Radionuclides and Inorganics in Surface Water and Sediments at Selected Reservoirs

Introduction

As part of the WIPP EM project, surface water and sediments are routinely sampled from three regional reservoirs situated on the Pecos River. Brantley Lake and Red Bluff Reservoir were selected for sampling because they are impoundments located "upstream" and "downstream", respectively, relative to surface and ground water flows from the area immediately surrounding the WIPP site (Figs. 21 and 22). Both reservoirs support a warm-water fishery and are used for irrigation, livestock watering, wildlife habitat and recreation. Lake Carlsbad is an impounded section of the Pecos River within the city of Carlsbad (Fig. 23) that is used extensively by the local population for recreational warm-water fishing, boating and swimming.

In 1997, a pilot study of the surface water and sediments in Brantley Lake was conducted, in which 15 sediment and three surface water samples were collected during March and April and three additional water samples in September. A summary of the sample analyses was included in the 1997 CEMRC Report. In 1998, 24 sediment and 17 surface water samples were collected from Brantley Lake, Lake Carlsbad and Red Bluff Reservoir. These included 12 sediment samples and 11 surface water samples collected during January-April and the remaining samples (12 sediment and 6 surface water) collected during August-October. The results of actinide, elemental, inorganic and selected organic analyses of the first set of samples collected in 1998 were reported in the 1998 CEMRC Report. In 1999, six surface water and 12 sediment samples were collected from the three reservoirs during June and July and again in May and June of 2000.

Analyses reported herein summarize the baseline results for radiological constituents in regional surface water and results from the first monitoring phase samples collected in 1999 and 2000. A summary of baseline and monitoring phase measurements of gamma-emitting radionuclides in sediments is also presented. The baseline summary for inorganic analyses is updated to include the latest surface water and sediment measurements.

Results from monitoring phase radiological analyses of alpha-emitting radionuclides in sediments collected during 1999 and 2000 are scheduled for completion and posting on the CEMRC web site in February 2001.

Methods

Sediment and surface water samples were collected during May-June 2000 from previously selected sites within each reservoir. Four site locations at each lake were identified using sonar and a combination of triangulation to known shoreline locations and GPS coordinates established during the 1998 and 1999 sampling seasons. These locations fall within the deep basins of each reservoir (Figs. 21, 22, and 23). Deep basins were chosen for sampling to minimize the disturbance and particle mixing effects of current and wave action that occur at shallower depths. Also, many of the analytes of interest tend to concentrate in the fine sediments that settle in the deep reservoir basins; thus, measurements from these areas would typically represent the highest levels that might be expected for a given reservoir.

Sediments were collected using an Eckman dredge. The thickness of the sediment collected ranged from 5 to 10 cm. Excess water was decanted from the sediment. Approximately 5 L of sediment was sealed in a pre-cleaned plastic bucket in the field and transported to CEMRC for preparation prior to analyses.

In the laboratory, the sediment samples were air-dried, pulverized to pass a 2-mm sieve, homogenized and split into aliquots for radiochemical, inorganic and particle-size analyses. Samples destined for radiochemical analyses were dried at 105° for 24 hours and pulverized in a jar mill prior to analysis. Particle-size analysis was conducted using the

pipette method (Gee, G. W. and J. W. Bauder, 1986, Particle-size Analysis. In Klute, A. (ed.), *Methods of Soil Analysis. Part I. Physical and Mineralogical Methods-Agronomy Monograph No. 9.* American Society of Agronomy, Madison, WI).

Surface water was collected at one location within each reservoir in 1999 and 2000. The surface water samples were collected in the same general area as the sediment samples. At each sampling location, one sample was collected from the surface (~ 0.5 to 1 m depth) and a second sample from approximately 0.5 to 1 m above the sediment bed.

In the laboratory, surface water samples collected for radiological analyses were vacuum-filtered to 0.2 μm and acidified with HNO_3 to a pH < 2. A 3-L aliquot was removed for analysis of alpha and gamma-emitting radionuclides. Alpha-emitting radionuclides analyzed in surface water and sediment samples included ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, and ^{238}U. Gamma-emitting radionuclides included ^{228}Ac, ^{241}Am ^{7}Be, ^{212}Bi, ^{213}Bi, ^{214}Bi, ^{144}Ce, ^{249}Cf, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{40}K, ^{233}Pa, ^{234m}Pa, ^{212}Pb, ^{214}Pb, ^{106}Rh, ^{125}Sb, and ^{208}Tl.

Surface water samples collected for elemental analyses (1-L each) were prepared according to the applicable EPA standard methods for the instrumentation used. Inorganic analyses were determined by IC, ICP-MS and AAS, with methods described elsewhere in this report. Inorganic analytes included Ag, Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Er, Eu, Fe, Gd, Hg, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, Pb, Pr, Sb, Sc, Se, Sm, Sn, Sr, Th, Ti, Tl, U, V, Zn, chloride, fluoride, nitrate, phosphate and sulfate.

Results and Discussion

Comparison of Baseline and Monitoring Phase Radiological Analyses of Surface Water

Activity concentrations measured for ^{241}Am, ^{238}Pu, and $^{239,\ 240}$Pu were below the respective MDCs for each analyte in all filtered surface water samples collected in 1998, 1999 and 2000 from all three reservoirs. MDC ranges for CEMRC analyses were 0.049-0.105 mBq L^{-1} for ^{241}Am, 0.047-0.239 mBq L^{-1} for ^{238}Pu, and 0.030-0.168 mBq L^{-1} for ^{239,240}Pu. Unfiltered surface water samples collected in Brantley Lake and Red Bluff Reservoir in 1998 were analyzed by Los Alamos National Laboratory for ^{239}Pu using thermal ionization mass spectroscopy (TIMS). ^{239}Pu was not detected at MDC's of 1.3 μBq L^{-1} for the Brantley Lake sample and 2.2 μBq L^{-1} for the Red Bluff Reservoir sample.

In comparison, a detectable quantity of ^{241}Am (2.56 mBq L^{-1}) was reported by Westinghouse Waste Isolation Division (WID) in a surface water sample having a high level of suspended sediment that was collected from the Pecos River near Artesia in 1997 (approximately 65 km northwest of WIPP) (1998, *Waste Isolation Pilot Plant Annual Site Environmental Report Calendar Year 1997*, DOE/WIPP 98-2225). A higher ^{241}Am value of 3.05 mBq L^{-1} was reported for a sample collected from the Pecos River near Carlsbad during 1993-1995 by EEG (Kenny et al., 1998, *Preoperational Radiation Surveillance of the WIPP Project by EEG during 1993 through 1995*, EEG-67).

A detectable quantity of ^{238}Pu was reported by WID for a surface water sample collected from a stock tank approximately 16 km southwest of the WIPP in 1998 (1.07 mBq L^{-1}) (1999, *Waste Isolation Pilot Plant Site Environmental Report for 1998*, DOE/WIPP 99-2225). The same sample contained an activity concentration for ^{241}Am of 1.66 mBq L^{-1}. It was noted in the WID report that this sample had a high level of suspended sediment. In contrast to CEMRC and EEG sampling procedures, WID did not filter surface water samples. The inclusion of suspended sediment could possibly be a source of the ^{241}Am and ^{238}Pu occasionally detected in WID samples, but this does not explain the ^{241}Am observation by EEG (Kenny et al., *op. cit.*). ^{241}Am and ^{238}Pu were not detected in surface water samples collected by WID in 1999 (2000, *Waste Isolation Pilot Plant 1999 Site Environmental Report*, DOE/WIPP 00-2225). MDCs were not presented for the cited ^{241}Am values reported by EEG, and MDCs were only presented for the most recent ^{241}Am and ^{238}Pu values

reported by WID. However, the observed values for both radioisotopes are at least 20 times higher than MDCs achieved for surface water samples analyzed by CEMRC, so any similar activity concentrations in CEMRC samples would have been easily detectable.

Maximum activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 12) increased in the monitoring phase ($N \leq 4$) relative to the baseline phase ($N \leq 2$) for samples collected from Brantley Lake and Lake Carlsbad, but a similar trend was not apparent in the Red Bluff samples. The activity concentration ranges for the same isotopes across lakes, by year (Fig. 24) ($N \leq 6$), showed no significant difference between baseline and monitoring phases, considering the 95% confidence intervals of the radioanalytical uncertainty. The lower activity concentrations (minimum values) measured for the baseline data may be the result of prolonged holding times for the baseline samples prior to analyses, during which adsorption of analytes to container walls may have occurred.

Activity concentrations reported by WID in surface waters for ^{234}U from 1997-1999 ranged from < MDC to 274 mBq L^{-1} (WID, 1997, *op. cit.*; WID, 1998, *op. cit.*; WID, 1999, *op. cit.*). A similar range for ^{234}U activity concentrations was reported by CEMRC for surface water samples from 1998-2000 ranging from 70 to 214 mBq L^{-1}. The upper ranges of values reported by CEMRC for ^{235}U and ^{238}U were also comparable to upper ranges reported for these analytes by WID. EEG did not include uranium radioisotopes among analytes measured in surface water samples collected during 1993-1999 (Kenny et al., 1998, *op. cit.*; Kenny et al., 1999, *Preoperational Radiation Surveillance of the WIPP Project by EEG from 1996-1998*, EEG-73; Gray et al., 2000, *Operational Radiation Surveillance of the WIPP Project by EEG during 1999*, EEG-79).

^{228}Th was detected in all surface water samples collected from 1998-2000. However, a positive bias is present in the reported ^{228}Th activity concentrations that results from the addition of a ^{232}U tracer during analyses. ^{232}Th was detected only in samples from Red Bluff Reservoir during the baseline phase and in samples from Brantley Lake and Red Bluff Reservoir during the monitoring phase.

For surface water samples collected during May and June of 2000, ^{40}K was the only gamma-emitting radionuclide determined at activity concentrations above MDC, and it was only detected in samples from Red Bluff Reservoir (1.22–1.26 Bq L^{-1}). These levels were not significantly different from those determined in samples collected in 1998.

Comparison of Gamma-emitting Radionuclides in Baseline and Monitoring Phase Sediment Samples

Sediment samples collected from three regional reservoirs during 1998-2000 were analyzed by gamma spectroscopy for ^{228}Ac, ^{241}Am, ^{7}Be, ^{212}Bi, ^{213}Bi, ^{214}Bi, ^{144}Ce, ^{249}Cf, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{40}K, ^{233}Pa, ^{234m}Pa, ^{212}Pb, ^{214}Pb, ^{106}Rh, ^{125}Sb and ^{208}Tl. Those analytes having activity concentrations < MDC in all samples included: ^{241}Am, ^{213}Bi, ^{144}Ce, ^{249}Cf, ^{60}Co, ^{134}Cs, ^{152}Eu, ^{154}Eu, ^{233}Pa, ^{106}Rh, and ^{125}Sb.

Comparison of minimum and maximum activity concentrations of gamma-emitting radionuclides determined for sediment samples collected during the monitoring phase (1999 and 2000) and baseline phase (spring and fall of 1998) reflected no increase in any of the analytes with the possible exception of ^{7}Be (Table 13). Activity concentrations of ^{7}Be were < MDC in all samples collected in 1998 and 2000. However, ^{7}Be was detected in 6 of the 12 sediment samples collected in 1999, with at least one sample in each reservoir having detectable activity. Activity concentrations were only slightly above the MDC in all 6 samples.

In most cases there were no significant differences among sampling periods for ^{137}Cs and ^{40}K (Figs. 25 and 26). However, activity concentrations for both analytes were substantially lower in Lake Carlsbad relative to Brantley Lake and Red Bluff Reservoir. Activity concentrations of ^{137}Cs for samples collected from Brantley Lake in 2000 were lower than in samples collected in the two sampling periods of 1998, demonstrating the magnitude of variation in ^{137}Cs that could be expected in future sampling. No analyses of

comparable sediment samples for ^{137}Cs have been reported by WID or EEG.

Baseline Non-Radiological Analyses of Surface Water and Sediments

As no mixed (hazardous + radioactive) wastes had been received for deposition at the WIPP prior to collection of the 2000 samples, the data presented herein for inorganics represent a continuation of baseline characterization studies (1998, 1999, and 2000). Summaries for future sampling and analyses will include comparisons of monitoring phase data with baseline data.

To date, 18 surface water samples (six from each reservoir) have been analyzed for a suite of inorganic compounds (Ag, Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Er, Eu, Fe, Gd, Hg, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, Pb, Pr, Sb, Sc, Se, Sm, Sn, Sr, Th, Ti, Tl, U, V, Zn, chloride, fluoride, nitrate, phosphate and sulfate). The majority of analytes were detected in each of the samples collected from each sampling period with the exceptions of Ag, Be, Cd, Hg, Sn, Tl, nitrate, and phosphate (Table 14). Be was detected in samples collected from Red Bluff Reservoir but not in Lake Carlsbad or Brantley Lake. Nitrates were detected in Lake Carlsbad and Red Bluff Reservoir but not in Brantley Lake. Hg has not been detected in Lake Carlsbad to date, but was measured above detection limits in Brantley Lake and Red Bluff Reservoir.

To date, 36 sediment samples (12 from each reservoir) have been analyzed for the same suite of inorganic constituents as surface water samples. Most of the analytes were detected in all of the sediment samples from the three reservoirs (Table 15) with the exceptions of fluoride, nitrate and phosphate. Analyses of fluoride failed because of interference of soluble organics extracted from the sediments. As was the case with surface water, nitrate was detected in sediments from Lake Carlsbad and Red Bluff Reservoir, but not in Brantley Lake. Phosphate was detected in Lake Carlsbad sediments, but not in any samples from Brantley Lake or Red Bluff Reservoir.

Particle-size analyses for sediment samples collected in 2000 illustrate the fine particle-size nature of the sediment in the deep basin of each reservoir (Fig. 27). The maximum sand fraction in Brantley Lake and Red Bluff Reservoir was 2.7%. Lake Carlsbad ranged in sand content from 2.3% to 23.6%. The variation in clay content among the lake sediments was more extreme. Sediments from Brantley Lake had the highest clay composition (66.1%-71.3%). Sediments from Red Bluff Reservoir were intermediate in clay (40.3%-48.5%), while Lake Carlsbad sediments had the lowest clay contents (25.2%-29.0%). The coarse nature of the sediments from Lake Carlsbad might be expected considering the relatively shallow depths from which the sediments were collected in this reservoir (3.0 to 3.4 m). The sediment sampling depths from Brantley Lake and Red Bluff Reservoir are substantially deeper (12.2 to 13.3 m and 12.3 to 12.6 m, respectively). As Brantley Lake and Red Bluff Reservoir are both substantially larger and deeper than Lake Carlsbad, it would be expected that a higher degree of particle segregation would occur in the deep basins of these water bodies.

The contrast in clay content of Lake Carlsbad relative to Brantley Lake and Red Bluff Reservoir follows the general pattern of activity concentrations of ^{137}Cs and ^{40}K previously noted, with the exception of ^{137}Cs activity concentrations observed in Brantley Lake. A significant positive correlation ($r = 0.87$, $p < 0.001$) was observed between ^{40}K activity concentration (a naturally occurring radioisotope) and percent clay in samples from all three reservoirs, but there was no significant correlation between percent clay and activity concentration of ^{137}Cs (a nuclear fission product). However, if samples from Brantley Lake are excluded, there is a significant positive correlation ($r = 0.96$, $p < 0.001$) between percent clay and ^{137}Cs in samples from the other two lakes. These patterns may result at least partially from the differences in age and history of the reservoirs. Lake Carlsbad and Red Bluff Reservoir have been receiving sediment throughout the nuclear era, while Brantley Lake is relatively new, and has been receiving nuclear-era sediment for only approximately 10 years. However, Brantley Lake has

received some level of sediment input via the breached dam of an adjacent older reservoir (McMillan) that predated the nuclear era by 50 years (constructed in 1893). Thus Brantley Lake sediments may incorporate a large pre-nuclear age sediment contribution that would be free of ^{137}Cs, thus diluting the representation of this radioisotope. An association between fine particulates and radionuclides has also been observed in soil samples (CEMRC 1999 Report and this report).

Comparison of baseline to monitoring phase levels of radionuclides in surface water and sediment samples collected within the Pecos River valley revealed no detectable increases above those typical of natural variation. The saline nature of Red Bluff Reservoir relative to Brantley Lake and Lake Carlsbad is apparent from the elevated concentrations of inorganic constituents as well as radionuclides determined in surface water samples. This pattern of salinity is not apparent in sediments, but the association of some radionuclides with higher clay content is clear.

Tables presenting the surface water and sediment data summarized herein are available on the CEMRC web site at http://www.cemrc.org.

Table 12. Range of Activity Concentrations for Uranium Isotopes in Surface Water Samples Collected from Three Regional Reservoirs during 1998 - 2000

Analyte	Activity Concentration ($Bq\ L^{-1}$)					
	1998 - Baseline			1999 & 2000 - Monitoring		
	[a]N	[b]Min	[c]Max	N	Min	Max
Brantley Lake						
^{234}U	2	6.99E-02	7.54E-02	4	1.06E-01	1.68E-01
^{235}U	2	1.83E-03	1.94E-03	4	2.80E-03	4.88E-03
^{238}U	2	3.80E-02	3.89E-02	4	5.32E-02	7.86E-02
Lake Carlsbad						
^{234}U	2	1.13E-01	1.16E-01	4	1.19E-01	1.88E-01
^{235}U	2	2.69E-03	2.74E-03	4	2.65E-03	5.03E-03
^{238}U	2	5.66E-02	5.71E-02	4	5.55E-02	9.10E-02
Red Bluff Reservoir						
^{234}U	2	2.13E-01	2.14E-01	4	1.42E-01	2.04E-01
^{235}U	2	5.56E-03	5.78E-03	4	3.25E-03	6.44E-03
^{238}U	2	1.06E-01	1.06E-01	4	7.09E-02	1.01E-01

[a]N = number of samples; only samples > MDC included in calculations
[b]Min = minimum activity concentration above MDC
[c]Max = maximum activity concentration above MDC

Table 13. Range of Activity Concentrations for Selected Gamma-Emitting Radionuclides in Sediment Samples Collected from Three Regional Reservoirs during 1998 - 2000

Radionuclide	Activity Concentration ($Bq\ g^{-1}$)					
	1998 - Baseline			1999 & 2000 - Monitoring		
	[a]N	[b]Min	[c]Max	N	Min	Max
	Brantley Lake					
^{228}Ac	8	3.21E-02	4.76E-02	8	2.73E-02	4.13E-02
^{7}Be	0	[d] < MDC	< MDC	2	1.14E-02	1.54E-02
^{212}Bi	8	3.32E-02	4.97E-02	8	2.92E-02	4.41E-02
^{214}Bi	8	2.70E-02	4.20E-02	8	1.92E-02	2.86E-02
^{137}Cs	8	7.33E-03	9.00E-03	8	4.80E-03	9.00E-03
^{40}K	8	4.72E-01	6.21E-01	8	3.90E-01	5.41E-01
^{234m}Pa	3	4.20E-02	4.44E-02	3	4.09E-02	7.62E-02
^{212}Pb	8	3.19E-02	4.56E-02	8	2.84E-02	3.83E-02
^{214}Pb	8	2.82E-02	4.40E-02	8	2.04E-02	2.95E-02
^{208}Tl	8	1.01E-02	1.42E-02	8	8.77E-03	1.24E-02
	Lake Carlsbad					
^{228}Ac	8	1.70E-02	2.76E-02	8	1.68E-02	2.48E-02
^{7}Be	0	< MDC	< MDC	4	8.07E-03	2.46E-02
^{212}Bi	8	1.52E-02	2.92E-02	8	1.61E-02	2.86E-02
^{214}Bi	8	1.94E-02	2.87E-02	8	1.85E-02	2.76E-02
^{137}Cs	8	2.48E-03	5.19E-03	8	3.06E-03	5.00E-03
^{40}K	8	2.75E-01	4.51E-01	8	2.90E-01	4.29E-01
^{234m}Pa	0	< MDC	< MDC	0	< MDC	< MDC
^{212}Pb	8	1.63E-02	2.58E-02	8	1.59E-02	2.48E-02
^{214}Pb	8	1.93E-02	2.80E-02	8	1.93E-02	2.76E-02
^{208}Tl	8	5.04E-03	8.28E-03	8	4.80E-03	7.99E-03
	Red Bluff Reservoir					
^{228}Ac	8	2.33E-02	3.38E-02	8	2.69E-02	3.41E-02
^{7}Be	0	< MDC	< MDC	1	1.01E-02	1.01E-02
^{212}Bi	8	2.54E-02	3.91E-02	8	2.69E-02	4.22E-02
^{214}Bi	8	2.48E-02	3.46E-02	8	2.69E-02	3.50E-02
^{137}Cs	8	4.88E-03	1.11E-02	8	8.08E-03	9.78E-03
^{40}K	8	4.08E-01	4.55E-01	8	4.22E-01	4.76E-01
^{234m}Pa	4	5.04E-02	1.00E-01	6	4.41E-02	7.21E-02
^{212}Pb	8	1.99E-02	3.50E-02	8	2.73E-02	3.38E-02
^{214}Pb	8	2.56E-02	3.59E-02	8	2.79E-02	3.55E-02
^{208}Tl	8	6.96E-03	1.07E-02	8	8.70E-03	1.12E-02

[a]N = number of samples; only samples > MDC included in calculations
[b]Min = minimum sample concentration above MDC
[c]Max = maximum sample concentration above MDC
[d]MDC = minimum detectable concentration

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1998 - 2000 from Three Regional Reservoirs

Analyte	Concentration (mg L^{-1})								
	Brantley Lake			Lake Carlsbad			Red Bluff Reservoir		
	[a]N	[b]Min	[c]Max	N	Min	Max	N	Min	Max
Ag	1	1.11E-05	1.11E-05	0	[d] < MDL	< MDL	0	< MDL	< MDL
Al	5	5.20E-02	4.89E-01	6	6.65E-02	3.77E-01	2	1.91E-02	6.53E-02
As	6	1.09E-03	7.43E-03	6	1.11E-03	2.37E-03	6	1.77E-03	4.97E-03
Ba	6	1.91E-02	7.50E-02	6	1.75E-02	3.36E-02	6	4.69E-02	9.57E-02
Be	0	< MDL	< MDL	0	< MDL	< MDL	3	3.29E-05	5.96E-05
Ca	6	8.69E+01	5.00E+02	6	2.06E+02	3.34E+02	6	2.90E+02	4.98E+02
Cd	0	< MDL	< MDL	1	8.99E-05	8.99E-05	0	< MDL	< MDL
Ce	5	3.61E-05	4.63E-04	4	8.08E-05	4.16E-04	4	3.93E-05	9.77E-05
Co	6	1.64E-04	6.75E-03	6	1.67E-03	1.18E-02	6	1.38E-03	6.01E-03
Cr	4	6.27E-04	2.08E-03	4	6.12E-04	2.19E-03	5	4.59E-04	2.24E-03
Cu	4	4.69E-03	8.06E-03	6	2.59E-03	1.13E-02	6	6.73E-03	8.70E-03
Dy	4	5.79E-06	2.40E-05	4	6.67E-06	3.51E-05	2	4.01E-06	4.13E-06
Er	3	3.52E-06	2.16E-05	3	9.19E-06	1.51E-05	3	2.08E-06	8.33E-06
Eu	6	5.60E-06	3.35E-05	4	6.54E-06	1.81E-05	6	1.45E-05	3.43E-05
Fe	5	5.30E-02	3.68E-01	6	7.60E-02	3.96E+00	3	6.40E-02	8.23E-02
Gd	4	7.34E-06	5.26E-05	4	9.10E-06	4.84E-05	6	4.22E-06	1.51E-05
Hg	1	3.60E-07	3.60E-07	0	< MDL	< MDL	2	2.36E-07	2.72E-07
K	6	1.30E+00	7.65E+00	5	5.31E+00	6.55E+00	6	1.70E+01	2.67E+01
La	4	1.95E-05	1.82E-04	2	4.29E-05	2.21E-04	5	2.84E-05	7.40E-05
Li	5	5.89E-03	7.76E-02	3	6.01E-02	7.75E-02	6	5.14E-02	9.47E-02
Mg	6	1.68E+01	1.63E+02	6	7.31E+01	1.51E+02	6	1.12E+02	1.82E+02
Mn	5	3.61E-03	6.55E-01	5	1.84E-02	6.65E-02	6	1.22E-02	2.72E-01
Mo	6	1.07E-03	3.83E-03	6	1.17E-03	3.36E-03	6	3.00E-03	4.92E-03
Na	6	4.70E+01	8.85E+02	6	2.48E+02	4.48E+02	6	6.21E+02	1.20E+03
Nd	5	1.70E-05	2.18E-04	4	3.79E-05	2.31E-04	4	1.45E-05	3.12E-05
Ni	6	2.51E-03	2.91E-02	4	4.60E-03	2.28E-02	6	1.35E-02	2.87E-02
Pb	2	2.88E-04	6.78E-04	3	6.38E-04	2.65E-03	2	7.76E-04	9.74E-04
Pr	4	5.20E-06	5.87E-05	2	1.11E-05	5.66E-05	3	5.44E-06	8.10E-06
Sb	4	2.53E-04	4.40E-04	0	< MDL	< MDL	6	2.47E-04	6.58E-04
Sc	2	2.61E-03	4.00E-03	2	3.60E-03	3.88E-03	2	2.58E-03	2.63E-03
Se	2	2.83E-04	3.75E-04	4	4.66E-04	6.10E-04	3	8.85E-04	9.20E-04
Sm	4	7.57E-06	5.85E-05	2	1.69E-05	6.12E-05	4	2.26E-05	3.80E-05
Sn	0	< MDL	< MDL	0	< MDL	< MDL	0	< MDL	< MDL
Sr	6	1.00E+00	7.40E+00	6	3.07E+00	5.95E+00	6	4.59E+00	8.81E+00
Th	5	7.62E-06	8.69E-05	4	1.52E-05	6.01E-05	5	1.25E-05	1.97E-05
Ti	6	6.97E-02	7.70E-01	4	3.69E-01	5.45E-01	6	5.77E-01	7.90E-01
Tl	1	4.81E-05	4.81E-05	2	1.20E-04	1.35E-04	0	< MDL	< MDL
U	6	1.17E-03	7.93E-03	4	3.78E-03	9.17E-03	6	4.71E-03	9.50E-03

Table continued on next page

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1998 - 2000 from Three Regional Reservoirs (Cont.)

Analyte	Concentration (mg L^{-1})								
	Brantley Lake			Lake Carlsbad			Red Bluff Reservoir		
	[a]N	[b]Min	[c]Max	N	Min	Max	N	Min	Max
V	6	2.22E-03	5.90E-03	6	6.13E-03	9.30E-03	6	2.48E-03	5.65E-03
Zn	2	1.09E-02	1.12E-02	4	6.12E-03	1.73E-02	2	6.40E-03	1.09E-02
Chloride	6	5.25E+02	2.20E+03	6	6.81E+02	1.06E+03	6	1.61E+03	2.19E+03
Fluoride	6	1.54E+00	3.13E+00	6	1.49E+00	1.12E+00	4	4.05E-01	3.77E+00
Nitrate	0	< MDL	< MDL	6	4.95E+00	6.53E+00	1	2.38E+00	2.38E+00
Phosphate	0	< MDL	< MDL	0	< MDL	< MDL	1	5.68E+00	5.68E+00
Sulfate	6	1.35E+02	2.61E+03	6	1.37E+03	2.01E+03	6	2.33E+03	2.44E+03

[a]N = number of samples above MDL
[b]Min = minimum sample concentration above MDL
[c]Max = maximum sample concentration above MDL
[d]MDL = method detection limit

Table 15. Range of Concentrations for Baseline Inorganic Constituents in Sediment Samples Collected during 1998 - 2000 from Three Regional Reservoirs

Analyte	Concentration (mg kg^{-1})								
	Brantley Lake			Lake Carlsbad			Red Bluff Reservoir		
	[a]N	[b]Min	[c]Max	N	Min	Max	N	Min	Max
Ag	12	5.90E-02	9.44E-02	12	5.83E-02	1.22E-01	12	7.68E-02	1.11E-01
Al	12	1.86E+04	3.88E+04	12	7.64E+03	1.94E+04	12	1.20E+04	2.67E+04
As	12	3.94E+00	5.77E+00	12	2.36E+00	4.51E+00	12	4.39E+00	5.54E+00
Ba	12	1.82E+02	2.70E+02	12	1.12E+02	1.77E+02	12	2.33E+02	3.45E+02
Be	12	4.62E-01	1.54E+00	12	3.30E-01	8.87E-01	12	5.01E-01	8.92E-01
Ca	12	8.62E+04	1.70E+05	12	1.04E+05	2.29E+05	12	1.28E+05	2.04E+05
Cd	12	2.71E-01	4.32E-01	12	3.09E-01	7.58E-01	12	3.88E-01	4.89E-01
Ce	12	2.55E+01	3.93E+01	12	1.30E+01	2.59E+01	12	1.90E+01	3.20E+01
Co	12	7.28E+00	1.09E+01	12	3.00E+00	6.43E+00	12	6.27E+00	7.53E+00
Cr	12	1.67E+01	3.32E+01	12	9.11E+00	2.39E+01	12	1.08E+01	2.53E+01
Cu	12	1.33E+01	1.72E+01	12	1.00E+01	2.28E+01	12	1.15E+01	1.88E+01
Dy	12	1.32E+00	2.61E+00	12	8.07E-01	1.91E+00	12	1.11E+00	2.59E+00
Er	12	6.30E-01	1.27E+00	12	3.96E-01	9.74E-01	12	5.40E-01	1.35E+00
Eu	12	5.28E-01	1.33E+00	12	2.89E-01	7.63E-01	12	4.24E-01	1.13E+00
Fe	12	1.60E+04	2.57E+04	12	7.53E+03	1.72E+04	12	1.26E+04	1.94E+04
Gd	12	2.36E+00	6.65E+00	12	1.32E+00	3.96E+00	12	1.89E+00	5.33E+00
Hg	12	1.17E-02	2.47E-02	12	2.24E-02	6.00E-02	12	1.75E-02	3.54E-02
K	12	3.42E+03	8.72E+03	12	1.70E+03	4.68E+03	12	2.93E+03	7.95E+03
La	12	1.24E+01	1.97E+01	12	6.91E+00	1.33E+01	12	1.00E+01	1.52E+01
Li	12	1.79E+01	3.08E+01	12	8.06E+00	2.28E+01	12	1.12E+01	2.66E+01
Mg	12	1.26E+04	2.34E+04	12	9.81E+03	1.95E+04	12	1.01E+04	1.24E+04
Mn	12	4.05E+02	6.97E+02	12	2.59E+02	4.81E+02	12	4.04E+02	5.33E+02
Mo	12	9.50E-01	1.69E+00	8	4.43E-01	1.08E+00	12	8.59E-01	3.14E+00
Na	12	1.38E+03	6.04E+03	12	1.07E+03	5.64E+03	12	3.79E+03	8.19E+03
Nd	12	1.25E+01	2.19E+01	12	6.86E+00	1.42E+01	12	1.08E+01	1.85E+01
Ni	12	2.11E+01	3.87E+01	12	1.19E+01	3.86E+01	12	1.75E+01	3.86E+01
Pb	12	9.94E+00	1.64E+01	12	9.53E+00	4.41E+01	12	9.37E+00	1.63E+01
Pr	12	3.35E+00	5.93E+00	12	1.78E+00	3.82E+00	12	2.70E+00	4.84E+00
Sb	9	6.63E-02	2.23E-01	8	6.74E-02	2.34E-01	8	8.13E-02	1.73E-01
Sc	4	2.13E+00	2.22E+00	4	1.49E+00	3.03E+00	4	3.80E+00	4.03E+00
Se	12	1.07E+00	2.51E+00	12	1.25E+00	2.87E+00	12	1.90E+00	2.83E+00
Sm	12	2.56E+00	4.87E+00	12	1.41E+00	3.09E+00	12	2.06E+00	4.23E+00
Sn	4	1.52E+00	1.72E+00	4	1.28E+00	3.75E+00	4	1.34E+00	5.43E+00
Sr	12	3.76E+02	7.76E+02	12	3.83E+02	9.00E+02	12	2.84E+02	7.50E+02
Th	12	2.34E+00	8.09E+00	12	1.31E+00	4.70E+00	12	2.13E+00	6.44E+00
Ti	12	1.44E+02	3.90E+02	12	2.27E+02	4.20E+02	12	2.68E+02	5.50E+02
Tl	7	1.26E-01	1.78E+00	8	3.31E-01	1.96E+00	4	3.27E-01	4.08E-01

Table continued on next page

Table 15. Range of Concentrations for Baseline Inorganic Constituents in Sediment Samples Collected during 1998 - 2000 from Three Regional Reservoirs (Cont.)

Analyte	Concentration (mg kg^{-1})								
	Brantley Lake			Lake Carlsbad			Red Bluff Reservoir		
	[a]N	[b]Min	[c]Max	N	Min	Max	N	Min	Max
U	12	1.29E+00	2.27E+00	12	9.18E-01	1.89E+00	12	1.66E+00	4.13E+00
V	12	2.92E+01	4.68E+01	12	1.57E+01	3.23E+01	12	2.27E+01	4.04E+01
Zn	12	4.84E+01	6.61E+01	12	5.62E+01	1.28E+02	12	4.47E+01	1.08E+02
Chloride	12	1.57E+03	1.18E+04	12	7.20E+02	1.07E+04	12	3.76E+03	1.80E+04
Fluoride	0	[d] < MDL	< MDL	0	< MDL	< MDL	0	< MDL	< MDL
Nitrate	0	< MDL	< MDL	4	2.70E+00	1.25E+02	4	1.93E+01	1.02E+02
Phosphate	0	< MDL	< MDL	3	5.99E+00	2.99E+01	0	< MDL	< MDL
Sulfate	12	4.03E+03	1.13E+04	12	1.80E+03	2.45E+04	12	6.09E+03	1.29E+04

[a]N = number of samples above MDL
[b]Min = minimum sample concentration above MDL
[c]Max = maximum sample concentration above MDL
[d]MDL = method detection limit

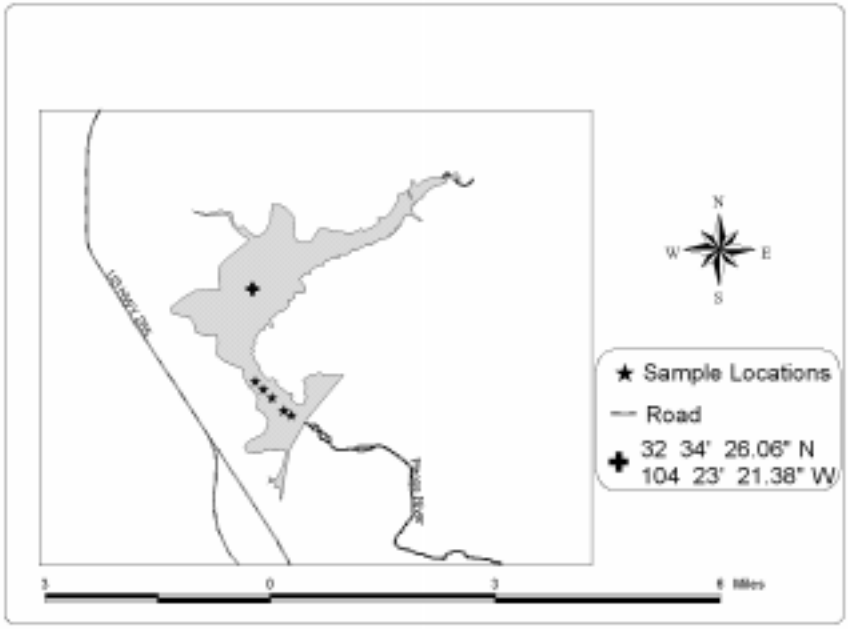

Figure 21. Surface Water and Sediment Sampling Locations at Brantley Lake

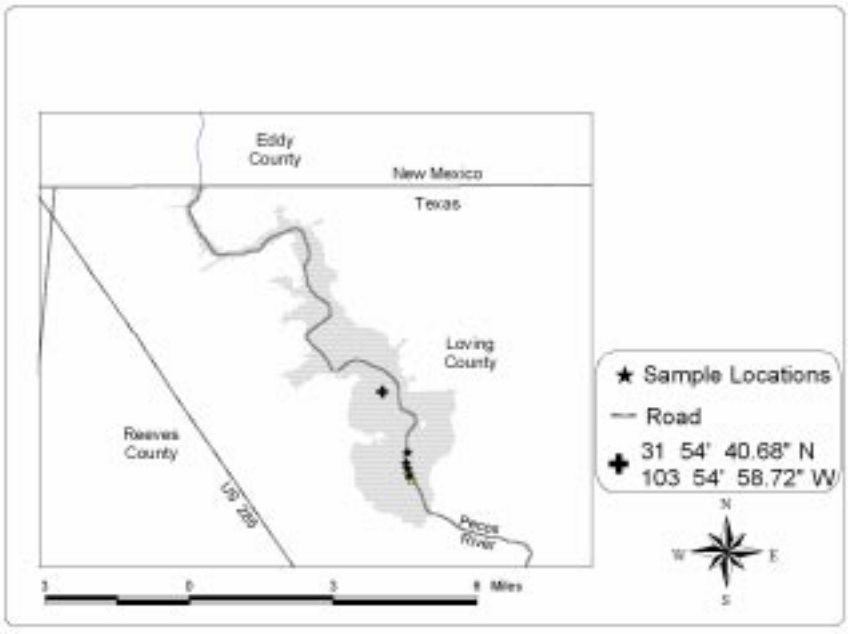

Figure 22. Surface Water and Sediment Sampling Locations at Red Bluff Reservoir

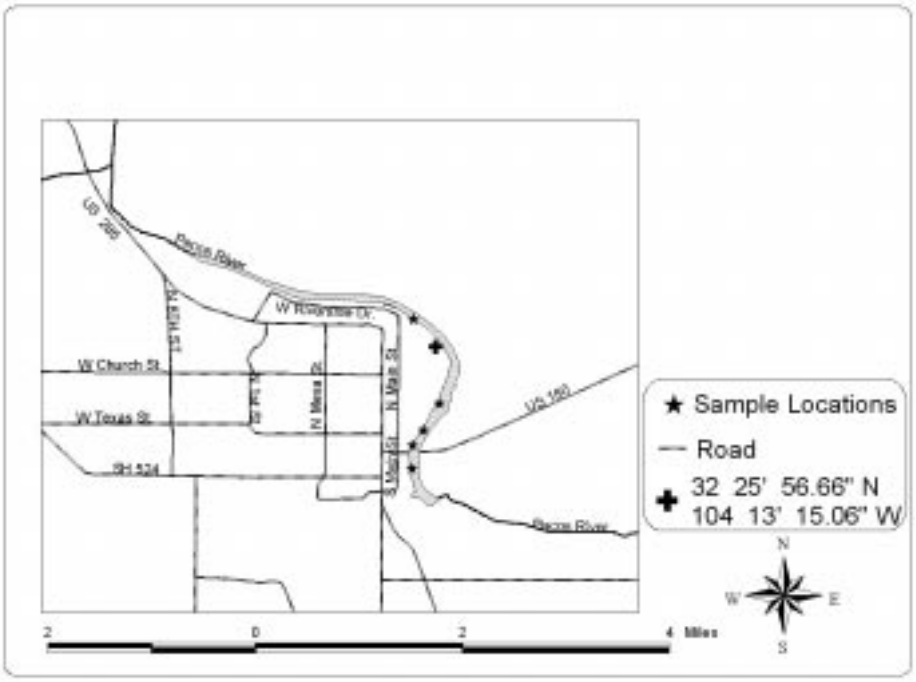

Figure 23. Surface Water and Sediment Sampling Locations at Lake Carlsbad

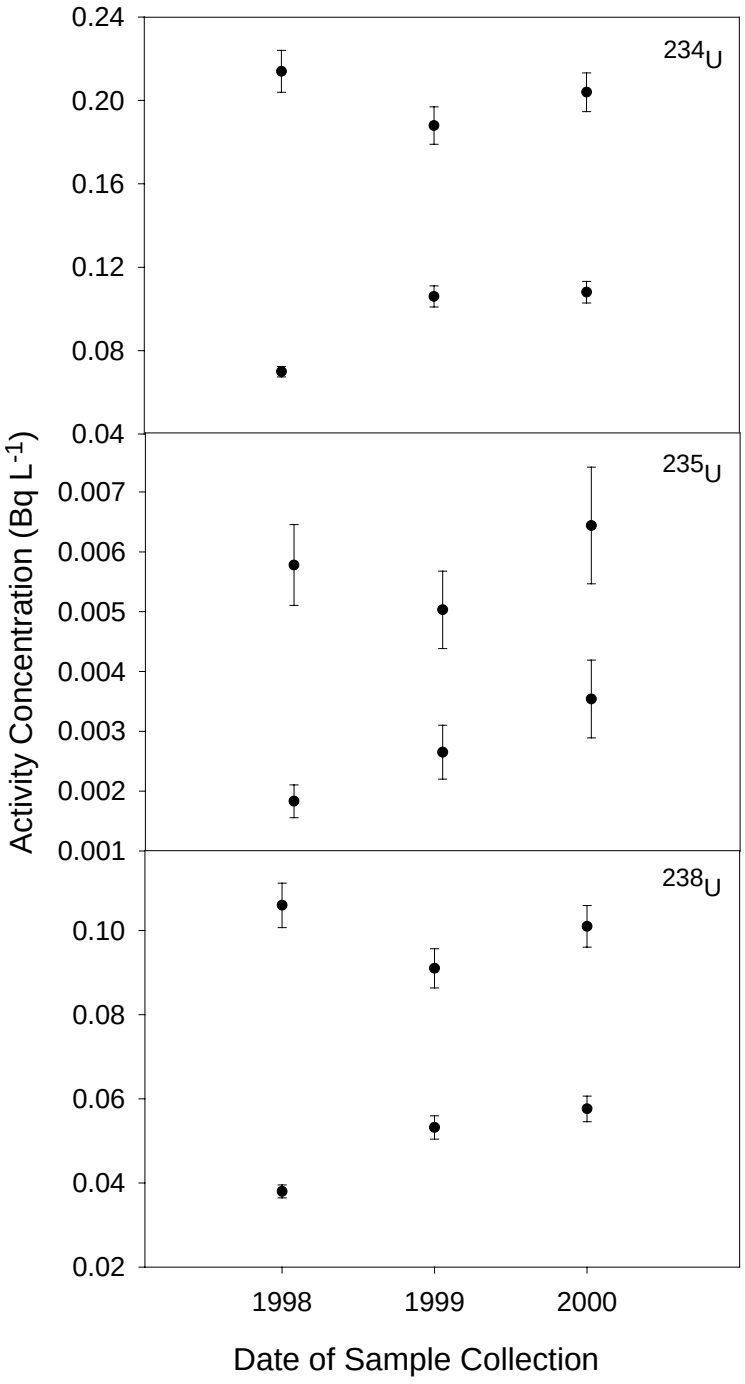

Figure 24. Range in Activity Concentrations for Uranium Isotopes in Surface Water Samples Collected from Three Regional Reservoirs during 1998 - 2000

Error bars represent the total radioanalytical uncertainty at the 95% confidence interval.

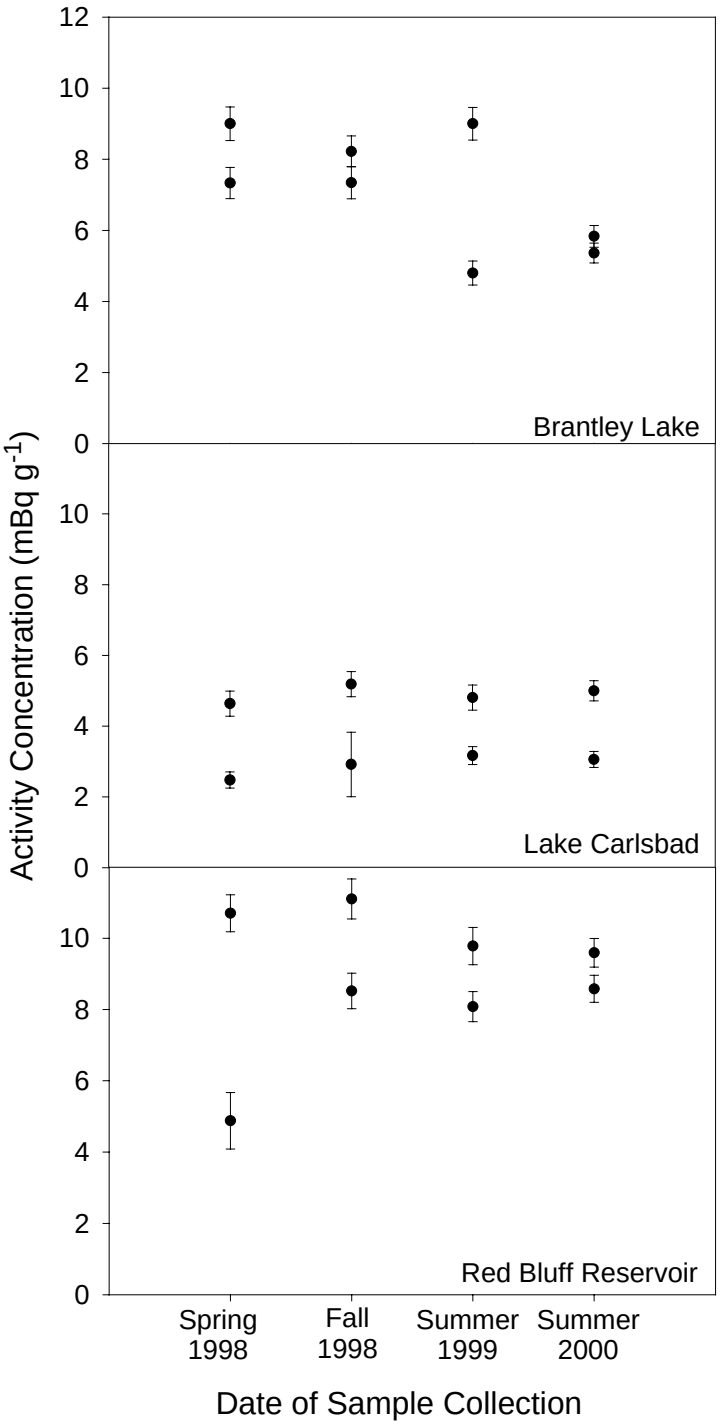

Figure 25. Maximum and Minimum Activity Concentrations for ^{137}Cs in Sediment Samples Collected from Three Regional Reservoirs during 1998 - 2000

Error bars represent the total radioanalytical uncertainty at the 95% confidence interval.

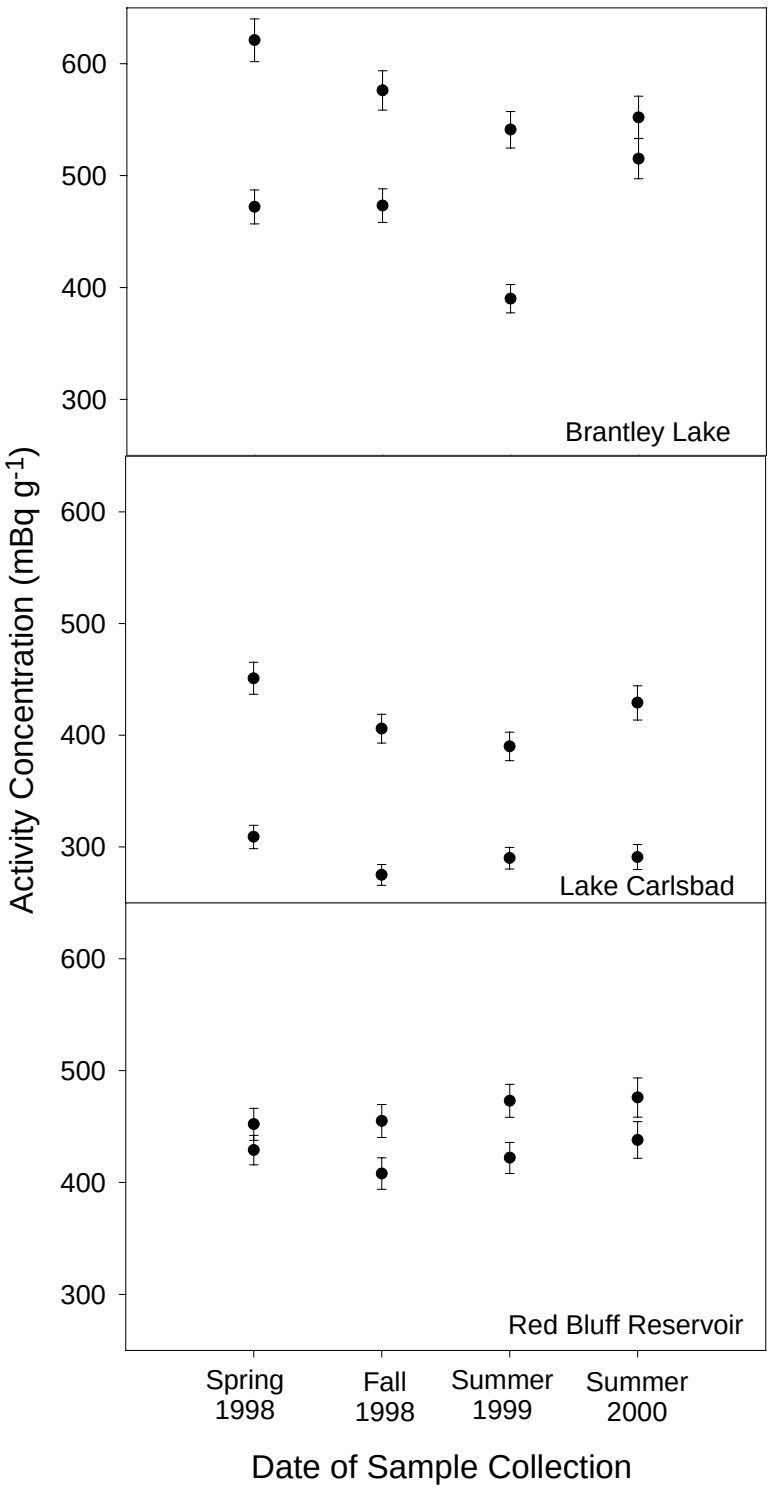

Figure 26. Maximum and Minimum Activity Concentrations for ^{40}K in Sediment Samples Collected from Three Regional Reservoirs during 1998 - 2000

Error bars represent the total radioanalytical uncertainty at the 95% confidence interval.

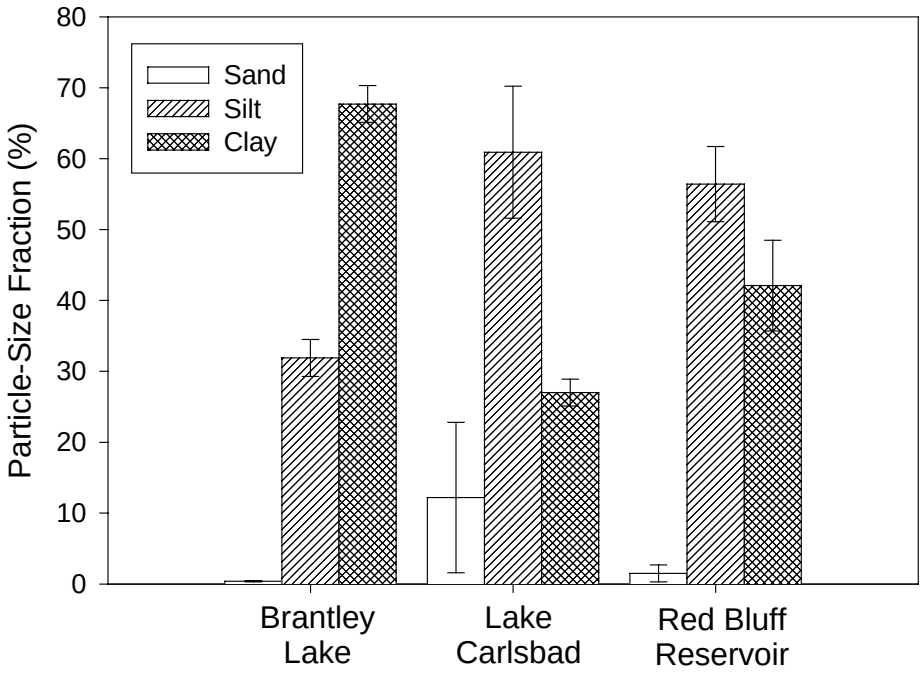

Figure 27. Mean Particle-Size Fractions for Sediment Samples Collected in 2000 from Three Regional Reservoirs

Lines bracket ranges in particle-size fraction
among the four individual samples from each reservoir.