Appendix A: Summary of Land Use Impacts Using GIS

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In case of a severe accident involving a nuclear shipment, the dose to individuals and the population will be much higher. In contrast to incident-free transportation, such an accident would cause both acute and long-term exposures, because radioactive particulates would be dispersed in the environment and continue to lead to radiation exposures. A severe transportation accident leading to a release of radioactive particulates is possible and credible. It could be caused by high impact, long duration fire or sabotage. Such an accident would lead to high radiation exposures due to inhalation (acute dose) and ground shine (long-term dose). Additional exposure to radiation would arise from ingestion of food, water and soil, even though the dose due from the ingestion pathway is very small in comparison to the inhalation and ground shine pathways. However, since food produced in the Fallon area is exported to and consumed in large parts of Nevada and California, an accident in Fallon could have health impacts throughout the region, if this food source is not interdicted.

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that is approximately 26 miles in length. Combined with growth and development along U.S. 95, the urban corridor through Churchill County may require even longer travel times than would be experienced in the Las Vegas Metropolitan Area.

One of the primary reasons for a greater emphasis on transportation planning in Churchill County and other rural Nevada communities is the recognition that Interstate routes through Las Vegas and other major metropolitan areas will not be used primarily due to political demands of highly populated areas. This situation has occurred on several major waste transportation shipping programs most notably those for the Waste Isolation Pilot Project in New Mexico and low-level waste shipments to the Nevada Test Site. Extensive use of secondary routes and avoidance of metropolitan areas are key elements of these shipping campaigns. With respect to Las Vegas, recent Congressional (House Energy and Water Appropriations Subcommittee) language directed DOE to,

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The GIS also helps to remedy the misconceptions that often surround transportation routing through so-called rural areas. Churchill County offers very diverse land uses along potential shipment corridors. In addition to urbanization (residential, commercial and industrial development) along highway corridors, Churchill County has highly productive farm lands including prime and unique farmlands, an extensive river and wetland system including a national wildlife refuge, critical national defense facilities (Fallon Naval Air Station), and a man-made reservoir that stores irrigation water provides one of the prime recreational facilities in northern Nevada.

The maps accompanying this analysis show accident scenario results in relationship to various land use. Accidents locations north of the City of Fallon on U.S. 95 and accidents to the west on U.S. 50 are shown GIS base layers. Implications of accident associated with these sites include:

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- An accident with a release on either route would have similar consequences with respect to impacts on land use.

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Possible Contamination of the Humboldt River

Ground contamination isopleths for the hypothetical accident at the Carlin Tunnel were developed. The isopleth was used to estimate the extent of radioactive cesium that could enter into the Humboldt River system. This section discusses the possible level of contamination and associated effects resulting from the contamination of the Humboldt River system.

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In a pure water system, cesium will ionize and dissolve, forming a solution. However, it will behave radically different in a natural river system, which may contain suspended solids, sediments, clays, and other ions. The behavior of cesium in natural systems is highly variable and highly dependent on the composition of the sediments interfacing the water. Cesium is a monovalent cation with an extremely high ion exchange capacity, meaning that it will selectively sorb to negatively charged particles (such as clays), displacing those ions which are not as strongly sorbed [68]. In fact, the bonding energy of the cesium ion is stronger than virtually all cations commonly found in natural rivers (such as potassium or sodium), suggesting that it will tend to preferentially be removed from the liquid phase, eventually being deposited at bends in meandering rivers or spots of low flow. For river systems that do not contain significant quantities of clay materials, the amount of cesium sorbed by sediments is highly dependent on the quantity of other ions in the system [69].

An equilibrium between ions in the liquid and sediment phases of a typical system is often described by the following empirical equation, known as the Freundlich isotherm:

Cs = kCd n ; where:
Cs = concentration of contaminant per gram sediment
Cd = concentration of contaminant per mL water
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For contaminant equilibrium between liquid and sediments, the empirical constant *n* generally has a value of between 0.5 and 0.1 [70]. The use of the non-linear Freundlich isotherm suggests that cesium tends to adsorb strongly to suspended sediments, especially strongly to negatively-charged colloids. Often, the parameter *n* is set equal to 1 and *k* is then simply defined as the ratio of the concentration of the contaminant in the solid (grams of contaminant/grams of sediment) to the concentration of the contaminant in the water (grams of contaminant/liters of water). This value is often called the distribution coefficient, Kd. The National Council on Radiation Protection and measurements (NCRP) compiled measured values of Kd for Cs-137 for a variety of water systems, which were found to be in the range of 500-1500 L/mg for rivers having relatively low concentrations of clay, and up to 50,000 L/mg for high-clay rivers [71.]

Other measurements have corroborated these values. For example, studies of contamination at the Oak Ridge facility have suggested that over 80% of Cs-137 passing through a dam in the White Oak River are associated with suspended sediment [72]. Moreover, these sorption reactions occur quickly [~90% of Cs-137 is sorbed within 3 days] and are not readily reversible such that "...once these radionuclides are incorporated into bottom sediments the potential for their release through desorption is almost negligible" [73] .

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Site-specific information about the Humboldt River near the site of the hypothetical accident corroborates the hypothesis that much of the cesium deposited into the river will be adsorbed into the sediment phase, eventually being deposited. The Humboldt River is the largest river wholly contained within Nevada. The river and its basin are a closed system, meaning that the water never reaches the ocean, either leaving the system via infiltration or evaporation. The Humboldt River traverses a meandering path, winding through valleys en route to the Humboldt Sink in northwest Churchill County.

Because the Humboldt River has its origins in the mountains of Northern Nevada, its flow rate is extremely variable, high when the mountainous snowcaps melt and low during the winter months. The meandering nature of the river, coupled with its variable flow rate, makes deposition of suspended material (at river bends, and in areas with low flow) more prevalent than in more straight, steady rivers. The area near the Humboldt River is characterized by Oravada soil, characterized generally as a sandy loam-type soil [74]. This type of soil is dominated by particles larger than typical sand granules, but smaller than the fine loam particulates. Shepperd and Thibault[75] compiled partition coefficients for the liquid/soil interface, which are reproduced in Table 1 below.

Table 1: Kd (soil-water) Values for Cesium

Soil Type	**K_ds for Cesium (L/Kg)**
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It should be noted that the K_ds values in Table 1 are not the same as the Kd values discussed previously, because the values listed in Table 1 are experimental values tested under laboratory conditions (allowing the soil and water to come to equilibrium). A high Kd value means preferential partitioning into the soil compartment of the (assumed) 2-compartment system. The table above shows that the sandy loam soil predominant in the Humboldt River region will tend to strongly sorb cesium.

From the discussion above, we have determined that, in the event of a release of cesium into the Humboldt River, the great majority will be selectively adsorbed onto the soil at the bottom of the river or the suspended sediments. Because of the meandering nature of the river and its unsteady flow conditions, most of the cesium adsorbed into suspended sediments is expected to eventually deposit, onto riverbanks at curves in the flow, or at points of low flow. These "hot spots" are of most concern from a public exposure point of view.

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75 Sheppard, M.I. and D.H. Thibault, 1990. "Default Soil Solid/Liquid Partition Coefficients, KDs, for Four Major Soil Types : A Compendium." *Health Physics* Vol. 39, No.4. pp 471-482.

Potential Extent of Contamination

An attempt to calculate the amount of radionuclide particulates which might enter into the Humboldt River or its tributaries after a postulated hypothetical accident is at best an approximate one. Much is unknown or variable which would be required knowledge to provide an exact answer. However, the difficulty in this estimation does not undermine the fact that the possible contamination of the Humboldt River is an important issue to discuss, at least qualitatively, in the context of a hypothetical radionuclide release. This section estimates the total source term of cesium released into the Humboldt River. After this is completed, a discussion of the possible consequences of the levels of contamination will be initiated.

The extent of contamination of the Humboldt River was estimated by measuring the length of the Humboldt River and tributaries that were underneath the 10›Ï Ci/m 2 ground contamination isopleth. The affected length was estimated to extend 30 kilometers downwind. It should be noted that the meandering nature of the river makes this an underestimate, since it assumes that the river is essentially a straight line. In fact, a report by the State of Nevada 76 states that the actual length of the river may be double what it has been estimated, due to its tortuous path. Therefore, as an upper bound, we have also calculated the contamination to the river based on an affected length of 60 kilometers. The width of the river was assumed to be 50 feet, with the depth assumed to be 5 feet [77], resulting in an estimated surface area of contamination of 0.46km 2 to 0.91km 2 , depending on the length assumed.

The next step was to estimate the extent of contamination depositing on the river surface. This was done by using the ground contamination isopleths, with the area between the 100›Ï Ci/m 2 and 500 µCi/m 2 isopleths being the first to impact the river. The level of contamination at different sections of the river was estimated by breaking the river into discrete sections based on the location of the isopleths, then assuming that the entire area of river contained between two isopleths was contaminated at the average value between them. This is shown in Tables 2 and 3. For simplicity, the various contaminations were then averaged into a single contamination level for the entire affected part of the river, which was used as the initial concentration for further calculations. This is shown in Table 4.

Table 2: Estimated Contamination Levels of Humboldt River Following Hypothetical Accident, Low Estimate of Affected River Length

Ground Contamination Rage µCi/m	River length within Contamination Range km	Estimated Surface Contamination, µci/m^2	Amount Deposited, Ci	Cs-137 Deposited, Ci*	Cs-134 Deposited, Ci*
100-500	2.5	300	11.6	3.1	8.5
50-100	4.6	75	5.2	1.4	3.8
10-50	18.5	30	8.5	2.3	6.2

- * The relative amounts of Cs-134 and Cs-137 were estimated by the fractional inventories of each radionuclide (Cesium in the modeled spent fuel container was approximately 26.6% Cs-134 and 73.4% Cs-137 in terms of Curies).

Table 3: Estimated Contamination Levels of Humboldt River Following Hypothetical Accident, High Estimate of Affected River Length

Ground Contamination Rage µCi/m	River length within Contamination Range km	Estimated Surface Contamination, µci/m^2	Amount Deposited, Ci	Cs-137 Deposited, Ci*	Cs-134 Deposited, Ci*
100-500	5.05	300	23.1	6.1	17.0
50-100	9.13	75	10.4	2.8	7.7
10-50	37.01	30	16.7	4.5	12.4

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Table 4 Estimated Average Cesium Concentrations in Affected Length of Humboldt River Following Hypothetical Accident

Length Estimate	Total River Volume Affected (m^3)	Average Initial Concentration Cs-137 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µg/L	Total amount Cs-137 Deposited (mg)	Total Amount CS-134 Deposited (mg)
Low	5.94E+05	11.29	31.15	1.3E-04	2.38E-05	77.4	14.1
High	1.19E+06	11.29	31.15	1.3E-04	2.38E-05	154.8	28.3

Table 4 shows that an estimated 91.5 to 183.1 mg of cesium could be deposited into the Humboldt River system following the postulated accident. As was previously stated, it is expected that the vast majority of this will eventual be deposited, either into the river sediments or onto riverbanks. The distribution of deposited cesium is not random: it will occur at river bends and at areas of low flow, creating hot spots. Because of this, the concentration of cesium at this location will be significantly elevated compared to nearby concentrations that have been affected by the hypothetical accident but do not contain river-deposited cesium.

[76] *Humboldt River Chronology.* Volume I, Part I : Overview [77] Conservative values were used whenever data was unavailable or extremely variable

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75 Sheppard, M.I. and D.H. Thibault, 1990. "Default Soil Solid/Liquid Partition Coefficients, KDs, for Four Major Soil Types : A Compendium." *Health Physics* Vol. 39, No.4. pp 471-482.

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An attempt to calculate the amount of radionuclide particulates which might enter into the Humboldt River or its tributaries after a postulated hypothetical accident is at best an approximate one. Much is unknown or variable which would be required knowledge to provide an exact answer. However, the difficulty in this estimation does not undermine the fact that the possible contamination of the Humboldt River is an important issue to discuss, at least qualitatively, in the context of a hypothetical radionuclide release. This section estimates the total source term of cesium released into the Humboldt River. After this is completed, a discussion of the possible consequences of the levels of contamination will be initiated.

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The next step was to estimate the extent of contamination depositing on the river surface. This was done by using the ground contamination isopleths, with the area between the 100›Ï Ci/m2 and 500 µCi/m 2 isopleths being the first to impact the river. The level of contamination at different sections of the river was estimated by breaking the river into discrete sections based on the location of the isopleths, then assuming that the entire area of river contained between two isopleths was contaminated at the average value between them. This is shown in Tables 2 and 3. For simplicity, the various contaminations were then averaged into a single contamination level for the entire affected part of the river, which was used as the initial concentration for further calculations. This is shown in Table 4.

Table 2: Estimated Contamination Levels of Humboldt River Following Hypothetical Accident, Low Estimate of Affected River Length

Ground Contamination Rage µCi/m	River length within Contamination Range km	Estimated Surface Contamination, µci/m^2	Amount Deposited, Ci	Cs-137 Deposited, Ci*	Cs-134 Deposited, Ci*
100-500	2.5	300	11.6	3.1	8.5
50-100	4.6	75	5.2	1.4	3.8
10-50	18.5	30	8.5	2.3	6.2

- * The relative amounts of Cs-134 and Cs-137 were estimated by the fractional inventories of each radionuclide (Cesium in the modeled spent fuel container was approximately 26.6% Cs-134 and 73.4% Cs-137 in terms of Curies).

Table 3: Estimated Contamination Levels of Humboldt River Following Hypothetical Accident, High Estimate of Affected River Length

Ground Contamination Rage µCi/m	River length within Contamination Range km	Estimated Surface Contamination, µci/m^2	Amount Deposited, Ci	Cs-137 Deposited, Ci*	Cs-134 Deposited, Ci*
100-500	5.05	300	23.1	6.1	17.0
50-100	9.13	75	10.4	2.8	7.7
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Table 4 Estimated Average Cesium Concentrations in Affected Length of Humboldt River Following Hypothetical Accident

Length Estimate	Total River Volume Affected (m^3)	Average Initial Concentration Cs-137 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µCi/ m^3)	Average Initial concentration Cs-134 in affected area (µg/L	Total amount Cs-137 Deposited (mg)	Total Amount CS-134 Deposited (mg)
Low	5.94E+05	11.29	31.15	1.3E-04	2.38E-05	77.4	14.1
High	1.19E+06	11.29	31.15	1.3E-04	2.38E-05	154.8	28.3

Table 4 shows that an estimated 91.5 to 183.1 mg of cesium could be deposited into the Humboldt River system following the postulated accident. As was previously stated, it is expected that the vast majority of this will eventual be deposited, either into the river sediments or onto riverbanks. The distribution of deposited cesium is not random: it will occur at river bends and at areas of low flow, creating hot spots. Because of this, the concentration of cesium at this location will be significantly elevated compared to nearby concentrations that have been affected by the hypothetical accident but do not contain river-deposited cesium.

76 *Humboldt River Chronology.* Volume I, Part I : Overview 77 Conservative values were used whenever data was unavailable or extremely variable

Appendix A: Summary of Land Use Impacts Using GIS

If a high-level waste repository opens at Yucca Mountain, south of Fallon on US 95, a large number of truck shipments of nuclear waste are expected on US 95. Truck shipments of nuclear waste through Fallon would lead to a radiation dose to the public even if the transport is incident-free, because no shielding material can reduce direct gamma radiation by 100 %. As a result, residents, drivers, pedestrians and workers will get a radiation dose, which depends on the recipient's exposure proximity and duration. Depending on the population estimate, the population dose due to incident-free transportation of the entire waste that is planned to pass Fallon is as high as 9.45 person-rem. Even though this dose and the resulting population risk are relatively small, it nevertheless increases the risk to develop cancer.

In case of a severe accident involving a nuclear shipment, the dose to individuals and the population will be much higher. In contrast to incident-free transportation, such an accident would cause both acute and long-term exposures, because radioactive particulates would be dispersed in the environment and continue to lead to radiation exposures. A severe transportation accident leading to a release of radioactive particulates is possible and credible. It could be caused by high impact, long duration fire or sabotage. Such an accident would lead to high radiation exposures due to inhalation (acute dose) and ground shine (long-term dose). Additional exposure to radiation would arise from ingestion of food, water and soil, even though the dose due from the ingestion pathway is very small in comparison to the inhalation and ground shine pathways. However, since food produced in the Fallon area is exported to and consumed in large parts of Nevada and California, an accident in Fallon could have health impacts throughout the region, if this food source is not interdicted.

As part of its oversight activities Churchill County has been in the process of developing a geographic information system (GIS) to assist in transportation analysis, provide access to technical mapping and data developed by the Yucca Mountain program, and assist with public information requests. The extent to which radiation exposure from accident and non-accident scenarios is ,in part, dependent upon the types of surrounding land uses.

The GIS is being used to better assess impacts associated with accident and non-accident scenarios described in the *Fallon Impact Report Transportation of Spent Nuclear Fuel by Highway to Yucca Mountain.* This appendix contains several GIS layers superimposed with results from accident scenarios developed for Churchill County.

Intensive land development in Churchill County and the City of Fallon generally occurs within one mile of either side of the U.S. Highway system. Although this area is primarily rural in nature, urbanization stretches out along highway corridors for some distance. Even between Fallon and the City of Fernley 26 miles to the west, urbanization continues along highway corridors. It is possible that when shipments are scheduled to begin in 2010, U.S. Highway 50 and Highway 95 in Churchill County as well as neighboring Lyon County may be connected forming an urban corridor along U.S. 50 that is approximately 26 miles in length. Combined with growth and development along U.S. 95, the urban corridor through Churchill County may require even longer travel times than would be experienced in the Las Vegas Metropolitan Area.

One of the primary reasons for a greater emphasis on transportation planning in Churchill County and other rural Nevada communities is the recognition that Interstate routes through Las Vegas and other major metropolitan areas will not be used primarily due to political demands of highly populated areas. This situation has occurred on several major waste transportation shipping programs most notably those for the Waste Isolation Pilot Project in New Mexico and low-level waste shipments to the Nevada Test Site. Extensive use of secondary routes and avoidance of metropolitan areas are key elements of these shipping campaigns. With respect to Las Vegas, recent Congressional (House Energy and Water Appropriations Subcommittee) language directed DOE to,

> *"move aggressively to work with state and local governments to develop safe transportation routes to the selected repository site, beginning with the development of transportation routes and modes in Nevada that* ***will avoid the Las Vegas metropolitan area."***

Clearly the emphasis of transportation in Nevada falls on communities that lie on those transportation links outside Clark County.

The GIS also helps to remedy the misconceptions that often surround transportation routing through so-called rural areas. Churchill County offers very diverse land uses along potential shipment corridors. In addition to urbanization (residential, commercial and industrial development) along highway corridors, Churchill County has highly productive farm lands including prime and unique farmlands, an extensive river and wetland system including a national wildlife refuge, critical national defense facilities (Fallon Naval Air Station), and a man-made reservoir that stores irrigation water provides one of the prime recreational facilities in northern Nevada.

The maps accompanying this analysis show accident scenario results in relationship to various land use. Accidents locations north of the City of Fallon on U.S. 95 and accidents to the west on U.S. 50 are shown GIS base layers. Implications of accident associated with these sites include:

- Impacts to public facilities including school, emergency services, public administration, jails, and communications systems. Emergency services and communications are located in the center of Fallon. Churchill County Communication (local telephone provider), the Churchill County Sheriff's office, Fire Department Headquarters, City Hall, County Administration, all lie within contaminated areas.

- The inclusion of sizeable areas of residential, commercial and industrial development as well as public facilities previously described.

- An accident with a release on either route would have similar consequences with respect to impacts on land use.

- Natural resources would also be affected. The Carson River system is adjacent to U.S. 50 and crosses under both U.S. 95 and 50. The River system support irrigated agriculture as well as sizeable wetland and wildlife habitat areas in Carson Lake and Pasture (State of Nevada) and the Stillwater National Wildlife Refuge which both are down gradient from highway locations. As a result, storm drainage as well as irrigation drains empty into Carson Lake and Pasture as well as Stillwater National Wildlife Refuge.

- Productive farmlands lie within close proximity to the highway system. Alfalfa, the predominate crop, is used to feed local diary herds, shipped to California diaries as supplemental feed as well as to international locations. Milk product from the Fallon area is also distributed throughout the west.

- Lands along the corridor routes are primarily designated for more intensive land uses associated with commercial, industrial and residential growth. Based upon existing zoning, future growth and development will continue along the highway corridors.

- Churchill County has identified a potential by-pass route that would allow trucks carrying hazardous materials to avoid much of the urbanized area. Such routes could limit population exposure but would not avoid accident related contamination of surface water resources and productive farmlands. The by-pass routes could potentially lower the non-accident radiation exposure to the surrounding population. Also, the accident consequences for locations along the bypass route could be lower than compared to existing routes.

One of the key land use feature not well understood and has not been analyzed in much detail is the impact to water resources. Churchill County and more specifically the Lahontan Valley is significantly different than most of Nevada in terms of water resources. The Newlands Irrigation Project provides surface water to about 60,000 acres of cropland and wildlife use areas in Carson Lake and Stillwater National Wildlife Refuge. In addition to the Carson Reservoir, the Newlands Irrigation Project is made-up of over 350-miles of major canals, laterals, and ditches as well as four major regulating reservoirs.

The State of Nevada in its 2001 study entitled, *Worst Case Credible Nuclear Transportation Accidents: Analysis for Urban and Rural Nevada.* The analysis considers impacts to the Humboldt River system from an accident near Elko, Nevada. The results of the analysis may provide some insights into possible contamination of the irrigation system, the Carson River, and associated wetlands. What is less well understand is the impact that an accident may have on groundwater supplies. The surface irrigation system in the Newlands Project provides 95 percent of the groundwater recharge in Lahontan Valley. Exerpts from the report follows.

Possible Contamination of the Humboldt River

Ground contamination isopleths for the hypothetical accident at the Carlin Tunnel were developed. The isopleth was used to estimate the extent of radioactive cesium that could enter into the Humboldt River system. This section discusses the possible level of contamination and associated effects resulting from the contamination of the Humboldt River system.

Cesium Partitioning in Water

In a pure water system, cesium will ionize and dissolve, forming a solution. However, it will behave radically different in a natural river system, which may contain suspended solids, sediments, clays, and other ions. The behavior of cesium in natural systems is highly variable and highly dependent on the composition of the sediments interfacing the water. Cesium is a monovalent cation with an extremely high ion exchange capacity, meaning that it will selectively sorb to negatively charged particles (such as clays), displacing those ions which are not as strongly sorbed [68]. In fact, the bonding energy of the cesium ion is stronger than virtually all cations commonly found in natural rivers (such as potassium or sodium), suggesting that it will tend to preferentially be removed from the liquid phase, eventually being deposited at bends in meandering rivers or spots of low flow. For river systems that do not contain significant quantities of clay materials, the amount of cesium sorbed by sediments is highly dependent on the quantity of other ions in the system [69].

An equilibrium between ions in the liquid and sediment phases of a typical system is often described by the following empirical equation, known as the Freundlich isotherm:

$Cs = kCd^n$; where:
Cs = concentration of contaminant per gram sediment
Cd = concentration of contaminant per mL water
k, n = empirical constants.

For contaminant equilibrium between liquid and sediments, the empirical constant *n* generally has a value of between 0.5 and 0.1 [70]. The use of the non-linear Freundlich isotherm suggests that cesium tends to adsorb strongly to suspended sediments, especially strongly to negatively-charged colloids. Often, the parameter *n* is set equal to 1 and *k* is then simply defined as the ratio of the concentration of the contaminant in the solid (grams of contaminant/grams of sediment) to the concentration of the contaminant in the water (grams of contaminant/liters of water). This value is often called the distribution coefficient, Kd. The National Council on Radiation Protection and measurements (NCRP) compiled measured values of Kd for Cs-137 for a variety of water systems, which were found to be in the range of 500-1500 L/mg for rivers having relatively low concentrations of clay, and up to 50,000 L/mg for high-clay rivers [71].

Other measurements have corroborated these values. For example, studies of contamination at the Oak Ridge facility have suggested that over 80% of Cs-137 passing through a dam in the White Oak River are associated with suspended sediment [72]. Moreover, these sorption reactions occur quickly [~90% of Cs-137 is sorbed within 3 days] and are not readily reversible such that "...once these radionuclides are incorporated into bottom sediments the potential for their release through desorption is almost negligible" [73].

68 Sayre, Guy, and Chamberlain. "Transport of Radionuclides by Streams: Uptake and Transport of Radionuclides by Stream Sediments." U.S. Government Printing Office, 1963.
69 Chapter 3 in NCRP Report No. 76, *Radiological Assessment : Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment.* National Council on Radiation Protection and Measurements, 1984.
70 Sayre, Guy, and Chamberlain, pp. A-12

Site-specific information about the Humboldt River near the site of the hypothetical accident corroborates the hypothesis that much of the cesium deposited into the river will be adsorbed into the sediment phase, eventually being deposited. The Humboldt River is the largest river wholly contained within Nevada. The river and its basin are a closed system, meaning that the water never reaches the ocean, either leaving the system via infiltration or evaporation. The Humboldt River traverses a meandering path, winding through valleys en route to the Humboldt Sink in northwest Churchill County.

Because the Humboldt River has its origins in the mountains of Northern Nevada, its flow rate is extremely variable, high when the mountainous snowcaps melt and low during the winter months. The meandering nature of the river, coupled with its variable flow rate, makes deposition of suspended material (at river bends, and in areas with low flow) more prevalent than in more straight, steady rivers. The area near the Humboldt River is characterized by Oravada soil, characterized generally as a sandy loam-type soil [74]. This type of soil is dominated by particles larger than typical sand granules, but smaller than the fine loam particulates. Shepperd and Thibault[75] compiled partition coefficients for the liquid/soil interface, which are reproduced in Table 1 below.

Table 1: Kd (soil-water) Values for Cesium

Soil Type	**K_ds for Cesium (L/Kg)**
Sand	280
Loam	4600
Clay	1900
Organic	270

It should be noted that the K_ds values in Table 1 are not the same as the Kd values discussed previously, because the values listed in Table 1 are experimental values tested under laboratory conditions (allowing the soil and water to come to equilibrium). A high Kd value means preferential partitioning into the soil compartment of the (assumed) 2-compartment system. The table above shows that the sandy loam soil predominant in the Humboldt River region will tend to strongly sorb cesium.

From the discussion above, we have determined that, in the event of a release of cesium into the Humboldt River, the great majority will be selectively adsorbed onto the soil at the bottom of the river or the suspended sediments. Because of the meandering nature of the river and its unsteady flow conditions, most of the cesium adsorbed into suspended sediments is expected to eventually deposit, onto riverbanks at curves in the flow, or at points of low flow. These “hot spots” are of most concern from a public exposure point of view.

71 NCRP Report No. 76. *Radiolocigal Assessment : Predicting the Transport, Bioaccumulation, and Uptkae by Man of Radionuclides Released to the Environment.* National Council on Radiation Protection and Measurements, March 1984. pp. 126 72 Carrigan, Jr., P.H.; Pickering, R.J.; Tamura, T.; Forbes, R., 1967, Radioactive Materials in Bottom Sediment of Clinch River: Part
A, Investigations of Radionuclides in Upper Portion of Sediment: ORNL-3721 Supplement 2A to Status Report No. 5 on Clinch River
Study, 3/1967. 73 *Ibid.,* pg. 35. 74 U.S.Department of Agriculture National Resources Conservation Service National Soil Survey Center. Online at
http://www.statlab.iastate.edu/soils/photogal/statesoils/nv_soil.htm

75 Sheppard, M.I. and D.H. Thibault, 1990. “Default Soil Solid/Liquid Partition Coefficients, KDs, for Four Major Soil Types : A Compendium.” *Health Physics* Vol. 39, No.4. pp 471-482.

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