REQUEST FOR APPROVAL OF
TRANSFER OF CONTAMINATED SEDIMENT
TO THE H. B. ROBINSON ASH POND

Safety Analysis Report

January 5, 1983

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INTRODUCTION

This report is submitted to the Commission pursuant to the requirements of 10CFR20.302, Method for Obtaining Approval of Proposed Disposal Procedures. The proposed disposal procedure is for transfer by hydrovacuum truck of slightly contaminated sediment from two settling ponds within the H. B. Robinson Plant restricted area to the fossil unit Ash Pond in the owner-controlled area. Carolina Power & Light (CP&L) requests that such transfers be allowed as needed for sediments not exceeding an average concentration of 3.0 E-5 μCi/g wet for Co-60.

1.0 BACKGROUND

Two settling ponds were constructed at the H. B. Robinson Plant in 1976 to meet National Pollutant Discharge Elimination System (NPDES) permit limits. These ponds are used to treat water collected by the Unit 1 (coal-fired) and Unit 2 (nuclear) storm drains. Treatment consists of retention to settle particulates (coal ash and dust) and skimming to remove oil. Clean effluent is released to Black Creek via a drainage ditch.

Over a period of time, particulates accumulate in the settling ponds and must be removed to ensure proper functioning of the settling ponds. Experience to date indicates that the ponds become filled with sediment about every two years. The accumulated sediment is contaminated by very low levels of man-made radioactivity, primarily Co-60. The source of this contamination is trace amounts of radioactivity from primary to secondary coolant leaks which occasionally enter the Unit 2 storm drains. This contamination can come into contact with ash in the drains themselves since there are several cross-ties between the two drain systems. In addition, any clean sediment in the settling ponds can also become contaminated since both drains enter a common splitter box which can divert flow to either pond.

Steps being considered to separate the two storm drain systems are briefly discussed in Section 5.1. While these modifications should eliminate contamination of the sediment in the future, the problem of disposing of the sediment now in both ponds has become critical. The West Settling Pond has

already filled with sediment and has been taken out of service and drained. The East Settling Pond is filled to near capacity, and its effluent will soon exceed NPDES permit limits for suspended solids if the sediment is not removed. It is anticipated that the East Pond will be filled by the end of February 1983.

A similar situation existed in the summer of 1980, and in July of that year, about 3,000 cubic meters of sediment were transferred from the East Settling Pond to the Ash Pond. Although the sediment contained only 20 millicuries of Co-60, the transfer was made without prior approval of NRC and resulted in a citation for violation of 10CFR20.302. The situation was complicated by the fact that the Ash Pond is located in the owner-controlled area. CP&L responded to this violation by committing to obtain the required approval prior to any future transfers of sediment. Accordingly, the purposes of this report are to request NRC approval for the immediate transfer of an additional 6,000 cubic meters of contaminated sediment containing 75 millicuries of Co-60 to the Ash Pond and for future transfers of sediment in which the concentration of man-made gamma emitters does not exceed a specified level. Although CP&L has the right to restrict access to owner-controlled areas, the supporting safety analysis assumes that public access to the Ash Pond is not restricted.

2.0 SUMMARY AND CONCLUSIONS

The impacts of contaminated sediment disposal are minimal regardless of the method of disposal; however, costs vary by two orders of magnitude. These impacts and costs are summarized in Table 2-1. An expenditure of $13 million and use of nearly 300,000 cubic feet of valuable disposal space to prevent a hypothetical exposure of 1.6 mrem/yr is totally unreasonable and provides compelling support for disposal by transfer to the Ash Pond.

It is expected that contaminated sediment will continue to accumulate in the settling ponds for some time even if all of the modifications being considered for the storm drain system are implemented. These additional accummulations would occur as any residual contaminated sediments are gradually flushed from the system. Although smaller volumes of sediment are anticipated, the cost of commercial disposal is still expected to be on the order of several million dollars.

In view of these circumstances and the mimimal impacts associated with transfer of the present 6000 m^3 of sediment to the Ash Pond, it would be beneficial to establish a concentration limit for man-made radioactivity in sediment to be transferred to the Ash Pond which would simplify screening the sediment while providing adequate protection to the general public. Since this safety analysis shows that direct gamma exposure is by far the largest contribution to the potential dose for the maximum individual and since Co-60 is the largest contributor to the direct gamma exposure pathway, it would be convenient to use Co-60 to determine the suitability of

sediment for transfer. The general public would be protected by limiting the total potential dose to the critical individual to 5 mrem/yr. A dose of 5 mrem/yr corresponds to a Co-60 concentration in sediment of 3.0 E-5 μCi/g wet. Based on these considerations, CP&L requests that the Commission grant approval for transfer of sediment to the Ash Pond whenever the average Co-60 concentration does not exceed 3.0 E-5 μCi/g wet. Records of such transfers would be maintained in accordance with 10CFR20.401(b).

Table 2-1 Comparison of Impacts and Costs of Sediment Disposal Options

Impact	Transfer to Ash Pond	Cement Solidification
Exposure to Critical Individual (mrem/yr)	1.6[a]	Negligible
Occupational Exposure (mrem)	7.7[b]	11.7[c]
Cost (Dollars)	$100,000	$13,148,000

[a] Whole body dose to maximum teenager

[b] Two-man crew

[c] Three-man crew

3.0 SEDIMENT CHARACTERISTICS

3.1 Physical & Chemical Characteristics

The sediment consists mainly of ash from the combustion of coal in Unit 1 and also contains some coal dust. In this regard it is similar to, if not identical to, the ash and coal dust routinely discharged directly from Unit 1 to the Ash Pond.

The chemical composition of fly and bottom ash can be highly variable reflecting the variability in the composition of coal. The average chemical composition (weight percent) based on nine samples of ash from Unit 1 is given below.

Fe_2O_3	CaO	Na_2O	Al_2O_3	MgO	K_2O	SiO_2	P_2O_5	SO_3
18.9	3.3	0.8	20.5	1.2	2.2	47.5	0.3	3.9

Trace amounts of compounds of other elements are also present in fly ash from Robinson and other coal-fired plants. These elements include Sr, Cr, Mn, Co, Ni, Zn, Cd and Ce as well as U, Th, and their daughters.

Fly ash can be separated into three fractions - glass beads, mullite-quartz, and magnetic spinel (HU 80). Particle sizes depend on the method of ash collection but frequently are in the range of 0.3 to 100 micrometers (GR 78). These particles tend to be spherical. Particle sizes in bottom ash are expected to be larger.

Fly ash exhibits varying degrees of affinity for cations which is attributable to its relatively high content of Fe_2O_3 (ferric oxide) and Al_2O_3 (alumina). This affinity is probably responsible for retention of man-made radioactivity in the Robinson settling ponds and suggests that this radioactivity is not readily released. Metals are known to leach from fly ash; however, since leaching of radioactive isotopes competes with leaching of nonradioactive isotopes of the same element, the presence of stable metals would tend to reduce introduction of their radioactive counterparts into the environment.

3.2 Radiological Characteristics

The sediment in the settling ponds contains both man-made radionuclides from Unit 2 and naturally occurring radionuclides from the coal burned in Unit 1. The latter group of radionuclides, members of the uranium and thorium decay chains, emit a large number of gamma photons and can interfere with the determination of man-made radionuclides since computer programs available for state-of-the-art counting systems cannot separate the contributions of more than one radionuclide to a single gamma peak. As a result, each radionuclide contributing to the peak is validated as being present and its concentration calculated as if it were the only radionuclide present. Since Bi-214 and Pb-214 were detected in most sediment samples analyzed, this type of interference is believed to have affected all man-made radionuclides reported in sediment except Co-60. Other interfering natural radionuclides are Ac-228, Th-228, and Tl-208.

Because of the pressing need to remove the sediment, CP&L has elected to use the available data as is rather than perform hand calculations for the large number of samples involved. This course of action is conservative since man-made radionuclides not believed to be present have been retained and concentrations of other man-made radionuclides have probably been overestimated. Methods of correcting for this type of interference, either automatically or by hand, are now being evaluated.

The results of analysis of two types of samples are tabulated in the appendix and summarized in Table 3-1. The two types of samples are (1) routine grab samples collected from each settling pond and (2) core samples collected from the West Settling Pond after it was taken out of service and drained. As shown in Table 3-1, Co-60 is clearly the principal man-made radionuclide in the sediment in spite of any interference in the analysis. The weighted average Co-60 concentration in the sediment is 8.55 E-6 µCi/g wet compared to a weighted average total concentration of man-made radionuclides of 9.72 E-6 µCi/g wet. No significance is attached to the slightly higher concentrations seen in the West Settling Pond since the counting error is relatively large at these low concentrations.

Most samples were also found to contain Bi-214 and Pb-214. If secular equilibrium is assumed, the resulting Ra-226 concentration is comparable to that of Co-60. Radium-226 and other naturally occurring radionuclides have been excluded from consideration since they are already present in the Ash Pond in similar concentrations and since their presence in the Ash and Settling Ponds is independent of the operation of Unit 2 and whether the sediment is transferred.

Table 3-1 Average Concentrations (μCi/g Wet) of Man-Made Radionuclides in Settling Pond Sediment

Nuclide	Routine Samples: East Settling Pond	Routine Samples: West Settling Pond	Core Sample From West Settling Pond	Weighted Average
Mn-54	2.16E-7[a] (8)[b]	1.18E-7 (2)	(0)	1.96E-7 (10)
Co-58	5.29E-7 (18)	2.85E-7 (11)	(0)	4.36E-7 (29)
Co-60	1.55E-5 (47)	3.06E-6 (45)	5.59E-6 (27)	8.55E-6 (119)
Nb-95	3.31E-7 (9)	1.77E-7 (9)	(0)	2.54E-7 (18)
Cd-109	2.54E-6 (11)	2.46E-6 (15)	1.79E-6 (2)	2.44E-6 (28)
Cs-134	4.13E-7 (1)	1.40E-7 (1)	(0)	5.53E-7 (2)
Cs-137	4.41E-7 (39)	2.43E-7 (28)	9.88E-7 (13)	4.61E-7 (80)
Ce-144	(0)	5.16E-7 (2)	(0)	5.16E-7 (2)
Total	1.68E-5 (47)[c]	4.08E-6 (46)	7.12E-6 (28)	9.72E-6 (121)

[a] $2.16E-7 = 2.16 \times 10^{-7}$

[b] Number of samples in which nuclide was detected.

[c] Total number of samples.

4.0 SITE AND ENVIRONMENT

This section is intended to provide an overview of the site and its environs and presents information taken from the Updated Final Safety Analysis Report and preliminary results of studies now being conducted in connnection with its revision.

4.1 Site

The H. B. Robinson Plant is located in the western corner of Darlington County, South Carolina, on the southwest shore of Lake Robinson about 4.5 miles WNW of Hartsville and 56 miles ENE of Columbia. The plant consists of a 182 MWe coal-fired unit (Unit 1) and a 665 MWe nuclear unit (Unit 2). Lake Robinson is an impoundment which was constructed to provide cooling water for Unit 1 and future units at the site. The site was originally planned to generate 1200 MWe.

Figure 4-1 shows the relative locations of the facilities of interest. The Ash Pond is located approximately 1 1/4 miles WNW of the H. B. Robinson Plant. The Darlington County Electric Plant, which supplies auxiliary power at peak loads, is located at the northern tip of the Ash Pond and is within the CP&L property boundary. The settling ponds are located about 500 feet south of the H.B. Robinson Plant and are not visible in Figure 4-1.

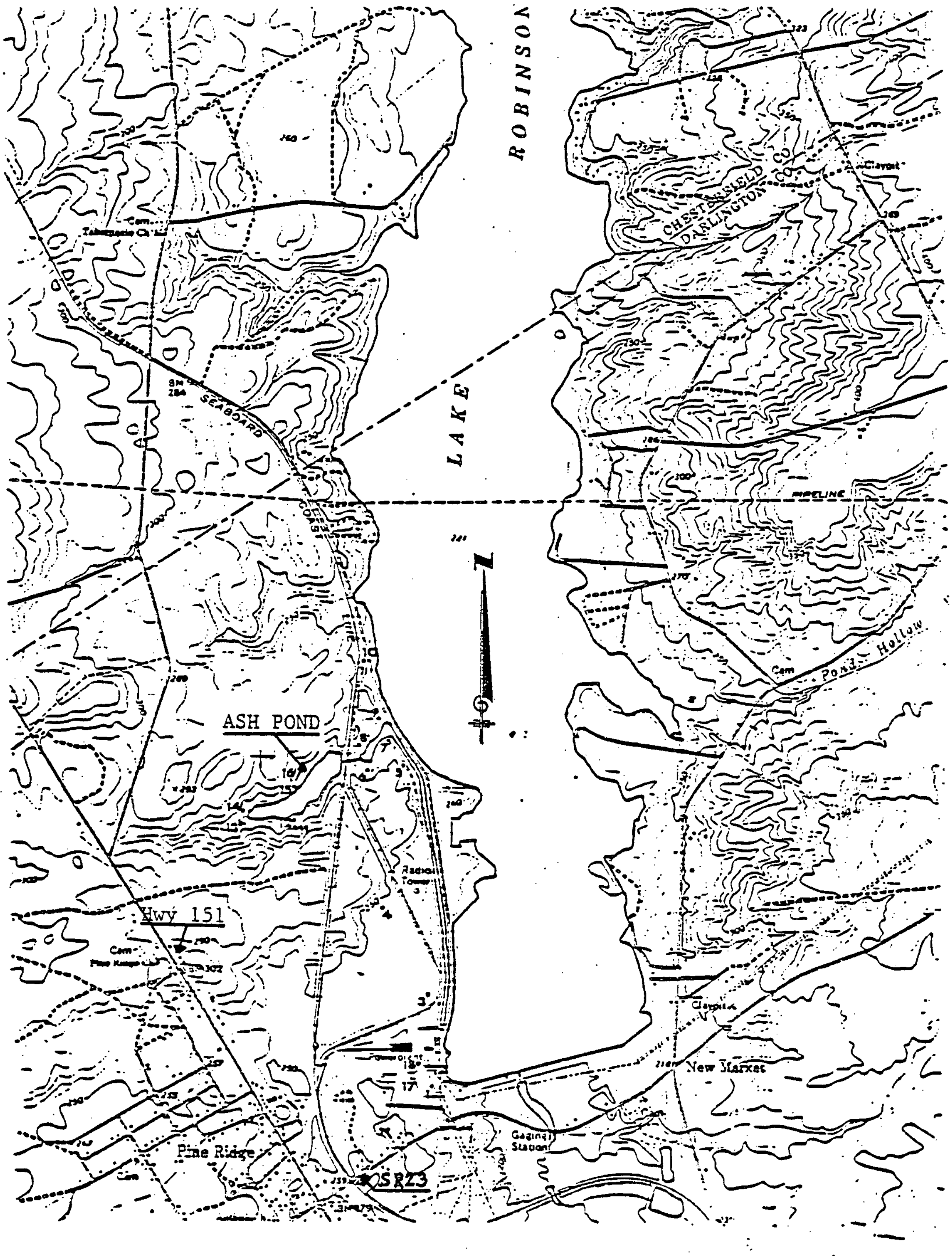

Figure 4-1. H. B. Robinson Plant and Environs

4.2 Topology

The site is on the southern edge of the Sandhills Region of South Carolina. This region is typified by rolling hills interspersed with water courses and wooded areas. The terrain becomes flatter and marshy in the coastal plain to the south and east of the site.

Lake Robinson is about 4,000 feet wide at the plant site and about 7.5 miles long at its maximum water level of 222 feet mean sea level (MSL). The land surface surrounding the lake rises to about 40-50 feet above the maximum lake elevation, and the surrounding terrain rises to 510 feet MSL about 5 miles northeast of the site.

The Ash Pond lies in a depression about 1,000 feet west of Lake Robinson. The current maximum water level in the pond is 256 feet MSL, and as discussed in Section 5.1, this level will be increased to 264 feet MSL. The land surrounding the Ash Pond rises about 290 feet MSL.

4.3 Geology

Surficial materials at the Robinson site are recent sands or soils developed from the Middendorf formation. This formation consists of light-colored feldspathic and slightly micaceous quartz sand interbedded with red, purple, gray, and brown silty and sand clay. Because of the high quartz content of the sands and the climatic environment, surficial soils may not weather sufficiently to be distinguishable from the parent material.

The Middendorf is about 400 feet thick and overlies an eroded, slightly sloping surface of the piedmont crystallines. This formation is also referred to as the Tuscaloosa formation. In general, the upper alluvial sands and gravels are moderately compact with layers of compressible material occurring in the upper 30 to 50 feet. Because of the quantity of fines in the sand and gravel, they cannot be considered to be free draining. The underlying Middendorf contains generally compact sands and firm-to-hard clayey soils. Several strata of cemented sandstones were encountered in borings at roughly 90 to 100 feet.

4.4 Hydrology

4.4.1 Descriptive Hydrology

The major surface water feature in the vicinity of the site is Lake Robinson. The water level in the lake is quite constant with a typical wet season level of 221 feet MSL and dry season level of 220.7 feet MSL. The present Ash Pond water level is 256 feet MSL. Since the Lake Robinson dam and spillway structures are designed to prevent the lake level from exceeding 222 feet MSL to protect the plant site from flooding, lake water could not reach the Ash Pond.

It is conceivable that contaminated sediment could be transported from the Ash Pond by flooding of the pond itself during heavy rains. Since 8 feet of freeboard is normally maintained and the drainage area of the pond is relatively small, the possibility of such flooding is extremely remote. If it should occur, the topography of the pond area is such that water would flow over the dike and into Lake Robinson. Since dilution in Lake Robinson is so

4.5 Meteorology

The climate of the region is relatively temperate with the Appalachian Mountains acting as a buffer from most winter storms. Winters are usually mild with a few cold waves during which the temperature drops below 20°F. Summers are hot with temperatures in excess of 100°F occurring during a few days.

The H.B. Robinson site lies in a potential hurricane area but sustained hurricane force winds (> 74 mph) have never been recorded by the Columbia (South Carolina) Weather Service. Prevailing winds are from the north and northeast. During the period 1976-1981, the on-site average wind speed was 6.2 mph and the maximum wind speed was 28 mph which was recorded in February 1981. Both the average and maximum wind speeds are 15-minute averages recorded at 10 meters. A maximum one-minute average wind speed of 60 mph was recorded by the Columbia Weather Service during a hurricane in March 1954.

Hurricanes are also responsible for the maximum 24-hour precipitation at the site during the period 1976-1981. The maximum on-site 24-hour maximum precipitation of 4.76 inches occurred during September 1979 and was associated with Hurricane David. The maximum 24-hour precipitation in the site vicinity of 7.61 inches was recorded at Columbia, South Carolina in August 1949. This amount of precipitation is comparable to that produced by thunderstorms.

The probability that a tornado will strike a given location in the site vicinity is 0.00195. This is equivalent to one tornado every 513 years.

5.0 PREFERRED DISPOSAL METHOD

The section discusses the preferred method of disposal--transfer to the Ash Pond. Section 5.1 describes the current settling and ash ponds and the modifications planned for each. Section 5.2 briefly describes the proposed method for sediment handling. Section 5.3 discusses impacts of these operations and Section 5.4 discusses costs.

5.1 Facility Description

5.1.1 Settling Ponds

The settling ponds are located inside the controlled area and are identical in their construction. The ponds are 56 feet wide and 136 feet long at their bottoms and 134 feet wide and 234 feet long at their tops (ground elevation, 225 feet MSL). Each pond is equipped with a weir which maintains a combined water and sediment depth of 8 feet with 5 feet of free-board. The slopes of the ponds are covered with rip-rap. The active volume of each pond is 3000 cubic meters. Each pond discharge is equipped with an automatic compositing water sampler, pH and radiation monitors, and an oil skimmer. A junction box/splitter equipped with an oil skimmer is located just north of the ponds and receives flow from both storm drain systems.

Modifications planned for the settling ponds include installation of sluice gates on the discharges. These gates will allow the discharges to be

shallow aquifers are recharged by direct accretion from precipitation. Recharge to the artesian aquifers is mainly controlled by the difference in head between the water in the artesian aquifer and that in the water aquifers and also by that in other artesian aquifers above and below.

Preliminary results of a hydrological investigation now in progress at Robinson generally confirm the information just presented. The clay lenses are present in the immediate vicinity of the Ash Pond and grade laterally into each other. Grades are rather steep with a given lens rising or falling tens of feet in a relatively short distance. These lenses are not continuous so that the aquifers are generally unconfined. Preliminary results indicate that vertical permeabilities are roughly 1/10 the horizontal permeabilities. The horizontal groundwater velocity is estimated at 2-20 feet/day. Since the water table slopes toward Lake Robinson, seepage may eventually reach the lake.

4.4.3 Dilution in Lake Robinson

The available hydrogeologic information indicates that water can readily seep from the Ash Pond. This seepage would migrate towards Lake Robinson where any radioactivity would be diluted. The Updated Final Safety Analysis Report for the Robinson Plant estimates that the concentration in Lake Robinson at one mile from the Unit 2 discharge is 2.4 E-13 $\mu Ci/cm^3$ per μCi discharged for short-term releases. It is reasonable to assume a similar dilution factor should contamination from the Ash Pond reach the lake. At this dilution, roughly 125 Ci of Co-60 could be released exclusive of plant releases without exceeding the maximum permissible concentration for Co-60 in unrestricted areas.

large (Section 4.4.3) and since even instantaneous leaching of all man-made radioactivity in the sediment would not cause maximum permissible concentrations to be exceeded in the much smaller Ash Pond (Table 5-3), potential impacts of flooding are not considered further.

4.4.2 Groundwater

The drainage area of Black Creek above the dam site is underlain and bounded by the Tuscaloosa (Middendorf) formation, a sequence of unconsolidated and semiconsolidated, cross-bedded, micaceous, feldspathic quartz sand and gravel beds. These beds are intercolated with clayey sands and impure clays and lenses of white kaolin. These kaolin lenses can extend laterally for quite some distance and have a maximum thickness of about 35 feet. These lenses are frequently responsible for the existence of perched groundwater in the overlying sands. The sand and clay beds of the Tuscaloosa are lenticular and grade laterally into one another or pinch out within comparatively short distances.

The Tuscaloosa is a permeable formation and in several areas of the Coastal Plain yields up to 2000 gpm from individual wells. Groundwater occurs under both water table and artesian conditions. In the former, the water surface is unconfined (under atmospheric pressure) and is free to move in a vertical direction. Under artesian conditions, the water in the aquifer is confined under a relatively impermeable bed and hydrostatic pressure causes the water to rise above the bottom of the confining bed when the aquifer is penetrated or exposed to the surface. Water in shallow aquifers is generally unconfined, and in deeper aquifers it is under artesian conditions. Since here the water table is fairly close to the surface, the

closed and water levels raised so that the ponds can be used as temporary impoundments to better control release of effluents. Plans are also being developed to reduce or eliminate accumulation of contaminated sediments. Actions being considered include elimination of cross-ties between Units 1 and 2 storm drains and elimination of the splitter box.

5.1.2 Ash Pond

The Ash Pond was formed by building a dike across one end of a natural depression. Currently, the water level is maintained at 256 feet MSL. As shown in Figure 5-1, slurried ash from Unit 1 is pumped into the east end of the pond. The slurry is carried by a 12-inch line and pumped at a rate of 2000 gpd. A baffle dike just north of the slurry pipe aids in phase separation. An overflow pipe and oil skimmer are located to the north of the baffle dike. Any overflow would enter Lake Robinson.

Figure 5-1 also shows a relatively flat shelf at 260 feet MSL on the northern shore due west of the baffle dike. The rise to 270 feet MSL occurs in a short distance forming a small bluff. Current plans are to raise the main and baffle dikes by 8 feet in early 1983. The new water level of 264 feet MSL would submerge this shelf.

5.2 Operations

Sediment would be removed from the settling ponds and transported to the Ash Pond using hydrovacuum trucks. Since the west pond is out-of-

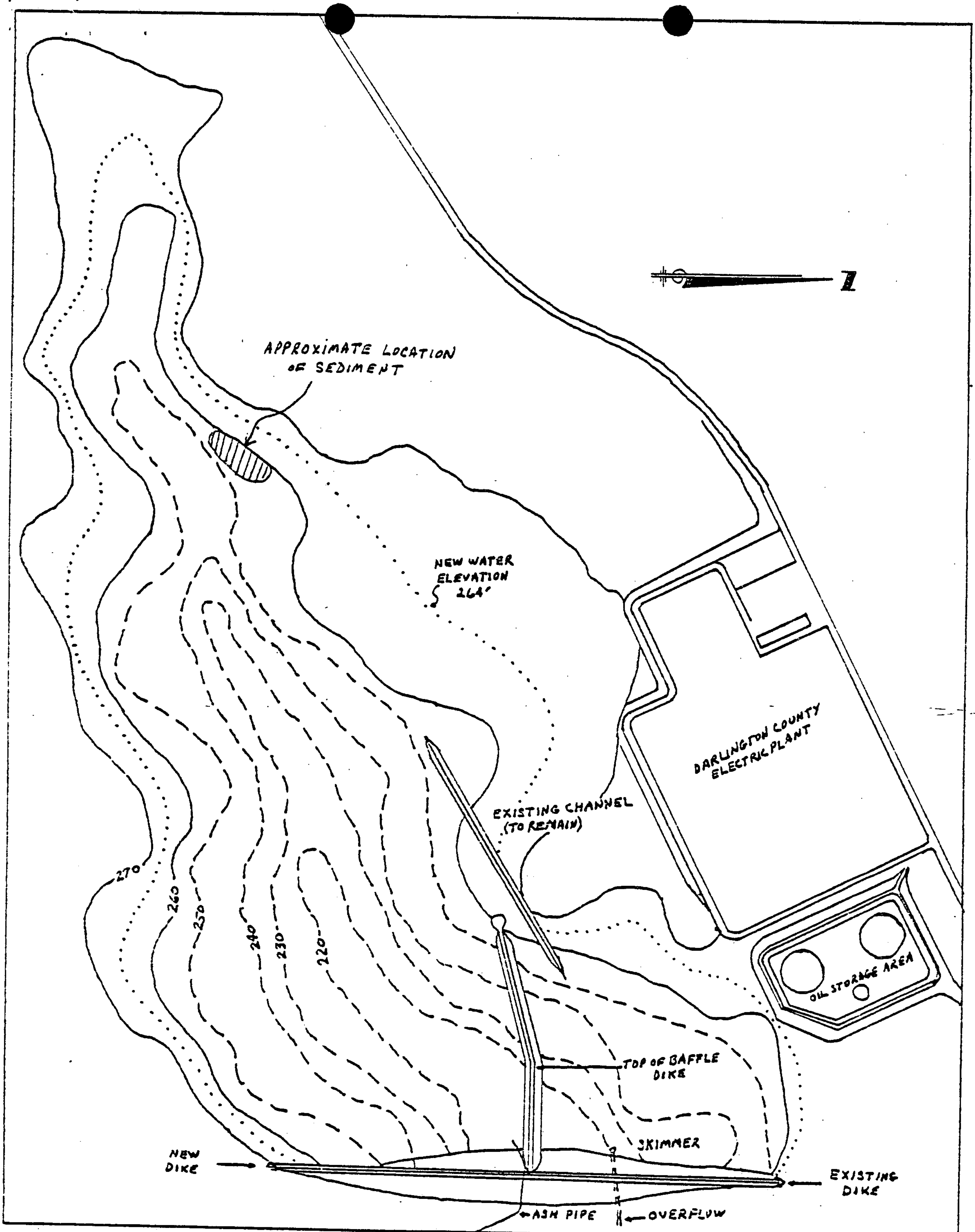

Figure 5-1. H. B. Robinson Ash Pond

service and has been drained, it may be necessary to add water to obtain a suitable consistency. This water is readily available from the east pond. Once the west pond is emptied and returned to service, the east pond would be hydrovacuumed.

The loaded hydrovacuuming trucks would travel approximately 1.3 miles on public roads (Route 23 and Highway 151, see Figure 4-1) to reach the shelf on the northern shore of the Ash Pond. The contaminated sediment would be slurried down the face of the bluff and washed into the pond using pond water. Since the sediment will be handled as a slurry, there will be no airborne releases of particulates.

5.3 Impacts

This section discusses the impacts of the proposed transfer of contaminated sediment to the Ash Pond. Although direct exposure is considered to be the only credible exposure pathway, very conservative analyses of the ingestion and inhalation pathways have also been included. All radiological impacts are based on the contribution of man-made radionuclides now contained in the settling ponds since the proposed transfer will not affect the concentration of naturally occurring radionuclides already in the Ash Pond.

5.3.1 Direct Exposure

Although the Ash Pond is in an owner-controlled area, it is assumed for purposes of analysis that members of the general public could gain

access and receive a direct radiation exposure by standing on the shoreline of the pond. Several simplyfying and conservative assumptions can be made in estimating this exposure. To simplify calculations, it is assumed that the weighted average total man-made concentration of activity of 9.72E-6 µCi/g wet is due to Co-60 alone. For the radionuclides detected in the sediment, this is a conservative assumption. It is also assumed that the contaminated sediment forms a homogeneous, infinitely thick, infinite slab after being transferred to the Ash Pond. This assumption is very conservative since the sediment would be deposited in a small area and, as a result, no exposure would occur unless an individual were near this area. On the other hand, if the sediment were uniformly distributed over the entire area of the pond, the layer of contaminated material would be less than 2 inches thick and would yield a much lower flux than the infinite slab model. The final conservative assumption is to ignore the shielding effect of the several feet of water which would normally cover the contaminated sediment.

The dose to an individual standing on this infinite slab can be estimated using Table 2 of HASL-195 (BE 68). This table gives the total exposure rate in air at one meter above the slab as 0.364 MeV/g · sec per gamma photons/cm^3 · sec for an energy of 1.25 MeV and soil density of 1.6 g/cm^3. The gamma flux in sediment with a Co-60 concentration of 9.72 E-6 µCi/g and a density of 1.3 g/cm^3 is 0.9324 photons/cm^3 · sec. After correcting for the lesser density of the sediment, an exposure rate in air of 0.0273 mR/hr is obtained. The conversion of exposure rate to absorbed dose is complicated by the fact that the energy distribution of the incident photons is unknown; however, if it is assumed that the ratio of mass-energy

absorption coefficients for air and muscle is unity over the energy range of interest, the maximum possible error is 5%. Applying this assumption yields a dose rate at one meter of 0.0241 mrem/hr. This dose rate is 1.2% and 2.4% of the limits set forth in 10CFR20.105 (b)(1) and (2), respectively.

Since the Ash Pond is accessible to the general public, it is appropriate to estimate the annual direct gamma exposure. Although the Ash Pond is readily recognizable as a waste disposal area and not suitable for recreational use, these exposures can be conservatively estimated using the shoreline usage factors for maximum individuals given in Table E-5 of Regulatory Guide 1.109 (NRC 77). These usage factors and the corresponding doses are given below.

Age Group	Shoreline Usage (hr/yr)	Dose (mrem/yr)
Adult	12	0.29
Teenager	67	1.61
Child	14	0.34
Infant	-	-

A more credible direct gamma exposure pathway is occupational exposure of the contractor personnel who would transfer the sediment. Based on previous experience, it is assumed that a two-man crew would require 160 hours to effect the transfer. The dose to these workers can be quickly and conservatively estimated by ignoring shielding provided by the trucks and using the infinite slab dose rate of 0.0241 mrem/hr. The resultant occupational dose is 7.7 mrem.

5.3.2 Inhalation

It is conceivable that the contaminated sediment could dry out after transfer to the Ash Pond and become airborne. This scenario is considered very improbable for several reasons. For example, sediment in the West Settling Pond which was pumped dry in early 1982 has remained too moist to become airborne. In addition, once transferred to the Ash Pond, the sediment would normally be submerged under several feet of water and would soon be covered by uncontaminated sediment. Raising the Ash Pond dike will increase the depth of covering sediment and water. Thus an extended outage of Unit 1 combined with dry weather would be required to dry the sediment and expose it to wind.

In spite of the factors just mentioned, dusting from the Ash Pond has been observed at least once during its lifetime. Thus an estimate of an upper bound for the dose to the maximum individual due to inhalation of suspended contaminated sediment is included here. It is conservatively assumed that only contaminated sediment becomes airborne and that the EPA maximum particulate loading of 260 $\mu g/m^3$ for fugitive emissions is maintained for a period such that the maximum individual is exposed for 24 hours. The respirable fraction can be conservatively estimated from data obtained during filtration of oil collected from the settling pond skimmer pits since the size distribution of these particulates are expected to be shifted towards smaller sizes. Because of the size of filters available, it is necessary to use 25 rather than 30 μm as the cutoff for respirable particles and 250 rather than 300 μm as the cutoff for suspended particles. These

filtration experiments showed that 3% by weight of the particles passing a 250 μm filter also passed a 25 μm filter. The respirable fraction is obtained by assuming the same size distribution for suspended particulates. Since the available radionuclide concentration data is in units of wet weight, it is necessary to correct for the concentration increase as the sediment dries. It is assumed that all the activity is retained by the sediment (i.e., none has been leached) and that the suspended particles have a density of 2.6 g/cm^3. This doubles the concentration relative to wet sediment. Concentrations in dry sediment and in air are summarized and compared to maximum permissible concentrations (MPC) for unrestricted areas in Table 5-1. Airborne concentrations of each radionuclide are approximately a million to a billion times less the applicable MPC values and the total airborne concentration is only 6.7 E-5 percent of MPC for this mixture of isotopes.

Doses to the maximum individual in each age group can be calculated by multiplying the airborne concentration of each radionuclide given in Table 5-1 by each age group's total air inhalation during the assumed 24-hour exposure (derived from Table E-5) and by the dose conversion factors taken from Tables E-7 through E-10 of Regulatory Guide 1.109 (NRC 77) and summing over all radionuclides for each organ. Dose conversion factors for Cd-109 uptake by the reference man were taken from ICRP 30 (ICRP). Dose factors for the other age groups were obtained by multiplying these values by 1.5 for teenagers, 2.5 for children, and 4.5 for infants. These multipliers were arbitrarily selected after inspection of ratios of dose conversion factors for these age groups for other isotopes found in the sediment. The results of these calculations are presented in Table 5-2 and identify the lung as the critical organ. About 83 percent of the lung dose is due to Co-60.

Table 5-1. Radionuclide Concentrations in Dry Sediment and in Air

	Dry Sediment ($\mu Ci/g$)	Airborne ($\mu Ci/cm^3$)	MPC[a] ($\mu Ci/cm^3$)
Mn-54	3.92E-7[b]	3.06E-18	1E-9
Co-58	8.72E-7	6.80E-18	2E-9
Co-60	1.72E-5	1.33E-16	3E-10
Nb-95	5.08E-7	3.96E-18	3E-9
Cd-109	4.88E-6	3.81E-17	3E-9
Cs-134	1.11E-6	8.66E-18	4E-10
Cs-137	9.22E-6	7.19E-17	5E-10
Ce-144	1.03E-6	8.03E-18	2E-10

a From 10CFR20, Appendix B, Table II, and Column 1 for insoluble particulates.

b 3.92E-7 = 3.92×10^{-7}.

Table 5-2. Doses Due to Inhalation of Maximized Airborne Particulate Concentrations for 24 Hours

	Dose (mrem)					
	Bone	Liver	Total Body	Kidney	Lung	GI-LLI
Adult	1.79E-7[a]	1.84E-7	1.02E-7	1.72E-7	2.63E-6	1.28E-7
Teenager	2.52E-7	2.44E-7	8.77E-8	2.51E-7	3.90E-6	1.19E-7
Child	3.42E-7	2.38E-7	4.68E-8	2.08E-7	3.17E-6	8.54E-8
Infant	1.88E-7	1.68E-7	1.90E-8	1.32E-7	2.10E-6	1.57E-8

a 1.79E-7 = 1.79×10^{-7}

The potential for occupational exposure is negligible since water would be added to the sediment to achieve the consistency required for hydrovacuuming.

5.3.3 Ingestion

As is the case with inhalation, it is conceivable that radioactivity from the contaminated sediment could enter the food chain and be consumed by humans. Since the Ash Pond can be readily recognized as a waste disposal area, it is assumed that humans would not drink directly from the pond. Because the deep aquifers in the vicinity of the Ash Pond are artesian, it is extremely unlikely that any seepage would enter drinking water supplies. There are no known wells (other than the CP&L test wells shown as numbered dots in Figure 4-1) tapping the unconfined auqifer or known gardens between the Ash Pond and Lake Robinson, the direction of the prevailing hydraulic gradient, as the area is within the owner-controlled area. Thus the normal exposure pathways are not applicable.

There is a significant deer population in the vicinity of the plant, and deer hunting is a popular local activity. To place an upper bound on the ingestion pathway, it is assumed that deer derive their entire food and water intake from the Ash Pond and that the maximum individuals in each age group derive their entire meat intake from these deer. Since exposure from this pathway would occur throughout the year, radionuclide concentrations are corrected for 6 months decay. The following sections discuss each stage of the calculations.

Concentration in Water

The constant influx of water into the Ash Pond combined with fluctuation in pH and dissolved cations will eventually overcome the natural affinity of the ash for the man-made radionuclides it now contains. Since insufficient data is available to evaluate the effects of these parameters, it is conservatively assumed that all of the 75 mCi of radioactivity is instantaneously released to the water in the Ash Pond. The concentrations of each radionuclide given in Table 5-3 are calculated by assuming that 20% of the current pond volume of 385,000 m^3 is occupied by water. In spite of these conservative assumptions, all concentrations are below MPC. These concentrations would be about 25% less if the volume of the pond after the dike is raised were used.

Table 5-3. Radionuclide Concentrations in Environmental Media for the Ingestion Pathway

	Conc. in Water (μCi/ml)	MPC for Water[a] (μCi/ml)	Conc. in Vegetation (μCi/g)	Conc. in Meat[b] (μCi/kg)
Mn-54	1.99E-8[c]	1E-4	5.68E-9	1.54E-1
Co-58	4.42E-8	1E-4	4.10E-9	4.90E+0
Co-60	8.67E-7	5E-5	8.04E-8	9.65E+1
Nb-95	2.57E-8	1E-4	2.39E-9	6.16E+1
Cd-109	2.47E-7	2E-4	7.32E-7	3.38E+0
Cs-134	5.60E-8	9E-6	5.53E-9	1.92E+0
Cs-137	4.68E-8	2E-5	4.61E-9	1.61E+0
Ce-144	5.23E-8	1E-5	1.29E-9	5.11E-1

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a From 10CFR20, Appendix B, Table II, and Column 2 for soluble species

b Corrected for 6 months decay

c 1.99E-8 = 1.99×10^{-8}

Concentration in Vegetation

Radionuclide concentrations in vegetation can be calculated by multiplying concentrations in sediment (weighted average concentrations from Table 3-1) by soil-to-plant stable element transfer data given in Table E-1 of Regulatory Guide 1.109 (NRC 77). Data for Cd-109 was taken from Table C-5 of the 1976 version of this guide.

Concentration in Wildlife

Radionuclide concentrations in deer meat can be calculated using Equation A-11 from Regulatory Guide 1.109 (NRC 77) as shown below.

$$C_i = F_i \left(C_{if} Q_f + C_{iw} Q_w\right) \qquad \text{Eq. 5-1}$$

where:

C_i = concentration of the "i-th" radionuclide in deer meat (pCi/kg).

F_i = food (forage or water) to meat transfer factor for the "i-th" radionuclide (days/kg).

C_{if} = concentration of the "i-th" radionuclide in forage (pCi/kg).

Q_f = forage consumption rate for deer (kg/day).

C_{iw} = Concentration of the "i-th" radionuclide in water (pCi/l).

Q_w = Water consumption rate for deer (l/day)

Using values of F_i from Table E-1 and values of Q_f and Q_w for goats from Table E-3 of Regulatory Guide 1.109 (NRC 77); converting concentrations in vegetation and water to units of pCi/kg and pCi/l, respectively; and correcting for 6 months decay yields the concentrations in deer meat shown in Table 5-3. The value of F_i for Cd-109 was obtained from Table C-5 of the 1976 version of Regulatory Guide 1.109.

Dose to Man

The dose to the maximum individual for each organ and age group from eating deer meat can be calculated following Regulatory Guide 1.109 as indicated below.

$$\sum_i R_{aij} = C_i \, U_a \, D_{aij} \qquad \text{Eq. 5-2}$$

where:

R_{aij} = dose to organ "j" and age group "a" for the "i-th" radionuclide (mrem/yr)

C_i = concentration of the "i-th" radionuclide in deer meat (pCi/kg)

U_a = deer meat consumption rate for age group "a" (kg/yr)

D_{aij} = dose conversion factor for organ "j" and age group "a" for the "i-th" radionuclide

Values of U_a and D_{aij} were obtained from Table E-5 and Tables E-11 through 13, respectively, of Regulatory Guide 1.109 (NRC 77). Values of D_{aij} for Cd-109 were obtained as described in Section 5.3.2. The resulting doses are summarized in Table 5-4. The gastrointestinal track is the critical organ for all age groups with Co-60 responsible for about 96% of the dose. As would be expected from the very conservative assumption regarding radionuclide concentrations in water, ingestion of pond water by deer is the major factor in determining the dose to humans.

Table 5-4. Doses from Ingestion of Contaminated Deer Meat

	Dose (mrem/yr)					
	Bone	Liver	Total Body	Kidney	Lung	GI-LII
Adult	2.50E-2[a]	7.46E-2	8.12E-2	5.79E-2	4.98E-3	4.17E-1
Teenager	2.04E-2	5.96E-2	5.23E-2	4.99E-2	4.56E-3	2.26E-1
Child	3.68E-2	7.27E-2	6.64E-2	5.37E-2	5.23E-3	1.17E-1

[a] 2.50E-2 = 2.50×10^{-2}

6.0 ALTERNATE DISPOSAL METHODS

It was originally planned to present two alternate disposal methods. These were to be dewatering in high integrity containers (HICs) and cement solidification is 55-gallon drums. The packaged waste was to be shipped to the Barnwell, South Carolina, site. The site operators have since informed CP&L that the contaminated sediment is not acceptable because it contains Ra-226 in concentrations which are not incidental to that of the man-made activity and because they consider the Ra-226 to be technologically enhanced as a result of volume reduction during coal combustion. In the meantime, the state of Nevada has declined to renew the license for the Beatty site. These circumstances, combined with the fact that the Richland, Washington, site does not accept HICs, somewhat restrict disposal options and emphasize the need for an alternate method of disposal. Only cement solidification in 55-gallon drums and shipment to Richland is considered here.

6.1 Operations

It is envisioned that the sediment would be easiest to handle as a slurry. Thus water would be added to the West Pond which is now drained. The slurried sediment would then be pumped to the cement solidification rig for processing. It is anticipated that a three-man crew would be required. The schedule for solidification would allow time for the construction activities mentioned in Section 5.1.1 and must provide for keeping one pond in service at all times.

6.2 Impacts

Potential impacts are limited to direct exposure of workers during operations and of the general public during transport to Richland. Exposure to the public would be negligible. No occupational exposure to airborne radioactivity would occur since the sediment would be handled as a slurry.

The occupational direct gamma dose can be conservatively estimated using the infinite slab dose rate of 0.0241 mrem/yr (Section 5.3.1) and an assumed exposure time of 160 hrs/man. This yields a total dose of 11.7 mrem or 3.9 mrem/man.

6.3 Costs

The total estimated cost of this disposal option is $13,148,000. A breakdown of costs is given in Table 6-1. These costs assume that the cement-like properties of fly ash in the sediment would allow mixing 75 percent by volume sediment with cement.

7.0 REQUEST FOR EXTENSION OF NRC APPROVAL TO POSSIBLE FUTURE SEDIMENT TRANSFERS

As discussed in Sections 1.0 and 5.1, CP&L is in the process of developing plans to modify both the settling ponds and ash pond to reduce accumulation of contaminated sediment in the settling ponds and mitigate the already small potential impacts of transfer of the sediment to the ash pond. However, all modifications to reduce accumulation of contaminated sediment may not be performed at the same time and may not completely eliminate sediment accumulation. For example, the settling ponds must be cleaned by the end of February 1983 to prevent shutting down both plants to avoid exceeding NPDES permit limits for the settling ponds. It is probable that the ponds will need to be cleaned again in 1983 in connection with modifications to control cross contamination and ash accumulation. It is not unlikely that the ponds will require at least one additional cleaning as residual contaminated sediment is flushed from the storm drains.

In view of the very low levels of radioactivity and the small impacts involved, CP&L requests that the Commission allow transfers of contaminated sediments from the settling ponds to the ash pond to be made without the specific approval of the Commission whenever the average concentration of Co-60 in sediment does not exceed 3.0 E-5 µCi/g wet. The derivation of this limit is discussed below.

The requested concentration limit is based on Co-60 alone for three main reasons. First it is the major, if not the only, radionuclide present. Second, for the critical organ and age group, whole body exposure of the maximum teenager, Co-60 is responsible for virtually all of the dose in the

Table 6-1 Estimated Costs of Commercial Disposal of Cement-Solidified Sediment

Quantity	Unit	Description	Unit Cost ($)	Cost ($)
37,664	each	55-gallon drums	23	866,000
282,480	cubic feet	Cement solidification	110	4,143,000
738	each	Waste shipments to Richland	5,000	3,690,000
282,480	cubic feet	Disposal fee	15.75	4,449,000
			Total	$13,148,000

direct exposure and ingestion pathways. Third, although Co-60 is not the principal contributor to the inhalation whole body dose, the total dose from this pathway is insignificant when compared to that for the direct exposure and ingestion pathways. Thus basing the requested concentration limit on Co-60 alone does not reduce the high degree of conservatism of the pathway analysis presented in Section 5.3 for the existing sediment.

In estimating direct exposure doses in Section 5.3, it was conservatively assumed that the weighted average total activity of 9.72 E-6 µCi/g wet was attributable to Co-60. This assumption is not conservative in the ingestion pathway, so weighted average concentrations for each radionuclide were used. If the teenager whole body ingestion dose is recalculated for Co-60 alone, a value of 4.24 E-2 mrem/yr is obtained. Although this value is 19 percent less than that obtained using average concentrations of each radionuclide, this change causes a negligible reduction (0.6 percent) in total dose for all pathways. The total dose to the critical individual, the maximum teenager, becomes 1.64 mrem/yr if Co-60 at a concentration of 9.72E-6 µCi/g wet is the only radionuclide present.

Having demonstrated that the use of Co-60 alone has a negligible effect on the total dose, the Co-60 concentration corresponding to a particular dose can now be calculated. A dose limit of 5 mrem/yr to the critical individual provides more than adequate protection to the general public, especially in view of the extreme conservatism of the dose calculations, without placing impractical restrictions on future sediment transfers. A dose of 5 mrem/yr corresponds to a Co-60 concentration of 2.90 E-5 µCi/g wet in sediment. Following the usual practice, the Co-60 concentrations has been rounded 3.0 E-5 for use as a limit.

It should be noted that sampling of the Ash Pond is now part of the H. B. Robinson environmental monitoring program and provides additional assurance that exposure to the public can be minimized. Sample types, frequencies, and analyses are given in Table 7-1.

Table 7-1 Radiological Monitoring of the Robinson Ash Pond

Sample Type	Frequency	Analysis
Surface Water	Monthly	Gross Alpha, Gross Beta, Tritium on Quarterly Composite. Gamma & Sr-89/90 if Gross Beta >100 p Ci/l
Soil (ash)	Semiannual (1 square foot by 1 inch deep)	Gross Beta, K-40, Gamma
Aquatic Vegetation	Semiannual	Gamma

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APPENDIX

Radiological Analysis of Contaminated Sediment

This Appendix presents the results of Ge (Li) analysis of samples of contaminated sediment from the two Robinson storm drain settling ponds. The data presented in Tables A-1 and A-2 are for grab samples taken from the surface of sediments in the two ponds. Table A-3 presents the results of analysis of cores samples taken from the West Settling Pond. Each core was 6 inches in diameter and 4 feet deep and was blended to ensure homogeneity. All samples were counted wet.

Table A-1 Concentrations (µCi/g Wet) of Man-Made Radionuclides in Routine Grab Samples of Sediment Collected From the East Settling Pond.

Date	Mn-54	Co-58	Co-60	Nb-95	Cd-109	Cs-134	Cs-137	Total
07/31/80			6.35E-8[a]					6.35E-8
08/27/80			7.51E-5				1.71E-6	7.68E-5
08/28/80		2.44E-7	5.16E-6			4.13E-7	2.83E-6	8.65E-6
09/27/80[b]			1.59E-5				4.00E-7	1.63E-5
09/27/80[c]	2.00E-7	4.04E-7	2.15E-6				1.44E-7	2.90E-6
10/30/80		9.33E-7	3.45E-6				1.69E-7	4.55E-6
11/07/80	2.55E-7	9.59E-7	1.19E-5				8.37E-7	1.40E-5
12/02/80	2.02E-7		8.52E-6				2.30E-7	8.95E-6
01/06/81		9.76E-7	8.40E-7				4.80E-7	2.30E-6
01/20/81			4.48E-5					4.48E-5
01/28/81		1.61E-7	8.26E-6				3.52E-7	8.77E-6
02/02/81	2.67E-7	6.04E-7	9.33E-6				2.46E-7	1.04E-5
02/03/81			4.00E-7					4.00E-7
02/13/81		1.86E-6	4.31E-5				7.19E-7	4.57E-5
02/20/81	1.71E-7	3.62E-7	1.86E-5					1.91E-5
04/03/81			2.59E-5	3.62E-7			3.95E-7	2.67E-5
04/10/81			1.76E-5	4.63E-7				1.81E-5
04/16/81		2.38E-7	1.82E-5		1.61E-6		2.83E-7	2.03E-5
04/23/81	1.59E-7		2.39E-5				1.54E-6	2.56E-5
04/30/81			1.44E-5		2.92E-6		5.84E-7	1.79E-5
05/01/81	9.25E-8		8.82E-6	2.61E-7			2.69E-7	9.44E-6
05/08/81			1.04E-5				2.83E-7	1.07E-5
05/14/81			9.80E-5					9.80E-5
05/19/81			1.61E-5	7.12E-7			3.77E-7	1.72E-5
05/22/81			1.70E-6				7.62E-8	1.78E-6
06/05/81			1.92E-6				4.65E-8	1.97E-6
06/11/81		2.77E-7	1.21E-5	2.95E-7			2.05E-7	1.29E-5
06/19/81			7.44E-6	2.83E-7			8.03E-8	7.80E-6
06/26/81			7.25E-6				9.97E-8	7.35E-6
07/03/81		1.99E-7	1.64E-5	1.66E-7			2.15E-7	1.70E-5
07/16/81		1.73E-6	4.16E-5				7.63E-7	4.41E-5
07/23/81			2.06E-5				4.25E-7	2.10E-5
07/30/81		6.10E-8	3.25E-6				2.50E-7	3.56E-6
08/06/81			1.61E-6		1.96E-6		1.36E-7	3.71E-6
08/13/81		1.20E-7	6.21E-6				1.85E-7	6.52E-6
08/21/81		1.66E-7	9.22E-6		2.52E-6		3.47E-7	1.23E-5
08/28/81			4.84E-7					4.84E-7
09/04/81	3.85E-7		3.22E-5	1.71E-7	2.50E-6		3.16E-7	3.56E-5
09/09/81			1.28E-5				3.79E-7	1.32E-5
09/17/81		1.25E-7	1.54E-5		2.99E-6		1.80E-7	1.87E-5
09/25/81		1.09E-7	6.82E-6		2.76E-6		2.10E-7	9.90E-6
10/01/81			9.25E-6	2.63E-7	1.42E-6		3.12E-7	1.12E-5
10/22/81			1.98E-6		3.58E-6		8.55E-8	5.65E-6
10/29/81			1.93E-5				5.89E-7	1.99E-5
11/06/81			1.36E-5		2.37E-6		2.34E-7	1.62E-5
12/04/81			5.45E-6		3.35E-6		2.17E-7	9.02E-6
01/07/82			1.47E-6					1.47E-6
Average	2.16E-7	5.29E-7	1.55E-5	3.31E-7	2.54E-6	4.13E-7	4.41E-7	1.68E-5

[a] 6.35E-8 = 6.35×10^{-8}

[b] Sample collected at 0950

[c] Sample collected at 1530

Table A-2 Concentrations (μCi/g Wet) of Man-Made Radionuclides in Routine Grab Samples of Sediments Collected from the West Settling Pond.

Date	Mn-54	Co-58	Co-60	Nb-95	Cd-109	Cs-134	Cs-137	Ce-144	Total
08/27/80			7.36E-6[a]				3.76E-7		7.74E-6
08/28/80		1.19E-7	1.44E-6		3.44E-6		1.90E-7		5.19E-6
09/27/80		4.35E-7	3.30E-6				2.92E-7		4.13E-6
10/30/80			1.09E-5				5.29E-7		1.14E-5
10/31/80			2.41E-6		3.02E-6		7.12E-8		5.50E-6
11/07/80		3.03E-7	1.61E-6				1.78E-7		2.09E-6
12/02/80			1.75E-6				2.84E-7		2.03E-6
01/06/81	2.03E-7	4.09E-7	1.15E-5		3.93E-6		6.21E-7		1.67E-5
01/20/81		2.59E-7	3.74E-6						4.00E-6
01/28/81		1.50E-7	1.53E-6						1.68E-6
02/02/81		4.50E-8							4.50E-8
02/03/81			4.23E-6						4.23E-6
02/13/81		5.16E-7	5.54E-6						6.06E-6
02/20/81		7.82E-7	2.66E-6						3.44E-6
04/03/81			1.72E-6						1.72E-6
04/10/81		7.08E-8	1.76E-6						1.83E-6
04/16/81			2.46E-6						2.46E-6
04/23/81			1.57E-6				7.12E-8		1.64E-6
04/30/81			1.57E-6	9.48E-8	2.51E-6				4.17E-6
05/08/81		4.38E-8	2.76E-6	3.05E-7			2.80E-7		3.39E-6
05/14/81			2.38E-6						2.38E-6
05/22/81			7.24E-7	4.34E-8					7.67E-7
06/06/81			8.95E-7				5.77E-8		9.53E-7
06/11/81			3.23E-7		3.68E-7				6.91E-7
06/19/81			5.53E-7						5.53E-7
06/26/81			3.52E-7						3.52E-7
07/03/81			4.63E-7	5.18E-8			3.41E-8		5.49E-7
07/10/81			2.11E-6				8.81E-8		2.20E-6
07/16/81			6.23E-7				8.39E-8		7.07E-7
07/23/81			1.45E-6		1.45E-6		7.35E-8		2.97E-6
07/30/81			2.22E-6	1.90E-7			2.67E-7		2.68E-6
08/06/81			1.31E-6	7.89E-8			1.25E-7		1.51E-6
08/13/81			5.87E-6	4.11E-7			1.96E-7	4.33E-7	6.91E-6
08/21/81			1.56E-6		2.32E-6		1.55E-7		4.04E-6
08/28/81			2.59E-6	3.02E-7	2.07E-6		2.90E-7	5.99E-7	5.85E-6
09/04/81			5.65E-6			1.40E-7	1.02E-6		6.81E-6
09/09/81			3.01E-6		1.23E-6		3.54E-7		4.59E-6
09/17/81			3.13E-6		4.43E-6		1.09E-7		7.67E-6
09/25/81			1.21E-6		9.58E-7		1.17E-7		2.29E-6
10/01/81	3.23E-8		5.97E-7		3.73E-6				4.33E-6
10/22/81			2.15E-6	1.18E-7	8.52E-7		1.38E-7		3.26E-6
10/29/81			1.33E-6				4.35E-7		1.77E-6
11/06/81			6.95E-6						6.95E-6
12/04/81			1.84E-5				2.88E-7		1.87E-5
01/07/82			7.83E-7		4.46E-6		7.95E-8		5.32E-6
02/04/82			1.47E-6		2.15E-6				3.62E-6
Average	1.18E-7	2.85E-7	3.06E-6	1.77E-7	2.46E-6	1.40E-7	2.43E-7	5.16E-7	4.08E-6

a7.36E-6 = 7.36×10^{-6}

Table A-3 Concentrations (μCi/g Wet) of Man-Made Radionuclides in Cores of Sediment Collected from West Settling Pond in April 1982.

Sample Number	Co-60	Cd-109	Cs-137	Total
1	5.11E-6[a]		3.64E-7	5.47E-6
2	2.46E-5		5.41E-6	3.00E-5
3	3.68E-6		6.53E-7	4.33E-6
4	1.59E-6			1.59E-6
5	6.58E-7			6.78E-7
6	8.05E-6		3.77E-7	8.43E-6
7	2.36E-6		3.74E-7	2.73E-6
8	4.50E-6	1.94E-6		6.44E-6
9	1.01E-6	1.63E-6		2.64E-6
10	2.43E-6		3.25E-7	2.76E-5
11	9.21E-6		9.49E-6	1.02E-5
12	1.57E-5		2.94E-7	1.60E-5
13	1.12E-5			1.12E-5
14	1.67E-5		2.12E-7	1.69E-5
15	5.65E-6		1.76E-6	7.41E-6
16	4.18E-6			4.18E-6
17	3.97E-6			3.97E-6
18	1.01E-6			1.01E-6
19	2.43E-6		1.79E-6	4.22E-6
20	9.50E-7			9.50E-7
21	2.24E-6			2.24E-6
22	2.25E-6		2.40E-7	2.49E-6
23	7.16E-7			7.16E-7
24				b
25	1.01E-6		9.01E-8	1.10E-6
26	8.37E-7			8.37E-7
27	1.44E-6			1.44E-6
28	1.74E-5			1.74E-5
Average	5.59E-6	1.79E-6	9.88E-7	7.12E-6

[a] $5.11E-6 = 5.11 \times 10^{-6}$

[b] Not included in total number of samples for calculation of average total activity.