-volatile organics, explosives, herbicides, pesticides, polychlorinated biphenyls, metals, nutrients, and other components reflecting water quality (DOE 1996, 1997). Results are compared to TNRCC water quality Maximum Contaminant Levels (MCLs) or water quality limits. When no MCL is available, results are compared to values previously observed at Pantex Plant, which serve as a baseline. Comparisons to these historic values are primarily for metals, explosives, and inorganic constituents. None of the historic values have ever been a source of concern. Co-sampling by the TNRCC confirms these conclusions. In addition, Pantex Plant has been issued a wastewater permit from the TNRCC and a NPDES permit from EPA that requires monitoring of effluents and outfalls. Other than occasional pH excursions due to biological activities, exceedances resulting from naturally occurring metals in soils, Pantex Plant has been in compliance with requirements (i.e. permit requirements were met 98.8% of the time in 1996 [DOE 1997]).

Ground Water

At both the Hanford Site and Pantex Plant, samples are collected from ground-water wells and analyzed for chemical constituents. In addition, onsite drinking water sources are sampled and analyzed for water quality. At Hanford, detected constituents include several metals, anions, coliform bacteria, and total organic carbon. Many of these constituents are common in natural ground water. However, several hazardous chemicals have been identified in Hanford ground water at concentrations greater than either existing of proposed federal drinking water standards (Dirkes et al. 1994; Dirkes and Hanf 1995, 1996, 1997). These include nitrate, chromium, cyanide, fluoride, carbon tetrachloride, trichloroethylene, and tetrachloroethylene. Wells containing these constituents mainly occur near operating areas and are not used for drinking water.

With few exceptions, chemical constituents in onsite drinking water wells at Pantex Plant are well below the MCLs, and there is no evidence of contamination by explosives, organic compounds, or metals in the Pantex water supply wells or in the nearby well field operated by the City of Amarillo. The MCL for iron was exceeded at two wells and these high values may reflect corrosion of casing material. Water from wells constructed with polyvinyl chloride did not exceed the MCL. Chromium was detected in drinking water samples from the Pantex Plant and in some control samples, but at levels below the MCL. The occurrence of chromium may reflect corrosion in pumps and piping (DOE 1994).

Several contaminants, for example, chromium, nickel, trichloroethylene, dichloroethane, benzene, explosives and explosive degradation products have been found in the perched aquifer beneath the Plant (DOE 1996, 1997). A Resource Conservation and Recovery Act Facility Investigation has determined the extent of contamination, and remediation has been initiated.

BIOLOGICAL MONITORING

Restricted land use at Hanford has favored native wildlife that frequent riverine habitats, for example, mule deer (*Odocoileus hemionus*), Canada geese (*Branta canadensis*), and great blue heron (*Ardea herodias*). The Site also serves as a refuge for other migratory waterfowl, elk (*Cervus elaphus*), coyote (*Canis Latrans*), and a variety of other plants and animals (Gray and Rickard 1989; Fitzner and Gray 1991). The Columbia River at Hanford supports up to 48 species of fish (Gray and Dauble 1977) and serves as a migration route for upriver runs of Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and sockeye salmon *(O. nerka*) and steelhead trout (*O. mykiss*). Steelhead trout spawn in the Hanford Reach (Gray and Richard 1991; Watson 1993) and the Reach supports the last remaining mainstream spawning habitat for fall Chinook salmon. Based on redd (nest) counts from the air, fall Chinook salmon spawning in the Hanford Reach of the mainstream Columbia River increased dramatically from 1980 through 1989 (Figure 3a). The increase in salmon spawning attracted increasing numbers of wintering bald eagles (*Haliaeetus leucocephalus*), and the eagle population now fluctuates with the salmon population (Figure 3b). The marked decrease in salmon redds observed in the 1990s is of considerable interest because of the need to preserve declining runs of salmon in the Columbia River watershed.

The sparsely vegetated islands in the Columbia River have historically been used as nesting habitat by Canadian geese (Fitzner et al. 1994). From the mid-1950s to the mid-1970s, the number of goose nests declined from over 300 to about 100 annually (Figure 3c). From the late 1970s to the early 1990s, the number of nests gradually increased to over 300 and now fluctuates at about 200-250. Initially, closure of the Hanford Reach was beneficial to the geese by providing freedom from human intrusion. However, the coyote also benefited and is believed to have caused the decline in numbers of goose nests into the mid-1970s.

When monitoring began, there were no nesting great blue heron on the Hanford Site. However, there are now four active colonies consisting of 35-40 or more birds each, and herons are present year-round (Gray and Rickard 1989). Their major food source is Columbia River fish.

Elk first arrived on the Hanford Site in 1972 (Rickard et al. 1977). From a small founding population, herd size grew (Figure 3d) to about 120 animals in 1990 (Woodruff et al. 1991) and now exceeds 550 (Dirkes and Hanf 1997). The rapid increase in elk is attributed to the lack of predation or human disturbance during calving, absence of onsite hunting, and the lack of competition from sheep and cattle for available forage. The mule deer population at Hanford is estimated at several hundred animals and appears stable even in the absence of onsite hunting. Coyote predation on fawns is believed to be an important factor that maintains the stable deer population.

The Southern High Plains in which Pantex Plant lies includes short-grass prairie and farmland, and offers only slight relief expressed as playa basins. In this semiarid region, the playas are typically ephemeral, yet highly productive. Most of Pantex Plant's non-industrial areas are under cultivation or used for grazing by Texas Tech University or their leasing farmers. Population monitoring and biological studies are now being planned for implementation at the Pantex Plant. To date, some characterization efforts have been completed and several species lists have been developed (Rylander 1994; Seyffert 1994; Blair 1995; Johnson 1995).

Agricultural and industrial activities have reduced biological diversity across most of the Southern High Plains and the playa areas at Pantex have been intensively grazed in the past. The only remaining areas of native habitat at the Plant are small and primarily centered on the playas, as an aquatic habitat (Playa 1, Figure 1), and as wetlands and short-grass prairie upland in and around all playas. Plant operations in several industrial areas, such as the Burning Ground and firing sites, have precluded agricultural activities, and therefore have provided additional protection for native habitat.

During field surveys at Pantex Plant in May, July, and September 1993, and June, July, and September 1995; 262 floral species were identified (Johnston and Williams 1993; Johnston 1995). Because the surveys focused on natural areas of the Plant, playas were strongly represented. Many of the species found were non-native, weedy species, and only a few individuals were represented as native species.

Although no federal or state endangered species were found, several species of barrel cactus were noted, a variety of which is protected. The green-flowered barrel cactus *Echinocereus viridiflorus* var. *viridiflorus* is the rarest species at Pantex Plant, represented by a single population at Playa 1. Another barrel cactus, the more common cerise-flowered *Coryphantha vivipara*, grows on the slopes and short-grass prairie uplands at the playas, the Burning Ground, and the firing sites.

Several animal surveys were initiated in 1993 and 1994. A general survey (Rylander, 1994) lists a total of 65 species, including protistans, invertebrates, amphibians, reptiles, birds, and mammals. Field surveys (Mazeroll et al. 1994) to identify amphibians and reptiles showed few amphibian species due in part to the lack of precipitation during the summer of 1994. One Texas horned lizard (*Phrynosoma cornutum*), a state-listed threatened species, was encountered.

Seyffert (1994) compiled a bird checklist for Pantex Plant that indicates expected abundances during various seasons of the year, based on habitat types and knowledge of bird migrations through the local area. The largest concentrations of waterfowl occur at Playa 1. Hundreds of mallard ducks and widgeons (*A. americana*) and lesser numbers of Canada geese winter on the water and in the cattail cover. Playa 1 is used seasonally by many other species, the most notable being the bald eagle, red-tailed hawk (*Buteo jamaciensis*), northern harrier (*Circus cyaneus*), white-faced ibis (*Plegadis chihi*), black-drowned night heron (*Nycticorax nycticorax*), yellow-crowned night heron (*Nyctanassa violacea*), eared grebe (*Podiceps nigricollis*), canvasback duck (*Aythya valisineria*), and Wilson's phalarope (*Phalaropus tricolor*).

Depending on precipitation and quality of habitat, different playas provide different habitat to various species. Playas 2, 3, and 4 and Pantex Lake support greater numbers of small rodent species than Playa 1, which contained permanent water during the survey period. Birds of prey are also common in playas that contain water only seasonally. Although white-faced ibises are occasionally seen at Playa 1, they are most common during spring and fall migrations at Playas 2 and 4. Black terns (*Chlodonias niger*) have only been seen at Playa 4.

The short-grass prairie uplands surrounding Playas 2, 3, 4, and 5 support prairie dogs (*Cynomys ludovicianus*) and form part of the wintering habitat for bald eagle, golden eagle (*Aquila chrysaetos*), ferruginous hawk (*Buteo regalia*), and rough-legged hawk (*B. lagopus*). In summer, prairie dog towns provide nesting sites for burrowing owls (*Athene cunicularia*). Swift foxes (*Vulpes velox*) are known to den near prairie dog towns, although none have been seen at Pantex Plant since 1970. Migrating mountain plovers (*Charadrius montanus*) and other grassland birds also use prairie dog towns as seasonal habitats. A few Texas horned lizards are also found in short-grass prairie uplands surrounding the playas and at the firing site north of Zone 4.

SUMMARY

Monitoring for radiological emissions at the Hanford Site and Pantex Plant has been ongoing for several decades and includes air, surface and ground waters, foodstuffs, fish, wildlife, soils, and vegetation. Measured and calculated radiation doses to the public have consistently been below applicable regulatory limits. At the Hanford Site, monitoring of fish and wildlife populations is also a significant component of the program. The Hanford Site now serves as a refuge for various plant and animal species.

The low radiological doses and stable or growing populations of key biotic species are remaining consistent. This suggests beneficial effects from Hanford's 50+ years of protection from public intrusion, and show that under certain conditions, industrialization may aide wildlife management. Similar studies now being implemented will determine if this phenomenon also occurs at the Pantex Plant.

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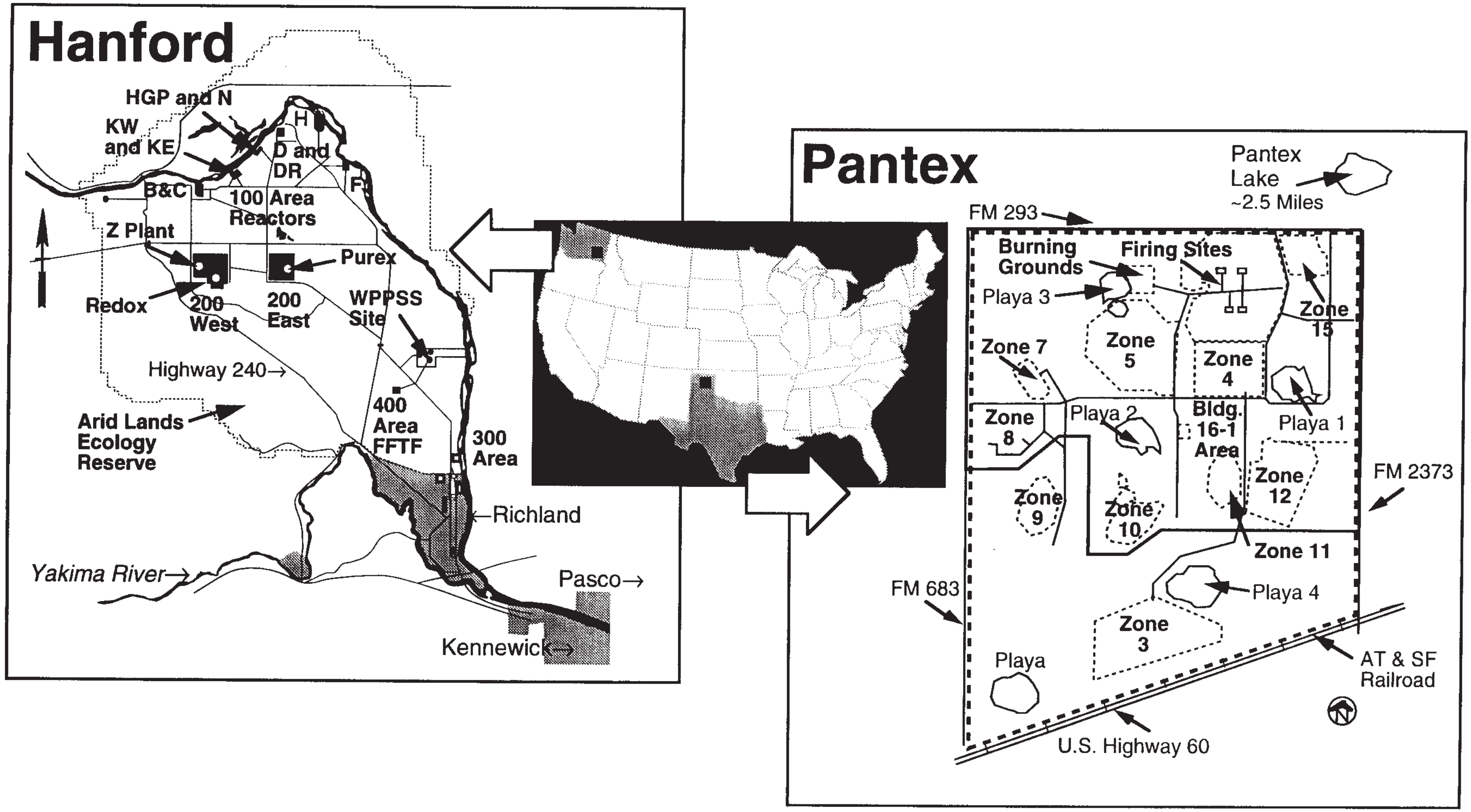

Figure 1 - U.S. Department of Energy's Hanford Site in Southeastern Washington State and Pantex Plant in the Texas Panhandle.

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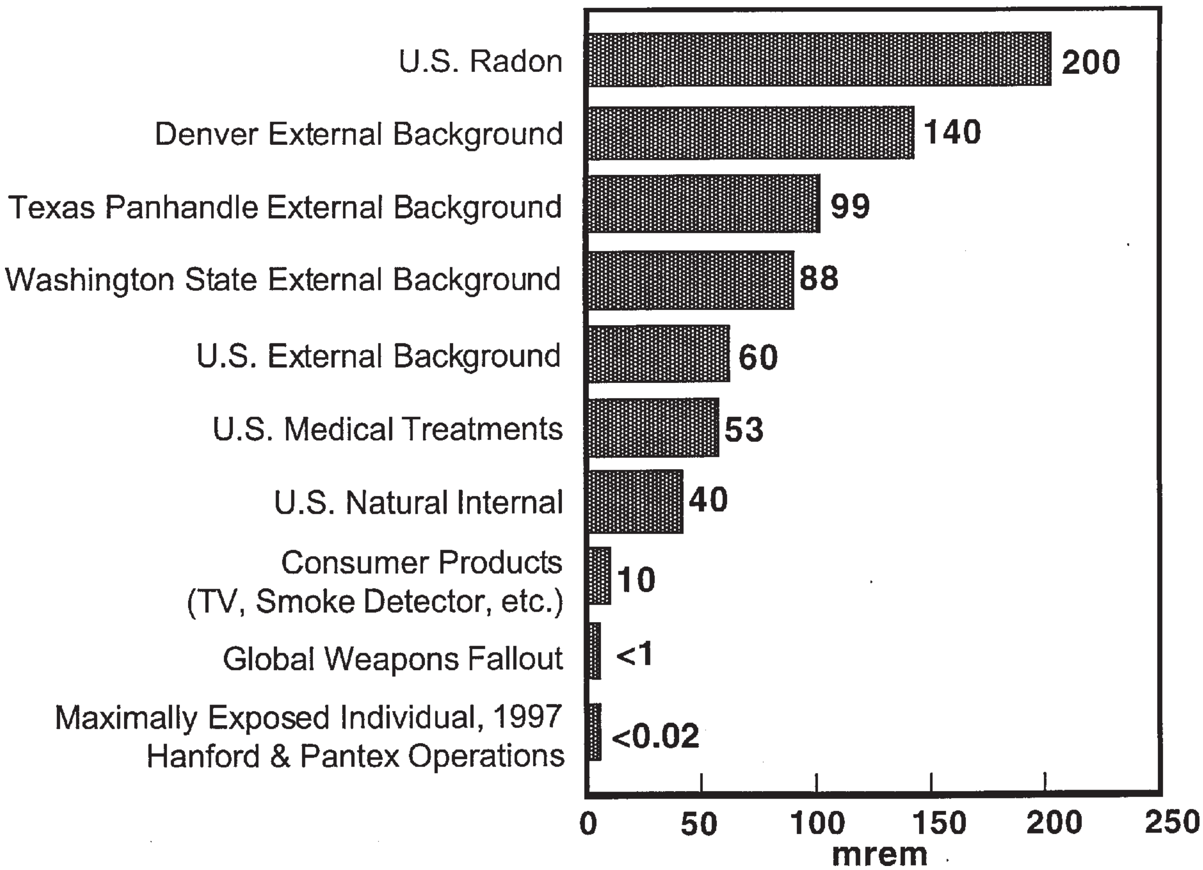

Figure 2 - Average annual radiation doses (per capita) from various sources: U.S. average radon, external background, medical and internal doses, consumer product radiation and weapons fallout (NCRP 1987a); external background, Denver, Colorado (NCRP 1987b); Washington State (Oakley 1972); Texas Panhandle (DOE 1995); mrem/yr = millirem per year.

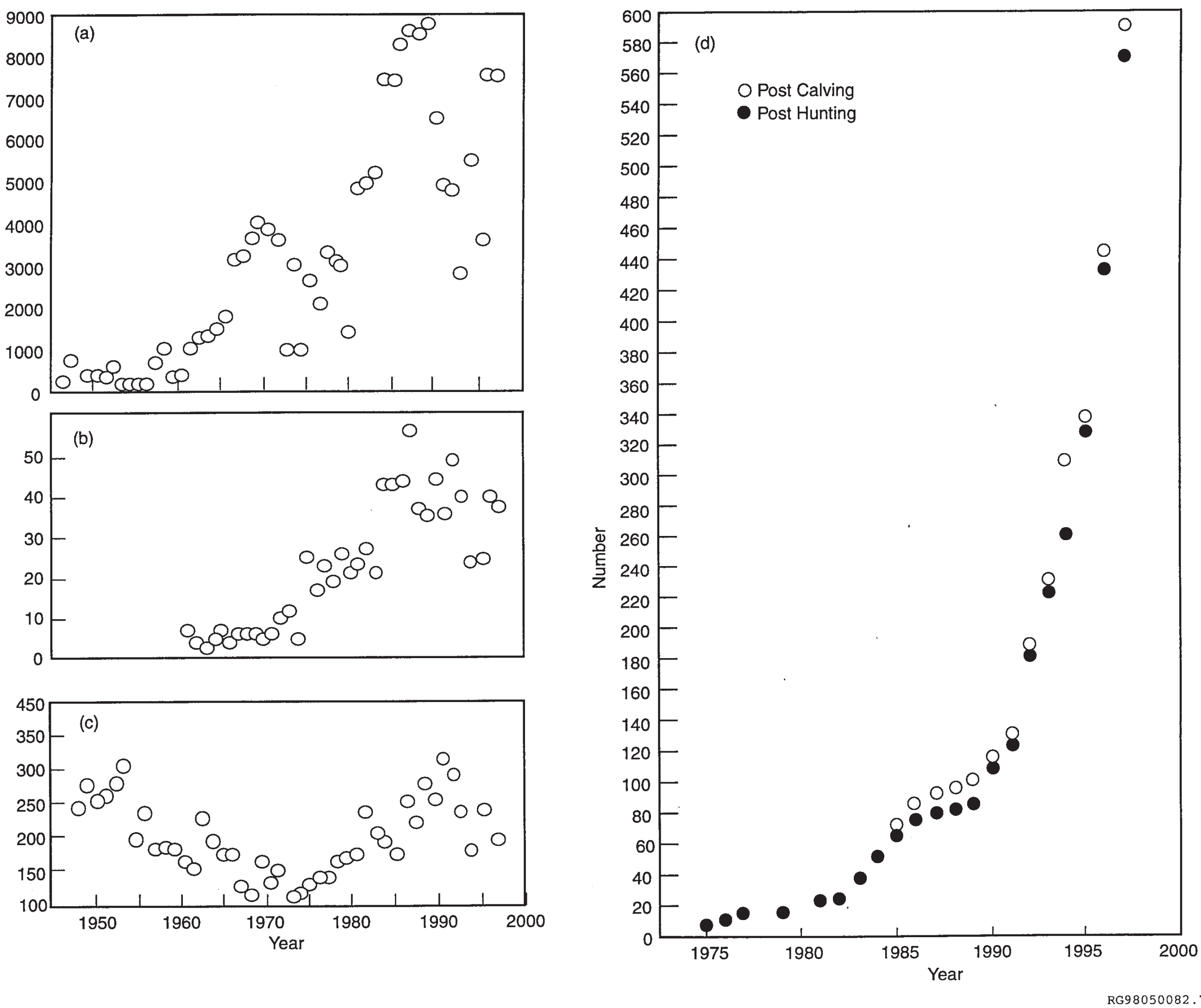

Figure 3 - Number of (a) chinook salmon redds (nests), (b) wintering bald eagles, (c) Canada goose nests, and (d) elk at Hanford. Special permit hunting for elk began in 1986 (Gray and Rickard 1989; Woodruff et al. 1991, 1992; Dirkes and Hanf 1994).