An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site

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March 1991

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SUMMARY

West Lake and its immediate surrounding basin represent a unique habitat that is dominated by highly saline water and soil. The basin offers a valuable research site for studies of a rare and complex wetland area in the desert. This report is an evaluation of the chemical, radiological, and ecological conditions at West Lake and describes how ground water influences site properties. The scope of this evaluation consisted of a sampling program in 1989 and a review of data from the perspective of assessing the impact of Hanford Site operations on the physical, chemical, and ecological conditions of West Lake and its surrounding basin.

The water level in West Lake fluctuates in relation to changes in the water table. These changes are influenced by aquifer recharge from past and present discharges of water to the ground in the 200 Areas. The connection between West Lake and ground water is also supported by the presence of ^3H and ^{99}Tc in the ground water and in the lake.

There are relatively high concentrations of uranium in West Lake; the highest concentrations are found in the northernmost isolated pool. Analyses of water, sediment, vegetation, and soil indicate possible shifts of isotopic ratios that indicate a reduction of ^{235}U . Uranium-236 was not detected in West Lake water; its presence would indicate neutron-activated ^{235}U from fuel reprocessing at Hanford.

Trace metals are found at elevated concentrations in West Lake. Arsenic, chromium, copper, and zinc were found at levels in excess of U.S. Environmental Protection Agency water quality criteria. It is not known if the presence of trace metals is normal for this highly saline lake or if past human sources contributed to the current level of metals in the lake. There was no indication of contamination by organic compounds, herbicides, or pesticides in West Lake water.

Levels of radiological and chemical contamination in the West Lake basin are relatively low. Concentrations of fission isotopes exceed those that could be explained by atmospheric fallout, but fall short of action levels for active waste management areas.

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INTRODUCTION

West Lake is a highly saline and alkaline pond in a depression in the terrain southwest of Gable Mountain on the Hanford Site (Figure 1). Currently, West Lake consists of the main pond and three separate, smaller pools located to the immediate north (see Figure 1). The white areas along the shoreline consist of accumulated salt deposits. In the foreground lie the three smaller pools. Depending on water level, these smaller pools may have been connected; however, the growth of three-spined bulrush, *Scirpus americana*, the topography, and the filling in of sediment in these areas have apparently isolated the pools.

Aerial photographs taken between 1964 and 1989 give some indication of the water-level fluctuations and sedimentation that have occurred over the years (Figure 2). As recorded by aerial photography, the extensive exposed areas of white salt and alkali deposits show the pond at its lower level in 1979. In contrast, water levels in 1964 appear to represent a high-water mark for West Lake.

Historically, West Lake was an intermittent natural pond that appeared in response to a rise in the water-table elevation as a result of seasonal fluctuations (Strait and Moore 1982). Jenkins (1922) referred to West Lake as a spring, reported to have been flowing when the Columbia River was high and to have been dry when the Columbia River was low. It is not clear at the present time if West Lake (a.k.a. West Pond, Honey Hill Pond) was present in 1945 when operations began in the 200 Areas. Records for 1945-1946 indicate that a "Spring 13" was sampled just north of "Honey Hill" for environmental monitoring purposes, but descriptions of the location of Spring 13 are unclear. Moreover, the location of Honey Hill has not been confirmed, except that it was described as being near Highway 4N at Mile Post 3. The term Honey Hill apparently refers to the location of a disposal site for sanitary sewage sludge from early Hanford construction camps. Documentation of the sludge disposal practice has not been located to date. Sampling at Spring 13 began in June 1945 and ended in July 1946. It is possible that Spring 13 was an incipient West Lake prior to the disposal of large quantities of water

FIGURE 2 Aerial Photographs of West Lake Taken in 1964 1975 1979, and 1989

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FIGURE 2 (contd)

FIGURE 1. West Lake and Associated Pools (looking south), August 1989

upgradient in the 200 Areas beginning in 1945. The influence of ground-water mounding in the 200 Areas at that time may have resulted in an increase in the elevation of the water table in the West Lake basin.

The surface of West Lake is continuous with the water-table surface (ERDA 1975). In 1957, waste water disposal to the then newly developed Gable Mountain Pond caused the water table to rise in the West Lake basin, and West Lake became a permanent pond soon after (Gephart et al. 1976; Strait and Moore 1982). Strait and Moore (1982) reported that water from West Lake was ^{14}C dated as modern (i.e., younger than 1950).

The pond has at times been designated a radiation control area because of relatively high levels of natural uranium. The extent of radiological and chemical contamination has been the subject of several earlier investigations (Gephart et al. 1976; Emery and McShane 1978; Riley et al. 1986). The purpose of this report is to evaluate past studies of the lake, the relationship of the lake to historical changes in the water table and ground-water chemistry, and the extent of past and current levels of contamination. Sampling was conducted in the West Lake basin, its underlying aquifers, and West Lake proper in August 1989. The objective was to further characterize the basin and expand the existing data to further define the degree that Hanford Site activities have affected the lake.

This report consists of a review of the hydrogeology of the West Lake basin, including an evaluation of past radiological studies of ground and surface water; an ecological profile of the lake and associated terrestrial habitat; a description of the current sampling program; and the sampling results. Appendixes A, B, and C contain the data tables and profiles of the chemical constituents found in West Lake.

This investigation was conducted by the Pacific Northwest Laboratory^(a) (PNL) Surface Environmental Surveillance Project for the Hanford Site.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

HYDROGEOLOGY

The unconfined aquifer near West Lake lies entirely within coarse-grained deposits of the Hanford formation and is approximately 15 m thick (Graham et al. 1984). Extensive erosion caused by late-Pleistocene catastrophic flooding occurred in the vicinity of West Lake, removing the Elephant Mountain Member and the Rattlesnake Ridge interbed. This historic event exposed the underlying basalt to the unconfined aquifer (Strait and Moore 1982; Graham et al. 1984). The Rattlesnake Ridge interbed of the uppermost confined aquifer (Rattlesnake Ridge aquifer) lies just to the south of West Lake (Graham et al. 1984). The most productive and permeable confined aquifer beneath West Lake is the Mabton interbed, whose surface is approximately 67 m below ground surface (Gephart et al. 1976).

Discharges of large amounts of waste water to Gable Mountain Pond and other surface impoundments and subsurface structures (i.e., cribs) were associated with the startup of the plutonium-uranium (PUREX) plant in the 200 East Area in 1957. These discharges are believed to have caused the rise of the water table and the creation of West Lake as it is now known (Emery and McShane 1978). This theory is supported by a comparison of lake photographs for 1964, 1975 (low-level year), 1979, and 1989 (see Figure 2) with water-level data collected from wells in the vicinity of West Lake and Gable Mountain Pond (Figure 3). The hydrographs in Figure 3 indicate that the water table rose approximately 3 m between 1957 and 1969, then declined approximately 1 m between 1969 and 1983. The water table began rising again after 1983 and is currently about a meter below its 1969 level.

Gephart et al. (1976) report that the hydraulic gradient of the unconfined aquifer near West Lake sloped gently to the east before waste water was disposed to Gable Mountain and B Ponds. The Hanford hindcast water-table map for 1944 in the area just south of Gable Mountain also indicates an easterly direction of ground-water flow (ERDA 1975). Ground-water flow in this area has since been directed northward through the gap between Gable Butte and

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FIGURE 3. Ground-Water Level Fluctuations in Selected Wells Near West Lake, 1949 Through 1989

Gable Mountain (Gephart et al. 1976). Waste-water discharge to Gable Mountain and B Ponds raised the water table, partially blocking the natural easterly flow direction. Gephart et al. (1976) reported that the West Lake basin appeared to represent nearly stagnant ground-water conditions in 1976.

A recent water-table map of the West Lake area (June 1989; Figure 4) shows that unconfined ground water passing West Lake flows from the 200 East Area plateau north through the gap between Gable Butte and Gable Mountain. Figure 5 shows the **potentiometric**^(a) surface map of the underlying Rattlesnake Ridge confined aquifer for June 1989. These figures indicate that the flow direction of these two entirely different systems (i.e., unconfined and uppermost confined) are coincidental near West Lake (i.e., flow is generally to the northwest for both systems).

It is possible that ground water may be moving up from deeper aquifers along fracture joints associated with the Gable Mountain anticline (Graham et al. 1984). Ledgerwood and Deju (1976) indicated hydraulic interconnection between the uppermost confined aquifers and the unconfined aquifer due to the breaching of tilted basalt interbeds between Gable Butte and Gable Mountain. A comparison of the **potentiometric** surface of the Rattlesnake Ridge confined aquifer and the water table of the unconfined aquifer for June 1989 indicates an upward potential exists between the unconfined aquifer and the underlying Rattlesnake Ridge confined aquifer just south of West Lake. Graham et al. (1984) also reported that an upward potential of ground water existed beneath West Lake as a result of the Rattlesnake Ridge confined aquifer (and perhaps deeper aquifers) discharging to the unconfined aquifer.

GROUND-WATER CHEMISTRY

Historical chemical data for water samples collected from West Lake and the confined and unconfined aquifers near West Lake indicate the possibility of aquifer leakage between the uppermost confined aquifers and the overlying unconfined aquifer (Gephart et al. 1976). Water in West Lake is anomalously high in alkalinity and salt content; however, the ratios of the major constituents are similar to those in waters of the confined aquifers. The major buffering component of samples from well 699-60-57, located northwest of West Lake, is sodium carbonate, the same as the Mabton interbed (Graham et al. 1984). This may indicate that the deeper aquifers are discharging ground

(a) The potentiometric surface is the surface to which a given aquifer will rise by hydrostatic pressure.

FIGURE 4 Water-Table Elevation Map, June 1989 (modified from Kasza and Schatz 1989)

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FIGURE 5. Potentiometric Surface Elevation Map, June 1989 modified from Kasza and Schatz 1989

water to the unconfined aquifer and West Lake. However, Early et al. (1988) showed that downward flow between the unconfined aquifer and the Wanapum Basalt in the vicinity of West Lake occurs along Tractures 'associated with the Umtanum Ridge-Gable Mountain anticline. The Wanapum Basalt lies below the Mabton interbed. The Umtanum Ridge-Gable Mountain anticline is the most prominent structural feature in the area of West Lake.

Fuel reprocessing activities use large quantities of nitric acid, and the nitrate ion has been detected in ground water adjacent to the 200 East Area. Wells near West Lake indicate low concentrations of nitrate (as NO_3^-); generally less than 20 mg/L. The highest NO_3^- levels were found in well 699-49-57, approximately 2,700 m south of West Lake, and ranged between 40 and 120 mg/L between 1985 and 1989 (see Appendix C, Figure C.6).

AQUATIC ECOLOGY

Very little information is available on the physical and biological characterization of West Lake. Emery and McShane (1978) investigated and reported the aquatic ecology of West Lake in 1975-1976. Their study involved a limnological characterization of the lake as well as a qualitative survey of the biota.

Physical Characterization

West Lake occupies an area of approximately 77,800 m² (19.2 acres), with a mean depth of 0.4 m (1.3 ft); the volume is 31,100 m³ (25.1 acre-feet) (Emery and McShane 1978). The dimensions of West Lake vary directly with changes in elevation of the underlying water table.

As indicated previously, West Lake appears to have been formed by a rise in elevation of the water table in the 200 Areas as a result of discharges of water to the unconfined aquifer. An additional minor source of water to the lake may be snow runoff, following periods of unseasonable, rapid warming in winter.

Water Chemistry

Water in the lake is very saline and alkaline (pH range = 9.7 to 10.0), a characteristic resulting from high rates of evaporation, stagnation, low

percolation, and possible infusion of water from underlying aquifers. Mean alkalinity ($\pm 95\%$ confidence interval) by titration is 9,000 $\pm 1,900$ mg CaCO_3 equivalents/L (Table 1). Conductivity measurements also indicate a high level of dissolved solids: 23,000 to 25,000 $\mu\text{mhos/cm}$ at 25°C. The 14,550- $\mu\text{mhos/cm}$

TABLE 1. Water Quality Parameters of West Lake^(a)

Parameter	Units	1975-1976 ^(b)	1976 ^(c)	1987 ^(d)	1989 ^(e)
pH	unitless	9.7 to 10.0	9.6	9.5 to 9.6	NA
Alkalinity	mg/L	9,009	NA	NA	NA
Hardness	mg/L	122	NA	NA	NA
Conductivity	$\mu\text{mhos/cm}$	229,700	14,550	23,000 to 25,000 ^(f)	NA
Total dissolved solids	mg/L	NA	15,410	NA	NA
Calcium	mg/L	NA	5	NA	7.72
Magnesium	mg/L	NA	13	NA	10.7
Sodium	mg/L	NA	7,000	4,120 to 4,260	7,520
Potassium	mg/L	NA	400	209 to 219	325
Carbonate	mg/L	NA	5,860	NA	NA
Total carbon	mg/L	NA	NA	NA	1,880
Total organic carbon	mg/L	NA	600	113	NA
Sulfate	mg/L	NA	1,375	2,410 to 3,060	3,800
Sulfide	mg/L	NA	NA	NA	1.58
Chloride	mg/L	NA	2,080	1,230 to 1,640	2,000
Fluoride	mg/L	NA	158	76 to 91	NA
Nitrate	mg/L	NA	0.25	1.7-1.8	<5.0
Ammonium	mg/L	2.61	NA	NA	0.367
Phosphorus	$\mu\text{g PO}_4^-$ P/L	2,160	NA	6,600	NA
Silicate	mg SiO_2^- Si/L	0.23	NA	1	NA

(a) See Table 2 for two eastern Washington saline lakes.

(b) Mean values from Emery and McShane (1978), also reported in Rogers and Rickard (1977).

(c) Gephart et al. (1976).

(d) Data collected by EG&G Idaho, Idaho Falls, Idaho.

(e) Data collected for this study.

(f) Values reported as $\mu\text{Seimens}$; 1 $\mu\text{Seimens}$ = 1 $\mu\text{mhos/cm}$.

NA = Not analyzed.

TABLE 2. Water Quality Parameters of Lake Lenore and Soap' Lake

Parameter	Units	Lake Lenore				Soap Lake			
		1949 ^(a)	1950-51 ^(b)	1954 ^(a)	1956 ^(a)	1949 ^(a)	1950-51 ^(b)	1954 ^(a)	1956 ^(a)
pH	unit less	9.7	9.7-10.0	9.8	9.7	9.8	9.4-10.0	10.0	10.0
Conductivity	$\mu\text{mhos/cm}$	23,206	14,158	10,640	43,000	30,087	24,980	NA	NA
Total dissolved solids	mg/L	18,600	14,080	11,040	7,500	38,954	35,280	25,440	20,600
Calcium	mg/L	9	10.2	8	5	5	20.6	8	5
Magnesium	mg/L	20	13.8	20	15	17	8.2	20	16
Sodium	mg/L	6,969	5,129	3,887	2,622	14,260	11,868	8,763	7,291
Potassium	mg/L	508	438	321	239	739	1,134	774	602
Carbonate	mg/L	3,990	3,000	1,746	936	7,440	6,870	4,050	3,360
Bicarbonate	mg/L	4,636	3,544	3,221	2,885	6,893	5,209	5,020	3,788
Sulfate	mg/L	2,923	2,112	1,627	1,378	6,960	6,240	4,560	3,782
Chloride	mg/L	1,856	1,438	1,093	724	5,183	5,467	3,444	2,570
Nitrate	mg/L	NA	NA	8.7	NA	NA	NA	8.7	NA
Phosphorus	$\mu\text{g PO}_4\text{-P/L}$	NA	2.8-195 ^(c)	NA	NA	NA	~2-2,085 ^(c)	NA	NA

(a) Castenholtz (1960).

(b) Anderson (1958); all values, except pH and PO_4 , collected in November 1950.

(c) Values greatly influenced by seasonal fluctuations or stratification; values reported as $\mu\text{g atoms}\cdot\text{L}^{-1}$.
NA = Not analyzed.

reported by Emery and McShane (1978) appear suspect. Water hardness,^(a) in contrast, was $122 \pm 8 \text{ mg CaCO}_3 \text{ equivalents/L}$ (Emery and McShane 1978). The relatively low hardness is a result of calcium removal by precipitation of calcium carbonate because of high pH and algal photosynthesis.

In comparison to other saline lakes in eastern Washington, West Lake has a more saline environment. Lake Lenore and Soap Lake (see Table 2), highly saline lakes located approximately 220 km (138 mi) north of West Lake in arid, eastern Washington, were studied extensively in the late forties and fifties (Anderson 1958; Castenholz 1960; Edmonson and Anderson 1965). The water chemistry of West Lake is very similar to these larger, saline lakes; the main differences are conductivity and dissolved salts. The differences in conductivity are best explained by the fact that West Lake is small and shallow, while Lake Lenore and Soap Lake are considerably larger, deeper, and subject to stratification and formation of chemoclines. The mean depth of Lake Lenore

(a) Hardness is total divalent cations measured by EDTA (ethylenediamine tetraacetic acid) titration. Alkalinity is the capacity of water to neutralize acid. Both are expressed in terms of $\text{CaCO}_3 \text{ equivalents/L}$.

was 6.5 m and Soap Lake was 10.02 m deep (Anderson 1958). Both lakes have established hypolimnions, with considerably higher solute concentrations than indicated by the surface measurements given in Table 2. Moreover, during the years these data were collected, the lakes were undergoing continued dilution from regional irrigation practices.

Nutrient Balance

The availability of plant nutrients is significant from the standpoint of supporting phytoplankton and, to a lesser extent, vascular aquatic plants. Total phosphorus levels in 1976 were $2,160 \pm 140 \mu\text{g PO}_4\text{-P/L}$, while the concentration of soluble phosphorus (orthophosphate) was $2,050 \pm 180 \mu\text{g PO}_4\text{-P/L}$. These levels represent a very high content of phosphorus. Generally, levels greater than $100 \mu\text{g PO}_4\text{-P/L}$ constitute a hypereutrophic system. Mean reported values for ammonia ($\text{NH}_3\text{-N}$) were 2.61 mg/L , and nitrate (NO_3) levels were 1.7 to 1.8 mg/L . Collectively, the total amount of inorganic nitrogen, as both NH_3 and NO_3 place the trophic status of West Lake as hypereutrophic. Various authors have speculated that the high phosphorus and nitrogen levels are the result of disposal of sanitary sewage sludge to the West Lake basin (Rogers and Rickard 1977; Emery and McShane 1978; Meinhardt and Frostenson 1979).

Productivity

The planktonic community of West Lake is dominated by periphyton, an attached colony dominated by diatoms and fresh-water brown algae. The dominance of diatoms and algae is characteristic of alkaline and saline lakes and, with few taxonomic exceptions, parallels algal taxonomic profiles of Lake Lenore and Soap lake (Castenholtz 1960; Emery and McShane 1978). Emery and McShane (1978) noted that periphyton colonization rates (expressed as $17 \pm 10 \mu\text{g chlorophyll } a/\text{cm}^2$) were relatively low compared to other waste ponds on the Hanford Site. Other ponds at Hanford had mean colonization rates 2.5 to 4.3 times higher than West Lake. The low level of periphyton colonization may be attributed to the high level of dissolved salts in West Lake.

No rooted submergent vascular plants have been observed in West Lake. Three-spined bulrush had colonized the southernmost tip of West Lake in 1964 (see Figure 2). In comparison, by 1989, bulrush had spread to sections of all

shores of the lake and to areas where springs emerge in the northern tip of the West Lake basin. Emery and McShane (1978) reported that cattails, *Typha* sp., inhabited the pond in 1976; however, cattails presently are not found at West Lake.

Fauna

Emery and McShane (1978) observed fresh-water annelids, Oligochaeta, and flying insects, including damselflies, Odonata, back swimmers, Notonectidae, water boatman, Corixidae, caddisfly, Trichoptera, midge fly, Chironomidae, and shore fly, Ephydriidae. Segmented worms, Oligochaeta, were reported as a notably abundant organism. No record was found that documented the observation of fish in West Lake.

TERRESTRIAL ECOLOGY

There have been no definitive studies of the terrestrial ecology of the West Lake basin. Inspection of soil maps indicates that the areas adjacent to the basin consist of Ephrata sandy loam or Burbank sandy loam (Hajek 1966). A band of salt-tolerant vegetation encircles West Lake, and is dominated by salt grass, *Distichlis* stricta. The zonation changes to a distinct sagebrush, Artemisia tridentata, grass zone, consisting of bunch grass species and cheat-grass, Bromus tectorum, farther away from salt-influenced soil (see Figures 1 and 2). Plantain, Plantago elongatum, an introduced species, and rattle box, Swainsona salsula, are found in other areas around the lake. Three-spined bulrush inhabits moist areas, where springs emerge and along segments of the shoreline.

Terrestrial fauna include those common to the Hanford Site and are summarized in Cushing (1989). Of particular significance to this study are populations of American coot, Fulica americana, that breed on the pond. Coot eggshells from West Lake and Morgan Lake, a control lake, were monitored for ⁹⁰Sr and uranium isotopes. Ducks, shorebirds, blackbirds, and swallows also frequent the lake (Fitzner and Price 1973; Fitzner and Rickard 1975). Morgan Lake is located approximately 76 km (48 mi) northeast of West Lake on the Columbia National Wildlife Refuge.

METHODS

All sampling activities were performed by PNL personnel, and chemical and radiological analyses were performed by United States Testing Company, Inc. Data on mass spectroscopy were provided by PNL. Samples were collected in August 1989.

GROUND WATER

Ground-water samples were collected from wells 699-53-55A, 699-56-53, 699-59-58, and 699-60-57 in the vicinity of West Lake in August 1989 (Figure 6). Well 699-56-53 is open to the Rattlesnake Ridge confined aquifer, wells 699-53-55A and 699-60-57 are open to the full thickness of the unconfined aquifer, and well 699-59-58 is open to the uppermost part of the unconfined aquifer. Of the three wells open to the unconfined aquifer, two (699-59-58 and 699-60-57) are considered downgradient from the lake (McGhan 1989). The depths, monitored aquifer description, and coordinates of the wells used in this study are listed in Table 3.

Ground-water samples were analyzed for cations, anions, trace metals, and radionuclides (Table 4). Unfiltered ground-water samples were collected for anion analyses, and both filtered and unfiltered samples were collected for cation and trace metal analyses.

All 1989 ground-water samples were collected from wells 699-53-55A, 699-56-53, 699-59-58, and 699-60-57 by methods similar to those described in PNL (1989). These PNL methods follow established guidelines for sampling ground water described in EPA (1986). The wells were not purged, and sample collection was limited to "grab" samples.

The purging of wells is designed to ensure the removal of stagnant water and allow the collection of a "representative" ground-water sample adjacent to the well. Because purging of the wells was not conducted, the ground-water samples may not be representative of ground water in the aquifer, and the analytical results may be indicative of stagnant water conditions. Under

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FIGURE 6. Location Map of Wells Used for Evaluating Ground Water in the West Lake Basin

TABLE 3. Wells Sampled to Evaluate Ground Water in the Vicinity of the West Lake Basin

<u>Well Number</u>	<u>Depth of Completion Interval (m)</u>	<u>Monitored Aquifer</u>	<u>Hanford Plant Coordinates</u>		<u>Lambert Coordinates^(a)</u>	
			<u>North</u>	<u>West</u>	<u>North</u>	<u>West</u>
699-49-55A	38.1 to 41.1	Shallow-unconfined	48,803	54,926	465,742	1,195,446
699-49-57	43.9 to 49.1	Shallow-deep unconfined	48,600	56,913	465,747	1,195,525
699-50-53	43.3 to 48.5	Shallow-unconfined	49,919	53,267	465,770	1,195,379
699-51-63	47.9 to 55.8	Shallow-unconfined	50,667	63,060	465,817	1,195,768
699-53-55A ^(b)	50.3 to 82.3	Shallow-deep unconfined	53,006	55,014	465,858	1,195,448
699-55-50C	10.7 to 17.1	Shallow-unconfined	55,017	49,940	465,911	1,195,245
699-56-51	16.8 to 32.0	Shallow-deep unconfined	56,343	50,500	465,938	1,195,267
699-56-53 ^(b)	57.9 to 82.3	Confined	56,772	52,779	465,948	1,195,357
699-59-58 ^(b)	25.9 to 30.5	Shallow-unconfined	59,445	57,763	466,019	1,195,555
699-60-57 ^(b)	16.8 to 46.9	Shallow-deep unconfined	60,030	59,964	466,059	1,195,508
699-60-60	30.5 to 33.5	Shallow-unconfined	60,030	59,964	466,051	1,195,642
699-61-62	26.2 to 30.5	Shallow-unconfined	61,062	62,217	466,066	1,195,731
699-64-62	27.4 to 33.5	Shallow-unconfined	65,000	61,746	466,155	1,195,711

(a) Also referred to as Washington Coordinate System.

(b) Wells sampled in August 1989.

TABLE 4. Laboratory Analyses Performed on Ground-Water Samples

<u>Analytical Category</u>	<u>Analytical Species</u>
Cations	Calcium, magnesium, sodium, potassium, iron
Anions	Chloride, sulfate, nitrate, nitrite, fluoride, phosphate, bromide
Trace metals	Aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, cobalt, lithium, manganese, molybdenum, nickel, tin, titanium, silver, silicon, strontium, vanadium, zinc, zirconium
Radionuclides	³ H, ⁶⁰ Co, ⁹⁰ Sr, ⁹⁹ Tc, ¹⁰⁶ Ru, ¹³⁷ Cs, ²³⁴ U, ²³⁵ U, ²³⁸ U

stagnant water conditions, chemical reactions (e.g., redox reactions, desorption, adsorption) between the well materials and chemicals in the ground water may influence the interpretation of the ground-water results.

Ground-water grab samples (filtered and unfiltered) were collected from well 699-56-53 with a Teflon bailer and from the other three wells (699-53-55A, 699-59-58, and 699-60-57) with submersible pumps. Cation, trace metal, and radionuclide samples were preserved at the time of sample collection with a nitric acid solution. Filtered samples were obtained with a 0.45- μ m pore-sized filter. Duplicate samples were collected from each well, and were analyzed to estimate the variability caused by the laboratory measurement technique and as a check for gross errors. The pH, temperature, and electrical conductivity of the sample water were measured in the field at the time of sample collection.

WEST LAKE BASIN

For the purposes of this study, the West Lake basin includes West Lake and the zone of salt grass surrounding the lake (Figure 7). Sample stations were established on two transects within the basin for soil and vegetation samples. The north transect contained six sites situated from the northernmost pool to the area where sagebrush starts to grow. The south transect radiated in a southern direction from a stand of bulrush to where sagebrush was first found. Terrestrial sample collection sites (Table 5) were numbered from north to south (N1 through N6 and S1 through S5). Two samples of salt deposits also were collected adjacent to N6. Water and sediment samples were collected from nine stations, designated L1 through L9, located in the main body of West Lake and in three peripheral pools.

SAMPLE ANALYSES

Radiological Analyses

Table 6 summarizes the types of radiochemical analyses performed on the samples. Gamma scans provided information on ^{40}K , ^{60}Co , ^{95}Zr , ^{95}Nb , ^{106}Ru , ^{134}Cs , ^{137}Cs , ^{154}Eu , ^{155}Eu , ^{212}Pb , and ^{214}Pb . Other radionuclides were sampled for in specific environmental matrices: ^3H , ^{90}Sr , ^{99}Tc , and isotopes

FIGURE 7. Location of Sample Sites for Sediment, Water, Soil, and Vegetation

TABLE 5. Primary Surface Environmental Sample Sites in the West Lake Basin

Sample Site	Lambert Coordinates		Samples			
	North	East	Soil	Vegetation	Water	Sediment
S1	462,786	2,240,744	x	x		
S2	462,824	2,240,738	x	x		
S3	462,864	2,240,732	x	x		
S4	462,902	2,240,726	x	x		
S5	462,942	2,240,718	x	x		
N1	465,425	2,240,210	x	x		
N2	465,392	2,240,205	x	x		
N3	465,354	2,240,217	x	x		
N4	465,317	2,240,229	x	x		
N5	465,279	2,240,241	x	x		
N6	465,242	2,240,252	x	x		
L1	463,223	2,240,631			x	x
L2	463,590	2,240,494			x	x
L3	463,939	2,240,363			x	x
L4	464,108	2,240,299			x	x
L5	463,695	2,240,241			x	x
L6	464,417	2,240,585			x	x
L7	464,651	2,240,486			x	x
L8	464,739	2,240,427			x	x
L9	465,134	2,240,321			x	x

TABLE 6. Matrix of Samples Collected from the West Lake Basin for Radioisotopic Analyses, 1989

Sample Type	Gamma Scan	Low-Energy Photon	Uranium Isotopes		Mass Spectroscopy	³ H	⁹⁰ Sr	⁹⁹ Tc
			α -Spectrometry					
Soil	X	X					X	
Vegetation	X			X			X	
Sediment	X			X				
Salt deposit	X			X			X	
Lake water	X			X	X	X	X	X
Ground water	X			X		X	X	X
Eggshell	X			X			X	

of uranium. Isotopic analyses included ^{234}U , ^{235}U , and ^{238}U by alpha spectrometry (AS), and for soil samples only ^{235}U and ^{238}U by low-energy photon (LEP) analysis. High-resolution mass spectroscopy (MS) was also performed on water samples by PNL to determine isotopic ratios of ^{234}U , ^{235}U , ^{236}U , and ^{238}U . The presence of ^{236}U in environmental samples would indicate the presence of Hanford-derived uranium. Uranium-236 is an activation product of ^{235}U and is not a naturally occurring isotope.

Chemical Analyses

Chemical analyses were performed on ground water and lake water only. Analyses were performed to detect trace metals by inductively coupled plasma emission spectroscopy (ICP) ; semivolatile and volatile organic compounds by gas chromatography-mass spectroscopy (GC-MS) of hexane extracts, organic compounds by GC coupled to flame ionization detector; polychlorinated biphenyls (PCB) with methylene chloride extractions, thiourea compounds, organophosphorus pesticides, other pesticides, and herbicides by GC.

SAMPLING RESULTS

Radiochemical analyses were conducted on ground water, lake water, sediment, salt deposits, soil, vegetation, and coot eggshells. A constituent was considered present in the sample if the analytical result was positive and exceeded 2 standard deviations of the counting data. Data were compared to representative control samples and expected isotopic ratios for uranium. Analyses of inorganic constituents were limited to ground water and West Lake surface water, and focused on a number of constituents. West Lake water was also analyzed for organic constituents, and the data are presented by the environmental medium in the appendixes.

GROUND WATER

Historical analytical results, dating to January 1987, have been summarized with the data from the wells sampled in August 1989. Well 699-59-58, the well nearest West Lake that was sampled, was the only one of the four wells sampled in which radionuclides were detected (see Appendix A, Table A.1). The presence of ^3H and ^{99}Tc provides the strongest link with waste disposal practices in the 200 Areas because these radionuclides tend to move with the flow of ground water.

Technetium-99 was detected in well 699-59-58 in duplicate August 1989 samples at 53.8 and 55.1 pCi/L. Concentrations of ^{99}Tc in the other three wells sampled in August 1989 were below detection limits.

Tritium also was detected in well 699-59-58. The concentrations for the August 1989 samples ranged between 839 and 949 pCi/L (see Appendix A, Table A.1) and have fluctuated between 442 and 951 pCi/L between 1987 and 1989. Tritium levels in well 699-60-57 were consistently lower than in well 699-59-58.

Isotopes of uranium, gamma emitters (^{60}Co , ^{106}Ru , and ^{137}Cs), and ^{90}Sr were not detected in the wells sampled in August 1989 (see Appendix A, Table A.1).

LAKE WATER

Radiochemical analyses of West Lake water indicate elevated levels of ^3H , ^{90}Sr , and ^{99}Tc (Table 7 and see Appendix A, Table A.2). Concentrations of ^3H were approximately five times greater than those reported at Priest Rapids Dam on the Columbia River for 1988 (Table 8). Strontium-90 levels were approximately 100 times greater in West Lake water than in Columbia River water measured at Priest Rapids Dam. Levels of ^{106}Ru and ^{137}Cs frequently were below the limits of detection (see Table 7).

Concentrations of uranium in West Lake water ranged from 98 to 179 pCi $^{238}\text{U}/\text{L}$ (see Appendix A, Table A.3). Uranium values for sample 9 were not used for the calculation of isotopic ratios or mean water concentrations because the sample had a large quantity of resuspended sediment that contaminated it during collection. Isotopic analysis by MS did not detect ^{236}U , which would have suggested a Hanford source for uranium in West Lake. Further analysis of isotopic ratios of $^{234}\text{U}/^{238}\text{U}$ and $^{235}\text{U}/^{238}\text{U}$ (Table 9) indicated that mass ratios for $^{235}\text{U}/^{238}\text{U}$ were not significantly different than a theoretical value of 0.00725 based on MS data. However, the mass ratios calculated from AS data were significantly different than the theoretical ratio ($P < 0.10$). Ratios generated from MS data and calculated from AS data for $^{234}\text{U}/^{238}\text{U}$ were

TABLE 7. Concentrations (pCi/L) of Radionuclides in West Lake Water, August 1989

<u>Isotope</u>	<u>Mean</u>	<u>S.E. of Mean</u>	<u>Range</u>	<u>n(a)</u>
^3H	395	30.3	255 to 512	8
^{60}Co	2.64	0.654	1.21 to 1.93	8
^{90}Sr	1.67	0.104	1.21 to 1.93	8
^{99}Tc	59.7	9.69	20.9 to 107	8
^{106}Ru	1.86	16.0	-56.1 to 79.7	8
^{137}Cs	0.964	1.24	-2.28 to 7.03	8

(a) Nine samples were collected, but sample 9 was deleted because of high sediment content.

TABLE 8. Concentrations of Radionuclides in Water and Sediment Collected from Priest Rapids Dam, 1986 Through 1989

Isotope	Water (pCi/L)(a)		Sediment (pCi/g-dry weight)(b)	
	Mean	2 S.E.	Mean	2 S.E.
^3H	75.9	5.73	NA	NA
^{60}Co (b) P	BDL	BDL	-0.002	0.009
D	0.0012	0.0005	BDL	BDL
^{90}Sr	0.12	0.01	0.014	0.002
^{134}Cs	BDL	BDL	-0.079	0.061
^{137}Cs P	BDL	BDL	0.265	0.051
D	0.002	0.001	NA	NA
^{234}U	0.234	0.018	NR	NR
^{235}U	0.009	0.003	0.038	0.045
^{238}U	0.192	0.015	0.761	0.132

(a) Values are the mean and ± 2 times the standard error (S.E.) of the mean for 12 water samples collected from 1986 to 1989 (except ^{60}Co).

(b) Sediment samples and ^{60}Co taken from four samples collected in 1989, as reported by Jaquish and Bryce (1990).

BDL = Below detection limit.

D = Dissolved fraction ($< 0.45 \mu\text{m}$).

NR = Not reported.

P = Particulate fraction.

TABLE 9. Comparison of Isotopic Ratios of Uranium in West Lake Water, Sediment, and Terrestrial Vegetation

Medium	Method	$^{234}\text{U}/^{238}\text{U}$			$^{235}\text{U}/^{238}\text{U}$		
		Mean	S.D.	n(a)	Mean	S.D.	n(a)
Lake water	MS	5.82E-5	1.29E-6	9	7.24E-3	3.34E-5	9
	AS	5.98E-5	1.06E-6	8	6.66E-3	8.21E-4	8
Sediment	AS	5.14E-5	9.52E-6	9	4.87E-3	1.49E-3	9
Vegetation	AS	6.03E-5	5.89E-6	11	4.48E-3	2.63E-3	11

(a) Sample number.

MS = High-resolution mass spectroscopy.

AS = Alpha spectrometry.

significantly greater ($P < 0.001$) than the theoretical value of $5.5147E-5$. These observations suggest the possible presence of uranium depleted in the ^{234}U and ^{235}U isotopes; however, the existing data are inadequate for a definitive conclusion.

SEDIMENT

Gamma scan results indicated detectable concentrations of ^{40}K , ^{137}Cs , ^{212}Pb , and ^{214}Pb in sediments (Table 10 and see Appendix A, Table A.4). Of these, only ^{137}Cs is of potential Hanford origin, but the concentrations are also within the range of those associated with atmospheric fallout from nuclear weapons testing. The mean radionuclide concentrations in

TABLE 10. Concentrations (pCi/g-dry)^(a) of Radionuclides in Sediment Samples Collected from West Lake

<u>Radionuclide</u>	<u>Mean</u>	<u>S.E. of Mean</u>	<u>Range</u>	<u>n^(b)</u>	<u>Number of Samples Above Detection</u>
^{40}K	18.7	0.588	16.1 to 21.9	9	9
^{60}Co	0.002	0.002	-0.007 to 0.009	9	0
^{90}Sr	0.494	0.166	0.050 to 1.57	9	0
^{106}Ru	0.0000222	0.027	-0.096 to 166	9	1
^{134}Cs	-0.044	0.013	-0.108 to 0.007	9	0
^{137}Cs	1.22	0.283	0.491 to 2.45	9	9
^{154}Eu	-0.022	0.014	-0.066 to 0.082	9	1
^{155}Eu	0.025	0.017	-0.095 to 0.085	9	1
^{212}Pb	0.767	0.031	0.574 to 0.859	9	9
^{214}Pb	0.594	0.027	0.49 to 0.743	9	9
^{234}U	1.54	0.314	0.213 to 3.29	9	9
^{235}U	0.054	0.012	0.003 to 0.121	9	7
^{238}U	1.82	0.495	0.201 to 5.13	9	9

(a) Values reported to three significant figures unless reported otherwise in statistical analysis summary.

(b) Number of samples.

West Lake sediments are higher than those reported for Priest Rapids Dam sediments collected upstream of the Hanford Site (see Table 8).

The concentrations of uranium in West Lake sediments are elevated when compared to background concentrations of uranium typically reported in the surrounding soil type (Price 1988; Poston 1990). Based on AS analysis, concentrations in West Lake sediments ranged from 0.2 to 5.1 pCi ^{238}U /g-dry (see Appendix A, Table A.5). Isotopic mass ratios of $^{234}\text{U}/^{238}\text{U}$ and $^{235}\text{U}/^{238}\text{U}$ were $5.14\text{E-}5$ and $4.87\text{E-}3$, respectively (see Table 9). The mass ratio for $^{235}\text{U}/^{238}\text{U}$ ($4.87\text{E-}3$), calculated from AS data, was significantly lower than the theoretical value of $7.25\text{E-}3$ ($P(0.01)$); however, the concentrations of ^{235}U were close to the AS detection limit, and there were two samples below the detection limit. The ratio of $^{234}\text{U}/^{238}\text{U}$ was $5.14\text{E-}5$, and was not significantly different than the theoretical value of $5.51\text{E-}5$.

Uranium concentrations in sediment sample 9 contained 1.94 pCi ^{238}U /g (see Appendix A, Table A.5); however, this level of contamination, on its own, does not account for the high level of ^{238}U in water sample 9 (5,500 pCi ^{238}U /L; see Appendix A, Table A.3) collected from this northernmost pool.

SALT DEPOSITS

In close association with sediments are samples of salt deposits collected at the north end of West Lake adjacent to the northernmost pool, where samples designated L9 were collected. There is an apparent concentration of about a factor of 10 of uranium in these salt deposits compared to sediments (Tables 11 and 12 and see Appendix A, Table A.5) and a factor of 20 to 80 for West Lake basin soils (see Table 10 and Appendix A, Table A.6). Concentrations of ^{40}K , ^{90}Sr , and ^{137}Cs , in salt deposits were less than those reported in sediment and soil samples.

SOIL

Soil samples had detectable concentrations of ^{40}K , ^{90}Sr , ^{137}Cs , ^{212}Pb , ^{214}Pb , and ^{238}U (see Table 12 and Appendix A, Tables A.6, A.7, and A.8).

TABLE 11. Concentrations of Radionuclides in Salt Deposits Collected from the North End of the West Lake Basin (value in italics is ± 2 standard deviations of count data)

Sample weight, g	Radionuclide, pCi/g					
	^{40}K	^{60}Co	^{90}Sr	^{106}Ru	^{134}Cs	^{137}Cs
178	5.17E+00 <i>8.16E-01</i>	-1.71E-04 <i>1.86E-02</i>	1.96E-02 <i>9.24E-03</i>	-8.10E-02 <i>1.74E-01</i>	-9.40E-03 <i>1.97E-02</i>	7.09E-02 <i>2.44E-01</i>
703	9.44E+00 <i>1.08E+00</i>	2.37E-03 <i>1.32E-02</i>	1.25E-01 <i>2.77E-02</i>	-1.17E-02 <i>1.03E-01</i>	-2.06E-02 <i>1.28E-02</i>	3.20E-01 <i>4.20E-02</i>
	Radionuclide, pCi/g					
	^{155}Eu	^{212}Pb	^{214}Pb	^{234}U	^{235}U	^{238}U
178	5.01E-02 <i>6.83E-02</i>	1.57E-01 <i>4.13E-02</i>	1.51E-01 <i>5.77E-02</i>	1.74E+01 <i>1.70E+00</i>	5.68E-01 <i>9.15E-02</i>	1.64E+01 <i>1.60E+00</i>
703	3.64E-02 <i>3.79E-02</i>	3.68E-01 <i>4.58E-02</i>	2.72E-01 <i>4.16E-02</i>	6.61E+00 <i>7.22E-01</i>	2.47E-01 <i>6.35E-02</i>	6.23E+00 <i>6.83E-01</i>

Levels of ^{90}Sr and ^{137}Cs exceed background levels reported in Yakima, Washington, for 1989 (Table 13). Concentrations of ^{238}U were slightly higher in soils than for other uncontaminated soils typical of the Hanford Site. Isotopic ratios of uranium were not calculated for soil samples because the LEP method lacks the sensitivity to measure ^{235}U and ^{234}U at the concentrations found in soil on the Hanford Site (Poston 1990).

VEGETATION

Vegetation samples had detectable concentrations of ^{40}K , ^{90}Sr , ^{137}Cs , ^{234}U , and ^{238}U (Table 14 and see Appendix A, Tables A.9 and A.10); however, concentrations were more variable than those observed in water, soil, and sediment. Mean concentrations of ^{90}Sr and ^{137}Cs were generally higher in vegetation samples collected from the south transect but the differences were not statistically significant ($P = 0.05$). In contrast, mean concentrations of ^{234}U and ^{238}U were higher in samples collected from the north transect. Samples collected near the northernmost pool had the highest uranium concentrations of all vegetation samples (see Appendix A, Table A.11). This is

TABLE 12. Concentrations (pCi/g-dry)^(a) of Radionuclides in Soil Samples Collected from the West Lake Basin, August 1989

Isotope	Mean	S.E. of Mean	Range	n ^(b)	Number of Samples Above Detection ^(c)
South Transect					
⁴⁰ K	16.1	0.504	14.1 to 16.9	5	5
⁶⁰ Co	-0.007	0.010	-0.032 to 0.023	5	0
⁹⁰ Sr	0.290	0.105	0.109 to 0.671	5	5
⁹⁵ Zr ⁹⁵ Nb	-0.031	0.005	-0.042 to -0.017	5	0
¹⁰⁶ Ru	0.058	0.011	0.023 to 0.092	5	0
¹³⁴ Cs	-0.004	0.016	-0.054 to 0.044	5	1
¹³⁷ Cs	0.934	0.243	0.229 to 1.52	5	3
¹⁵⁴ Eu	0.019	0.027	-0.041 to 0.100	5	1
¹⁵⁵ Eu	0.027	0.016	-0.019 to 0.075	5	1
²¹² Pb	0.706	0.034	0.603 to 0.818	5	5
²¹⁴ Pb	0.582	0.028	0.514 to 0.684	5	5
²³⁵ U	0.062	0.018	0.011 to 0.122	5	3
²³⁸ U	0.871	0.268	0.390 to 1.91	5	5
North Transect					
⁴⁰ K	17.2	0.303	16.4 to 18.3	6	6
⁶⁰ Co	-0.002	0.006	-0.023 to 0.013	6	0
⁹⁰ Sr	0.239	0.044	0.130 to 0.35	6	6
⁹⁵ Zr ⁹⁵ Nb	-0.017	0.011	-0.065 to 0.013	6	0
¹⁰⁶ Ru	-0.030	0.044	-0.127 to 0.155	6	1
¹³⁴ Cs	-0.030	0.014	-0.091 to -0.003	6	0
¹³⁷ Cs	10.5	9.39	0.928 to 1.34	6	6
¹⁵⁴ Eu	-0.004	0.020	-0.075 to 0.052	6	0
¹⁵⁵ Eu	0.042	0.027	-0.049 to 0.120	6	3
²¹² Pb	0.690	0.009	0.658 to 0.713	6	6
²¹⁴ Pb	0.563	0.019	0.513 to 0.620	6	6
²³⁵ U	0.078	0.021	0.019 to 0.149	6	3
²³⁸ U	0.954	0.188	0.535 to 1.79	6	6

(a) Values reported to three significant figures unless reported otherwise in the statistical analysis summary.

(b) Number of samples.

(c) Value exceeds ± 2 standard deviations of count data.

TABLE 13. Concentrations of Radionuclides in Soil and Vegetation Collected Upwind of Hanford at Yakima, Washington, 1986 Through 1989^(a)

<u>Isotope</u>	<u>Soil (pCi/g-dry)</u>		<u>Vegetation (pCi/g-dry)</u>	
	<u>Mean</u>	<u>S.E.</u>	<u>Mean</u>	<u>S.E.</u>
⁹⁰ Sr	0.07	0.02	0.024	0.006
¹³⁷ Cs	0.22	0.17	0.063	0.099
²³⁸ U	0.64	0.42	0.023 ^(b)	0.007

- (a) Values are the mean and ± 2 times the standard error of the mean for 38 samples; environmental monitoring data for 1986-1989 provided by R. L. Dirkes, PNL
- (b) 1989 data only.

noteworthy from the standpoint that the water sample collected from this pool and the salt deposits and adjacent soil samples all had high levels of uranium.

COOT EGGSHELLS

Detectable concentrations of ⁹⁰Sr, ²³⁴U, and ²³⁸U were found in coot eggshells collected from West Lake and Morgan Lake, a control site. Concentrations of ²³⁸U were found to be approximately equal in eggshells from both sites and, in both cases, were only slightly greater than the ± 2 standard deviations (see Appendix A, Table A.12). Strontium-90, however, was distinctly elevated in eggshells sampled at West Lake, and the concentrations of 4.7 to 5.6 pCi/g were approximately 50 times greater than the 0.06 to 0.1 pCi/g found in eggshells from Morgan Lake.

NONRADIOLOGICAL ANALYSES

Ground Water

The analyses of cations and anions sampled from four wells during August 1989 are shown in Table 15. The concentrations of calcium and magnesium ions were at or below background in Hanford Site ground water (as reported by Evans

TABLE 14. Concentrations (pCi/g-dry)^(a) of Radionuclides in Vegetation Samples Collected from the West Lake Basin, August 1989

Isotope	Mean	S.E. of Mean	Range	n ^(b)	Number of Samples Above Detection ^(c)
South Transect					
⁴⁰ K	6.30	0.738	3.75 to 8.34	5	5
⁶⁰ Co	0.022	0.021	-0.021 to 0.092	5	1
⁹⁰ Sr	0.201	0.082	0.061 to 0.503	5	5
¹³⁴ Cs	-0.037	0.034	-0.157 to 0.049	5	0
¹³⁷ Cs	0.137	0.044	0.050 to 0.267	5	4
¹⁰⁶ Ru	0.093	0.187	-0.363 to 0.726	5	0
¹⁵⁴ Eu	0.023	0.030	-0.074 to 0.087	5	0
¹⁵⁵ Eu	-0.029	0.065	-0.156 to 0.218	5	0
²¹² Pb	0.023	0.030	-0.074 to 0.087	5	4
²³⁴ U	0.153	0.101	0.016 to 0.554	5	5
²³⁵ U	0.004	0.003	0.001 to 0.017	5	3
²³⁸ U	0.140	0.092	0.015 to 0.505	5	5
North Transect					
⁴⁰ K	8.94	1.13	6.18 to 12.8	6	6
⁶⁰ Co	-0.005	0.011	-0.032 to 0.031	6	0
⁹⁰ Sr	0.119	0.065	0.018 to 0.419	6	6
¹⁰⁶ Ru	0.104	0.182	-0.674 to 0.464	6	0
¹³⁴ Cs	-0.016	0.021	-0.100 to 0.059	6	1
¹³⁷ Cs	0.048	0.023	-0.039 to 0.135	6	2
¹⁵⁴ Eu	-0.051	0.016	-0.191 to 0.086	6	0
¹⁵⁵ Eu	0.024	0.044	-0.015 to 0.095	6	0
²¹² Pb	0.092	0.038	-0.001 to 0.221	6	3
²¹⁴ Pb	0.102 ^(d)	---	---	1	1
²³⁴ U	0.520	0.316	0.021 to 1.79	6	6
²³⁵ U	0.018	0.012	-0.0003 to 0.068	6	2
²³⁸ U	0.490	0.299	0.019 to 1.68	6	6

(a) Values reported to three significant figures unless reported otherwise in the statistical analysis summary.

(b) Number of samples.

(c) Value exceeds ± 2 standard deviations of count data.

(d) Single value.

TABLE 15 Concentrations $\mu\text{g/L}$) of Cations and Anions from Selected Wells, August 1989

<u>Sample</u>	<u>Calcium</u>	<u>Magnesium</u>	<u>Sodium</u>	<u>Potassium</u>	<u>Iron</u>	<u>Chloride</u>	<u>Sulfate</u>	<u>Nitrate</u>	<u>Fluoride</u>	<u>Phosphate</u>	<u>Bromide</u>	<u>Nitrite</u>
Well 699-53-55A												
Unfiltered	31,700	9,550	17,000	8,550	9,420	20,000	4,000	< 500	< 500	< 10	< 1,000	< 1,000
Filtered	26,730	8,560	14,610	7,360	3,550	---	---	---	---	---	---	---
Well 699-56-53												
Unfiltered	9,790	8,030	22,000	7,810	8,700	26,000	< 500	1,400	< 500	< 1,000	< 1,000	< 1,000
Filtered	8,550	7,600	20,530	7,230	2,470	---	---	---	---	---	---	---
Well 699-59-58												
Unfiltered	19,200	6,190	25,500	4,890	35,300	6,200	18,400	3,600	1,100	< 1,000	< 1,000	< 1,000
Filtered	16,950	5,880	23,210	4,350	< 30	---	---	---	---	---	---	---
Well 699-60-57												
Unfiltered	16,900	5,010	36,300	7,140	7,120	8,000	13,200	< 500	2,100	< 1,000	< 1,000	< 1,000
Filtered	16,070	5,100	35,780	7,000	33	---	---	---	---	---	---	---
Background ^(a)	40,400	11,800	18,260	4,950	---	10,300	34,300	---	370	< 1,000	---	---
	$\pm 10,300$	$\pm 3,400$	$\pm 10,150$	$\pm 1,240$	---	$\pm 6,500$	$\pm 16,900$	---	± 100	---	---	---

<u>Well</u>	<u>Field Measurements</u>		
	<u>Temperature</u> (°C)	<u>pH</u>	<u>Conductivity</u> ($\mu\text{mhos/cm}$)
99-53-55A	7.6	7.44	320
99-56-53	15.5	8.07	230
99-59-58	16.9	7.99	253
99-60-57	18.5	8.14	278

(a) Background levels taken from Evans et al. (1989).
 --- = Less than detection.

TABLE 16. Concentrations ($\mu\text{g/L}$) of Trace Metals in Well Water, August 1989

<u>Element</u>	<u>Well 699-53-55A</u>		<u>Well 699-56-53</u>		<u>Well 699-59-58</u>		<u>Well 699-60-57</u>	
	<u>Filtered</u>	<u>Unfil.</u>	<u>Filtered</u>	<u>Unfil.</u>	<u>Filtered</u>	<u>Unfil.</u>	<u>Filtered</u>	<u>Unfil.</u>
Aluminum	<150	<150	<150	<150	<150	<150	<150	<150
Antimony	<100	<100	<100	<100	<100	<100	<100	<100
Barium	42	47	7	7	6	20	12	19
Beryllium	<5	8	<5	<5	<5	7	<5	<5
Boron	<10	29	<10	<10	22	31	57	53
Cadmium	<2	3	<2	4	<2	7	<2	<2
Chromium	<10	<10	<10	<10	<10	12	<10	<10
Copper	<10	<10	43	36	<10	16	<10	<10
Cobalt	<20	<20	<20	<20	<20	<20	<20	<20
Lithium	<10	<10	<10	<10	<10	<10	<10	<10
Manganese	54	70	208	265	58	196	88	114
Molybdenum	<40	<40	<40	<40	<40	<40	<40	<40
Nickel	<10	<10	<10	13	<10	<10	<10	<10
Tin	<30	<30	<30	<30	<30	<30	<30	<30
Titanium	<60	<60	<60	<60	<60	<60	<60	<60
Silver	<10	<10	<10	<10	<10	<10	<10	<10
Silicon	14,278	17,213	636	954	14,904	19,715	16,371	17,977
Strontium	240	272	61	68	87	101	81	84
Vanadium	8	<5	<5	<5	6	69	<5	<5
Zinc	272	333	97	118	257	1172	9	2258
Zirconium	<50	<50	<50	<50	<50	<50	<50	<50

West Lake Surface Water

Trace metals were analyzed for in samples of West Lake water in 1989. Of these (Table 17), arsenic, chromium, copper, and zinc exceeded EPA criteria for acute toxicity to fresh-water aquatic organisms (45 FR 79318). The EPA criteria were established to protect aquatic life and are based on numerous toxicity evaluations using fresh-water organisms. However, the levels are probably not toxic to organisms found in West Lake because of the lake's high salt content and alkaline state. Additionally, mercury, was found at concentrations in excess of the chronic toxicity criteria. When compared to trace

et al. 1989). The background concentrations for calcium and magnesium ion were $40,400 \pm 10,300$ and $11,800 \pm 3,400$ $\mu\text{g/L}$, respectively (Evans et al. 1989).

Concentrations of sodium and potassium ions were above background for these constituents in some of the wells. The sodium concentration in well 699-60-57 was greater than the background level (see Table 15). The concentrations of potassium in wells 699-53-55A and 699-56-53 were higher than background. The background concentrations of potassium and sodium range between 3,710 and 6,190 and 8,110 and 28,410 $\mu\text{g/L}$, respectively (Evans et al. 1989).

The concentration of sulfate was at or below background: $34,300 \pm 16,900$ $\mu\text{g/L}$ for wells 699-53-55A, 699-59-58, and 699-60-57, and was not detected in well 699-56-53 (see Table 15).

The difference in the concentration between the unfiltered and filtered samples in wells 699-53-55A, 699-56-53, 699-59-58, and 699-60-57 indicates that iron compounds are suspended as particulate matter in these wells. High concentrations of chloride, associated with high concentrations of iron in samples from wells 699-53-55A and 699-56-53, indicate that iron also may be dissolved as an iron chloride complex. These chloride concentrations are higher than the background range of $10,300 \pm 6,500$ $\mu\text{g/L}$ (see Table 15). The possibility of this complex is most likely the result of a lack of purging the well during sample collection and is probably not representative of the ground water.

Barium, zinc, manganese, strontium, and silicon were consistently detected in all samples (Table 16). Graham et al. (1984) reported that the concentration of barium is probably controlled by the solubility of barite. Calculation of the molar activity of barium, using the solubility product of barite and the concentration of sulfate from each of the wells, indicated that the sample from well 699-53-55A was saturated with respect to barium and that the samples from the other three wells were below saturation with respect to barium. Most of the remaining trace metals analyzed were near the detection limit. The high concentration of vanadium in an unfiltered water sample from well 699-59-58 was 69 $\mu\text{g/L}$ and may be a result of suspended particulate matter in the sample.

TABLE 17. Concentrations ($\mu\text{g/L}$) of Trace Metals in Unfiltered Water Samples Collected from West Lake

<u>Element</u>	<u>Detection Limit^{a)}</u>	<u>August 1989 Concentration</u>	<u>Gephart et al. (1976) Concentration</u>
Aluminum	150	<150	<20
Antimony	100	<100	>1,000
Arsenic	50	900	NR
Barium	60	141	830
Beryllium	5	<5	60
Boron	100	6,156	5,000
Cadmium	2	<2	<30
Chromium	100	131	128
Cobalt	20	<20	20
Copper	10	30	355
Cyanide	10	<10	NR
Iron	300	323	360
Lead	5	<5	500
Lithium	10	<10	NR
Manganese	500	10,749	40
Mercury	0.1	0.3	<0.2
Molybdenum	400	2,236	1,280
Nickel	10	<10	150
Selenium	5	<5	NR
Silicon	2,000	4,522	1,000 ^(b)
Silver	10	<10	40
Strontium	100	626	250
Thallium	5	<5	3,000
Tin	30	<30	2,500
Titanium	60	<60	NR
Vanadium	5	<5	<100
Zinc	50	119	18,000
Zirconium	50	<50	NR

(a) Detection limit applies to 1989 data only.

(b) Reported as SiO_2 .

NR = Not reported.

metal levels reported by Gephart et al. (1976), current levels of beryllium, copper, lead, nickel, silver, thallium, tin, and zinc were lower in 1989 than in 1976. There are other inconsistencies in the comparison of the Gephart et al. (1976) data with our results that cannot be addressed because of the scarcity of samples analyzed for each of the two studies.

The GC and MS analyses of lake water covered a total of 59 organic compounds, 30 pesticides and herbicides, 7 thiourea compounds, and 7 formulations of PCBs (see Appendix B). Of these 103 compounds, only hexachlorophene was reported at a concentration in excess of the 26- $\mu\text{g/L}$ detection limit. On a broader scale, the concentration of total halogenated organic compounds (TOX) was 97 $\mu\text{g/L}$ (minimum detection limit is 20 $\mu\text{g/L}$).

DISCUSSION

Sampling was conducted in the West Lake basin, its underlying aquifers, and West Lake proper in August 1989. The objective was to further characterize the basin and expand the existing data to further define the degree to which Hanford Site activities have affected the lake. The historical record indicates that West Lake was formed as a permanent lake from contributions of waste water to the underlying aquifer by activities associated with nuclear fuels reprocessing activities in the 200 Areas on the Hanford Site.

While the hypothesis that the lake was formed as a result of aquifer recharge is convincing, profiles of radionuclide and chemical contamination suggest that Hanford activities have only contributed in a minor degree to the radioactive material found in West Lake. Specifically, ^3H and ^{99}Tc are found at concentrations in West Lake water that are indicative of a link between a ground-water source and the lake's burden of radioactive material. Pond surface levels are believed to follow fluctuations in the water table, which, in turn, follows fluctuations in water disposal activities.

Historical environmental data on ^3H , ^{99}Tc , ^{129}I , uranium isotopes, gross alpha, and gross beta have been collected from samples taken from wells that penetrate the unconfined aquifer. The following are considered tracers for ground-water migration: tritium, as tritiated water (TOH); ^{99}Tc ; and ^{129}I ; because they exist as mobile anions with a low propensity for sorption to soil.

Technetium-99 was detected in only one of the four wells sampled in August 1989 (699-59-58); however, other nearby wells have shown significant levels of ^{99}Tc between 1987 and 1989 (Figure 8). Concentrations of ^{99}Tc generally increased between 1988 and 1989 in wells 699-59-58 and 699-60-60, both of which are located in the gap between Gable Butte and Gable Mountain west and downgradient of West Lake (see Figure 6). Elevated levels of ^{99}Tc have been detected in other downgradient wells (699-61-62 and 699-64-62, which are open to the unconfined aquifer). The concentration of ^{99}Tc in wells 699-49-55A, 699-49-57, and 699-50-53 upgradient from West Lake fell between 1988 and 1989. These upgradient wells are open also to the unconfined

FIGURE 8. Concentrations of ⁹⁹Tc in Ground-Water Wells Near West Lake, 1987 Through 1989

Iodine-129 is also considered to be a good tracer of ground water because it is not readily adsorbed by the aquifer materials. Gephart et al. (1976) reported ^{129}I concentrations in West Lake that ranged from 0.08 to 0.11 pCi/L and in upgradient wells 699-53-47 and 699-55-50C that ranged from 0.10 to 0.11 and 0.12 to 0.14 pCi/L, respectively. Recent ^{129}I concentration data for wells near West Lake are listed in Table 18. Concentrations of ^{129}I in the Rattlesnake Ridge confined aquifer in 1982 were 0.000015 and 0.000031 pCi/L in wells 699-54-57 and 699-56-53, respectively (Graham et al. 1984). The concentration of ^{129}I in the unconfined aquifer (well 699-55-50C) was 0.052 pCi/L in 1982. In this study, ^{129}I was not analyzed for in West Lake. No firm conclusions can be drawn regarding ground-water flow patterns based on ^{129}I concentrations because of the existing limited data.

Concentrations of ^{90}Sr in West Lake have remained rather stable, not exceeding 3 pCi/L since 1985. The concentrations of ^{90}Sr in two upgradient wells, 699-53-55A and 699-55-50C (see Appendix C, Figure C.2), also are stable; however, the values are lower and generally do not exceed 1 pCi/L. Data for ^{90}Sr concentrations in other wells near West Lake are essentially zero (see Appendix C, Figure C.2). Strontium-90 is not considered to be a good ground-water tracer because it is readily adsorbed by aquifer materials.

Although elevated concentrations of ^{235}U and ^{238}U are present in West Lake, little data exist for these constituents from wells in the vicinity of

TABLE 18. Concentrations of ^{129}I from Wells Near West Lake

<u>Well Number</u>	<u>Zone Sampled</u>	<u>Date</u>	<u>Concentration (pCi/L)</u>
699-49-57	Unconfined	6/01/88	3.40E-01
699-49-57	Unconfined	3/27/89	6.94E-01
699-51-63	Unconfined	4/19/88	<-1.03E-01
699-55-50C	Unconfined	6/02/88	<2.79E-02
699-59-58	Unconfined	4/26/88	<3.10E-02
699-59-58	Unconfined	1/18/89	<5.61E-02
699-60-60	Unconfined	1/18/89	<-1.71E-02

aquifer. These data suggest a possible ^{99}Tc plume moving downgradient of the 200 Areas through the gap between Gable Butte and Gable Mountain. Elevated concentrations of ^{99}Tc in wells near West Lake suggest that ^{99}Tc in the ground water is derived principally from Hanford Site operations because it does not occur naturally. The presence of ^{99}Tc in West Lake also suggests a connection between the ground water and West Lake.

Tritium concentrations in West Lake have declined from approximately 1,000 pCi/L in 1984 to approximately 400 pCi/L in 1988. The ^3H concentration abruptly rose to approximately 700 pCi/L in the latter part of 1988. Tritium concentrations for unconfined aquifer wells 699-49-57, 699-55-50C, 699-59-58, and 699-60-57 indicate general downward trends since the early to mid-1970s (see Appendix C, Figure C.1). The concentrations in well 699-49-57 decreased from approximately 400,000 pCi/L in 1975 to approximately 1,500 pCi/L by 1989. Trends in ^3H concentrations in well 699-49-57 parallel those observed in West Lake between 1984 and 1989 with a delay of approximately one year. This indicates that a possible source of ^3H in West Lake may be the 200 Areas separations facilities, and that the travel time of movement from well 699-49-57 to West Lake is approximately one year. More data, however, are needed to support this hypothesis.

Other possible sources of ^3H in West Lake as a result of ground-water migration include Gable Mountain Pond (decommissioned in 1987 and no longer in existence; see Figure 4), BY Crib in the 200 East Area, and B Reactor along the Hanford Site's northern boundary (Gephart et al. 1976). Gable Mountain Pond received waste water that contained very low levels of contamination; consequently, ^3H contamination of the underlying unconfined aquifer has been minimal (Graham et al. 1984). The ^3H concentration in well 699-55-50C, located near Gable Mountain Pond, has generally been lower than 1,500 pCi/L since 1975 (see Appendix C, Figure C.1). Because of changes in ground-water flow direction since Gable Mountain Pond was deactivated, a possible source of ^3H may be from ground water beneath B Pond. Recent data indicate that ^3H concentrations beneath B Pond are as high as 79,500 pCi/L (Smith et al. 1989).

the lake. Data from wells 699-59-58 and 699-60-57 indicate uranium concentrations of less than 1 pCi/L for 1988 and 1989. The concentration of uranium in West Lake was reported to have been 526 mg/L (Gephart et al. 1976). Conversion of West Lake uranium activity data to a gravimetric value indicates a concentration range of 295 to 542 $\mu\text{g/L}$ (excludes the sample from station L9). An uncertainty exists about the difference between the 1976 value and those for the August 1989 samples.

Another observation regarding the distribution of uranium in West Lake involves the interpretation of the high concentrations of uranium in water reported from station L9. The L9 sample was equivalent to 16.5 mg/L, approximately 30 to 56 times greater than water samples collected from other areas of the pond. Moreover, uranium concentrations in soil (see Appendix A, Table A.6) and vegetation (see Appendix A, Table A.11) samples collected from station N6, closest to the L9 pool, also tended to have the highest concentrations of uranium isotopes compared to other samples collected in August 1989. The sediment sample collected from the L9 pool did not contain uranium in excess of the range of sediment uranium levels from the other eight sample stations in the lake (see Appendix A, Table A.5). These observations suggest that the area around the northern tip of West Lake contains higher concentrations of uranium than other areas in the lake and basin.

Isotopic analysis of water samples by MS did not detect ^{236}U . The presence of ^{236}U in West Lake water would indicate a uranium contribution from fuel reprocessing activities. Additionally, altered ratios of ^{235}U to ^{238}U would indicate either depleted or enriched uranium. Only water and sediment samples had reproducible values of ^{235}U , and in both cases, the $^{235}\text{U}/^{238}\text{U}$ mass ratios were less than the theoretical value calculated from AS data, but the ratios were not statistically different ($P < 0.05$). Mass ratios of $^{234}\text{U}/^{238}\text{U}$ were, for all analyses, significantly greater than the expected theoretical ratios. Collectively, these test results suggest that the isotopic distribution of uranium in the West Lake basin indicates the presence of depleted uranium; however, this analysis is hampered somewhat by the small number of samples involved and by the fact that, for vegetation and soil samples, the

levels of ^{235}U are very close to detection limits (see Appendix A, Tables A-6 and A-11). This compromises the interpretation of isotopic mass ratios calculated from AS data.

Historically, alpha and beta concentrations in West Lake have fluctuated. Water samples from West Lake for 1979 indicated an annual average total alpha activity of <500 pCi/L and a monthly maximum of 1,100 pCi/L, and an annual average total beta activity of 300 pCi/L and a monthly maximum of 1,900 pCi/L (Strait and Moore 1982; also see Appendix C, Figures C.3 and C.4). Emery and McShane (1978) reported comparable beta activity for 1975 through 1976; however, combined filterable (0.45 μm) and particulate alpha were lower than the 1979 data. Between 1973 and 1980, high concentrations of gross beta were found in well 699-49-57, located south of West Lake near the 200 East Area. Since 1984, concentrations of gross alpha and gross beta in West Lake (see Appendix C, Figure C.5) have been approximately one order of magnitude greater than concentrations for those constituents detected in nearby wells. It is believed that the gross alpha and gross beta in West Lake are the result of high concentrations of naturally occurring uranium (Jaquish and Mitchell 1988).

The presence of nitrate (as NO_3^-) in West Lake provides another possible link with ground water. Concentrations of NO_3^- in West Lake water (0.25 to <5 mg/L; see Table 1) are approximately a factor of 10 to 25 lower than values reported in ground water (see Appendix C, Figure C.6) but are considered high for natural lakes (Wetzel 1975). Elevated levels of NO_3^- have been attributed to unsubstantiated reports of past dumping of sewage in the basin (Emery and McShane 1978; Meinhardt and Frostenson 1979). However, it does not appear that the authors considered the contribution of ground-water to lake-water NO_3^- concentrations. Elevated levels of NO_3^- have been reported in well 699-49-57, located approximately 2.8 km south of West Lake. The NO_3^- concentrations in the lake are probably lower than for ground water sampled from the unconfined aquifer because of assimilation by phytoplankton and algae and subsequent denitrification to N_2 . Nitrogen would be given up to the atmosphere because of the shallow depth of the lake, high summer insolation, water stagnation, and high surface-to-volume ratio of 2.5 (Emery and McShane 1978). It should

be noted that phosphate ($\text{PO}_4\text{-P}$) falls below the detection limit of 1,000 $\mu\text{g/L}$ in ground water, but was two times that concentration in West Lake water in 1976 and almost ten times that level in 1989 (see Table 1). This observation indicates an increase in $\text{PO}_4\text{-P}$ concentrations in West Lake, but the data are insufficient to indicate historical dumping of sewage sludge in West Lake.

CONCLUSIONS

West Lake contains slightly elevated levels of several radionuclides generally associated with Hanford Site activities, worldwide weapons testing fallout, and natural sources. Concentrations of trace metals are elevated, but it is not clear if they are the result of Hanford Site activities or are simply the naturally elevated concentrations found in conjunction with the highly saline character of the basin. The data suggest a minor level of radioactive contamination for certain radionuclides (i.e., ^3H , ^{99}Tc , and ^{129}I) attributable to Hanford Site activities; however, the levels of basin contamination are low and are below action levels specified in waste management plans for sites contaminated by radioactivity (WHC 1988). West Lake and its surrounding saline basin is a unique habitat that offers an opportunity to conduct basic ecological research. Studies could be designed to investigate nutrient requirements and cycling in the rare and complex chemical environment of the basin for both rooted emergent vegetation, phytoplankton, attached algae, and terrestrial plant communities.

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APPENDIX A

CONCENTRATIONS OF RADIONUCLIDES IN ENVIRONMENTAL MEDIA COLLECTED FROM THE WEST LAKE BASIN

APPENDIX A

CONCENTRATIONS OF RADIONUCLIDES IN ENVIRONMENTAL MEDIA COLLECTED FROM THE WEST LAKE BASIN

This appendix contains data taken from analytical reports provided by United States Testing Company, Inc. of selected radionuclides in environmental media collected from the West Lake basin in August 1989 (Tables A.1 through A.12). The environmental media include ground water, surface water, sediment, soil, vegetation, and coot eggshells.

The data include the value of the count and two standard deviations of the count data. Data have been taken directly from the reports, and the following considerations apply to their evaluation. Individual values for samples are considered significant (i.e., above the limits of detection) when the value is positive and exceeds two standard deviations of the count data. The data were originally reported in scientific notation to three figures; however, three figures are reported here when the value is at least 0.100 pCi/g or pCi/L for a specific radionuclide. Values less than 0.001 pCi/g or pCi/L are reported as 0.000.

Minimum detectable concentrations for specific radionuclides have been reported in Jaquish and Bryce (1990) and are summarized in Table A.13.

REFERENCE

Jaquish, R. E., and R. W. Bryce, eds. 1990. **Hanford Site Environmental Report for Calendar Year 1989**. PNL-7346, Pacific Northwest Laboratory, Richland, Washington.

TABLE A.1 Concentrations (pCi/L) of Radionuclides in Ground-Water Monitoring Wells Near West Lake

<u>Well</u>	<u>Date</u>	<u>³H</u>	<u>⁶⁰Co</u>	<u>⁹⁰Sr</u>	<u>¹⁰⁶Ru</u>	<u>¹³⁷Cs</u>	<u>⁹⁹Tc</u>	<u>²³⁴U</u>	<u>²³⁵U</u>	<u>²³⁸U</u>
699-53-55A	4/6/87		4.87	-0.2	-99	4.91				
	7/8/87		5.36	0.185	-14.3	4				
	10/6/87		2.81	0.268	3.66	7.7				
	1/8/88		-3.04	0.017	-6.31	5.64				
	9/21/88		-0.188	0.506	-21.2	0.228				
	2/24/89		-0.408	0.357	16.8	1.38				
	8/22/89	147	-3.97	0.034	11.9	0.353	2.0	0.259	0.017	0.141
	8/22/89	324	-2.98	-0.112	3.13	-2.24	0.5	0.308	0.003	0.131
699-56-53	6/17/87	82								
	9/16/87	75								
	3/6/88	-29		-0.114			1 26			
	6/10/88			0.366						
	7/21/88	52		0.177			6 93			
	3/3/89	-21								
	3/28/89						-1 94			
	4/3/89			-0.259						
	8/22/89	64.7	-13.0	-0.126	-48.2	-2.76	1.43	-0.007	-0.003	0.004
	8/22/89	15.9	2.23	-0.202	12.6	-3.01	2.63			
699-59-58	1/30/87	951								
	4/26/87	709		-0.44						
	7/9/87	766		-0.30						
	12/21/87	652								
	3/6/88	751		0.009			5 31			
	4/26/88	800		0.178						
	7/19/88	530		-0.511			24 2			
	11/10/88	442		-0.582						
	1/18/89			0.098			18 1			
	4/3/89	894		0.089						
	8/22/89	839	8.5	-0.243	22.0	1.88	53.2	0.671	0.010	0.438
	8/22/89	949	3.51	-0.063	3.13	-6.08	55.2	0.609	0.010	0.467

TABLE A.1. (contd)

<u>Well</u>	<u>Date</u>	<u>³H</u>	<u>⁶⁰Co</u>		<u>¹⁰⁶Ru</u>	<u>¹³⁷Cs</u>	<u>⁹⁹Tc</u>	<u>²³⁴U</u>	<u>²³⁵U</u>	<u>²³⁸U</u>
699-60-57	2/4/87	412								
	4/26/87	515								
	8/23/87	616								
	11/8/87	614								
	2/22/88	495								
	4/26/88	505								
	7/19/88	479								
	11/15/88	227								
	4/3/89	483								
	8/22/89	327	3.59	-0.038	2.97	1.77	-0.082	0.055	-0.002	0.060
	8/22/89	488	-2.67	-0.145	17.6	3.2	0.872	0.0850	-0.007	0.075

NOTE: Blanks indicate no analysis.

TABLE A.2. Concentrations (pCi/L) of Beta-Emitting Radionuclides in Water Collected from West Lake and Adjacent Pools

<u>Sample Site</u>	<u>^3H</u>	<u>± 2 Standard Deviations</u>	<u>^{90}Sr</u>	<u>± 2 Standard Deviations</u>	<u>^{99}Tc</u>	<u>± 2 Standard Deviations</u>	<u>^{106}Ru</u>	<u>± 2 Standard Deviations</u>
L1	449	247	1.91	0.551	70.8	12.9	-56.1	73.1
L2	468	249	1.93	0.552	52.0	11.3	16.7	63.6
L3	303	239	1.92	0.562	86.9	14.7	16.7	72.7
L4	512	251	1.85	0.538	48.4	10.9	79.7	73.1
L5	419	246	1.77	0.627	10.7	17.0	28.2	68.5
L6	386	244	1.38	0.546	53.9	11.3	-46.9	85.5
L7	255	237	1.21	0.497	41.4	98.6	10.6	75.5
L8	366	242	1.39	0.525	20.9	81.6	-34.0	77.8
L9	287	137	1.27	2.78	11.7	18.0	2.72	83.0

TABLE A.3. Concentrations (pCi/L) of Uranium Isotopes in West Lake Water

<u>Sample Site</u>	<u>^{234}U</u>	<u>± 2 Standard Deviations</u>	<u>^{235}U</u>	<u>± 2 Standard Deviations</u>	<u>^{238}U</u>	<u>± 2 Standard Deviations</u>
L1	167	16.7	5.74	0.921	157	15.6
L2	191	19.6	9.56	1.43	179	18.4
L3	184	18.2	7.37	1.08	167	16.6
L4	157	15.5	5.56	0.874	146	14.4
L5	176	17.8	6.62	1.05	157	15.9
L6	107	10.7	4.18	0.728	977	9.83
L7	160	15.8	6.17	0.949	146	14.5
L8	184	19.0	6.56	1.12	169	17.6
L9(a)	5,630	488	376	37.8	5,500	488

(a) Sample contained large amounts of suspended sediment.

TABLE A.4. Concentrations (pCi/g) of Radionuclides in Sediments Collected from West Lake

Sample Site	⁴⁰ K	±2 Standard Deviations	⁶⁰ Co	±2 Standard Deviations	⁹⁰ Sr	±2 Standard Deviations	⁹⁵ Zr ⁹⁵ Nb	±2 Standard Deviations	¹⁰⁶ Ru	±2 Standard Deviations	¹³⁴ Cs	±2 Standard Deviations
L1	16.1	1.8	0.009	0.017	0.829	0.164	-0.033	0.047	-0.056	0.169	-0.048	0.020
L2	20.4	2.22	0.009	0.018	0.873	0.165	0.097	0.043	-0.096	0.168	-0.068	0.023
L3	17.9	1.96	0.003	0.018	0.258	0.051	-0.008	0.039	0.038	0.153	-0.043	0.018
L4	17.8	1.98	0.004	0.023	1.570	0.304	-0.046	0.048	0.055	0.171	-0.025	0.020
L5	18.9	2.09	-0.003	0.02	0.144	0.030	-0.019	0.047	0.023	0.150	0.007	0.015
L6	18.1	2.04	0.001	0.022	0.050	0.012	-0.030	0.049	-0.017	0.177	-0.009	0.016
L7	17.5	1.91	0.001	0.014	0.220	0.042	-0.016	0.036	-0.054	0.126	-0.009	0.013
L8	21.9	2.42	0.003	0.023	0.239	0.047	0.031	0.057	-0.060	0.177	-0.108	0.026
L9	20.0	2.19	-0.007	0.021	0.266	0.051	-0.032	0.052	0.166	0.161	-0.089	0.022

Sample Site	¹³⁷ Cs	±2 Standard Deviations	¹⁵⁴ Eu	±2 Standard Deviations	¹⁵⁵ Eu	±2 Standard Deviations	²¹² Pb	±2 Standard Deviations	²¹⁴ Pb	±2 Standard Deviations
L1	2.44	0.25.256	-0.029	0.064	0.016	0.061	0.761	0.089	0.557	0.080
L2	2.45	0.25.257	-0.041	0.062	0.044	0.062	0.849	0.098	0.612	0.083
L3	0.958	0.10.108	-0.051	0.067	0.050	0.055	0.574	0.073	0.521	0.058
L4	2.11	0.22.224	-0.066	0.066	0.045	0.074	0.804	0.095	0.529	0.083
L5	0.628	0.07.079	-0.024	0.069	0.019	0.051	0.733	0.087	0.596	0.084
L6	0.491	0.06.065	0.082	0.066	0.025	0.075	0.768	0.092	0.490	0.080
L7	0.576	0.06.069	-0.021	0.050	0.038	0.045	0.700	0.080	0.615	0.079
L8	0.772	0.09.095	-0.035	0.088	-0.095	0.067	0.859	0.105	0.743	0.101
L9	0.579	0.07.072	-0.014	0.068	0.085	0.059	0.855	0.098	0.680	0.090

TABLE A.5. Concentrations (pCi/g) of Uranium Isotopes in West Lake Sediments and Salt Deposits

<u>Sample Site</u>	<u>^{234}U</u>	<u>± 2 Standard Deviations</u>	<u>^{235}U</u>	<u>^{238}U</u>	<u>± 2 Standard Deviations</u>
L1	2.58	0.283	0.860	0.029	5.13
L2	3.29	0.361	0.121	0.038	3.13
L3	1.21	0.159	0.042	0.022	1.24
L4	1.74	0.208	0.063	0.026	1.70
L5	0.868	0.157	0.025 ^(a)	0.029	0.928
L6	0.213	0.068	0.003 ^(a)	0.015	0.201
L7	0.853	0.123	0.034	0.019	0.921
L8	1.30	0.177	0.047	0.025	1.21
L9	1.82	0.208	0.069	0.025	1.94
Salt Deposit R-1	17.4	1.70	0.568	0.092	16.4
Salt Deposit R-2	6.61	0.722	0.247	0.064	6.23

(a) Results by alpha spectroscopy are less than overall error of ± 2 standard deviations.

TABLE A.6. Concentrations (pCi/g by low-energy photon analysis) of Uranium Isotopes in West Lake Basin Soils

<u>Sample Site</u>	<u>^{235}U</u>	<u>± 2 Standard Deviations</u>	<u>^{238}U</u>	<u>± 2 Standard Deviations</u>
S1	0.043 ^(a)	0.066	0.390	0.224
S2	0.011 ^(a)	0.091	0.787	0.268
S3	0.061	0.061	0.566	0.210
S4	0.122	0.057	0.702	0.212
S5	0.075	0.060	1.91	0.350
N1	0.130	0.064	0.926	0.200
N2	0.036 ^(a)	0.089	0.726	0.294
N3	0.019 ^(a)	0.065	0.535	0.317
N4	5.10 ^(a)	0.067	1.12	0.244
N5	8.20	0.062	0.628	0.185
N6	1.49	0.089	1.79	0.358

(a) Results are less than overall error of ± 2 standard deviations.

TABLE A.7. Concentrations (pCi/g-dry) of Radionuclides in Soils Collected from the North Transect, West Lake Basin

Sample Site	^{40}K	± 2 Standard Deviations	^{60}Co	± 2 Standard Deviations	^{90}Sr	± 2 Standard Deviations	^{95}Zr ^{95}Nb	± 2 Standard Deviations	^{106}Ru	± 2 Standard Deviations	^{134}Cs	± 2 Standard Deviations
N1	16.4	1.83	-0.01	0.021	0.13	0.028	0.013	0.043	0.155	0.148	-0.008	0.022
N2	16.9	1.92	0.013	0.021	0.331	0.063	-0.065	0.051	-0.114	0.178	-0.016	0.018
N3	16.9	1.88	0.01	0.021	0.155	0.031	0.004	0.042	-0.102	0.165	-0.091	0.022
N4	18.3	2.07	-0.023	0.023	0.35	0.066	-0.011	0.053	-0.127	0.209	-0.003	0.019
N5	18.0	2.01	-0.01	0.021	0.326	0.066	-0.018	0.044	0.002	0.143	-0.049	0.019
N6	16.9	1.85	0.008	0.015	0.141	0.029	-0.026	0.036	0.009	0.123	-0.012	0.013

Sample Site	^{137}Cs	± 2 Standard Deviations	^{154}Eu	± 2 Standard Deviations	^{155}Eu	± 2 Standard Deviations	^{212}Pb	± 2 Standard Deviations	^{214}Pb	± 2 Standard Deviations
N1	0.928	0.106	-0.075	0.064	0.11	0.065	0.658	0.079	0.62	0.085
N2	1.06	0.122	0.052	0.074	0.005	0.077	0.705	0.087	0.526	0.081
N3	1.1	0.123	-0.051	0.065	-0.049	0.066	0.701	0.084	0.605	0.083
N4	1.34	0.152	0.02	0.071	0.12	0.088	0.696	0.088	0.513	0.085
N5	0.94	0.107	0.031	0.064	0.004	0.059	0.713	0.084	0.528	0.078
N6	57.4	0.069	-0.004	0.05	0.063	0.044	0.664	0.076	0.584	0.076

TABLE A.8. Concentrations (pCi/g-dry) of Radionuclides in Soils Collected from the South Transect, West Lake Basin

Sample Site	⁴⁰ K	±2 Standard Deviations	⁶⁰ Co	±2 Standard Deviations	⁹⁰ Sr	±2 Standard Deviations	⁹⁵ Zr ⁹⁵ Nb	±2 Standard Deviations	¹⁰⁶ Ru	±2 Standard Deviations	¹³⁴ Cs	±2 Standard Deviations
S1	16.5	1.84	-0.016	0.017	0.109	0.024	-0.034	0.033	0.058	0.117	0.005	0.013
S2	16.6	1.84	0.011	0.017	0.36	0.07	-0.018	0.042	0.061	0.135	-0.054	0.020
S3	16.9	1.86	-0.032	0.014	0.173	0.036	-0.041	0.036	0.057	0.123	-0.007	0.013
S4	16.3	1.91	0.023	0.023	0.136	0.029	-0.042	0.05	0.092	0.171	-0.006	0.023
S5	14.1	1.56	-0.018	0.016	0.671	0.13	-0.017	0.034	0.023	0.123	0.044	0.016

Sample Site	¹³⁷ Cs	±2 Standard Deviations	¹⁵⁴ Eu	±2 Standard Deviations	¹⁵⁵ Eu	±2 Standard Deviations	²¹² Pb	±2 Standard Deviations	²¹⁴ Pb	±2 Standard Deviations
S1	1.17	0.129	0.066	0.058	0.007	0.056	0.712	0.083	0.569	0.079
S2	1.25	0.137	0.1	0.054	0.039	0.053	0.707	0.082	0.556	0.076
S3	0.502	0.623	-0.041	0.054	0.033	0.045	0.603	0.073	0.514	0.073
S4	0.229	0.426	-0.003	0.08	-0.019	0.064	0.692	0.086	0.684	0.097
S5	1.52	0.16	-0.028	0.052	0.075	0.05	0.818	0.091	0.588	0.076

TABLE A.9. Concentrations (pCi/g) of Radionuclides in Vegetation Collected from the North Transect, West Lake Basin

Sample Site	⁷ Be	±2 Standard Deviations	⁴⁰ K	±2 Standard Deviations	⁶⁰ Co	±2 Standard Deviations	⁹⁰ Sr	±2 Standard Deviations	⁹⁵ Zr ⁹⁵ Nb	±2 Standard Deviations	¹³⁵ La	±2 Standard Deviations
N1	5.06	1.2	11	2.5	-7.930	0.104	0.419	0.085	-0.051	0.243	-0.674	0.836
N2	3.04	0.739	6.18	1.37	-0.032	0.048	0.173	0.035	-0.006	0.107	0.178	0.391
N3	2.98	0.716	7.11	1.68	-0.019	0.051	0.018	0.008	0.011	0.12	-0.16	0.415
N4	1.63	0.543	12.8	1.92	-0.029	0.045	0.024	0.01	-0.031	0.115	-0.393	0.341
N5	2.77	0.714	10.2	1.97	0.027	0.061	0.051	0.014	0.059	0.144	0.464	0.397
N6	4.04	0.871	6.34	1.21	0.031	0.047	0.028	0.009	-0.02	0.116	0.426	0.426
Sample Site	¹³⁴ Cs	±2 Standard Deviations	¹³⁷ Cs	±2 Standard Deviations	¹⁵⁴ Eu	±2 Standard Deviations	¹⁵⁵ Eu	±2 Standard Deviations	²¹² Pb	±2 Standard Deviations	²¹⁴ Pb	±2 Standard Deviations
N1	-0.1	0.094	0.062	0.097	-0.135	0.266	-0.015	0.2	0.174	0.164	NR	---
N2	-0.012	0.042	0.056	0.042	-0.058	0.127	-0.01	0.107	0.113	0.085	NR	---
N3	-0.029	0.048	0.031	0.046	0.086	0.142	0.03	0.113	0.004	0.089	NR	---
N4	-0.008	0.044	-0.039	0.045	0.063	0.137	0.095	0.111	0.038	0.082	NR	---
N5	0.059	0.052	0.135	0.058	-0.191	0.192	0.022	0.146	0.221	0.094	NR	---
N6	-0.008	0.047	0.046	0.049	-0.07	0.153	0.024	0.111	0.001	0.074	8.102	0.096

NR = Not reported.

TABLE A.10. Concentrations (pCi/g) of Radionuclides in Vegetation Collected from the South Transect, West Lake Basin

Sample Site	⁷ Be	±2 Standard Deviations	⁴⁰ K	±2 Standard Deviations	⁶⁰ Co	±2 Standard Deviations	⁹⁰ Sr	±2 Standard Deviations	⁹⁵ Zr ⁹⁵ Nb	±2 Standard Deviations	¹⁰⁶ Ru	±2 Standard Deviations
S1	4.02	0.897	8.34	1.51	-0.021	0.058	0.079	0.02	-0.173	0.125	0.099	0.446
S2	4.95	0.969	6.67	1.43	0.045	0.053	0.245	0.051	0.125	0.132	-0.192	0.454
S3	5.86	1.12	6.58	1.68	0.092	0.059	0.061	0.018	-0.102	0.158	0.194	0.544
S4	4.95	0.98	3.75	1.42	0.01	0.053	0.503	0.1	0.023	0.127	-0.363	0.457
S5	0.635	1.3	6.16	3.32	-0.014	0.124	0.119	0.035	0.144	0.281	0.726	1.16

Sample Site	¹³⁴ Cs	±2 Standard Deviations	¹³⁷ Cs	±2 Standard Deviations	¹⁵⁴ Eu	±2 Standard Deviations	¹⁵⁵ Eu	±2 Standard Deviations	²¹² Pb	±2 Standard Deviations
S1	-0.035	0.05	0.05	0.053	-0.096	0.152	0.08	0.143	0.135	0.101
S2	-0.002	0.05	0.096	0.061	-0.09	0.163	-0.007	0.163	0.097	0.11
S3	0.049	0.063	0.267	0.081	-0.156	0.186	-0.074	0.147	0.133	0.11
S4	-0.041	0.056	0.058	0.052	-0.022	0.156	0.029	0.141	0.495	0.129
S5	-0.157	0.129	0.212	0.156	0.218	0.349	0.087	0.308	0.353	0.194

A.1

TABLE A.11. Concentrations (pCi/g) of Uranium Isotopes in West Lake Basin Vegetation

<u>Sample Site</u>	<u>^{234}U</u>	<u>2 2 Standard Deviations</u>	<u>^{235}U</u>	<u>± 2 Standard Deviations</u>	<u>^{238}U</u>	<u>2 2 Standard Deviations</u>
S1	0.016	0.005	0.001 ^(a)	0.001	0.015	0.004
S2	0.043	0.007	0.001	0.001	0.044	0.008
S3	0.076	0.011	0.002	0.001	0.06	0.010
S4	0.076	0.012	0.001 ^(a)	0.002	0.073	0.011
S5	0.554	0.077	0.017	0.007	0.505	0.071
N1	0.043	0.009	0.002 ^(a)	0.002	0.036	0.008
N2	0.038	0.008	0.001 ^(a)	0.001	0.029	0.007
N3	0.021	0.005	0.0003 ^(a)	0.001	0.019	0.005
N4	0.039	0.008	-0.0003 ^(a)	0.001	0.037	0.008
N5	1.19	0.124	0.040	0.008	1.14	0.119
N6	1.79	0.176	0.068	0.011	1.68	0.166

(a) Results are less than overall error of 22 standard deviations.

TABLE A.12. Concentrations (pCi/g) of Selected Radionuclides in Coot Eggshells Collected from West Lake (WL) and Morgan Lake (ML)

<u>Sample Number</u>	<u>^{40}K</u>	<u>± 2 Standard Deviations</u>	<u>^{50}Co</u>	<u>± 2 Standard Deviations</u>	<u>^{55}Zn</u>	<u>± 2 Standard Deviations</u>	<u>^{90}Sr</u>	<u>± 2 Standard Deviations</u>
WL No. 1	2.04	2.37	-0.028	0.137	0.087	0.519	4.66	1.05
WL No. 2	8.73	3.48	-0.075	0.303	-0.628	0.889	5.59	1.02
ML No. 3	7.11	6.31	-0.244	0.285	-0.606	1.15	0.1	0.034
ML No. 4	18.3	3.69	0.066	0.163	-0.575	0.707	0.064	0.038
<u>Sample Number</u>	<u>^{137}Cs</u>	<u>± 2 Standard Deviations</u>	<u>^{234}U</u>	<u>± 2 Standard Deviations</u>	<u>^{235}U</u>	<u>± 2 Standard Deviations</u>	<u>^{238}U</u>	<u>± 2 Standard Deviations</u>
WL No. 1	-0.005	0.118	0.004	0.003	0.000	0.001	0.003	0.002
WL No. 2	-0.025	0.223	0.013	0.004	0.001	0.001	0.008	0.003
ML No. 3	-0.062	0.269	0.001	0.001	0.0002	0.001	0.002	0.001
ML No. 4	-0.046	0.132	0.005	0.035	0.004	0.003	0.004	0.003

TABLE A.13. Minimum Detectable Concentrations for Radionuclides in Environmental Samples^(a)

<u>Radionuclide</u>	<u>Water (pCi/L)</u>	<u>Sediment (pCi/g)</u>	<u>Soil (pCi/g)</u>	<u>Vegetation (pCi/g)</u>
³ H	300	NA	NA	NA
⁷ Be	NA	NA	NA	0.23
⁴⁰ K	140	0.35	0.35	0.53
⁶⁰ Co	9	0.02	0.02	0.03
⁶⁵ Zn	17	0.04	0.04	NA
⁹⁰ Sr	0.6	0.005	0.005	0.005
⁹⁵ Zr ⁹⁵ Nb	14	0.03	0.03	0.05
⁹⁹ Tc	15.0	NA	NA	NA
¹⁰⁶ Ru	69	0.017	0.017	0.26
¹³⁴ Cs	NA	0.02	0.02	0.03
¹³⁷ Cs	8	0.02	0.02	0.03
¹⁵⁴ Eu	22	0.05	0.05	0.08
¹⁵⁵ Eu	19	0.05	0.05	0.07
²¹² Pb(b)	NA	0.02	0.02	0.03
²¹⁴ Pb(b)	NA	0.02	0.02	0.03
²³⁴ U	0.6	NA	NA	0.1
²³⁵ U	0.6	1.0 ^(c)	1.0 ^(c)	0.1
²³⁸ U	0.6	1.0 ^(c)	1.0 ^(c)	0.1

(a) Analytical detection concentrations taken from contract specifications and Jaquish and Bryce (1990).

(b) Based on reported ¹³⁷Cs detection limit in Jaquish and Bryce (1990).

(c) Soil and sediment analyzed by low-energy photon detection (LEPD) system.

NA = Not analyzed.

APPENDIX B

ORGANIC CONTAMINANTS IN WEST LAKE WATER

APPENDIX B

ORGANIC CONTAMINANTS IN WEST LAKE WATER

This appendix contains data from analytical reports provided by United States Testing Company, Inc. on surface-water samples collected from West Lake in August 1989. The organic constituents summarized in this appendix include volatile and semivolatile organic compounds, nonvolatile organic compounds, herbicides, pesticides, polychlorinated biphenyls, and thiourea compounds.

B.1

TABLE B.1. Volatile and Semivolatile Organic Compounds Analyzed in West Lake Water

<u>Compound</u>	<u>Water (mg/L) (a)</u>	<u>Compound</u>	<u>Water (mg/L)</u>
Carbon tetrachloride	<5	1,2-Dichlorobenzene	<12
Benzene	<5	1,3-Dichlorobenzene	<12
Methyl ethyl ketone	<10	Hexachlorobenzene	<12
Toluene	<5	Pentachlorobenzene	<12
1,1,1-Trichloroethane	<5	Pentachlorophenol	160
1,1,2-Trichloroethane	<5	1,2,4,5-Tetrachlorobenzene	<12
Trichloroethylene	<5	1,2,4-Trichlorobenzene	<12
Tetrachloroethylene	<5	Hexachlorophene	26
Xylene (o,p)	<5	Naphthalene	<12
Chloroform	<5	1,2,3-Trichlorobenzene	<12
1,1-Dichloroethane	<5	Phenol	<12
1,2-Dichloroethane	<5	1,3,5-Trichlorobenzene	<12
Trans-1,2-Dichloroethylene	<5	1,2,3,4-Tetrachlorobenzene	<12
Methylene chloride	<5	1,2,3,5-Tetrachlorobenzene	<12
Vinyl chloride	<10	Kerosene	<12
Xylene (M)	<5	Strychnine	<12
Methyl isobutyl ketone	<10	Maleic hydrazide	<12
Acetone	<10	Nicotinic acid	<12
Tetrahydrofuran	<10	Tributylphosphate	<12
1-4-Dichlorobenzene	<5	Chlorobenzene	<12
Cresol	<12		

(a) The less than (<) sign indicates the reported detection limit

TABLE B.2. Nonvolatile Organic Compounds Analyzed in West Lake Water

<u>Compound</u>	<u>Water (mg/L) (a)</u>
Paraldehyde	<10
Acrylamide	<10
Allyl alcohol	<10
3-Chloropropionitrile	<10
Ethyl carbamate	<10
Ethyl cyanide	<10
Isobutyl alcohol	<10
n-Propylamine	<10
2-Propyn-1-OL	<10
1-Butanol	<10
Ethanol	<10
Monobutyl phosphate	<10
Di butyl phosphate	<10
Ethylene glycol	<10
1-Propanol	<10
3-Butyn-1-OL	<10

(a) The less than (<) sign indicates the reported detection limit.

TABLE B.3. Herbicides and Pesticides in West Lake Water

<u>Compound</u>	<u>Water (mg/L) (a)</u>	<u>Compound</u>	<u>Water (mg/L)</u>
2,4-D	<2.0	Kepone	<1.0
2,4,5-TP (Silvex)	<2.0	Dieldrin	<0.1
2,4,5-T	<2.0	Aldrin	<0.1
Endrin	<0.1	Chlordane	<1.0
Methoxychlor	<3.0	Endosulfan I	<0.1
Toxaphene	<1.0	Endosulfan II	<0.1
Alpha BHC	<0.1	Endo. Sulfate	<0.5
Beta BHC	<0.1	Chlorobenzilate	<300
Gamma BHC	<0.1	Tetraethyl pyrophosphate	<2.0
Delta BHC	<0.1	Carbophenothion	<2.0
4,4'-DDD	<0.1	Disulfoton	<2.0
4,4'-DDE	<0.1	Dimethoate	<2.0
4,4'-DDT	<0.1	Methyl parathion	<2.0
Heptachlor	<0.1	Parathion	<2.0
Heptepoxide	<0.1	Phorate	<2.0

(a) The less than (<) sign indicates the reported detection limit.

TABLE B.4. Polychlorinated Biphenyl (PCB) Congeners Analyzed in West Lake Water

<u>Compounds</u>	<u>Water (mg/L) (a)</u>
Arochlor-1016	<1
Arochlor-1221	<1
Arochlor-1232	<1
Arochlor-1242	<1
Arochlor-1248	<1
Arochlor-1254	<1
Arochlor-1260	<1

(a) The less than (<) sign indicates the reported detection limit.

TABLE B.5. Enhanced Thiourea Compounds in West Lake Water

<u>Compound</u>	<u>Water (mg/L) (a)</u>
Thiourea	<200
1-Acetyl-2-thiourea	<200
1-(0-chlorophenyl)-thiourea	<200
Diethylstilbestrol	<200
Ethylene thiourea	<200
1-Naphthyl-2-thiourea	<200
N-phenyl thiourea	<500

(a) The less than (<) sign indicates the reported detection limit.

APPENDIX C

HISTORICAL LEVELS OF CONTAMINANTS IN WEST LAKE AND GROUND WATER

APPENDIX C

HISTORICAL LEVELS OF CONTAMINANTS IN WEST LAKE AND GROUND WATER

This appendix contains a series of figures generated from the Hanford Ground Water Data Base (HGWDB). These figures **show** trends in the historical concentrations of contaminants in the ground-water samples collected from wells located in the vicinity of West Lake.

FIGURE C.1. Historical Levels of ^3H on the Hanford Site in Selected Wells

FIGURE C.2. Historical Levels of ^{90}Sr on the Hanford Site in Selected Wells

FIGURE C.3. Historical Levels of Total Alpha on the Hanford Site in Selected Wells

FIGURE C.4 Historical Levels of Total Beta on the Hanford Site in Selected Wells

FIGURE C.5. Historical Levels of Gross Alpha and Gross Beta

FIGURE C.6. Historical Levels of Nitrate (as NO₃⁻) on the Hanford Site in Selected Wells

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