AR TARGET SHEET

The following document was too large to scan as one unit, therefore it has been broken down into sections.

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SECTION 2 OF 2

5.2.7.24 Segment 24: Snake River Influence

In this segment, the Snake River joins the Columbia River. Contaminants tentatively identified here above background levels are ammonia, benzene, cesium-137, cobalt-60, europium-152 and -154, iodine-129, mercury, nitrates, strontium-90, sulfates, technetium-99, tritium (hydrogen-3), and uranium-238. Strontium-90 is present in sufficient quantity to score above the lower risk threshold, but the calculated result is dominated by a surface water estimate calculated with concentrations extrapolated from Segment 21.

The total risk in this segment to humans estimated using the scenarios developed for the screening assessment ranges from a stochastic median low for the Ranger Scenario of 2.7×10^{-5} lifetime risk and 7.7×10^{-4} hazard index to a median high for the Native American Subsistence Resident Scenario of 3.3×10^{-3} lifetime risk and 4.6 hazard index. These results are controlled by chromium and copper, respectively.

5.2.7.25 Segment 25: Boise Cascade

This segment of the Columbia River includes the oxbow lakes of the Columbia River National Wildlife Refuge and is affected by a large paper pulp plant. This segment is not noticeably different from the one above it in terms of identified contaminants. Contaminants tentatively identified here above background levels are ammonia, cesium-137, cobalt-60, europium-154, iodine-129, nitrates, sulfates, technetium-99, tritium (hydrogen-3), and uranium-238. None of the contaminants is present in sufficient quantity to score above the risk thresholds.

The total risk in this segment to humans estimated using the scenarios developed for the screening assessment ranges from a stochastic median low for the Ranger Scenario of 6×10^{-5} lifetime risk and 1.3×10^{-3} hazard index to a median high for the Native American Subsistence Resident Scenario of 7.1×10^{-3} lifetime risk and 6.5 hazard index. These results are controlled by chromium and copper, respectively.

5.2.7.26 Segment 26: Walla Walla River Influence

This segment corresponds with the influx of the Walla Walla River into the Columbia River. This segment is not noticeably different from the one above it in terms of identified contaminants. Contaminants tentatively identified here above background levels are ammonia, cesium-137, cobalt-60, europium-154, iodine-129, nitrates, strontium-90, sulfates, technetium-99, tritium (hydrogen-3), and uranium-238. Strontium-90 is present in sufficient quantity to score above the lower risk threshold, but the calculated result is dominated by a surface water estimate calculated with concentrations extrapolated from Segment 21. As in Segment 24, this indication is likely a statistical variation near the background level.

The total risk in this segment to humans estimated using the scenarios developed for the screening assessment ranges from a stochastic median low for the Ranger Scenario of 5.6×10^{-5} lifetime risk and

1.4×10^{-3} hazard index to a median high for the Native American Subsistence Resident Scenario of 6.7×10^{-3} lifetime risk and 5.7 hazard index. These results are controlled by chromium and copper, respectively.

5.2.7.27 Segment 27: McNary Dam and Reservoir

This segment includes the McNary Reservoir between the influx of the Walla Walla River and McNary Dam. This segment is not noticeably different from the one above it in terms of identified contaminants. Contaminants tentatively identified here above upstream background are ammonia, cesium-137, chromium, cobalt-60, europium-152 and -154, nitrates, strontium-90, sulfates, technetium-99, and uranium-238. Chromium appears above the upper reporting threshold in this segment but only for the Ranger Scenario. This seems to be a statistical artifact. Strontium-90 is present in sufficient quantity to score above the lower risk threshold, but the calculated result is dominated by a surface water estimate calculated with concentrations extrapolated from Segment 21. As in Segments 24 and 26, this indication is likely a statistical variation near the background level.

The total risk in this segment to humans estimated using the scenarios developed for the screening assessment ranges from a stochastic median low for the Ranger Scenario of 1.5×10^{-4} lifetime risk and 2.3×10^{-3} hazard index to a median high for the Native American Subsistence Resident Scenario of 0.016 lifetime risk and 7.8 hazard index. These results are controlled by chromium and copper, respectively.

6.0 Synthesis of Results

The objective of the screening assessment was to identify areas where the greatest potential exists for adverse effects on humans or the environment under current conditions. This required determining what contaminants are elevated because of past or ongoing Hanford Site operations, and, if those contaminants are elevated, what is the measure of potential risk to both humans and the ecosystem.

With the above in mind, the following assessment questions were established:

- Do current levels of contaminants in Columbia River water, sediment, and riparian zone materials pose a potential risk to ecological resources?

- Do current levels of contaminants in Columbia River water, sediment, and riparian zone materials pose a potential risk to humans who might be exposed to them?

If the answers to either of these questions were yes, then answers for the following sub-set of questions were sought:

- What contaminants contribute to risk? (For answer, see Figure 6.1 and Table 6.1.)
- Where in the study area are these contaminants located? (For answer, see Figure 6.1 and Table 6.1.)
- In what media are these contaminants concentrated? (For answer, see Table 6.1.)
- Which organisms or groups of organisms have the greatest likelihood of being adversely affected? (For answer, see discussion below in Section 6.3 and Table 4.22 in Section 4.2.)
- Humans in which economic or cultural categories have the greatest likelihood of being adversely affected? (For answer, see discussion below in Section 6.3 and Figure 5.4 in Section 5.2.)

6.1 Assessment Context

By agreement with the Tri-Parties and the CRCIA Management Team, this screening assessment addressed the current potential for ecological and human risk, resulting from known levels of contaminants in the Columbia River or in its immediate vicinity. The screening assessment does not address inventories currently moving towards the river from distant locations or other inventories that may be left by future remediation activities at other Hanford Site locations.

The contaminants that could possibly be associated with past Hanford Site operations were evaluated. This contaminant identification process, described in Section 2.2, was based on a preliminary review of easily available records, environmental measurements, and process knowledge. The initial list contained nearly 100 possible environmental contaminants. Although a considerable effort was expended to compile this list, its use was to focus the remaining data gathering on only those contaminants of greatest interest. The data and parameters used in the selection of contaminants for study were not the ones used in the remainder of the screening assessment because the data and parameters used for the risk assessment could only be determined once the contaminants were selected.

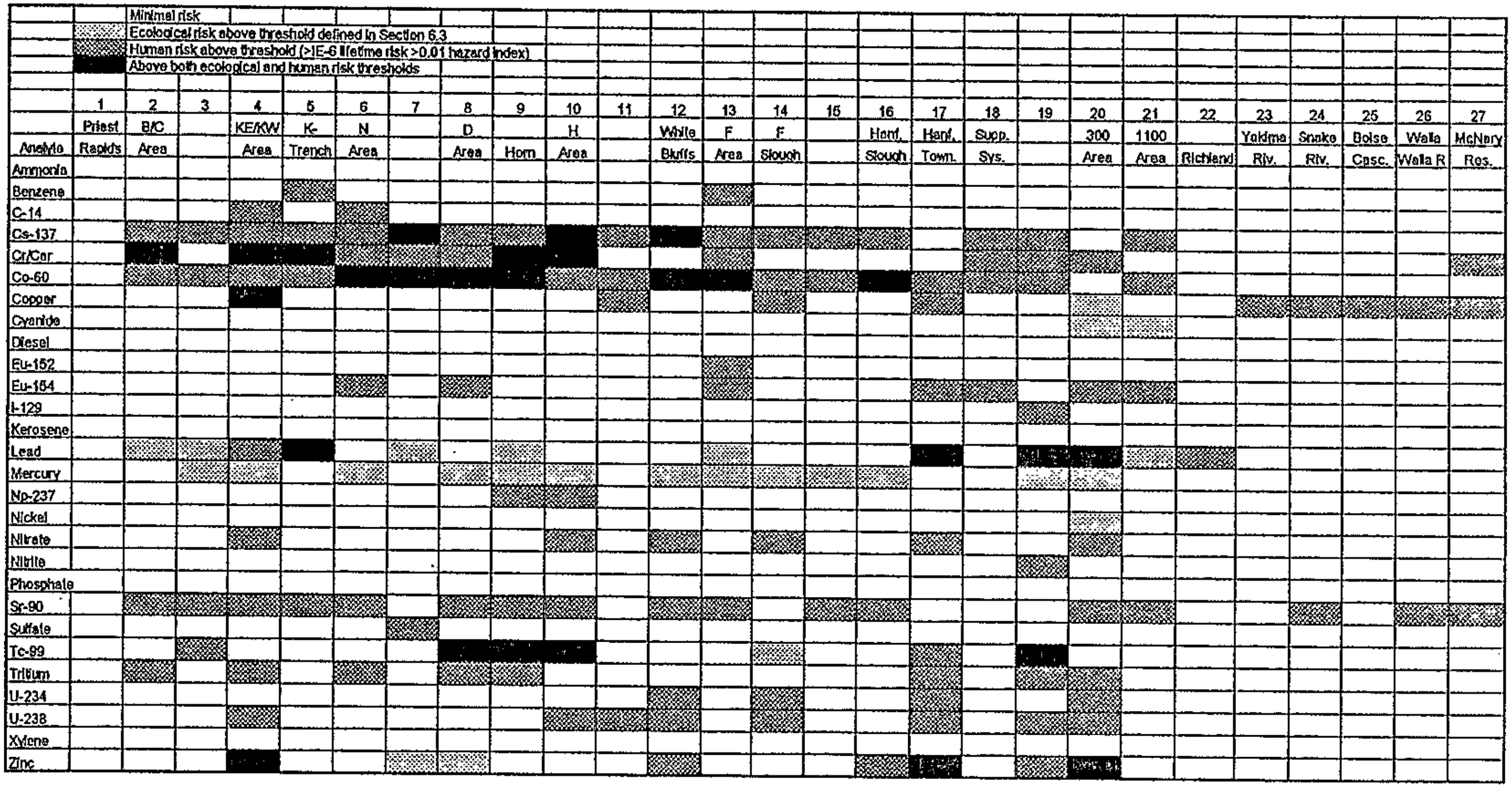

Figure 6.1. Summary of the Screening Assessment of Risk to the Ecosystem and Human Health (The reporting thresholds in this figure identify potentially hazardous contaminants, chronic and acute effects to all plants and animals, and toxic and carcinogenic impacts on human health for all scenarios considered in this report.)

Table 6.1. Potentially Hazardous Contaminants Identified by River Segment and Contaminating Media (This table presents the contaminants by river segment and media and the estimated range of human risk.)

	Ecological Risk		Human Risk					
	River Segment	Medium	River Segment	Medium	Ranger Scenario		Native American Sc.	
Contaminant					Haz. Index	Risk	Haz. Index	Life Risk
Benzene			5	SP				2.60E-05
			13	SP				2.60E-05
Carbon-14			4	SP				2.90E-05
			6	SP				1.20E-05
Cesium-137			2	SW				7.01E-06
			3	SW(2)				7.46E-06
			4	SW(2)				1.06E-05
			5	SW(2)				1.32E-05
			6	SW				1.76E-05
	7	SD	7	SW(6)				2.16E-05
			8	SW				2.78E-05
			9	SW(8)				2.81E-05
	10	SD	10	SW(8)				3.06E-05
			11	SW(8)				2.94E-05
	12	SD	12	SW(8)				2.92E-05
			13	SW(8)				3.32E-05
			14	SW(8)				2.43E-05
			15	SW(8)				2.39E-05
			16	SW(8)				2.63E-05
			18	SW				1.34E-05
			19	SW(18)				2.05E-05
			21	SP(GW)				1.59E-05
Chromium	2	SD+SP	2	SW+SD		2.60E-04	2.32E-02	2.58E-01
	4	SD+SP	4	SD+SP		2.10E-04	3.30E-02	1.09E-01
	5	SD+SP	5	SD		2.10E-04	1.43E-02	6.30E-02
			6	SW		5.90E-05		4.23E-02
			7	SD		1.50E-04		6.94E-02
			8	SW+SP		5.60E-05	1.35E-02	8.66E-02
	9	SD+SP	9	SD+SP		1.00E-04	2.46E-02	6.72E-02
	10	SD+SP	10	SD+SP		1.40E-04	1.71E-02	5.90E-02
			13	SD		7.20E-05		5.28E-02
			18	SD		1.90E-04		3.89E-02
			19	SD		2.50E-04		1.05E-01
			20	SD		1.60E-04		7.03E-02
			27	SD		1.50E-04		1.64E-02
Cobalt-60			2	SD				3.54E-06
(Diffuse)			3	SW(2)				2.22E-06
			4	SW(2)				2.96E-06

Table 6.1. (Cont'd)

	Ecological Risk		Human Risk					
	River		River		Ranger Scenario		Native American Sc.	
Contaminant	Segment	Medium	Segment	Medium	Haz. Index	Risk	Haz. Index	Life Risk
			5	SW(2)				2.71E-06
	6	SD	6	SD				1.08E-05
	7	SD	7	SD				2.58E-06
	8	SD	8	SW				3.71E-06
	9	SD	9	SD				2.49E-06
			10	SW(8)				1.86E-06
			11	SW(8)				2.16E-06
	12	SD	12	SW(8)				2.04E-06
	13	SD	13	SP(GW)				6.61E-06
			14	SW(8)				1.55E-06
			15	SW(8)				2.08E-06
			16	SW(8)				2.08E-06
			17	SP				2.15E-06
			18	SW				3.49E-06
			19	SW(18)				8.46E-06
			21	SP(GW)				2.89E-06
Copper	4	SP	4	SD			2.35E+00	
			11	SD			2.57E+00	
			14	SD			2.79E+00	
			17	SD			2.51E+00	
	20	SP						
			23	SW			6.51E+00	
			24	SW(23)			4.28E+00	
			25	SW(23)			6.32E+00	
			26	SW(23)			5.30E+00	
			27	SW(23)			6.90E+00	
Cyanide	20	SP(GW)						
	21	SP(GW)						
Europium-152			13	SP(GW)				6.30E-05
Europium-154			6	SP				2.92E-06
			8	SP				9.23E-06
			13	SP(GW)				1.26E-05
			17	SW				3.13E-06
			18	SW(17)				3.15E-06
			20	SP				1.68E-06
			21	SP(GW)				1.47E-05
Iodine-129			19	SP(GW)				2.20E-06

Table 6.1. (Cont'd)

	Ecological Risk		Human Risk					
	River		River		Ranger Scenario		Native American Sc.	
Contaminant	Segment	Medium	Segment	Medium	Haz. Index	Risk	Haz. Index	Life Risk
Lead	2	SD+SP						
	3	SD+SP						
			4	SD			4.30E-01	
	5	SD+SP	5	SD			3.65E-01	
	7	SD+SP						
	9	SD+SP						
	13	SD+SP						
	17	SD+SP	17	SD			1.22E+00	
	19	SD+SP	19	SD			6.47E-01	
	20	SD+SP	20	SD			4.74E-01	
	21	SD+SP						
			22	SW(21)			3.78E-01	
Mercury	3	SD						
	4	SD						
	6	SD						
	8	SD						
	9	SD						
	10	SD						
	12	SD						
	13	SD						
	14	SD						
	15	SD						
	16	SD						
	19	SD+SP						
	20	SD+SP						
Neptunium-237			8	SD				6.50E-05
			9	SD				8.30E-05
Nickel	20	SD						
Nitrates			4	SP			1.56E-01	
			10	SP			1.05E-01	
			12	SP(GW)			8.88E-02	
			14	SP			1.42E-01	
			17	SP			1.38E-01	
			20	SP			2.39E-01	
Nitrites			19	SP			1.08E-02	

Table 6.1. (Cont'd)

	Ecological Risk		Human Risk					
	River		River		Ranger Scenario		Native American Sc.	
Contaminant	Segment	Medium	Segment	Medium	Haz. Index	Risk	Haz. Index	Life Risk
Strontium-90			2	SD				8.35E-06
			3	SD				6.72E-05
			4	SW(3)				1.07E-05
			5	SD				1.28E-04
			6	SD				6.72E-04
			8	SP				1.79E-05
			9	SW				1.41E-05
			10	SD				1.10E-04
			12	SW(10)				6.43E-06
			13	SD				4.38E-05
			15	SD				5.95E-05
			16	SW				2.97E-05
			20	SW				6.09E-06
			21	SW				5.36E-06
			24	SW(21)				6.45E-06
			26	SW(21)				5.83E-06
			27	SW(21)				6.57E-06
Sulfates			7	SP(GW)			1.14E-02	
Technetium-99			3	SD				2.84E-06
	8	SD	8	SD				1.18E-06
	9	SD	9	SD				9.61E-07
	10	SD	10	SD				2.80E-06
	14	SD						
			17	SD				1.34E-06
	19	SD	19	SD				2.51E-06
Tritium (Hydrogen-3)			2	SP				1.31E-05
			4	SP(GW)				6.70E-06
			6	SP				1.70E-05
			8	SP				5.05E-06
			9	SP				4.31E-06
			17	SP				2.15E-04
			19	SP(GW)				2.38E-05
			20	SP				8.91E-06
Uranium-234			12	SD				4.62E-05
			14	SP				7.34E-05
			17	SP				7.62E-05
			20	SP				9.34E-04

Table 6.1. (Cont'd)

	Ecological Risk		Human Risk					
	River		River		Ranger Scenario		Native American Sc.	
Contaminant	Segment	Medium	Segment	Medium	Haz. Index	Risk	Haz. Index	Life Risk
Uranium-238			4	SD				5.18E-05
			10	SD				1.51E-04
			11	SD				4.93E-05
			12	SD				4.54E-05
			14	SP				6.49E-05
			17	SD				5.81E-05
			19	SW+SP				1.07E-04
			20	SP+SD				8.67E-04
Zinc	4	SP+SD	4	SD			1.72E-01	
	7	SP+SD						
	8	SP+SD						
			12	SP(GW)			3.78E-01	
			16	SD			1.47E-01	
	17	SP+SD	17	SD			1.59E-01	
			19	SD			2.29E-01	
	20	SP+SD						
GW = Groundwater			SP(GW) = Seep water surrogated with groundwater					
SD = Sediment			SW = Surface water					
SP = Seep water			SW(21) = Surface water extrapolated from upstream Segment 21					
Note: Only human risk values greater than 1.0E-6 or a hazard index of 0.01 are shown.								

The initial list of potential contaminants was screened, using a multi-stage screening process described in Section 2.3, to a manageable number of contaminants likely to produce the greatest risk to the environment or human health. This process was based on a set of simple exposure equations for people and biota. The final list was established to provide reasonable assurance that the preponderance of the risk of either acute toxicity or long-term carcinogenicity of humans and of either acute toxicity or long-term survival of aquatic biota was addressed. Additional considerations were given to known sources of radiation and radioactive materials.

The spatial domain and spatial scale of the analyses were established in consultation with the CRCIA Team. The agreed focus was on the Hanford Reach of the Columbia River and the areas immediately downstream as far as McNary Dam. To best represent the current environmental conditions and state of knowledge relative to contaminant concentrations in the Columbia River, the study area was divided into 27 segments along the river. The segmentation also provides meaningful information associated directly with the site operable units that will be useful in evaluating future remedial actions.

Although the primary focus is on the Columbia River and its associated riparian zone, the potential for influx of contaminants via groundwater through seeps and springs was addressed by relying on additional measurements of the potential contaminants in groundwater some distance inland from the river shoreline. Depending on the availability of groundwater measurements, this distance varies up to 0.8 kilometer (0.5 mile), the larger distances corresponding to areas with fewer measurements. The segments range in length from less than 1 kilometer to more than 30 kilometers (0.5 to 20 miles). Even the smallest segments are too large to clearly distinguish small areas of highly elevated concentration (in other words, hot spots). Several such areas are known, and other specific studies address them. However, discovery of additional hot spots was not the focus of this assessment.

To gather the data to be used in the screening assessment (a separate process from that to determine which contaminants to study), a detailed search for environmental measurements was made. Hanford and non-Hanford sources were queried, including Hanford contractors, local municipalities, the States of Washington and Oregon, and federal agencies. Data were collected for measurements in the surface water of the Columbia River itself, river sediment, seeps and springs within the Hanford Reach, and Hanford Site groundwater. Only relatively current data were used, defined as being within the period from 1990 to present, in order to avoid evaluating problems that no longer exist. A large database was prepared. However, for many of the contaminants of interest in many locations, measurements were not available for the time period of interest. In these cases, a series of surrogation and extrapolation rules were devised to allow approximation of the local contamination levels. Where use of these approximations has identified a contaminant of potential hazard, the use of the surrogate values is highlighted to indicate the need for further confirmatory measurements. The final database is much larger and better substantiated than that used in the initial selection of contaminants to consider, but it is limited to those that were selected for evaluation.

Concurrently with the data gathering, the CRCIA Team established the indicators that would be used to judge the degree of hazard. For the ecological risk assessment, this consisted of defining a set of indicator species for which comparisons against toxicological benchmarks would be made. The selection of these indicator species has been defined in Section 4.1. For the human risk assessment, a suite of twelve human exposure scenarios was prepared. These have been described in Section 5.1. Individual calculations for each of these scenarios were compared with both toxicity and carcinogenicity indices. The exposure scenarios used cover a wide range of possible behavior patterns, but they are not all-encompassing. Additional possible ways that people could be exposed are easily postulated. Some of the scenarios used have parameters that are not currently possible because of restricted use of the site. These were included because the CRCIA Team wanted to examine whether certain types of possible future land use would pose a risk to such individuals, although they do not represent recommendations about future land uses.

Computational models were developed for all of the ecological species and human scenarios. The computational models include algorithms and input data to produce quantitative results. The computerized models and their parameters have been described in Sections 4.2 and 5.2 and are provided on diskettes in the appendixes. The models were tested and verified prior to their use.

The levels of the contaminants showed variability among and within environmental media and among and within individual river segments. In addition, there is uncertainty in almost all of the parameters used in the ecological and human exposure risk calculations. This implies that there is also considerable variability and uncertainty in the results.

To attempt to quantify the uncertainty, two calculation methods were used: deterministic and stochastic. For the deterministic method, the equations were calculated with single, high values of the parameters to identify potential worst case results. For the stochastic method, the equations were calculated with all possible combinations of parameter values, resulting in an output distribution rather than a single value. For the human risk calculations, both deterministic and stochastic results are available for contaminants in each of the river segments where data or substitute data were available. For the ecological risk analysis, the deterministic calculations were performed for all contaminant-species-segment combinations, but the stochastic calculations were only performed for those combinations for which it appeared that any risk was possible.

A benefit of the stochastic calculations was they enabled the results to be subjected to statistical comparisons. In these comparisons, the concentrations and resulting risk of the contaminants in each Hanford-influenced river segment could be compared to those upstream in Segment 1 that supposedly has not been influenced by releases from the Hanford Site. These comparisons gave insight into the nature and magnitude of the incremental risk posed by Hanford releases.

The ecological risk evaluated is for injury to individual plants or animals. The current state of scientific knowledge does not allow extrapolation to impact on the ecosystem with this level of information. Human risk is limited to individual toxic response or long-term carcinogenicity. The scenarios cannot address cultural impact or multigenerational impact of the exposures.

6.2 Influence of Data Gaps and Potential Future Parameters on the Results

The analyses completed for the screening assessment are based on the currently available data. Information is not available for all of the contaminants studied in all river segments. Where appropriate, data were extrapolated or surrogated to fill some of the data gaps, but other data gaps remain. The final results of the screening assessment, therefore, are limited by the available information. The assessment has indicated that there are portions of the Hanford Reach of the Columbia River in which concentrations of contaminants, particularly in sediment and groundwater, are high enough to warrant additional investigation and possible remediation. These river segments have been identified in this report. However, because of the data gaps, it is not possible to state that the concentrations of some of the contaminants in other locations are not also excessive.

The density of data that were available for the assessment is illustrated in Section 3.0. For some river segments, relatively few data are available. These are areas for which sampling could be advisable. However, the existing sampling schemes were developed with knowledge of past Hanford Site operations and the results of past sampling. In some instances, the lack of data for certain contaminants in certain locations is because those locations never gave cause to warrant sampling for those contaminants during the period 1990 to present. They may have been sampled earlier. Before a recommendation can be made for further sampling, consideration should be given to the results of past sampling not used in this analysis and the likelihood of acquiring useful information with additional sampling. Systematic radiological surveys have been made in the past (for example, Sula et al. 1980, EG&G 1990) that indicate the potential for finding additional, highly radiologically contaminated areas is small.

A further difficulty is that the spatial extent of the river segments as defined for the analysis is large enough to partially mask the presence of hot spots. The risk results tend to average out over segments as much as a few miles long. While it is quite unlikely that individual humans would choose to spend large portions of their time and derive most of their food from single point locations, it is likely that specific biota (particularly plants) could live their entire lives in one spot.

In tandem with the data gaps is the fact that the scenarios used to establish the potential for human exposure, defined in Section 5.1, all have a common starting assumption: the individual described performs all of the described activities within the selected segment and within the river or immediately adjacent riparian zone. In many locations along the riverbanks of the study area, the riparian zone is quite narrow. The likelihood of a person's actually deriving all of her or his food and water from this narrow strip of land has not been included in the scenario definitions. However, to simplify the analyses and provide a common basis for comparison, the same assumptions have been used for all river segments. It is recognized that the screening assessment has been performed with scenarios that include parameters not currently allowed because access to the site is restricted. These parameters are included because the CRCIA Team desired to determine if future potential uses of the land could pose risk to certain types of individuals. Before remedial activities are considered, site-specific considerations should be added to the general results presented here.

The screening assessment was designed to focus attention on those contaminants with the most immediate potential for human and ecological risk. However, some parameters included are future potential parameters. In addition, some data gaps have limited the assessment. Therefore, it is important to take into consideration the focus, the assumptions, and the limitations of this assessment when evaluating the results. Because a contaminant has been identified as potentially posing a risk does not necessarily mean that there is imminent risk to humans or the environment from this contaminant. Just as important, the converse may also be true. Because the risk of a contaminant in certain segments has not been identified does not necessarily mean that a risk does not exist. It just may not have been measured yet.

6.3 Screening Assessment Results and Conclusions

The results of the screening assessment are provided in Section 4.2 for the ecological risk and Section 5.2 for the human risk. These sections show that when taken in the context of the screening assessment the answers to the two main assessment questions are yes. Environmental levels of some contaminants do appear to be elevated as a result of Hanford Site operations as well as resulting from other human activities upstream in the Columbia Basin. Both the ecological modeling and human exposure simulations identify contaminants and locations for which risk to both the environment and humans is evident and for which further analyses or measurements would be worthwhile.

Figure 6.1 is a high-level summary of the findings of the ecological risk and human health risk assessments. The contaminants and affected segments of the Columbia River that pose a potential risk according to the results of either the ecological or human risk assessments are identified. The overlapping results of the two assessments are also identified. For most of the contaminants, segments identified by the ecological risk analysis were also identified by the human health analysis, but sometimes the contaminants were in media that affect biota more directly than humans, so that human risk for those contaminant-segment combinations is below the reporting threshold. Conversely, segments identified via the human health analysis having indications of increased potential risk are not always identified in the ecological analysis.

The reporting thresholds used in Figure 6.1 to identify potentially hazardous contaminants include consideration of chronic and acute effects on the environment and toxic and carcinogenic impact on humans. For the chronic ecological effects, a contaminant is identified if the number of stochastic simulation results exceeding a chronic toxicity benchmark is more than 5 percent greater than the number estimated in the background segment for that contaminant (denoted by yellow in Figure 4.19 of Section 4.2. For acute ecological effects, a contaminant is identified as potentially hazardous if the sum of acute risk indices across all species for a contaminant is more than twice the equivalent total for the background segment (denoted by red in Figure 4.19 of Section 4.2). For humans, a contaminant is identified as potentially hazardous if the estimated hazard index for a given contaminant for any scenario is greater than 0.01 or if the estimated lifetime risk for any scenario is greater than 10^{-6}.

The contaminants identified in Figure 6.1 as potentially hazardous are listed in Table 6.1 with additional details about the magnitude and sources of the potential risk. Table 6.1 presents the contaminants of highest potential risk identified in either the ecological risk assessment or the human health risk assessment, the segments in which they were identified, the medium or media which provided the dominating component of the risk, and the range of estimated human risk. To demonstrate the range of human risk, the median stochastic values of lifetime risk (carcinogenic chemicals and radionuclides) and hazard index (toxic chemicals) for both the Ranger and Native American Subsistence Resident scenarios are given. Table 6.1 then answers the first three subset questions of which contaminants at what location and in which media are a potential threat.

To answer the fourth sub-set question, the types of organisms most likely to be adversely affected were identified. Terrestrial species that are potentially most affected by contaminants in the study area are swallows, mallards, American coots, harvest mice, Canada geese, and raccoons. However, risk within the study area that is above background levels is limited to only a few locations within the study area (see Figure 4.22). The other species, including bald eagles, have relatively low risk in both absolute and relative (to background) terms. Aquatic species most likely to be affected by acute or chronic toxic effects from contaminants of Hanford Site origin are Columbia pebblesnail, hyalella, daphnia magna, crayfish, Woodhouse's toad, suckers, clams, mussles, and salmon/trout larvae. Most of these aquatic organisms have a benthic life style, spending all or a high proportion of their life in direct contact with sediment or pore water, and the pore water concentrations tend to drive their body burdens. A key pathway of exposure for the terrestrial organisms is predation of the aquatic species with high body burdens, which is also ultimately related to the concentration of contaminants in pore water.

To answer the fifth sub-set question, the categories of humans most likely to be affected were identified. Humans in the region of the Hanford Site may have a wide variety of exposures, from low to high. Generally speaking, the scenarios for the Fish Hatchery Worker, Industrial Worker, and Ranger have the lowest exposures and, therefore, are lowest in terms of health risk. As defined in Section 5.1, none of the people involved in these scenarios consume foods grown in the Columbia River riparian zone or drink seep water. Therefore, the exposures are mostly incidental external exposures and inhalation of resuspended materials, although the Fish Hatchery and Industrial workers also consume a moderate amount of Columbia River water. The risk to workers from these pathways is quite low in comparison to those projected for people potentially exposed in other ways. At the other extreme, people postulated to live along the Columbia River, to eat substantial quantities of foods grown in the riparian zone, to eat fish and wildlife from the river, and to drink seep water have much larger potential exposures and, thus, estimated health risk. This category encompasses nearly all of the remainder of the scenarios described in Section 5.1. From a risk-assessment standpoint, very few differences appear between any of the Native American scenarios and recreational/residential scenarios. All postulate individuals who spend the bulk of their time in the vicinity and consume riparian-zone foods and drink untreated water.

Through the use of multiple exposure scenarios, the possible activities of people who could come into contact with the contaminants were evaluated. In general, risk to people today is low because of restricted access to the Hanford Site. Casual visitors and even people working in jobs associated with the Columbia River are not at risk unless they frequent limited areas and consume seep or spring water in which high concentrations of contaminants are present. However, potentially increased risk is possible if people were to move onto the Hanford Site and derive large percentages of their daily food intake from crops and animals in the river's riparian zone. In most instances, this higher risk is limited in extent to a few regions of highest contamination. Although there are numerous cultural differences between the general population and Native Americans, the common pathways of food and water consumption could affect both groups. These common pathways are the ones by which most exposure would be received. The key differences come in the source of the water and food products.

Because of scientific uncertainty, the overall potential impact on the riparian ecosystems is not known. There is insufficient knowledge about the distribution of species, their migration patterns, and their interactions over the entire Hanford Reach. It is possible to say that there is a risk to individual members of certain species, those that frequent the locations of highest contamination.

6.3.1 Hanford and Non-Hanford Sources of Contaminants

Contaminants for which a Hanford source appears to be indisputable include ammonia, cesium-137, chromium, cobalt-60, europium-152, europium-154, nitrates, strontium-90, technetium-99, tritium (hydrogen-3), and uranium isotopes. Other contaminants for which the Hanford Site may be a contributor, at least at specific locations, include copper, cyanide, lead, mercury, and zinc. The analyses indicate relatively high potential risk from these latter contaminants. However, the upstream risk from these contaminants is also high, and the Hanford Site increment over the upstream value is generally factors of two to three or less, making exact identification difficult.

As discussed in Section 4.2, there are sources of heavy metal releases to the Columbia River upstream of the Hanford Site. Thus, there are amounts of these metals, particularly chromium, copper, lead, mercury, and zinc, in sediment and water being transported through the Hanford Reach from operations, such as mining, upstream (Munn et al. 1995, Serdar 1993, Johnson et al. 1990). Recent events (Tri-City Herald 1997) have shown that upstream tributaries of the Columbia River may carry very high levels of metals, particularly during periods of high runoff. The concentrations are sufficient to be acutely toxic to wildlife. Contaminant metals tend to sorb to fine grained sediment, which deposit in slack water areas. Sizable quantities of sediment are deposited in the study area in the Hanford sloughs as well as behind both Priest

Rapids Dam upstream (a portion of Segment 1) and McNary Dam downstream (Segments 22-27). This sediment deposition with its relatively high concentrations of metals may help explain some of the results discussed below.

6.3.2 Uncertainty

Uncertainty is inherent in any risk assessment. The uncertainty within the ecological and human health assessments are discussed in Sections 4.2.10 and 5.2.3.3, respectively. Uncertainties include those associated with the exposure models, measured media data, representativeness of the data, use of surrogate and extrapolated data, exposure scenarios, accuracy of modeled processes, and toxicological and dose response references.

6.3.3 Potentially Hazardous Contaminants

The contaminants discussed in this section are those identified by the ecological and human health screening assessments to be potentially hazardous (see Figure 6.1 and Table 6.1). The intent of the following discussion of each potentially hazardous contaminant is to focus possible remedial decisions on those contaminants and media with the potential for the greatest risk reductions.

Benzene. Benzene is seen in low concentrations in seep water, frequently in conjunction with xylenes. It is a measurement surrogate for petroleum hydrocarbons. Some instances of petroleum contamination are known at the Hanford Site. The highest levels are seen at the 100-K and 100-F Areas. The primary exposure pathway is consumption of seep water.

Carbon-14. Carbon-14 is not detected in surface water. The Native American and Resident scenarios are uniformly controlled by ingestion of carbon-14 derived from seep water. Seep water was surrogated with groundwater in almost all segments along the Hanford Site. A single, particularly high value in the 100-K Area is evident in the deterministic data.

Cesium-137. Cesium-137 is a constituent of worldwide fallout and is present in soil and river sediment both upstream and downstream of the Hanford Site. Although in general the concentrations of cesium-137 in sediment are not greatly different from areas away from the Hanford Site, there is a greater variability in the measurements, indicating that a few localized zones of increased concentration exist. The primary risk is to biota that burrow into or live on the sediment. The primary pathway is external irradiation of these biota. For humans, the scenarios with high fish consumption show somewhat elevated risks from surface water, but this is largely driven by the surrogation process from a very few measured segments.

Chromium. This metal is identified as existing in elevated concentrations in several Hanford Reach river segments. For biota, the primary media of concern are sediment and pore water within the sediment (modeled using measurements of seep water or groundwater), and for humans the primary media are also sediment and the associated seeps. This indicates that the primary problem is groundwater contamination inland of the areas of the seeps, which is resulting in contamination of the sediment around the point where the groundwater issues into the river.

Cobalt-60. This radionuclide exists in both discrete particulate form and as generalized diffuse contamination. The particles have higher discrete activity and are somewhat easier to detect, but the more significant problem is with the diffuse sources. As with cesium-137, the primary ecological problem is direct external irradiation of biota that burrow into the sediment contaminated with diffuse cobalt-60 contamination.

Copper. In general, the risk to humans or biota from copper is similar above and below the Hanford Site. However, in absolute terms, this metal is one of highest risk to biota and humans. The modeling indicates that pore water (modeled using groundwater measurements) in the 100-K Area may be elevated, thus exposing biota. Copper is one of the metals that may also be enhanced from upstream sources.

Cyanide. The excess risk calculated for this chemical compound is associated with pore water (modeled using groundwater) for biota and with seep water (also modeled using groundwater) for humans.

Europium-152. Europium-152 is an activation product, similar in source to cobalt-60. Although discernible above background throughout the Hanford Reach in sediment, the risk to humans from europium-152 is primarily from ingestion of seep water in Segment 13.

Europium-154. Like europium-152, the activation product europium-154 is slightly elevated throughout the Hanford Reach. The primary exposures are via seep water, although the primary mechanism in Segments 17 and 18 is via surface water.

Iodine-129. Iodine-129 is detectable above background at very low levels in Hanford surface water, but the primary pathway of exposure is via drinking seep water. The only segment with concentrations measured sufficiently high to score over a risk of 10^{-6} is Segment 19.

Lead. The risk for lead to biota is dominated by concentrations in sediment and pore water, and the risk to humans is dominated by concentrations in sediment. Lead is one of the metals that may also be enhanced in sediment from upstream sources, but there are signs that lead may be somewhat enhanced in Hanford Site groundwater, particularly in the vicinity of the old Hanford townsite.

Mercury. The risk from mercury is primarily to biota from sediment. Mercury is one of the metals that may also be enhanced from upstream sources.

Neptunium-237. The only positive measurements for neptunium-237 occur in sediment in Segments 8 and 9, which in the modeling lead to small ingestion intakes. These are single point measurements and do not represent wide area contamination.

Nickel. The ecological modeling identifies nickel in sediment as a possible problem in the 300 Area only.

Nitrates. The risk to humans from nitrates is derived from the pathway of drinking seep water. Nitrates are known to be elevated in Hanford Site groundwater with samples in groundwater above the EPA drinking water standards in several of the reactor areas (see, for example, Dirkes and Hanf 1996).

Strontium-90. The primary risk to humans from strontium-90 comes from consuming foods grown in contaminated sediment. Risk from consumption of seep water comes in a close second. It is likely that the concentrations in the sediment are related to the seep water concentration at most of the locations that are coincident with reactor areas.

Sulfates. Sulfates are measured in surface water and seeps in numerous locations. The primary pathway is direct ingestion. The concentrations averaged in Segment 7 are slightly higher than elsewhere, but the risk from sulfates is generally low.

Technetium-99. Environmental concentrations of technetium-99 are not high, but the soil-to-plant uptake factor for technetium is very large. Vegetation has a strong propensity to concentrate technetium from soil. The key medium for technetium-99 is sediment. In the case of the ecological results, the risk is actually related to the chemical toxicity of technetium in plants. For the human health results, the risk is associated with consumption of food plants grown in the technetium-contaminated sediment in the riparian zone.

Tritium (Hydrogen-3). Tritium is widely distributed in Hanford Site groundwater. However, it has a low biological uptake and generally short retention time in plants and animals because it is associated with water. The primary route of exposure to humans is via consumption of seep water. The most extensive region where seep water contaminated with tritium enters the Columbia River is the vicinity of the old Hanford townsite.

Uranium-234/238. Although uranium is also ubiquitous in the environment, several areas have concentrations elevated above background levels. The media of interest include sediment and seep water near the 300 Area. A prominent pathway is the consumption of prey animals by animals farther up the food chain.

Zinc. The risk to biota is predominantly influenced by pore water and sediment. This metal provides the highest absolute contribution of risk to biota, but the median relative ratio to the upstream value is generally less than 1 for risk to humans. Zinc is one of the metals that may also be enhanced from upstream sources.

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Appendix I-A

Analytes Evaluated, Parameter Values, and Numerical Results

Appendix I-A
Analytes Evaluated, Parameter Values, and Numerical Results

The tables of data for this appendix are Microsoft Excel 5.0 files on diskette. Table A.1 (diskette file con-apa1.xls) provides a list of all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from the Columbia River and groundwater in the Hanford Site 100, 300, 1100 Areas, and other areas within 150 meters (500 feet) of the Columbia River. For those contaminants which had a detected level, the highest concentration reported is listed. A total of 568 analytes are listed. The 73 analytes for which detected levels were reported are listed in Table 2.1.

Table A.2 (diskette file con-apa2.xls) provides a list of all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from soil and sediment in the Hanford Site 100, 300, and 1100 Areas. For those contaminants which had a detected level, the highest concentration reported is listed. A total of 560 analytes are listed. The 86 analytes for which detected levels were reported are listed in Table 2.2.

The data depicted in Tables A.1 and A.2 are from a variety of documents containing different measurements. Whereas the measurements can at times appear contradictory, they reflect the data as they appear in the documents reviewed.

The equations detailed in Section 2.3 require parameters for each radionuclide and chemical evaluated. The parameters used to screen samples from the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River are provided in Table A.3 (diskette file con-apa3.xls). The parameters used to screen samples of soil and sediment are provided in Table A.4 (diskette file con-apa4.xls). The parameters used to screen samples of groundwater farther than 150 meters (500) feet from the Columbia River are provided in Table A.5 (diskette file con-apa5.xls).

This appendix also provides the numerical results of applying the screening equations in Section 2.5 to the detected analytes described in Sections 2.3 and 2.8. Table A.3 (diskette file con-apa3.xls) presents the numerical results of screening samples from the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River. Table A.4 (diskette file con-apa4.xls) presents the numerical results of screening soil and sediment samples. Table A.5 (diskette file con-apa5.xls) presents the numerical results of screening samples from groundwater farther than 150 meters (500 feet) from the Columbia River. Application of the equations and assumptions defined in Section 2.5 results in a series of complementary, but not necessarily intercomparable, screening values for each contaminant. The varying numbers of assumptions and associated varying degrees of conservatism require that each of the screenings be evaluated separately. The results of the combined screenings, however, then define the overall list of contaminants to be analyzed in the screening assessment.

The following abbreviations are used in the Microsoft Excel tables in this appendix. All units are as reported in the reviewed literature. The column headings, such as 100-KR-4, refer to sampling locations at operable units, described in Section 2.1.

aCi/L	=	attocuries per liter (one one-millionth of a pCi/L)
AWQC	=	ambient water quality criteria
Bkg	=	background denotes that the highest concentration found was at background level so eliminated from consideration
CAS#	=	Chemical Abstract Service number, a unique numerical identifier for chemicals
EPA-10	=	eliminated from the human risk assessment based on the guidance in EPA Region 10 Supplemental Risk Assessment Guidance for Superfund (EPA 1991).
GW	=	groundwater
HEIS	=	Hanford Environmental Information System database
Kd	=	sediment/water equilibrium partitioning coefficient
Koc	=	carbon matter partitioning coefficient
Kow	=	octanol/water partitioning coefficient
L/kg	=	liters per kilogram
LC_{50}	=	lowest concentration reported to be lethal to 50% of the organisms 100 days after exposure (EPA 1985)
LD_{50}	=	near limit of detection
µg/kg	=	micrograms per kilogram
µg/L	=	micrograms per liter
MeV	=	million electron volts
mg/kg	=	milligrams per kilogram
mg/L	=	milligrams per liter
ml/g	=	milliliters per gram
ND	=	not detected in sample; not all data compilers used this convention; some analytes show no entry where an ND is appropriate
pCi/g	=	picocuries per gram
pCi/kg	=	picocuries per kilogram
pCi/L	=	picocuries per liter
ppb	=	parts per billion
SD	=	sediment
SL	=	soil
Suspect	=	noted in the source database as being unreliable (see Section 3.4)
SW	=	surface water (Columbia River water)
SW-LD	=	reported sample in surface water very near the limit of detection and, therefore, unreliable
TLM	=	lowest concentration below which no effects on aquatic life are observed (EPA 1985)
w/Pu239	=	concentration included in the value reported for plutonium-239
w/U233	=	concentration included in the value reported for uranium-233
*	=	laboratory results marked as suspect data (see Section 2.4.5).

Appendix I-B

Media Files, Plots, and Final Data File

Appendix I-B
Media Files, Plots, and Final Data File

Media Files

The concentration input files resulting from the data selection process are called the media files. The media files were derived from the Microsoft Access database of raw files (see Appendix A in the final publication of Volume II of the draft data report). The media files are provided on diskette in this report as comma separated files that can be opened and read by Microsoft Excel 5.0

Each medium is provided in a separate file. The media are groundwater (GW), sediment (SD), seeps (SP), surface water (SW), and external radiation (ER). Each media file contains a record for each contaminant in each segment. The records are sorted by contaminant first, then segment. For each medium, a file is constructed that contains the following information:

Media Files

Media	Medium name
Segment_No	Segment number
Contaminant	Contaminant name
Units	Units of measurement
Max_Value	Maximum concentration
Max_Qualifier	Qualifier associated with the maximum concentration
Max_Conc_Flag	Concentration flag associated with the maximum concentration, used instead of the qualifier
Max_Samp_Num	Identifying number for the sample with the maximum concentration
Max_Samp_Date	Date of the sample with the maximum concentration
Max_Samp_Owner	Organization that has responsibility for the sample with the maximum concentration
Max_NScoord	North-south coordinate for the sample with the maximum concentration
Max_EWcoord	East-west coordinate for the sample with the maximum concentration
GM	Geometric mean
GSD	Geometric standard deviation
Nobs/Num_Obs	Number of records for that contaminant/medium combination
Nfit/Num_Obs_fit	Number of null or negative values that were estimated if the fitting process was used to calculate the geometric mean and geometric standard deviation (see "Compute Stochastic Parameters" in Section 3.4.3.2 for explanation of fitting process)
-999	Missing/not sampled
#####	Widen column so number can appear
GW	Groundwater

NA	Not available
ND	Not detected
NS	Not sampled
SD	Sediment
SP	Seeps
SW	Surface water
TLD	External radiation

If there were no data for a contaminant and segment combination, there is an "NA" in the media file for the pertinent record. This is the case for the maximum and its associated information and for the geometric mean and geometric standard deviation. If data are marked as undetected (qualifier of "u") in segments with no detected values for the particular contaminant in question, a geometric mean and geometric standard deviation were calculated on the detection limits reported (see Section 3.4.2), but the maximum value and its associated information are reported as not available (NA). The media file names are:

med-gw.csv	groundwater data	med-sw.csv	surfacewater data
med-sd.csv	sediment data	med-tld.csv	external radiation data
med-sp.csv	seep data		

Plots of the Maximum Values and Geometric Means

The plots in this appendix depict the maximum values and geometric means of the contaminants for which data, extrapolated data, or surrogate data are available. Extrapolation is the filling of data gaps using data from the same medium but from a different location. Surrogation is the filling of data gaps using data from the same location but from a different medium. The following rules were applied to fill some of the data gaps:

- Groundwater: No substitutions
- Sediment: No substitutions
- Seep Water: Use groundwater data as a surrogate where available
- Surface Water: If no measured data are available for Segment 1, extrapolate from Segment 2 if available. In Segments 2-27, extrapolate from the nearest upstream segment with measured data

Because Segment 1 is upstream of the operating areas, the values for Segment 1 indicate the background levels of the contaminants. The key to the plots is as follows:

x	Maximum concentration
■	Point where the maximum concentration and geometric mean coincide
•	Geometric mean
-	Connecting line for maximum values
...	Connecting line for geometric mean values

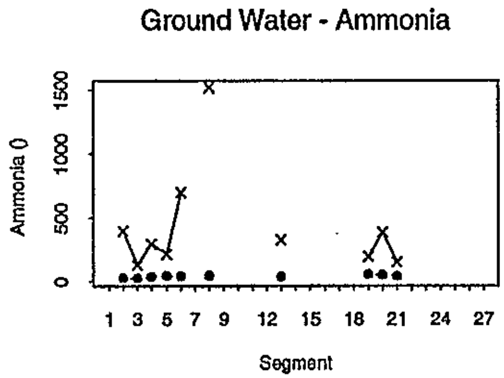
Final Data File

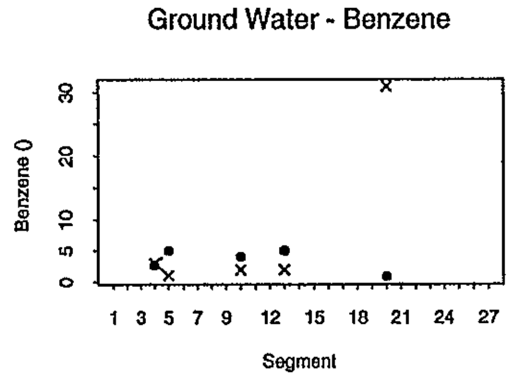
The file containing the selected data in the media files plus the substituted data is the "final data file." The final data file was the file used in the human health (along with the external radiation media file) and ecological screening risk assessments. Of the possible 3,024 data values, 1,153 have no data even after the substitution.

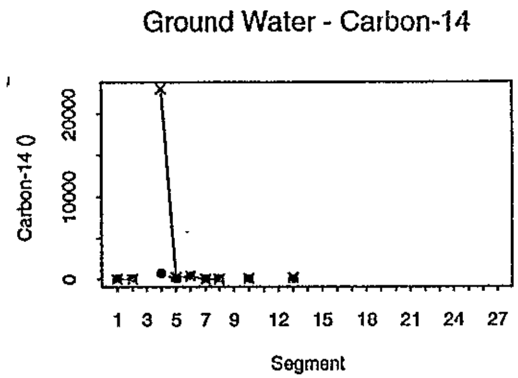
The final data file contains the original groundwater, seep, sediment, and surface water data. When no seep data were available, groundwater data were used as a surrogate. When no surface water data were available, values extrapolated for the same contaminant in the next upstream segment were used.

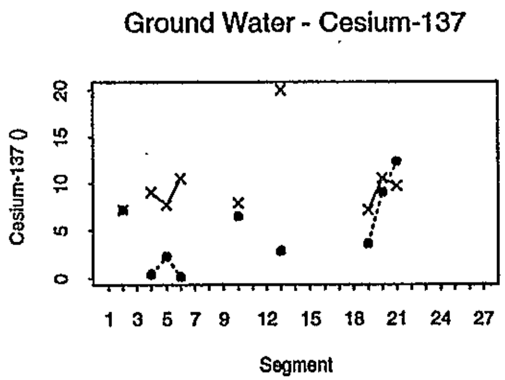
The final data file (fin-data.xls) is provided on diskette in this report as a comma separated file that can be opened and read by Microsoft Excel 5.0. The file contains the following information:

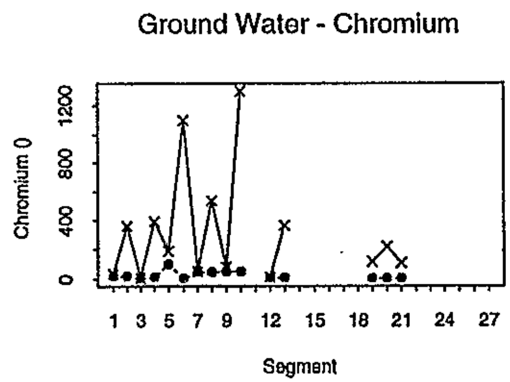
Segment	Segment number
Con_long_name	Contaminant name
gwmax (µCi/L or mg/L)	Maximum groundwater concentration
gwgm (log units)	Geometric mean of groundwater concentrations
gwgsd (log units)	Geometric standard deviation of groundwater concentrations
sdmax (µCi/kg or µmg/kg)	Maximum sediment concentration
sdgm (log units)	Geometric mean of sediment concentrations
sdgsd (log units)	Geometric standard deviation of groundwater concentrations
spmax (µCi/L or µg/L)	Maximum seep concentration
spgm (log units)	Geometric mean of seep concentrations
spgsd (log units)	Geometric standard deviation of seep concentrations
swmax (µCi/L or µmg/L)	Maximum surface water concentration
swgm (log units)	Geometric mean of surface water concentrations
swgsd (log units)	Geometric standard deviation of surface water concentrations
-9.99E+02	Missing/not sampled
#####	Widen column so number can appear

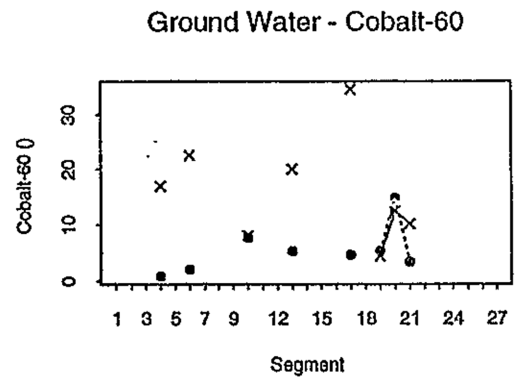

Ground Water - Ammonia
Ammonia ()
0
500
1000
1500
1 3 5 7 9 12 15 18 21 24 27
Segment

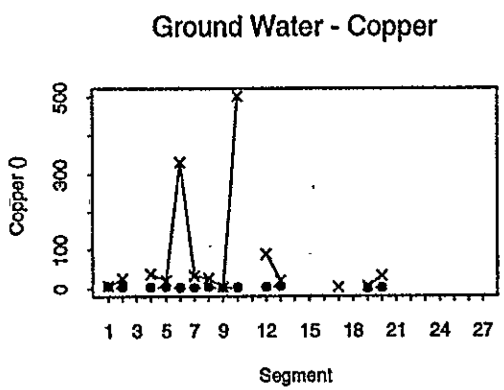

Ground Water - Benzene
Benzene ()
0
5
10
20
30
1 3 5 7 9 12 15 18 21 24 27
Segment

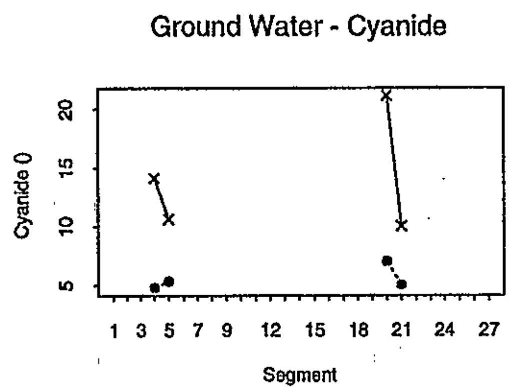

Ground Water - Carbon-14
Carbon-14 ()
0
10000
20000
1 3 5 7 9 12 15 18 21 24 27
Segment

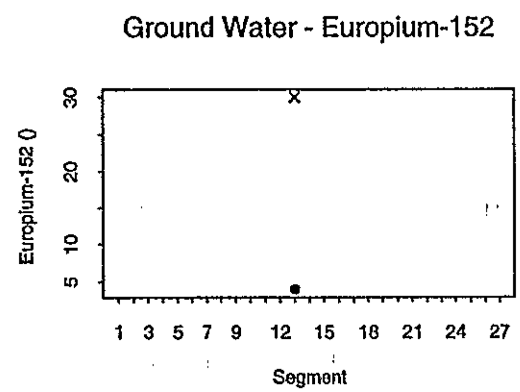

Ground Water - Cesium-137
Cesium-137 ()
0
5
10
15
20
1 3 5 7 9 12 15 18 21 24 27
Segment

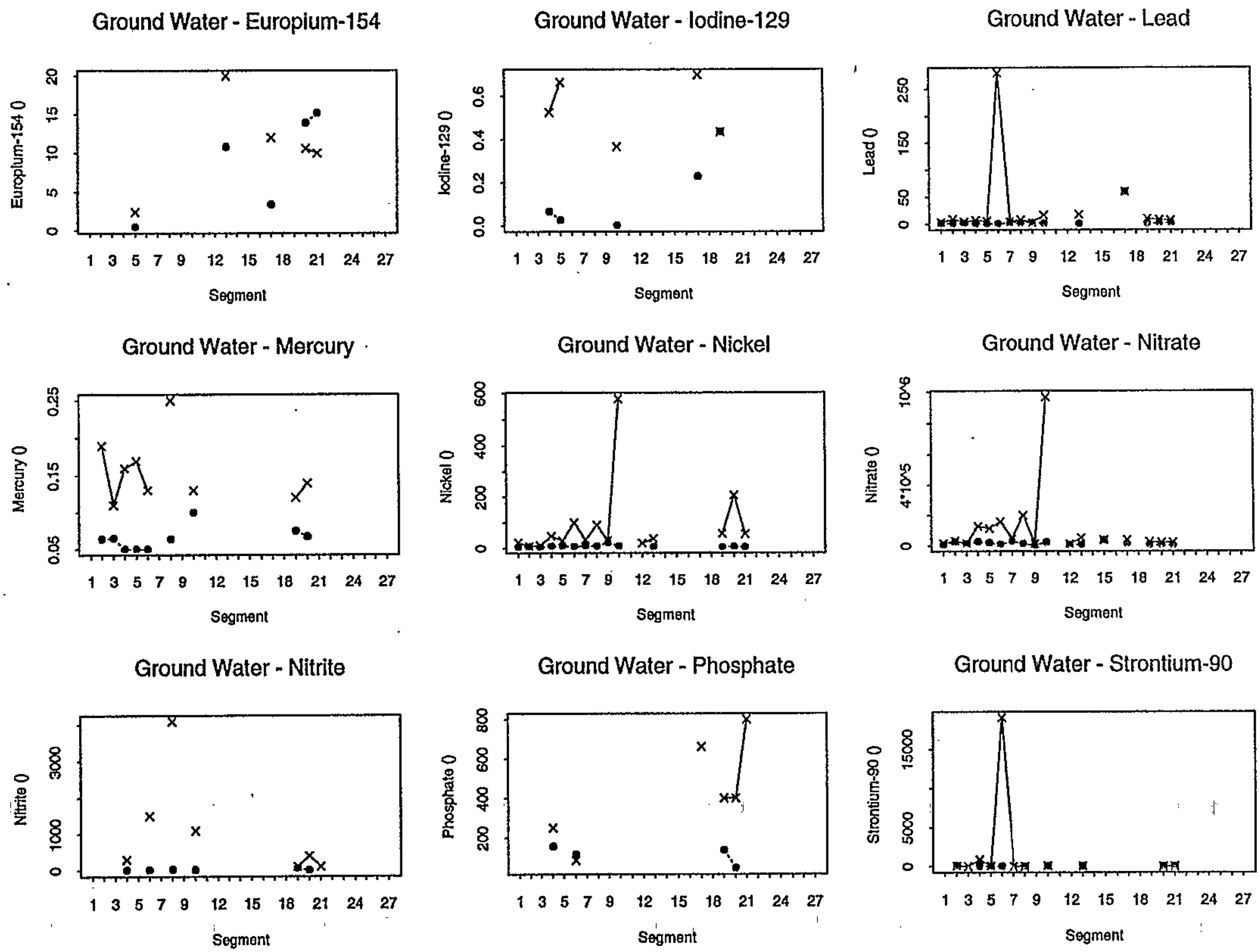

Ground Water - Chromium
Chromium ()
0
400
800
1200
1 3 5 7 9 12 15 18 21 24 27
Segment


Ground Water - Cobalt-60
Cobalt-60 ()
0
10
20
30
1 3 5 7 9 12 15 18 21 24 27
Segment

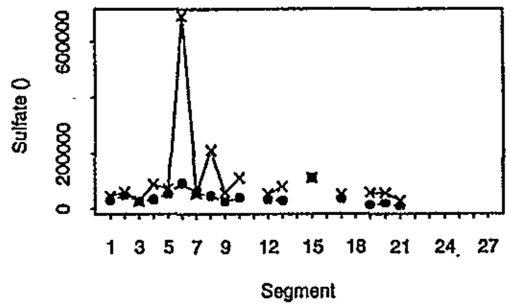

Ground Water - Copper
Copper ()
0
100
300
500
1 3 5 7 9 12 15 18 21 24 27
Segment


Ground Water - Cyanide
Cyanide ()
5
10
15
20
1 3 5 7 9 12 15 18 21 24 27
Segment

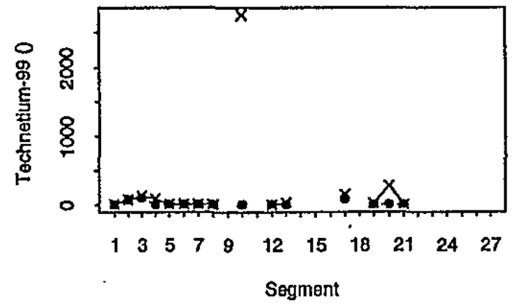

Ground Water - Europium-152
Europium-152 ()
5
10
20
30
1 3 5 7 9 12 15 18 21 24 27
Segment


Ground Water - Europium-154
Europium-154 0
Segment
Ground Water - Iodine-129
Iodine-129 0
Segment
Ground Water - Lead
Lead 0
Segment
Ground Water - Mercury
Mercury 0
Segment
Ground Water - Nickel
Nickel 0
Segment
Ground Water - Nitrate
Nitrate 0
Segment
Ground Water - Nitrite
Nitrite 0
Segment
Ground Water - Phosphate
Phosphate 0
Segment
Ground Water - Strontium-90
Strontium-90 0
Segment

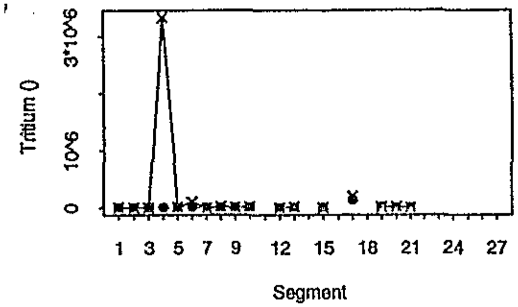
Ground Water - Sulfate



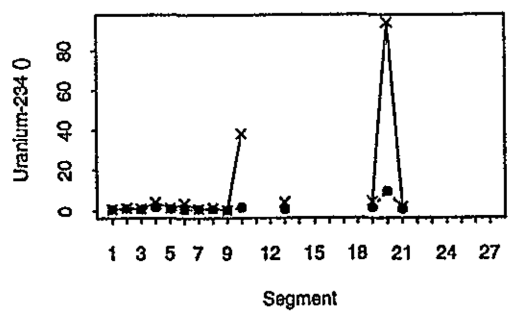
Ground Water - Technetium-99



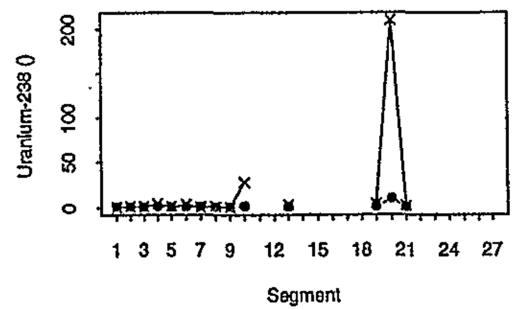
Ground Water - Tritium



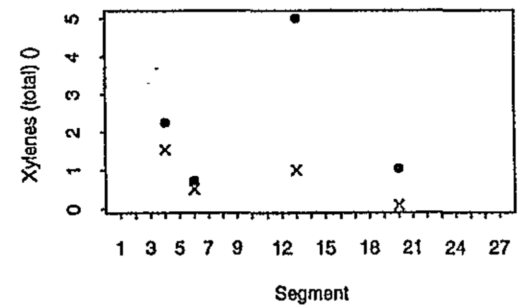
Ground Water - Uranium-234



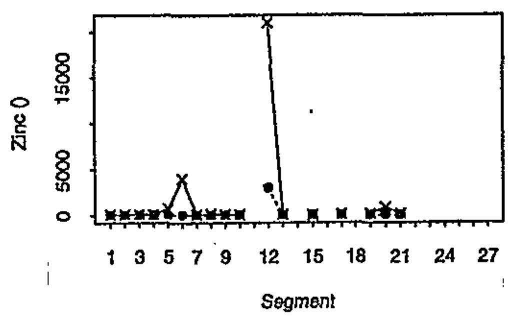
Ground Water - Uranium-238

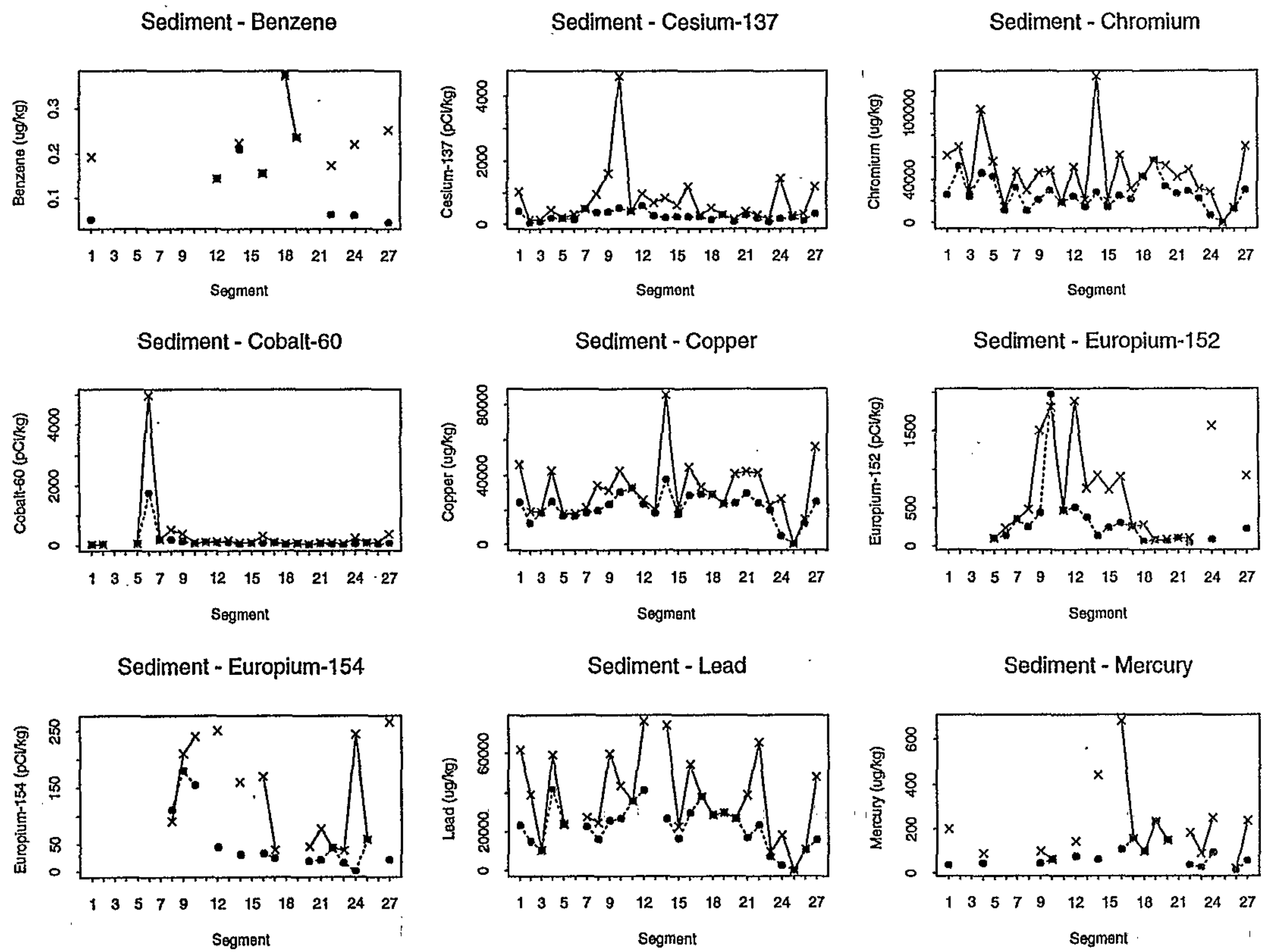


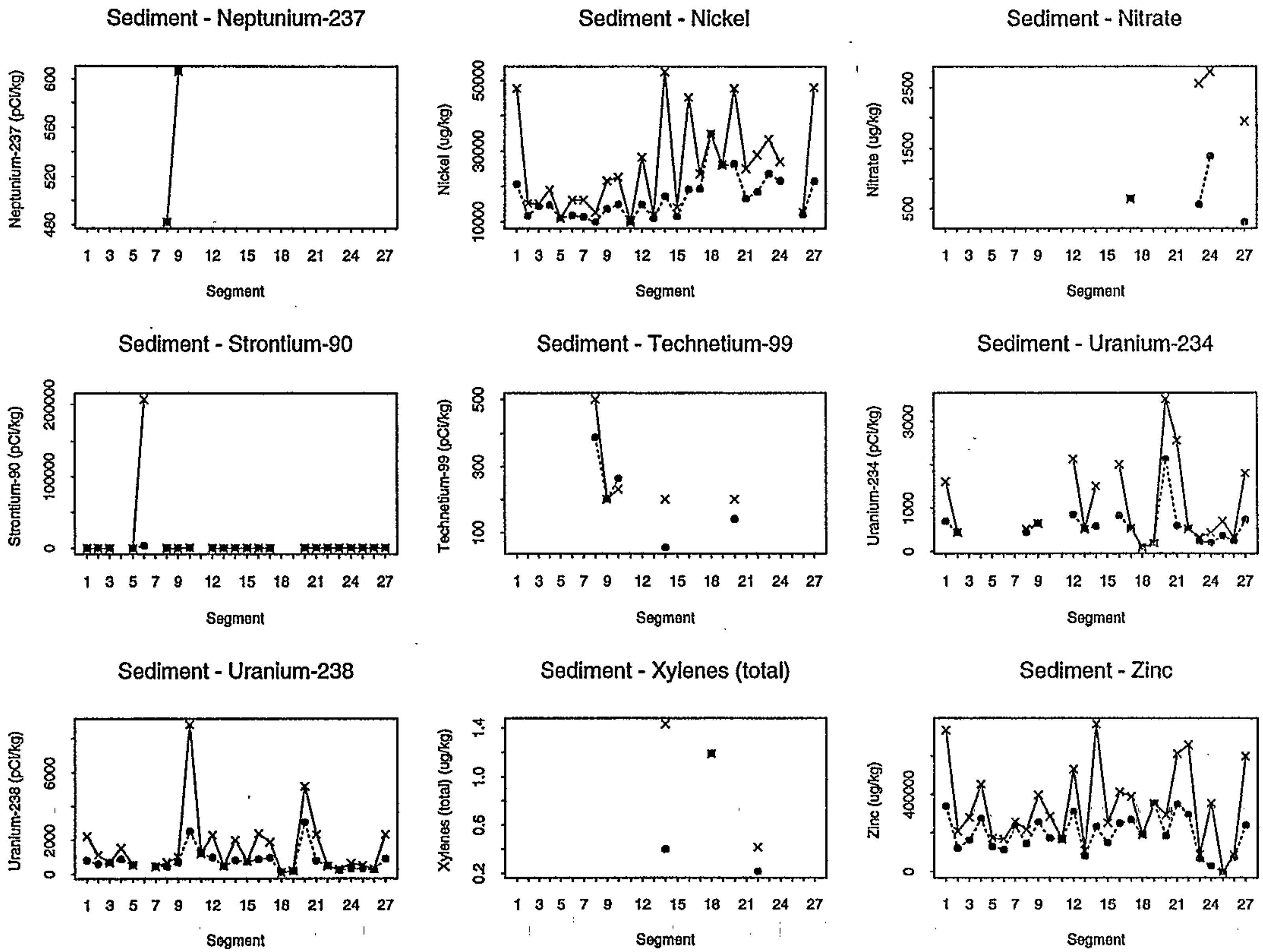
Ground Water - Xylenes (total)

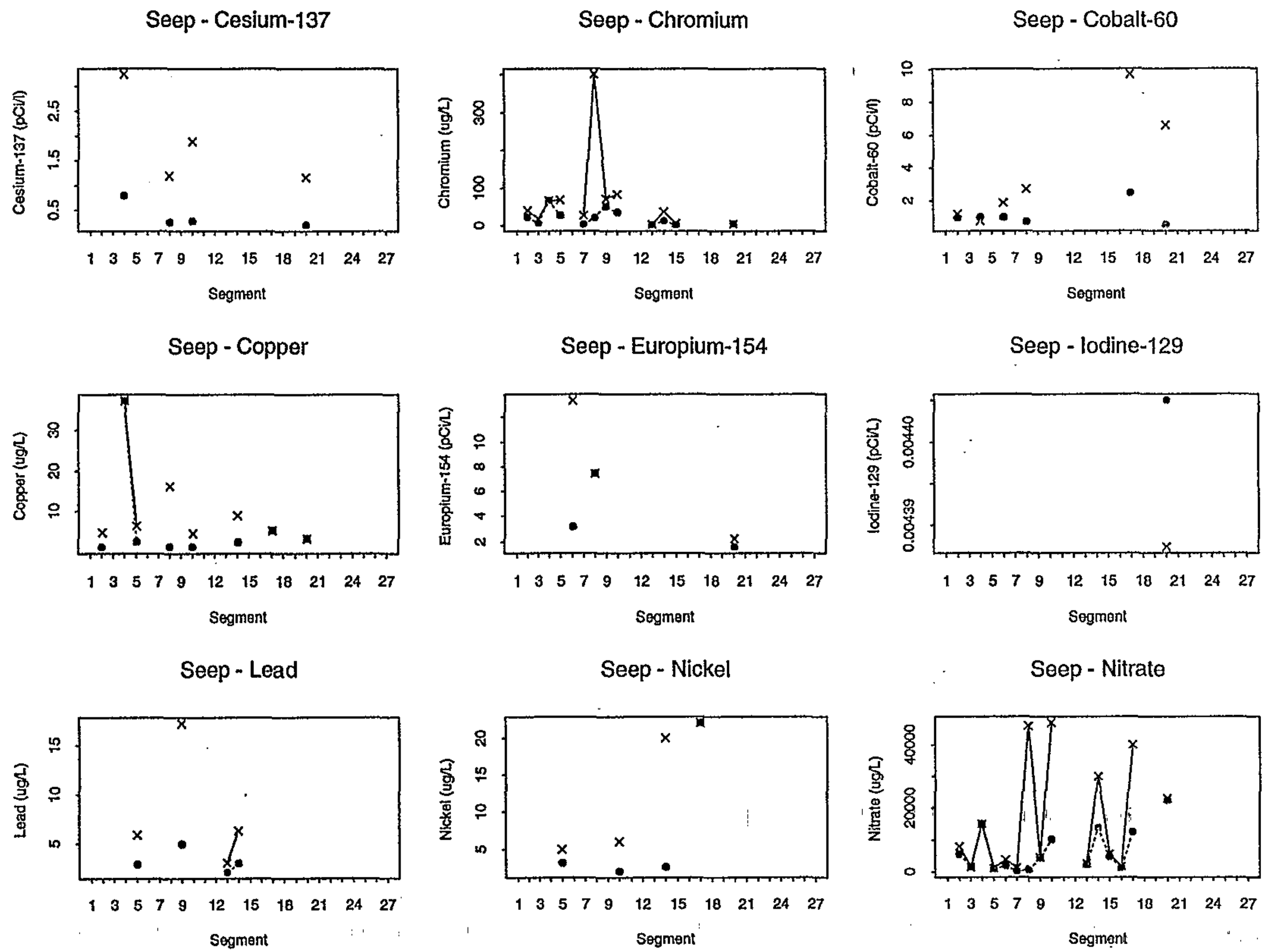


Ground Water - Zinc

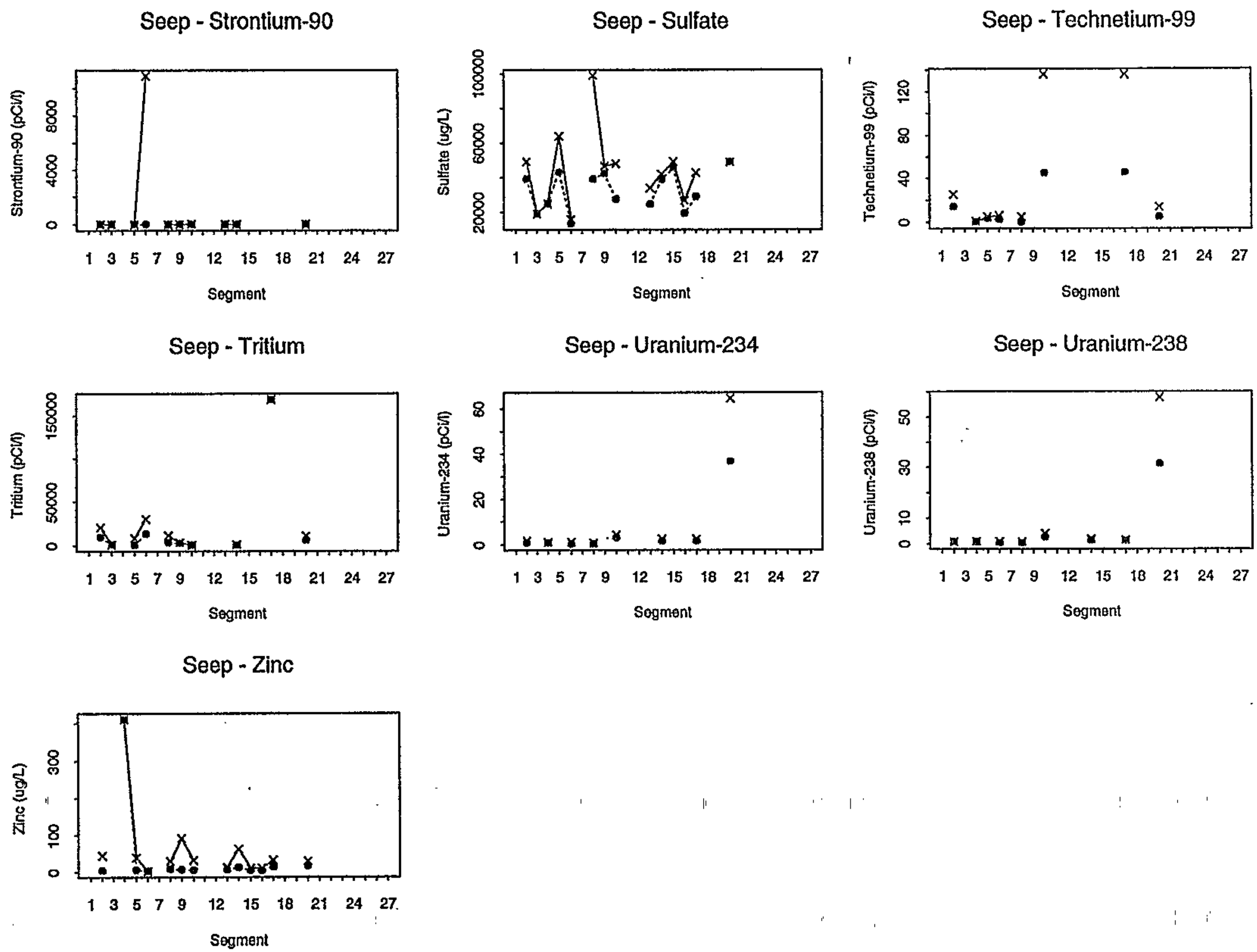


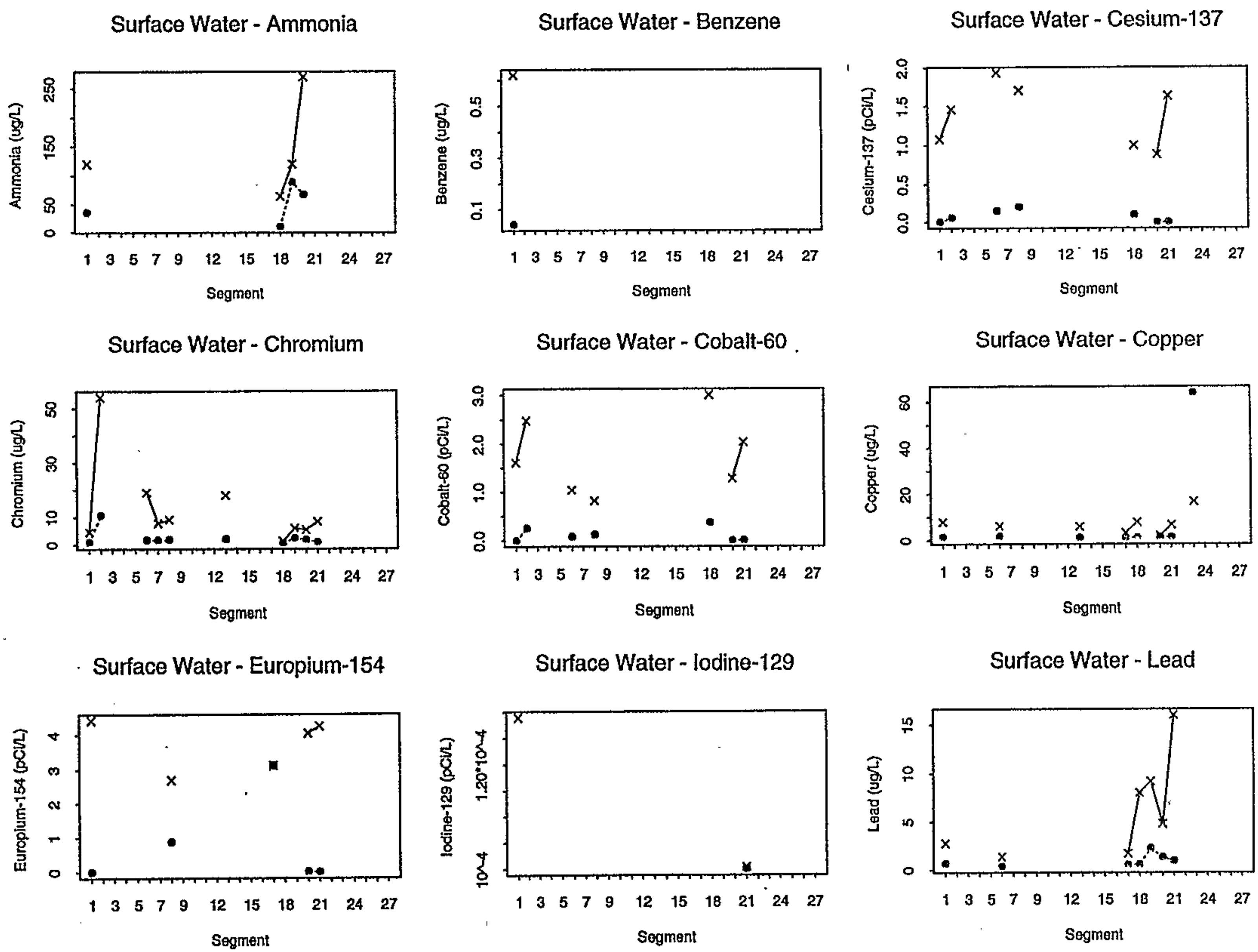

Sediment - Benzene
Benzene (ug/kg)
Segment
Sediment - Cesium-137
Cesium-137 (pCi/kg)
Segment
Sediment - Chromium
Chromium (ug/kg)
Segment
Sediment - Cobalt-60
Cobalt-60 (pCi/kg)
Segment
Sediment - Copper
Copper (ug/kg)
Segment
Sediment - Europium-152
Europium-152 (pCi/kg)
Segment
Sediment - Europium-154
Europium-154 (pCi/kg)
Segment
Sediment - Lead
Lead (ug/kg)
Segment
Sediment - Mercury
Mercury (ug/kg)
Segment

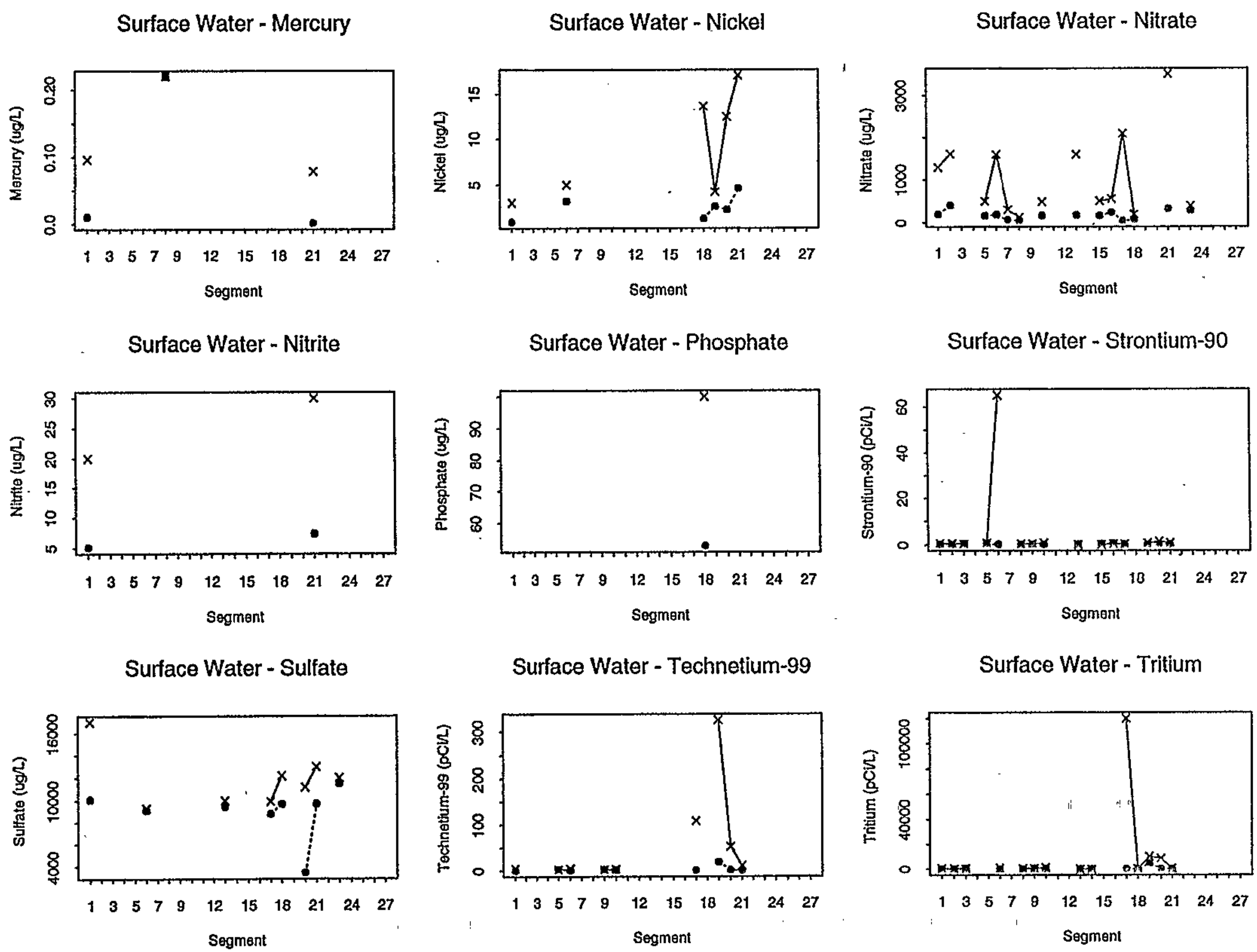

Sediment - Neptunium-237
Neptunium-237 (pCi/kg)
Segment
Sediment - Nickel
Nickel (ug/kg)
Segment
Sediment - Nitrate
Nitrate (ug/kg)
Segment
Sediment - Strontium-90
Strontium-90 (pCi/kg)
Segment
Sediment - Technetium-99
Technetium-99 (pCi/kg)
Segment
Sediment - Uranium-234
Uranium-234 (pCi/kg)
Segment
Sediment - Uranium-238
Uranium-238 (pCi/kg)
Segment
Sediment - Xylenes (total)
Xylenes (total) (ug/kg)
Segment
Sediment - Zinc
Zinc (ug/kg)
Segment

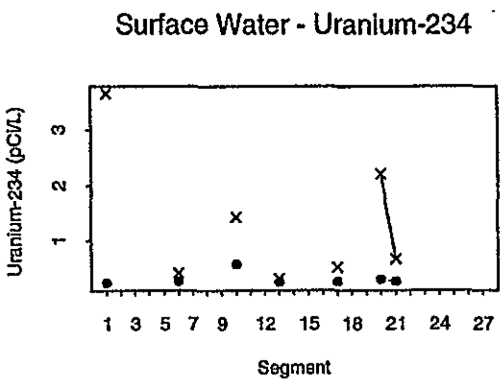


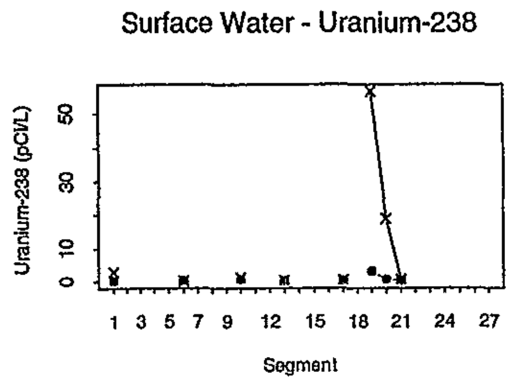
Seep - Cesium-137
Cesium-137 (pCi/l)
0.5
1.5
2.5
Segment
Seep - Chromium
Chromium (ug/L)
0
100
300
Segment
Seep - Cobalt-60
Cobalt-60 (pCi/l)
2
4
6
8
10
Segment
Seep - Copper
Copper (ug/L)
10
20
30
Segment
Seep - Europium-154
Europium-154 (pCi/L)
2
4
6
8
10
Segment
Seep - Iodine-129
Iodine-129 (pCi/L)
0.00439
0.00440
Segment
Seep - Lead
Lead (ug/L)
5
10
15
Segment
Seep - Nickel
Nickel (ug/L)
5
10
15
20
Segment
Seep - Nitrate
Nitrate (ug/L)
0
20000
40000
Segment
1 3 5 7 9 12 15 18 21 24 27

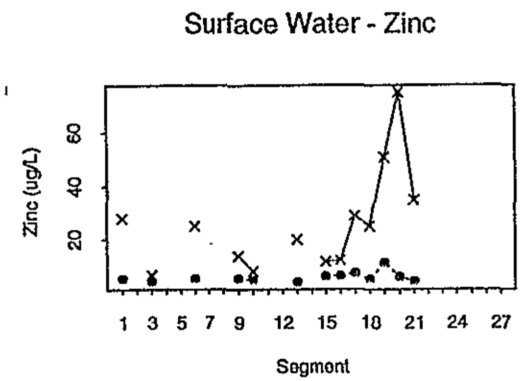

Seep - Strontium-90
Strontium-90 (pCi/l)
Segment
Seep - Sulfate
Sulfate (ug/L)
Segment
Seep - Technetium-99
Technetium-99 (pCi/l)
Segment
Seep - Tritium
Tritium (pCi/l)
Segment
Seep - Uranium-234
Uranium-234 (pCi/l)
Segment
Seep - Uranium-238
Uranium-238 (pCi/l)
Segment
Seep - Zinc
Zinc (ug/L)
Segment

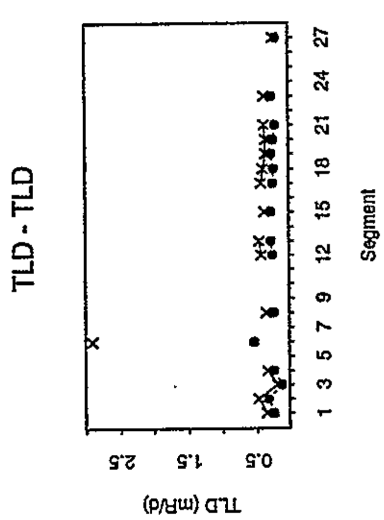

Surface Water - Ammonia
Ammonia (ug/L)
Segment
Surface Water - Benzene
Benzene (ug/L)
Segment
Surface Water - Cesium-137
Cesium-137 (pCi/L)
Segment
Surface Water - Chromium
Chromium (ug/L)
Segment
Surface Water - Cobalt-60
Cobalt-60 (pCi/L)
Segment
Surface Water - Copper
Copper (ug/L)
Segment
Surface Water - Europium-154
Europium-154 (pCi/L)
Segment
Surface Water - Iodine-129
Iodine-129 (pCi/L)
Segment
Surface Water - Lead
Lead (ug/L)
Segment


Surface Water - Mercury
Mercury (ug/L)
Segment
Surface Water - Nickel
Nickel (ug/L)
Segment
Surface Water - Nitrate
Nitrate (ug/L)
Segment
Surface Water - Nitrite
Nitrite (ug/L)
Segment
Surface Water - Phosphate
Phosphate (ug/L)
Segment
Surface Water - Strontium-90
Strontium-90 (pCi/L)
Segment
Surface Water - Sulfate
Sulfate (ug/L)
Segment
Surface Water - Technetium-99
Technetium-99 (pCi/L)
Segment
Surface Water - Tritium
Tritium (pCi/L)
Segment


Surface Water - Uranium-234
Uranium-234 (pCi/L)
1
2
3
1 3 5 7 9 12 15 18 21 24 27
Segment


Surface Water - Uranium-238
Uranium-238 (pCi/L)
0
10
30
50
1 3 5 7 9 12 15 18 21 24 27
Segment


Surface Water - Zinc
Zinc (ug/L)
20
40
60
1 3 5 7 9 12 15 18 21 24 27
Segment


TLD - TLD
TLD (mR/d)
0.5
1.5
2.5
Segment
1 3 5 7 9 12 15 18 21 24 27

Appendix I-C

Species List and Scoring of Tier I Species

The six criteria developed by the panel were:

- Commercial or recreational importance
- Protection status under the Endangered Species Act or similar state legislation
- Critical component of either the riparian or aquatic ecosystem: key predator or prey
- High potential exposure to contaminants
- Availability of toxicological benchmarks for the species
- Representative of a foraging guild

Each species received a positive or negative response to each of the six criteria. Three or more positive responses were selected as an arbitrary cutoff, resulting in selection of 93 (roughly 25 percent) of the 368 study area species. These 93 species were submitted to the CRCIA Team for review and input. An additional 88 species (based on their cultural and ecological importance) were provided by the CRCIA Team to create a list of 181 Tier I species. Table C.2 provides the list of 181 Tier I species. The table is a Word Perfect 5.1 for DOS file on diskette and provides the following information:

- Identification of which species met which of the six criteria
- Criteria scores for each species
- Identification of which species were selected by the CRCIA Team for further evaluation

Of the 181 Tier I species, some were grouped based on similar life styles and trophic levels resulting in 121 species. The CRCIA Team added 5 species to the 121 for a total of 126 species. The 126 species were scored (using the conceptual exposure model described in Section 4.1.2.2.1) for their potential exposure to contaminated media. Scores were scaled to reflect the general magnitude of a species potential exposure to contaminants in each medium, the duration of exposure, and acute radiation sensitivity. These scores represent an index for screening the relative exposure of species within taxonomic groups. These scores do not represent real differences in exposure. Species were scored specifically on:

- Exposure to biotic and abiotic media - ingestion of prey with separate scores assigned for biomagnifying and non-biomagnifying contaminants with individual contaminants not identified as biomagnifying or non-biomagnifying but rather only grouped generically as such; ingestion of sediment/soil, pore water/groundwater, and surface water; dermal contact with sediment/soil, pore water/groundwater, and surface water; and inhalation of airborne contaminants. All media scores were scaled from 1 to 4 to ensure that all pathways/media were considered of equal importance in their contribution to an individual's overall exposure. In some pathway/media exposure scenarios scores were scaled from 0 to 4 (see Sections 4.1.2.2.3-4.1.2.2.6) because these scenarios included the possibility of no exposure. The use of the zero, however, did not change the sum of the species' scores or the ultimate rankings. Sections 4.1.2.2.2-4.1.2.2.8 describe the basis and provide examples of the score assignments.

- Exposure duration - residence time in the study area. Exposure duration scores were scaled from 1 to 4. Section 4.1.2.2.9 describes the basis and provides examples of the score assignments.

Appendix I-C
Species List and Scoring of Tier I Species

A master species list was assembled that included terrestrial and aquatic plant and animal species known to occur in riverine and riparian habitats of the Columbia River between the vicinity of Priest Rapids Dam and the Columbia River estuary. The master list was developed by selecting species from databases and records maintained by federal and state resource management agencies associated with the Columbia River and its environs.

Species distributions and habitat preferences were also obtained from these agencies. The majority of information was obtained from the U.S. Fish and Wildlife Service national wildlife refuges. Information on species distributions and habitat preferences was used to exclude species that primarily use upland areas. From the resulting master species list, 368 species were identified as those that occur within the study area. Table C.1 provides the master species list. The table is a Word Perfect 5.1 for DOS file on diskette and provides the following information:

- Class categories: algae, amphibians, aquatic invertebrates, birds, emergent vegetation, fish, macrophytes, mammals, reptiles, terrestrial invertebrates, and terrestrial vegetation
- Common name
- Scientific name
- General location to indicate whether the species occur within the study area (the riverine and riparian areas between the vicinity of Priest Rapids Dam and McNary Dam)
- Habitat for each species: aquatic, benthic, buildings, coastal shoreline, cobble-gravel substrate, disturbed areas, estuarine, gravel substrate, island, marsh, riparian, sand-cobble substrata, sand-rock substrate, semi-aquatic, semi-pelagic, shoreline, upland, wetland
- Specific location to indicate where data were available on the distribution of the species

Because of redundancy in exposure and the increased uncertainty in the risk assessments of the species for which data are lacking, the 368 study area species were reduced further in number. The Pacific Northwest National Laboratory formed a panel of regional biologists who developed a set of six criteria that were approved by the CRCIA Team for screening the study area species.

- Acute radiation sensitivity - estimate using only the LD_{50} (dose that is lethal to 50 percent of test organisms) for radiation exposure (Whicker and Schultz 1982). Acute radiation sensitivity scores were also scaled from 1 to 4. Section 4.1.2.2.10 describes the basis and provides examples of the score assignments.

The scores and resulting ranks, which indicated the qualitative, relative exposure of species within taxonomic groups, are presented in Table C.3. The table is a Microsoft Excel 5.0 file on diskette. The scores and resulting ranks are described in detail in Section 4.1.2.2.11. A summary of that description is:

row 1	=	summation of rows 3, 5, 6, and 7
row 2	=	summation of rows 4, 5, 6, and 7
row 8	=	summation of rows 9, 10, and 11
row 13	=	summation of rows 1, 8, and 12
row 14	=	summation of rows 2, 8, and 12
row 16	=	multiplication of media weightings for in-river source areas from Table 4.14 with rows 3, 5, 6, 7, 9, 10, 11, and 12 followed by summation of these rows
row 17	=	multiplication of media weightings for in-river source areas from Table 4.14 with rows 4, 5, 6, 7, 9, 10, 11, and 12 followed by summation of these rows
row 18	=	rank based on score in row 16
row 19	=	rank based on score in row 17
row 20	=	multiplication of media weightings for outfall source areas from Table 4.14 with rows 3, 5, 6, 7, 9, 10, 11, and 12 followed by summation of these rows
row 21	=	multiplication of media weightings for outfall source areas from Table 4.14 with rows 4, 5, 6, 7, 9, 10, 11, and 12 followed by summation of these rows
row 22	=	rank based on score in row 20
row 23	=	rank based on score in row 21
row 24	=	average of rows 16 and 20
row 25	=	average of rows 17 and 21
row 26	=	rank based on score in row 24
row 27	=	rank based on score in row 25
row 28	=	maximum rank in rows 26 and 27
row 34	=	highest number in rows 24 and 25 divided by 15, then added to scores in rows 30 and 32
row 35	=	rank based on score in row 34

Appendix I-D

Ecological Risk

Appendix I-D
Ecological Risk

Whereas Section 4.2 presents the methodology and key results of the screening assessment of risk to the environment, this appendix provides the details of the input and output of the assessment.

Much of the information in this appendix is provided on diskette. Two of the files on diskette are very large. To make them available, they have been compressed with the commercial compression routine PKZIP (PKWARE 1992). "Exe" as the extension of the file name indicates those files that have been compressed and are capable of decompressing themselves. When these files are decompressed, they will automatically reestablish the computer code and necessary input files.

To decompress an "exe" file:

- Create a directory and copy the "exe" files into it from the diskette.
- To decompress the files:
  - In DOS, while in the directory you created, type the "exe" file name and hit enter.
  - In Microsoft Windows File Manager, double click on each "exe" file and it will decompress. To view the decompressed file names in File Manager, click on REFRESH under WINDOW.
  - In Microsoft Windows 95, click on START, then RUN, then BROWSE; indicate directory you have created; double click on each "exe" file to decompress it.
- To view the individual files, open the files in any text processing software or spreadsheet.

Information in this appendix is provided on the following:

- Measurement Endpoint Values Used in the Risk Assessment
- Exposure Model Description and Parameters
- Calibration Parameters for Copper and Zinc
- Environmental Hazard Quotients
- Risk Categories from Stochastic Modeling

Measurement Endpoint Values Used in the Risk Assessment

A Microsoft Excel file (meas-end.xls) on diskette lists the benchmark species and toxicological responses used in determining toxicological values for the species of interest. The file identifies the species, contaminants, LD_{50} and LOEL values, surrogate species used if there was one, and the sources of information.

Exposure Model Description and Parameters

The following description represents a compilation of exposure formulas that were primarily derived from EPA's wildlife exposure factors handbook (EPA 1993). The parameters used in the formulas are in a Microsoft Excel file (paramtrs.xls) on diskette.

Air-Respiring or Transpiring Species

Plants

Rain Splash

$$C_{par} = EC_{soil} * K_{ps1} \text{ (Hope 1995)}$$

where

C_{par} = Equilibrium concentration in above-ground plant parts from rain splash (μg/kg or μCi/kg wet)

EC_{soil} = Concentration in surface soil (top ~1 cm) (μg/kg or μCi/kg dry)

K_{ps1} = Plant-soil partition coefficient for rain splash on fresh-weight basis (kg soil / kg plant wet weight)

Calibration

K_{ps1} = 0.0034, Coefficient of Variation = 1 (McKone 1993)

EC_{soil} = Measured concentration from database or estimated from equilibrium with groundwater

Root Uptake to Above-Ground Plant Tissue. The equation below was modified from Hope (1995). One of the terms in parentheses would be used depending on whether the contaminant was organic (K_{ps2}) or inorganic [$B_v(1-f_w)$].

$$C_{pau} = EC_{soil} * [K_{ps2}, B_v(1-f_w)]$$

where

C_{pau} = Equilibrium concentration in above-ground plant parts from root uptake (μg/kg or μCi/kg wet)

K_{ps2} = Plant-soil partition coefficient for root-zone soil to above-ground plant parts for organic contaminants - fresh weight basis (kg soil / kg plant wet weight)

B_v = Bioconcentration factor for vegetative plant parts for inorganic contaminants - dry weight basis (unitless)

f_w = Weight fraction of plant tissue that is water (unitless)

Submodel. In the equation below the regression model was reported in McKone (1993). The coefficient of variation equals 4).

$$K_{ps2} = 7.7 * K_{ow}^{-0.58}$$

where

K_{ow} = Octanol-water partition coefficient

Calibration

B_v = See paramtrs.xls file on diskette
f_w from Spector (1956), Martin et al. (1951, p. 12) and EPA (1993, p. 4-14)
K_{ow} from MEPAS chemical database (Strenge and Peterson 1989)

Special Case for Tritium (Hydrogen-3). B_v in the model above incorporates field- or experiment-derived conversion of sediment-bound contaminants into a pore-water phase, which is the primary phase for uptake of metals (Kabata-Pendias and Pendias 1984). This conversion is problematic for tritium because tritium is carried entirely in the water phase ($K_d = 0$). Plants take up tritium from groundwater and porewater (for example, Rickard and Price 1989) at a concentration ratio of somewhat less than 1 (Driver 1994). Consequently, the present model was set up to utilize a $B_{porewater}$ value for tritium of 0.9, which was multiplied by the porewater (in other words, groundwater) concentration to obtain an equilibrium plant concentration.

Foliar Uptake from Soil by Vapor

$$C_{pav} = EC_{vap} * K_{pa1} \text{ (Hope 1995)}$$

where

C_{pav} = Equilibrium concentration in above-ground plant parts from vapor uptake (μg/kg or μCi/kg wet)
Ec_{vap} = Concentration of gas-phase contaminant (μg or $\mu Ci/m^3$)
K_{pa1} = Plant-air partition coefficient for air to above-ground plant parts for organic contaminants (m^3/kg wet weight)

Submodel: $\boldsymbol{K_{pa1}}$

$$K_{pa1} = (f_{pa} + (f_{pw} + f_{pl} * K_{ow}) \times (R \times T)/H) * (1/\rho_p)$$

(Reiderer 1990, coefficient of variation = 14, McKone 1993)

where

f_{pa} = Volume fraction of plant tissue in air (unitless)
f_{pw} = Volume fraction of plant tissue that is water (unitless)
f_{pl} = Volume fraction of plant tissue that is lipid (unitless)
R = Universal gas constant ($Pa\text{-}m^3$/mol-K)
T = Temperature (K)
H = Contaminant-specific Henry's law constant ($Pa\text{-}m^3$/mol)
ρ_p = Plant tissue density (kg/m^3)

Submodel: $\boldsymbol{EC_{vap}}$

EC_{vap} = $EC_{soil} * 1/\{(LS * V * Dh)/A) * [(3.14 * \zeta * I)^{0.5}/(2 * D_{ei} * E * K_{as} * 10^{-3} \text{ kg/g})]\}$ (EPA 1991)
LS = Length of side of contaminated area (m)

V = Wind speed in mixing zone (m/s)
Dh = Diffusion height (m)
A = Area of contamination (cm^2)
ζ = Effective diffusion rate (cm^2/s)
I = Exposure interval (s)
D_{ei} = Effective diffusivity (cm^2/s)
E = Soil porosity (unitless)
K_{as} = Soil/air partition coefficient (g soil/cm^3 air)

Submodel: ζ

$\zeta = (D_{ei} * E)/(E + (\rho_s * (1-E)/K_{as}))$
ρ_s = Soil density (g/cm^3)

Submodel: K_{as}

$$K_{as} = (H * 41)/(K_d * 1.0125E5\ Pa/atm)\ \text{(EPA 1991)}$$

where
41 = Units conversion factor
K_d = Soil-water partition coefficient (cm^3/g)

Submodel: K_d

$K_d = 0.62 * K_{ow} * f_{oc}$ (regression model in Nicholls 1991)
f_{oc} = Soil organic carbon content (unitless)

Submodel: D_{ei}

$$D_{ei} = D_i * E^{0.33}\ \text{(EPA 1991)}$$

where
D_i = Molecular diffusivity (cm^2/s)

Calibration

f_{pa} = 0.5 (McKone 1993)
f_{pw} = 0.4 (McKone 1993)
f_{pl} = 0.01 (McKone 1993)
R = 8.314
T = 285 K default Hanford average (Stone et al. 1983)
H = from MEPAS database (Strenge and Peterson 1989)
ρ_p = 1000 (McKone 1993)
ρ_s = for sediment or 2.65 default (EPA 1991)
E = 0.35 default

ρ_a = 0.05
f_{oc} = from segment or 0.01 default
K_{ow} = from MEPAS database
LS = 1000 m
V = 2.68 m/s default Hanford average @ 2.1 meters (7 feet) (Stone et al. 1983)
Dh = Average distance from ground to middle of foliage [fungi: 0.05 m, grasses/forbs: 0.1 m, trees: 5 m]
A = 50 cm * LS * 100 cm/m
D_i = Chemical-specific from MEPAS database
I = $3.1536 * 10^7$ sec default (1 year)

Foliar Adsorption of Particulates from Soil

$$C_{pap} = EC_{par} * K_{pa2} \text{ (Hope 1995)}$$

where
C_{pap} = Equilibrium concentration in above-ground plant parts from particulate adsorption (μg/kg or μCi/kg wet)
Ec_{par} = Air concentration of particulate-bound contaminant ((μg or $\mu Ci/m^3$)
K_{pa2} = Plant-air partition coefficient for air to above-ground plant parts for particulate-bound contaminants (m^3/kg wet weight)

Submodel: EC_{par}

$$Ec_{p\_air} = EC_{soil}/PEF \text{ (EPA 1991)}$$

where
PEF = Particulate emission factor (m^3/kg)

Submodel: PEF

$$PEF = (LS * V * Dh * 3600 \text{ s/hr}/A/10{,}000 \text{ cm}^2/\text{m}^2) * (1000 \text{ g/kg } (Rf * (1-G) * (U_m/U_t)^3 * F(x)))$$
(EPA 1991)

where
Rf = Respirable fraction (g/m^2-hr)
G = Fraction of vegetative cover (unitless)
U_m = Mean annual wind speed (m/s)
U_t = Erosion threshold wind speed at 10 m (m/s)
F(x) = Cowherd et al. (1985) function (unitless)

Submodel: U_t

$$U_t = TFV * \ln(10\ m/SRH)/0.4 \text{ (Cowherd et al. 1985)}$$

where

TFV = Threshold friction velocity (m/s)
SRH = Surface roughness height (m)

Submodel: TFV

$$TFV = NECF * (64 + 0.0055 * APSD * 1000)/100 \text{ (regression model in Cowherd et al. 1985)}$$

where

NECF = Non-erodible elements correction factor (unitless)
APSD = Aggregate particle size distribution (mm)

Calibration

K_{pa2} = 3300 (coefficient of variation = 1.5, McKone 1993)
Rf = 0.036 (EPA 1991)
U_m = 3.44 m/s (Stone et al. 1983)
SRL = 0.018 m (grass - Jørgensen et al. 1991, p. 230)
NECF = 0
APSD = 0.04 mm (coarse silt size - Gee and Bauder 1986, p. 384)
G = 0.5
F(x) = 0.0497 (EPA 1991)

Total Plant Burden

$$\text{Internal burden: } C_{pai} = C_{pav} + C_{pau}$$

where

C_{pai} = Equilibrium tissue concentration of contaminants ((μg or μCi/kg tissue)

(Note this derivation assumes that none of the adsorbed contaminant enters the plant.)

$$\text{Total burden (as eaten by herbivore): } C_{pat} = C_{par} + C_{pap} + C_{pai}$$

where

C_{pat} = Equilibrium concentration of contaminants in and on plant tissue (μg or μCi/kg tissue)

Terrestrial Animals

Dermal Contact - Sediment

$$C_{dersi} = D_{dersi}/K_{ei} \text{ (from Hope 1995)}$$

where

C_{dersi} = Equilibrium contaminant body burden in species i from dermal contact with soil (μg/kg or μCi/kg body weight)
D_{dersi} = Absorbed daily dose for species i from dermal contact with soil (μg/kg or μCi/kg/day)
K_{ei} = Contaminant-specific depuration rate for species i (1/day)

Submodel: D_{ders}

$$D_{ders} = [(SA_i * P_{csi} * S_{ai} * EC_{soil} * CF * \delta_i/W_i] * \theta_i * \iota_i \text{ (modified from EPA 1991)}$$

where

SA_I = Surface area of species i (cm^2)
P_{csi} = Fraction of surface area of species i in contact with soil per day (1/day)
S_{ai} = Skin adherence factor for species i (mg/cm^2)
CF = Conversion factor (10^{-6} kg/mg)
δ_i = Contaminant-specific dermal absorption factor for species i (unitless)
W_i = Body weight of species i (kg wet weight)
θ_i = Area use factor for species i (ratio of contaminant area to home range - unitless)
ι_i = Seasonality factor for species i (fraction of year spent at the contaminated site - unitless)

Submodel: Sa_i

Birds: $SA_i = 10 * (W_i * 1000 \text{ g/kg})^{0.667}$ (EPA 1993)
Mammals: $SA_i = 12.3 * (W_i x 1000)^{0.65}$ (EPA 1993)
Woodhouse's toads: $SA_i = 0.953 * (W_i * 1000)^{0.725}$ (EPA 1993)
Lizards: $SA_i = 8.42 * (W_i * 1000)^{0.694}$ (EPA 1993 - salamander applied to lizards)
Western aquatic garter snake: $= 2 x \pi x 1$ cm radius (1 cm + 106 cm length) (EPA 1993, Stebbins 1985)
Terrestrial arthropods: 0.0002 cm^2

Calibration

δ_i = See paramtrs.xls on diskette
K_{ei} = See paramtrs.xls on diskette
PCs = Mammal: 0.22 (Maughan 1993); other vertebrates: 0.25, arthropods: 1
W_i = for species using EPA (1993), Dunning (1993), Silva and Downing (1995), Nagy (1983)
S_a = 1.45 (EPA 1991)
θ_i = 1

ι_i = 1 for all species except common snipe (0.33), bufflehead (0.5), Forster's tern (0.5), cliff swallow (0.5), and bald eagle (0.5) (Ennor 1991)

Dermal Contact - Water

$$C_{derwi} = D_{derwi}/K_{ei} \text{ (Hope 1995)}$$

where

C_{derwi} = Equilibrium contaminant body burden for species i from dermal contact with water (μg or μCi/kg body weight)

D_{derwi} = Absorbed daily dose for species i from dermal contact with water ((μg or μCi/kg-day)

Submodel: D_{derw}

$$D_{derwi} = [(SA_i * P_{cwi} * ET_i * EC_{surface} * CF * K_{pi})/W_i] * \theta_i * \iota_i$$

(modified from EPA 1991 to include use and seasonality factors)

where

SA_I = Surface area of species i (cm^2)

P_{cwi} = Fraction of surface area of species i available for contact with water (unitless)

Et_{wi} = Average exposure time to water per day for species i (hr/day)

$Ec_{surface}$ = Concentration in surface water (μg/L or μCi/L)

CF = Volumetric conversion factor for water (1 L/1000 cm^3)

K_{pi} = Contaminant-specific dermal absorption factor for species i from water (cm/hr)

W_i = Body weight of species i (kg wet weight)

θ_i = Area use factor for species i (ratio of contaminant area to home range - unitless)

ι_i = Seasonality factor for species i (fraction of year spent at the contaminated site - unitless)

Calibration

K_{pi} = See paramtrs.xls file on diskette

ET and P_{cwi} (EPA 1993):

Species	ET_i	P_{cwi}
Woodhouse's toad	20	1
Western aquatic garter snake	12	1
Beaver, muskrat	20	1
Mule deer	1	0.8
Raccoon	2	0.1
Terrestrial arthropods, lizards, coyote, weasel, western harvest mouse, California quail, cliff swallow, northern harrier, American kestrel	0	0
Bald eagle	2	0.8
Forster's tern	8	0.5
Great blue heron	20	0.1
Other waterfowl	20	0.5

Total Dermal Dose. Equilibrium body burden from dermal exposure:

$$C_{deri} = C_{dersi} + C_{derwi}$$

where

C_{deri} = Total equilibrium body burden from dermal exposure for species i (μg or μCi/kg body weight)

Absorbed dose:

$$D_{derti} = D_{dersi} + D_{derwi}$$

where

D_{derti} = Total daily dermal absorbed dose for species i (μg or μCi/kg body weight/day)

Inhalation - Vapor

$$C_{ivi} = D_{ivi} * (\alpha_{vapi}/K_{ei}) \text{ (Hope 1995)}$$

where

C_{ivi} = Equilibrium contaminant body burden for species i from inhalation of vapor (μg/kg or μCi/kg)

D_{ivi} = Applied daily dose to species i from vapor inhalation (μg/kg or μCi/kg-day)

α_{vapi} = Inhalation absorption factor for species i (unitless)

Submodel: D_{ivi}

$$D_{ivi} = [(IR_i * EC_{vap})/W_i] * \theta_i \times \iota_i \text{ (modified from Hope (1995) using EPA (1993) calculation for } EC_{vap} \text{ as above)}$$

where

Ir_i = Resting inhalation rate of species i (m^3/day) and rest as above

Calibration

Ir_i:

Species	Resting IR	Correction Factor for Field IR	IR_i
Mammals	$= 0.5458 * W_i^{0.80}$ (EPA 1993)	2 (EPA 1993)	$2 * 0.5458 * W_i^{0.80}$
Birds	$= 0.4089 * W_i^{0.77}$ (EPA 1993)	2 (EPA 1993)	$2 * 0.4089 * W_i^{0.77}$
Woodhouse's toad	see below	2 (EPA 1993)	$5.8 * 10^{-4}$
Lizards (*Uta*) and western aquatic garter snake	see below		$0.00045 * (W_i \times 1000)^{0.8}$
Terrestrial arthropods	see below		$0.00045 * (W_i \times 1000)^{0.8}$

Woodhouse's toads - EPA (1993) gives the resting metabolic rate of 74.8 g bullfrog adults at 5°C as 1-L O_2/kg/d. Because gas exchange through the skin accounts for 18 percent of the O_2 uptake (EPA 1993), the respired intake fraction necessary to support the referenced metabolic demand is 0.82-L O_2 respired/kg/d. The fraction of O_2 in dry atmosphere is 20.95 percent (Schmidt-Nielson 1975, p. 8), thus the volume of respired air required to support the referenced metabolic rate is 0.82-L O_2/0.2095-L O_2/L air, or 3.914-L air/kg toad/d. Finally, multiplication of this result by a correction factor (1 m^3/1000 L) and the weight of the toads (0.0748 kg) gives the resting calibrated value of $2.9 * 10^{-4}$ m^3/d per toad, which is multiplied by 2 to provide a field-corrected inhalation rate of $5.8 * 10^{-4}$ m^3/d per toad.

Reptiles - EPA (1993) cites the formula for active field metabolic rate for adult lizards and snakes as:

$$MR\ (ml\ O_2/hr) = 0.013 * (W_i * 1000)^{0.80} * 10^{0.038 * {}^\circ C} * 10^{0.14}$$

Assuming these reptiles are in equilibrium with the average annual Hanford temperature (12°C - Stone et al. 1983), using the atmospheric composition of O_2 as above, and converting hours to days and milliliters to m^3 gives:

$$IR\ (m^3/day) = 10^{-6}\ m^3/ml * 24\ hr/day * 1\ ml\ air/.2095\ ml\ O_2 * 0.013\ ml\ O_2/hr * (W_i * 1000)^{0.80} * 10^{0.00456} * 10^{0.14}$$

or

$$IR_i\ (m^3/day) = 0.00045 * (W_i * 1000)^{0.80}$$

Terrestrial arthropods - inhalation treated as per reptiles.

α_{vapi} = See paramtrs.xls file on diskette

Inhalation - Particulates

$$C_{ipi} = D_{ipi} * (\alpha_{pari}/K_{ei})\ \text{(Hope 1995)}$$

where

C_{ipi} = Equilibrium contaminant body burden for species i from inhalation of particulates (μg/kg or μCi/kg)

D_{ipi} = Applied daily dose to species i from particulate inhalation (μg/kg or μCi/kg-day)

α_{pari} = Inhalation particulate absorption factor (unitless)

Submodel: D_{ipi}

D_{ipi} = $[(IR_i * EC_{par})/W_i] * \theta_i * \iota_i$ (modified from Hope (1995) using EPA (1993) calculation for EC_{vap} as above)

Calibration

α_{pari} = See paramtrs.xls file on diskette

Total Inhalation Dose. Absorbed dose:

$$C_{inhi} = C_{ivi} + C_{ipi}$$

where

C_{inhi} = Total equilibrium burden from inhalation for species i (μg or μCi / kg body weight)

Applied dose:

$$D_{inhi} = D_{ivi} + D_{ipi}$$

where

D_{inhi} = Total inhalation applied dose for species i (μg or μCi/kg body weight/day)

Ingestion - Water

$$C_{ingwi} = D_{ingwi} * (\alpha_{ingi}/K_{ei}) \text{ (after Hope 1995)}$$

where

C_{ingwi} = Equilibrium contaminant body burden for species i from ingestion of water (μg/kg or μCi/kg)

D_{ingwi} = Applied daily dose to species i from water ingestion (μg/kg or μCi/kg-day)

α_{ingi} = Ingestion absorption factor for species i (unitless)

Submodel: D_{ingwi}

$$D_{ingwi} = [(WI_i * EC_{surface} \text{ or } EC_{springs})/W_i] * \theta_i * \iota_i$$

(modified from EPA (1993) using site use fractions as above)

where

WI_i = Water ingestion rate of species i (L/day)

$EC_{springs}$ = Concentration in spring/seep water, where present (μg/L or μCi/L), otherwise, $EC_{surface}$ is used as the default

$EC_{surface}$ = Concentration in surface water

Calibration

WI_i: (EPA 1993)

Species	WI_i
Mammals	$= 0.099 \times W_i^{0.90}$
Birds	$= 0.059 \times W_i^{0.67}$
Woodhouse's toad	0
Lizards (*Uta*) and western aquatic garter snake	0
Terr. arthropods	0

α_{ing} = See paramtrs.xls file on diskette

Ingestion - Soil

$$C_{ingsi} = D_{ingsi} * (\alpha_{ingi}/K_{ei}) \text{ (after Hope 1995)}$$

where

- C_{ingsi} = Contaminant body burden to species i from ingestion of soil (μg/kg or μCi/kg body weight)
- D_{ingsi} = Applied daily dose to species i from soil ingestion (μg/kg or μCi/kg-day)
- α_{ingi} = Ingestion absorption factor for species i (unitless)

Submodel: ***D_{ingsi}***

$$D_{ingsi} = [(SI_i * NIR_{totali} * EC_{surface} * F_{dwi})] * \theta_i * \iota_i$$

(modified from EPA (1993) using site use fractions as above)

where

- SI_i = Soil ingestion rate of species i (kg soil ingested/kg dry diet)
- NIR_{totali} = Total normalized ingestion rate for species i (kg prey wet weight/kg predator body weight/day)
- F_{dwi} = Conversion factor, dry diet to wet diet for species i (kg dry/kg wet)

Submodel: ***NIR_{totali}***

$$NIR_{totali} = FMR_i/(\Sigma (P_{ij} * ME_j) * W_i)$$

(EPA 1993, equations 4-11 and 4-12)

where

- FMR_i = Free-living metabolic rate of predator (kcal/day)
- P_{ij} = Wet weight or volume fraction of i's diet consisting of prey j (unitless)
- ME_j = Metabolizable energy from prey j (kcal/kg prey wet wt)

Submodel: ***FMR_i***

Birds: $FMR_i = 3.12 * (W_i * 1000 \text{ g/kg})^{0.605}$ (EPA 1993)

Herbivorous mammals: $FMR_i = 1.419 * (W_i * 1000 \text{ g/kg})^{0.727}$ (EPA 1993)

Non-herbivorous mammals: $FMR_i = 0.6167 * (W_i * 1000 \text{ g/kg})^{0.862}$ (EPA 1993)

Rodents $= 2.514 * (W_i * 1000 \text{ g/kg})^{0.507}$ (EPA 1993)

Reptiles: $FMR_i = 0.053 * (W_i * 1000 \text{ g/kg})^{0.799}$ (EPA 1993)

Woodhouse's toads: $FMR_i = 0.000288 * (0.047 * (W_i * 10^6 \text{ mg/kg})^{1.06})^{0.878}$

(derived from EPA 1993 using tadpole FMR)

Terrestrial arthropods: as per reptiles

Submodel: ***ME_j***

$$ME_j = (GE_j * AE_j) \text{ (EPA 1993)}$$

where

GE_j = Gross energy from prey j (kcal/kg wet weight)
AE_j = Assimilation efficiency of prey j (unitless)

Calibration

SI_i: (Beyer et al. 1994)

Species	SI_i
Mule deer	0.02
Raccoon, muskrat, beaver	0.09
Western harvest mouse	0.02
Coyote	0.09
Weasel	0.03
American coot, snipe	0.18
Mallard	0.033
Canada goose	0.08
Raptors and fish-eating birds	0.02 (average of fish-eating species)
California quail	0.09 (used value for wild turkey)
Cliff swallow	0.02 (lowest value of birds)
Woodhouse's toad	0.06 (see below)
Lizards (*Uta*), and western aquatic garter snake	0.054 (see below)
Terr. arthropods	0.054 (as per reptiles)

For Woodhouse's toad and reptiles, SI was estimated using the average of box (4.5%) and painted turtle (5.9%) estimates because of the lack of data for these groups (Beyer et al. 1994).

F_{dw} = 1 - %H_2O = 0.17 for all diets (average of fresh diets in EPA 1993, p. 4-14)
P_{ij} = Species-specific values from Terres (1980), Martin, et al. (1951), Zeiner et al. (1990), Svendsen (1982), Becker (1973), Dauble et al. (1980), Brandt et al. (1993), Hanson and Browning (1956), Fitzner and Rickard (1975), Fitzner and Schreckhise (1979), Ehrlich et al. (1988), Johnsgard (1990); see paramtrs.xls file on diskette
GE_j = Values for species groups from EPA (1993, p. 4-13-4-14). Assigned values are shown below.
AE_j = Values were assigned to prey based on major taxon using EPA (1993, p. 4-15). Data were averaged between avian and mammalian predators where both values were given. Assigned values are shown below.

Prey Group	Assigned GE_j	Assigned AE_j
Birds	1900	(0.78 + 0.84)/2 = 0.81
Mammals	1700	(0.78 + 0.84)/2 = 0.81
Reptiles	1400	0.81 (as per birds, mammals)
Amphibians	1200	0.81 (as per birds, mammals)
Fish	1200 (bony fish value)	(0.79 + 0.91)/2 = 0.85
Salmon adults	1600 (Halfon et al. 1996)	0.85
Salmon larvae	1400 (Halfon et al. 1996)	0.85
Rainbow trout adults	2100 (Halfon et al. 1996)	0.85
Rainbow trout larvae	1500 (Halfon et al. 1996)	0.85
Terrestrial insects	1600 (average of insects)	(0.72 + 0.87)/2 = 0.80
Crayfish	1100 (shrimp value)	0.77
Insect larvae	1200	0.77
Daphnia	740 (cladoceran value)	0.77
Hyalella	1100 (amphipod value)	0.77
Tadpoles	1200 (as per amphibians)	0.77
Molluscs	800 (bivalves sans shells)	0.77
Periphyton, phytoplankton	510	0.23
Macrophytes	520	0.23
Emergent vegetation (tule, Columbia yellowcress)	1600	0.39
Reed canarygrass, sedges, rushes	1300	0.47 (as per leaves and grasses)
Black cottonwood, mulberry	3200 (stems and twigs, 25% water)	0.34 (as per stems, twigs)
Fern, fungi	630 (as per dicot leaves)	0.73 (as per green forb)

Ingestion - Food

$$C_{ingfi} = D_{ingfi} * (\alpha_{ingi}/K_{ei}) \text{ (after Hope 1995)}$$

where

C_{ingfi} = Equilibrium body burden for species i from ingestion of food (μg/kg or μCi/kg body weight)

D_{ingfi} = Applied daily dose to species i from food ingestion (μg/kg or μCi/kg - day)

Submodel: D_{ingfi}

$$D_{ingfi} = \Sigma(C_j * NIR_j) * \theta_i * \iota_i \text{ (modified from Hope (1995) using EPA (1993))}$$

where

C_j = Average contaminant concentration in jth food item (μg/kg or μCi/kg wet weight)

NIR_j = Normalized ingestion rate of jth food type on a wet-weight basis (kg prey/kg body weight predator/day)

Submodel: NIR_j

$NIR_j = P_{ij} \times NIR_{totali}$ (EPA 1993, equation 4-10)

Calibration: C_j. Plant prey:

$$C_j = C_{pat}$$

Animal prey:

$$C_j = C_{ingf} + C_{ings} + C_{ingw} + C_{inh} + C_{der}$$

Total Ingestion Dose. Applied daily dose:

$$D_{ingi} = D_{ingfi} + D_{ingsi} + D_{ingwi}$$

where

D_{ingi} = Applied daily dose for species i from ingestion (μg/kg or μCi/kg - day)

Absorbed dose:

$$C_i = C_{ingfi} + C_{ingsi} + C_{ingwi} + C_{inhi} + C_{deri}$$

where

C_i = Equilibrium body burden for species i from ingestion (μg/kg or μCi/kg body weight)

Water-Respiring or Transpiring Species

The basic models used in the screening assessment for estimating exposures of aquatic organisms to metal or organic contaminants in sediments, pore water, surface water, and the subsequent transfer through the food chain consist of mass-balance equilibrium models originally derived by R.V. Thomann and coworkers (Thomann 1989, Thomann et al. 1992, 1995). The basic equilibrium models presented in these papers were further modified by the authors to provide a system of equations generally applicable when only sediment data are available. The essential assumption used in that modification is that the aquatic system is not depurating contaminants, such that the three abiotic compartments (sediment, pore water, and surface water) are in static equilibrium (Thomann et al. 1992). This assumption may only be valid for large lacustrine systems. Clearly, it is invalid for the Columbia River. However, the basic models may be utilized directly with only minor modification to address the Columbia River system.

Derivation of Dose

The basic equation for contaminant mass balance in an organism i feeding on prey j (including sediment) is given by:

$$dV_i/dt = k_{ui}\,(b_{pore} * EC_{pore} + b_{surface} * EC_{surface}) + \Sigma\,(P_{ij} * \alpha_{ij} * I_{ij} * V_j) - (K_i + G_i)V_i$$

(after Thomann et al. 1992, 1995)

where

V_i = Body burden in predator species i (metals: μg or μCi/kg dry weight - Thomann et al. 1995; organics: μg or μCi/g lipid - Thomann et al. 1992)

V_j = Body burden in prey species j (metals: μg or μCi/kg dry weight - Thomann et al. 1995; organics: μg or μCi/g lipid - Thomann et al. 1992) or in sediment (metals: μg or μCi/kg dry sediment - Thomann et al. 1995; organics: μg or μCi/g organic carbon - Thomann et al. 1992)

k_{ui} = Contaminant uptake from dissolved sources for species i (metals: L/g dry weight / day - Thomann et al. 1995; organics: L / g lipid / day - Thomann et al. 1992)

b_{pore} = Relative exposure to pore water (unitless)

$b_{surface}$ = Relative exposure to surface water ($b_{surface} = 1 - b_{pore}$) (unitless)

Ec_{pore} = Contaminant concentration in pore water (μg/L or μCi/L)

$Ec_{surface}$ = Contaminant concentration in surface water (μg/L or μCi/L)

P_{ij} = Preference for consumption of food item j, including sediment as a separate prey item (unitless)

α_{ij} = Chemical assimilation efficiency for contaminant consumed along with prey j (g contaminant assimilated/g contaminant ingested)

I_{ij} = Feeding rate of species i on prey item j (organic model: g prey lipid/g predator lipid/day, metal model: g prey dry weight/g predator dry weight/day) or on sediment (organic model: g organic carbon ingested/g predator lipid/day, metal model: g sediment dry weight/g predator dry weight/day)

K_i = Loss rate of contaminant for species i, including depuration and metabolism (1/day)

G_i = Growth rate of species i (1/day)

At steady state, $dV_i/dt = 0$, and the above equation reduces to:

$$V_i = [k_{ui} (b_{pore} * EC_{pore} + b_{surface} * EC_{surface}) + \Sigma (P_{ij} * \alpha_{ij} * I_{ij} * V_j)]/(K_i + G_i)$$

This form is utilized directly by Thomann et al. (1992) for analyzing body burdens of organic contaminants in aquatic species. To analyze body burdens if metals in aquatic species, Thomann et al. (1995) condense this analysis further, utilizing the fact that $k_{ui}/(K_{ei} + G_i) = BCF_i$,which is the contaminant-specific bioconcentration factor reflecting uptake directly from the surrounding aqueous medium. This gives the following equation:

$$V_i = BCF * (b_{pore} * EC_{pore} + b_{surface} * EC_{surface}) + \Sigma (P_{ij} * \alpha_{ij} * I_{ij} * V_j)]/(K_i + G_i)$$

As given, the two equations return body burden estimates in units that differ between metals and organics. Further, the units are not comparable to those used in the in-air species exposure model (see previous section). Instead, the V_i must be converted to μg/kg wet weight (or pCi/kg wet weight for radionuclide contaminants). To accomplish that conversion, the following are applied:

$$\text{Metals: } C_i = Vi/awd_i$$
$$\text{Organics: } C_i = V_i * 1000 \text{ g/kg} * f_{Li}$$

where

awd_i = Wet-to-dry weight ratio for species i (g wet/g dry)

f_{Li} = Fraction lipid in species i (g lipid/g wet)

and C_i is as per in-air species given earlier.

It is these C_i's that are used as input into the in-air model as body burdens of aquatic prey for in-air species such as coyote and bufflehead.

Submodel: K_{ei} for Organic Contaminants

$$K_i = (k_{ui}/K_{ow}/1000\ g/L) + K_{mi} \text{ (Thomann 1989)}$$

where

K_{mi} = Chemical loss rate in species i due to metabolism and fecal loss (1/day)

Submodel: G_i

$$G_i = \delta * w_i^{-\beta} \text{ (Thomann et al. 1992)}$$

where

δ and β are regression parameters

Submodel: I_{ij}

For Intake of Organic Contaminants from Prey. For biotic prey:

$$I_{ij} = ((G_i + \rho_i)/a_i) * (awd_j/awd_i) * (f_{Lj}/f_{Li}) * (f_{oci}\ f_{ocj}) \text{ (Thomann et al. 1992)}$$

where

ρ_i = Oxygen respiration rate for species i (g O_2/g lipid/day)

a_i = Organic carbon assimilation rate for species i (g organic carbon assimilated/g organic carbon ingested)

f_{oci} = Fraction organic carbon in species i (g organic carbon/g dry weight)

For Intake of Metals/Radionuclides from Prey. The above equation return values with units of g prey lipid/g predator lipid/day. The equivalent units for the metal uptake model of Thomann et al. (1995) are g prey dry weight/g predator dry weight/day). For the purposes of evaluating metal and radionuclide uptake in aquatic systems, the following conversion was applied to produce consumption rates in the correct units:

$$\text{prey: } I_{metal} = I_{organic} * awd_j * f_{Lj}/awd_j/f_{Lj} = ((G_i + \rho_i)/a_i) * (f_{oci}/f_{ocj})$$

For Intake of Contaminants from Sediment Ingestion

Thomann et al. (1992, 1995) estimate sediment ingestion as a purposeful portion of the organism's diet, meaning the organism searches for and consumes the sediment as a carbon source for food. This is a valid assumption for species that consume sediment as the primary portion of their diet. None of the species identified for the screening assessment include sediment feeders. Instead, sediment intake can be more reasonably viewed as an incidental result of feeding on benthic organisms.

Using this assumption, sediment intake can be expressed as

$$BAF_{ised} = [P_{ised} * \alpha_{ised} * \Sigma (P_{ij} * \alpha_{ij} * I_{ij})]/(K_i + G_i)$$

where the subscript "ised" refers to organism i feeding on sediment, BAF_{ised} refers to the sediment-to-predator bioaccumulation factor (Thomann et al. 1992), and the remainder of the variables are as previously defined.

Submodel: k_{ui} for Organic Contaminants

$$k_{ui} = (2.67 \text{ g } O_2/\text{g C} * f_{oci} * \rho_i * E_c)/(awd_i * C_0 * f_{Li}) \text{ (Thomann 1989)}$$

where

w_i = Wet body mass for species i (g)
E_c = Chemical transfer efficiency (unitless)
C_0 = Oxygen concentration in the river (mg/L)

This parameter is not used in the model for metal uptake. Instead, the BCF relationship is used and BCF's are obtained from the literature, as described below.

Submodel: BCF_i for Organic Contaminants

$$BCF_i = k_{ui}/(K_i + G_i) \text{ (by definition)}$$

Submodel: ρ_i

$$\rho_i = \phi * w_i^{-\gamma} \text{ (Thomann 1989)}$$

where

ϕ and γ are regression parameters.

Calibration

BCF_i = For organic contaminants, the submodels for k_{ui} and BCF_i were used; otherwise, BCF values were obtained from the literature using a L/kg dry weight basis (see paramtrs.xls file on diskette)
E_0 = 0.8 (Thomann et al. 1992)
E_c = Function of K_{ow} (see below - Thomann et al. 1992)

Log K_{ow}	E_c
2	0.02511886
2.5	0.04466836
3	0.07943282
3.5	0.14125375
4	0.25118864
4.5	0.8
5	0.8
5.5	0.8
6	0.8
6.5	0.8
7	0.6
7.5	0.4
8	0.2
8.5	0.05
9	0.01

K_m = 0 (assumes no loss due to metabolism of contaminants)
α_{ij} = See paramtrs.xls file on diskette
K_i = See paramtrs.xls file on diskette for values for inorganics
C_0 = 0.011 @ 10°C (equilibrium solubility value)
δ = 0.002 @ 10°C (Thomann 1989)
β = -0.25 (range -0.2 - -0.3) (Thomann 1989)
ϕ = 0.032 (range 0.014 - 0.05) (Thomann 1989)
γ = -0.2 (range -0.2 - -0.3) (Thomann 1989)

Predation fractions for aquatic organisms were determined using studies in the Hanford Reach and the general literature. Bivalve, snail, aquatic insect, toad larvae, and juvenile lamprey diets were estimated based on their feeding behavior (in other words, grazers, filter feeders; C.E. Cushing, Pacific Northwest National Laboratory, personal communication August 12, 1996) and the known ratios of periphyton, phytoplankton, particulate matter, and periphyton in the water column. Crayfish diet composition was taken from Pennak (1989). Feeding habits of resident and anadromous fish have been described in both reports and the open literature, including largescale sucker (Dauble 1986), smallmouth bass (Battelle 1977a, 1977b, 1978, 1979a, 1979b), carp (Battelle 1977b), Pacific lamprey (Scott and Crossman 1973), mountain whitefish (Battelle 1977a, 1977b, 1978, 1979a, 1979b), white sturgeon (Battelle 1977a, 1977b, 1978, 1979a, 1979b), channel catfish (Battelle 1977a, 1977b, 1978, 1979a, 1979b), Battelle 1977a, 1977b, 1978, 1979a, 1979b), rainbow trout (Battelle 1977a, 1977b, 1978, 1979a, 1979b), and juvenile chinook salmon (Becker 1973, Dauble et al 1980). Relative proportions of food items were based on volume (Windell 1970) and items were grouped by taxa to provide consistency with uptake parameters selected for the ingestion model. Predation fractions used in this model are shown in the paramtrs.xls file on diskette.

Radiological Dose Estimation

The above exposure analyses return estimates of ingestion exposure to radiological contaminants in units of picocuries/kilogram body mass/day (units of radioactive decay rate density). However, radiological effects result from radioactive energy density absorbed by a body in a unit of time, which is usually expressed in units of rads/day. Consequently, decay rates had to be converted to energy equivalents. Similarly, an organism can receive external energy from radioactive decay occurring in the abiotic media (air, water, or soil). The primary media of concern to the ecological risk analysis are soil (in other words, sediment) and water.

The methodology that was used to estimate radiological doses in the ecological screening assessment followed that used in PNNL's CRITTER2 code (Baker and Soldat 1992). CRITTER2 has two model components: one component estimates body burden from ingestion by means of transfer factors. The second component converts body burden to radiological dose and estimates external dose from radioactive decay in sediment and water. It is this second component of CRITTER2 that was used in the CRCIA model.

Dose Equations

Internal total-body dose rate to an organism is the sum of the individual dose rates from each radionuclide in the body:

$$R_{i,int} = \Sigma\, C_{i,c} * E_{i,c}$$

where

$R_{i,int}$ = Radiological dose to organism i from internal radioactive decay (rad/day)
$C_{i,c}$ = Specific body burden of nuclide c in organism i (pCi/kg)
$E_{i,c}$ = Effective absorbed energy rate for nuclide c per unit activity in organism i (kg rad/ pCi/day)

and doses are summed across all radionuclides.

As shown in Baker and Soldat (1992), $E_{i,c}$ is a function of the effective absorbed energy in MeV/ disintegration ($\epsilon_{i,c}$), viz.

$$E_{i,c} = 1\ \text{Ci}/10^{12}\ \text{pCi} * \epsilon_{i,c}\ \text{MeV/ disintegration} * 3.7\text{E}10\ \text{disintegrations/sec/Ci} * 86{,}400\text{sec/day} * 1.602\text{E-}11\ \text{kg rad/MeV}$$

or

$$E_{i,c} = 5.12\text{E-}8 * \epsilon_{i,c}$$

External dose rates from water exposures are a similar sum of exposures from all radionuclide sources:

$$R_{i,imm} = \Sigma\, (b_{pore} * EC_{pore,c} + b_{surface} * EC_{surface,c}) * DF_{imm,c} * F_{water,i} * CF_{water}$$

where

$R_{i,imm}$ = External radiological dose to organism i from exposure to radioactive decay in water (rad/day)

$DF_{imm,c}$ = Water immersion dose factor for nuclide c (mrad $m^3/\mu Ci$/year)

$F_{water,i}$ = Fractional exposure of organism i to the water (unitless)

CF_{water} = 3.65E-8 (conversion factor: μCi rad year/pCi/mrad/day)

and other variables are as defined previously.

Finally, external dose received from contact with sediments is calculated as:

$$R_{i,sed} = \Sigma \, EC_{sed,c} * DF_{sed,c} * F_{sed,i} * CF_{sed}$$

where

$R_{i,sed}$ = External radiological dose to organism i from exposure to radioactive decay in sediment (rad/day)

$DF_{sed,c}$ = Sediment dose factor for nuclide c (mrad $m^2/\mu Ci$/year)

$F_{sed,i}$ = Fractional exposure of organism i to the sediment (unitless)

CF_{sed} = 5.4795E-5 (conversion factor: μCi rad year kg/pCi/m^2/mrad/day) and other variables are as defined previously.

Finally, total radiological dose is obtained by summing the above quantities:

$$R_{i,total} = \Sigma \, (R_{i,imm} + R_{i,sed} + R_{i,int})$$

Calibration

The environmental and body burden inputs to the above equations utilize field-derived media concentrations as described in Section 4.0 and body-burden estimates obtained from the air- and water-respiring species exposure equations described earlier. Dose factors and the effective absorbed energy in MeV/disintegration were obtained from Baker and Soldat (1992). Dose factors are a function of the radionuclide. Effective absorbed energies are a function of both the radionuclide and the radius of the organism being evaluated. Equivalent radii for each species were obtained by assuming organisms represent a sphere of unit density and calculating radii from average body weight data, which were presented earlier.

Calibration Parameters for Copper and Zinc

The exposure model was calibrated to produce approximate average tissue concentrations for copper and zinc within Segment 1. The calibration procedure focused on selecting ranges for bioconcentration factors, ingestion assimilation fractions, and depuration rates from within the published ranges for these parameters that would produce estimates between one-half and five times the average tissue concentrations for species obtained from uncontaminated areas.

The calibration parameters used are in a Microsoft Excel file (par-calb.xls) on diskette. The file shows the chemical assimilation efficiency and, for both copper and zinc, the bioconcentration factors and total loss rates.

Environmental Hazard Quotients

EHQs (the ratio of estimated exposure dose or concentration to LOEL endpoint values) were computed using the deterministic method for river segments and contaminants for each Tier II species. The EHQs that were 1 or greater identified segments, contaminants, and species that were evaluated further in the stochastic modeling.

The EHQs computed are in a compressed file (ehq-det.exe) on diskette. The compressed file will automatically decompress when opened (see instructions at the beginning of this appendix). In the file, the EHQ is given for each species by contaminant and location.

Risk Categories from Stochastic Modeling

Species-contaminant-river segment combinations were classified into four groups based on results of the stochastic simulations: nominal, low, medium, and high potential risk. The categories were based on the proportion of the simulation results that exceeded LC_{50}/LD_{50} or LOEL endpoints. Results of these simulations are presented in a compressed file (risk-cat.exe) on diskette. The compressed file will automatically decompress when opened (see instructions at the beginning of this appendix). In the file are tables and graphs that show for both aquatic and terrestrial species the resulting LC_{50}/LD_{50} or LOEL values.

Appendix I-E

Human Health Risk

Appendix I-E
Human Health Risk

Whereas Section 5.2 presents the methodology and key results of the screening assessment of risk to human health, this appendix provides the details of the input and output of the assessment.

Much of the information in this appendix is provided on diskette. Several of the files on diskette are very large. To make them available, they have been compressed with the commercial compression routine PKZIP (PKWARE 1992). "Exe" as the extension of the file name indicates those files that have been compressed and are capable of decompressing themselves. When these files are decompressed, they will automatically reestablish the computer code and necessary input files. The files provided, if all decompressed, will require a total of over 140 megabytes of hard disk storage. The reader is cautioned to have ample disk storage available.

To decompress an "exe" file:

- Create a directory on your hard drive and copy the "exe" files into it from the diskette.
- To decompress the files:
  - In DOS, while in the directory you created, type the "exe" file name and hit enter.
  - In Microsoft Windows File Manager, double click on each "exe" file and it will decompress. To view the decompressed file names in File Manager, click on REFRESH under WINDOW.
  - In Microsoft Windows 95, click on START, then RUN, then BROWSE; indicate directory you have created; double click on each "exe" file to decompress it.
- To view the individual files, open the files in any text processing software or spreadsheet.

Computer Code and Parameters of Calculations

A computer code, HUMAN, implemented the equations of Section 5.2.1. The HUMAN code was developed under quality assurance controls. Documentation of the code requirements, development specifications, development testing, and user's manual are available in project records. A compressed copy of the HUMAN code in compiled FORTRAN is included on diskette with this report. The compression routine PKZIP2 (PKWare 1992) was used to make self-extracting files. Upon execution, these compressed files uncompress into the full suite of original ASCII or FORTRAN files.

The HUMAN code used as input the media files described in Section 3.0. Compressed copies of the deterministic media files are included on the diskette as well. These files are directly related to the media files described in Section 3.0 and Appendix I-B. The files were converted to a format readable by the HUMAN code. In addition, all of the deterministic and stochastic input files for the scenarios are provided in compressed form. Note that the stochastic media files are too large to put on diskette even when compressed. They may be obtained upon request.

The contents of the diskette are:

Filename:	File description
humancod.exe	Compressed, self-extracting, executable HUMAN code
hh_dt_ex.exe	Compressed, self-extracting, deterministic, external measurements media file used by HUMAN
hh_dt_ss.exe	Compressed, self-extracting, deterministic, environmental media concentrations file used by HUMAN
det_key.exe	Eleven compressed, self-extracting, scenario input files for the HUMAN code for the deterministic calculations
sto_key.exe	Eleven compressed, self-extracting, scenario input files for the HUMAN code for the stochastic calculations

Results of the Calculations

All numerical results of the calculations described in Section 5.2 are provided in this appendix and included on a diskette provided with the report.

Human health risk estimated for each scenario at each location is shown in Figures E.1-E.9. For each scenario, there are three graphics: one depicting the estimate of risk from carcinogenic chemicals, one depicting the hazard index estimated from toxic chemicals, and one depicting the estimate of risk from radionuclides.

Figures E.1-E.9 follow the format described in Section 5.2 for Figures 5.5-5.6. As with the figures in Section 5.2, the absolute values of the risk estimates may be quite high. As described in Section 5.2, the absolute magnitude of the estimated risk is merely indicative of potential areas of concern because the estimates are based on conservative assumptions and do not apply to any real human populations at this time. However, the actual results are provided for those readers wishing to understand the nature of the screening level calculations performed for this assessment. The results of the screening assessment of human risk will be used to support cleanup decisions and to focus a subsequent and more comprehensive risk assessment.

The numerical results of the calculations are provided to the reader on diskette. The diskette contains all of the output from the input files described in the previous section. The calculations run were both deterministic (single valued input and output) and stochastic (parameters varied over their expected ranges).

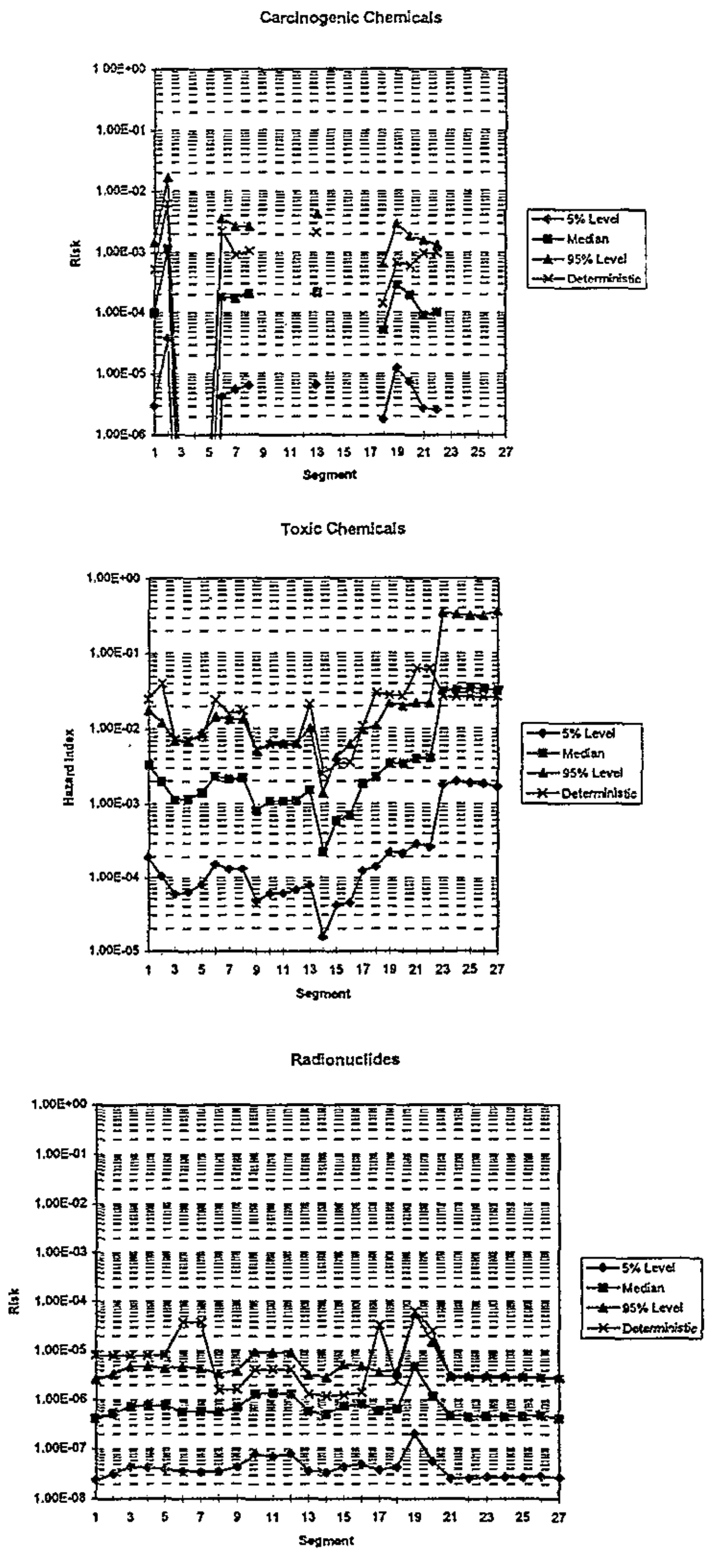


Figure E.1. Human Health Risk Estimate for the Industrial Worker Scenario

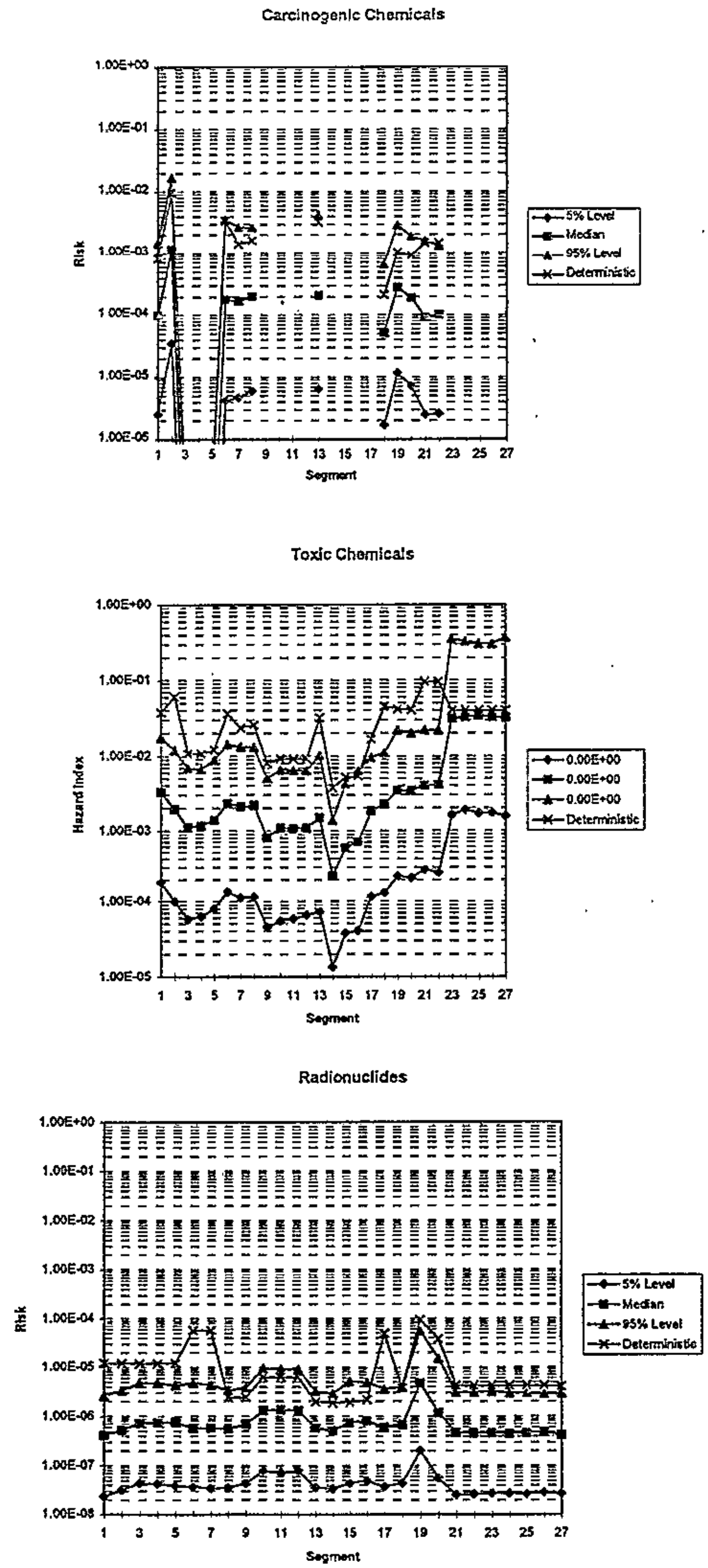


Figure E.2. Human Health Risk Estimate for the Fish Hatchery Worker Scenario

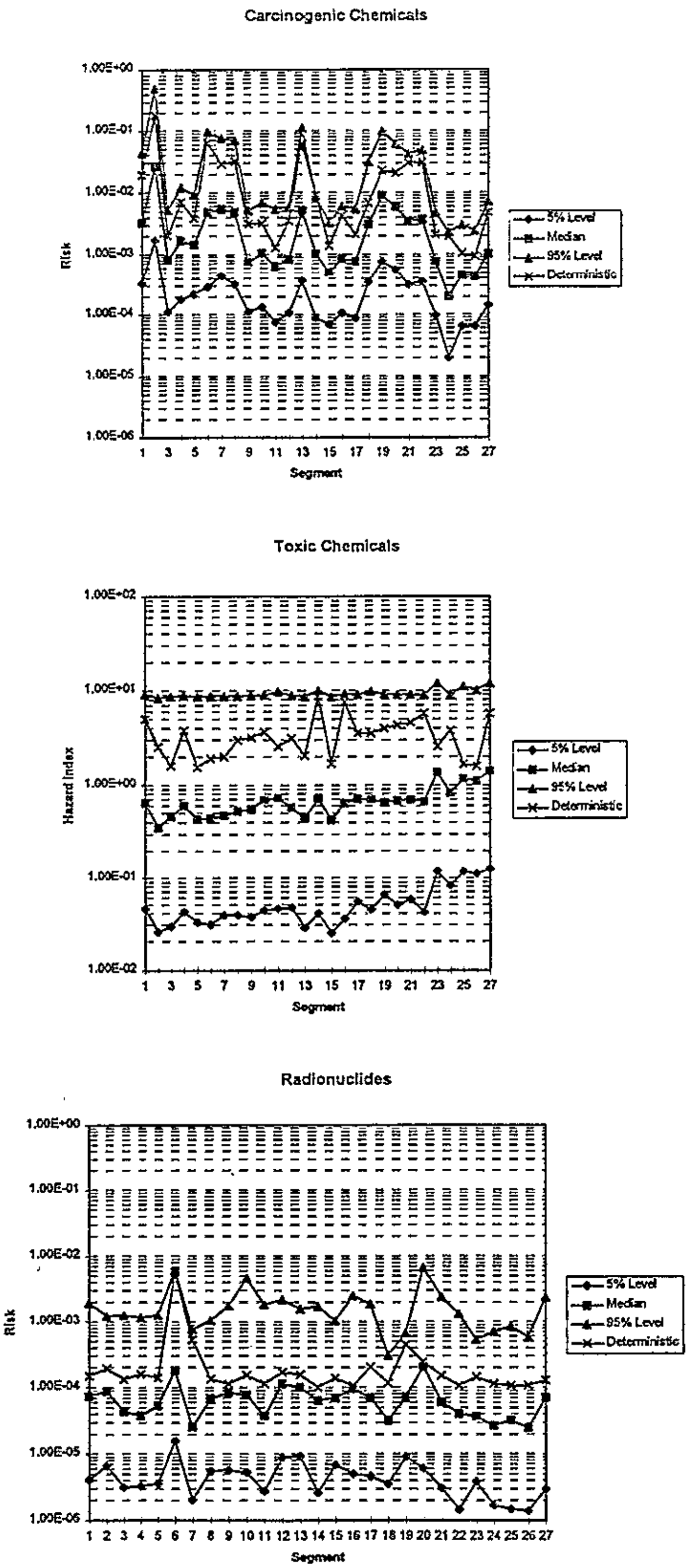


Figure E.3. Human Health Risk Estimate for the Avid Recreational Visitor Scenario

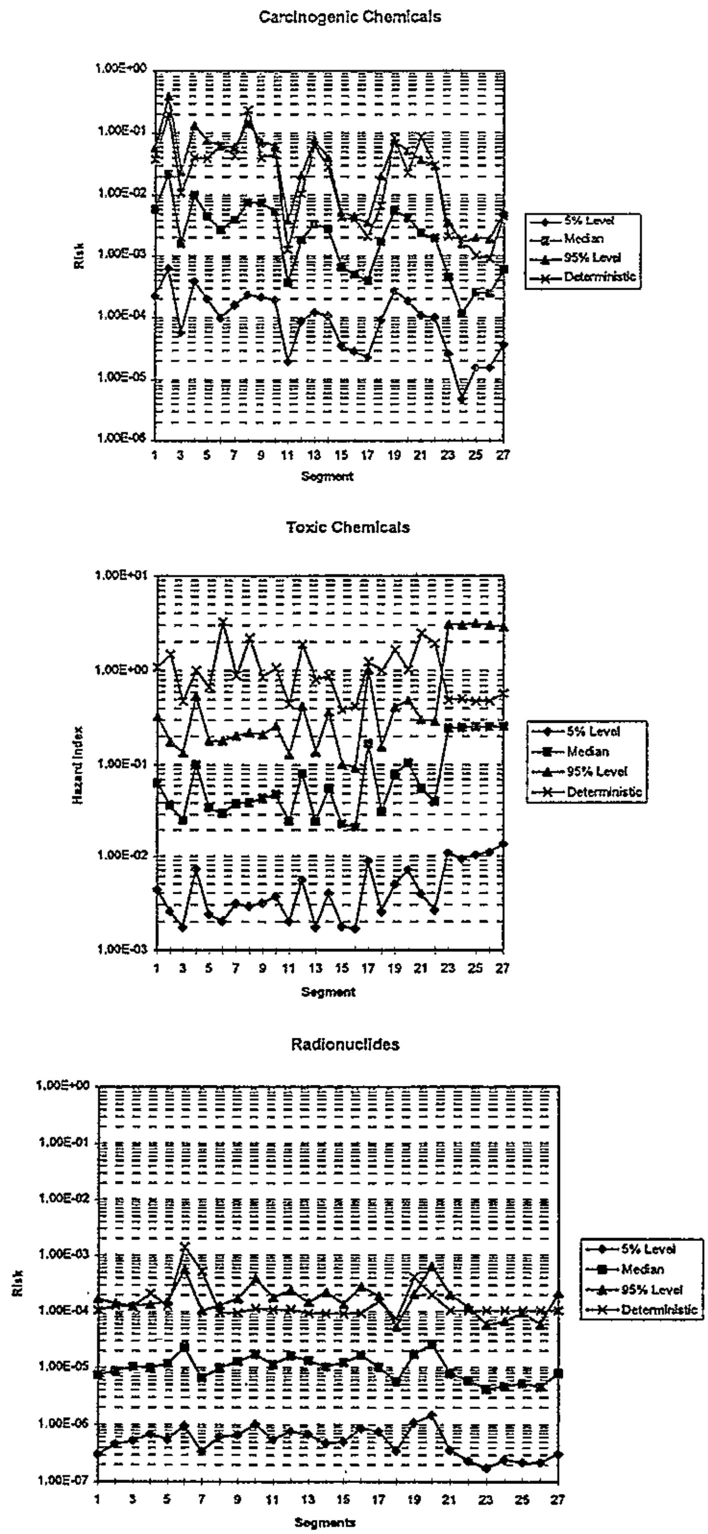


Figure E.4. Human Health Risk Estimate for the Casual Recreational Visitor Scenario

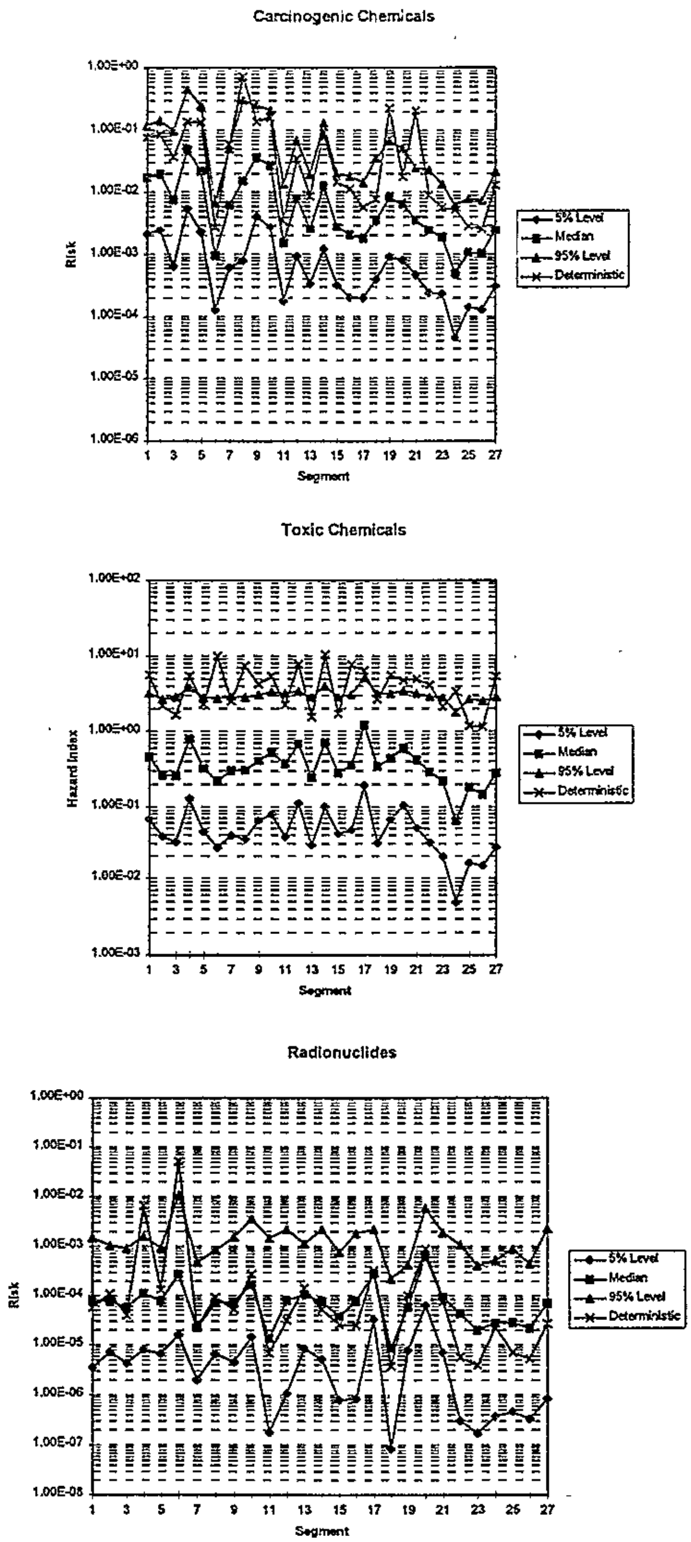


Figure E.5. Human Health Risk Estimate for the Native American Upland Hunter Scenario

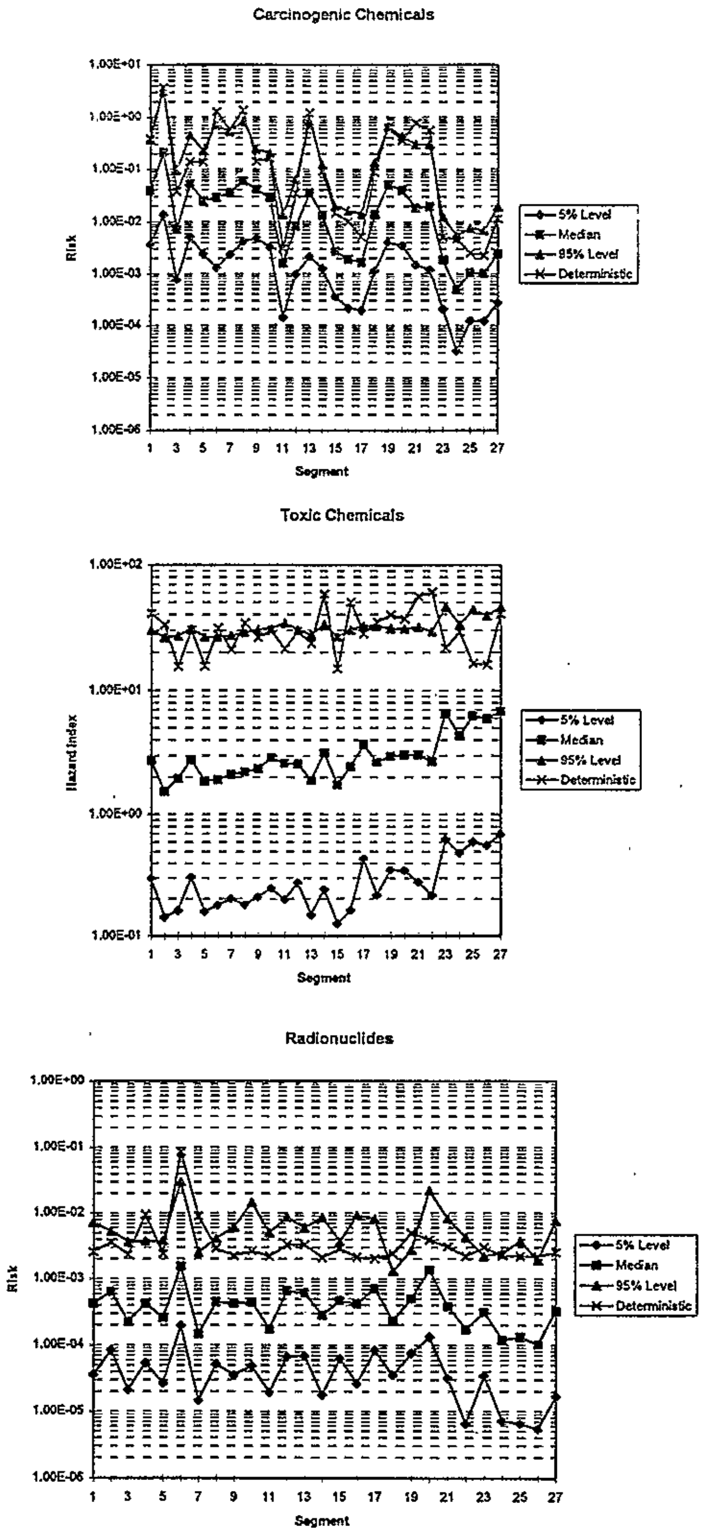


Figure E.6. Human Health Risk Estimate for the Native American River Focused Hunter and Fisher Scenario

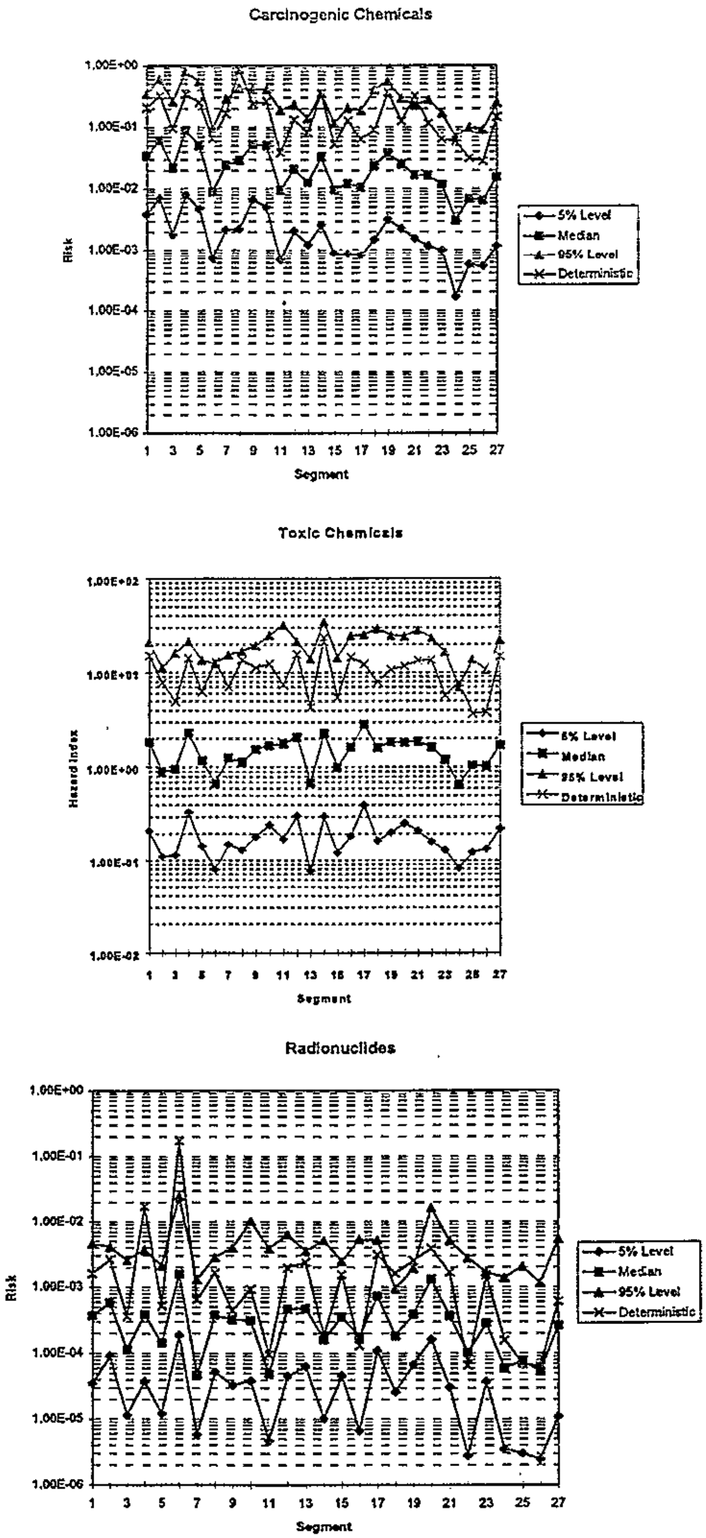


Figure E.7. Human Health Risk Estimate for the Native American Gatherer of Plant Materials Scenario

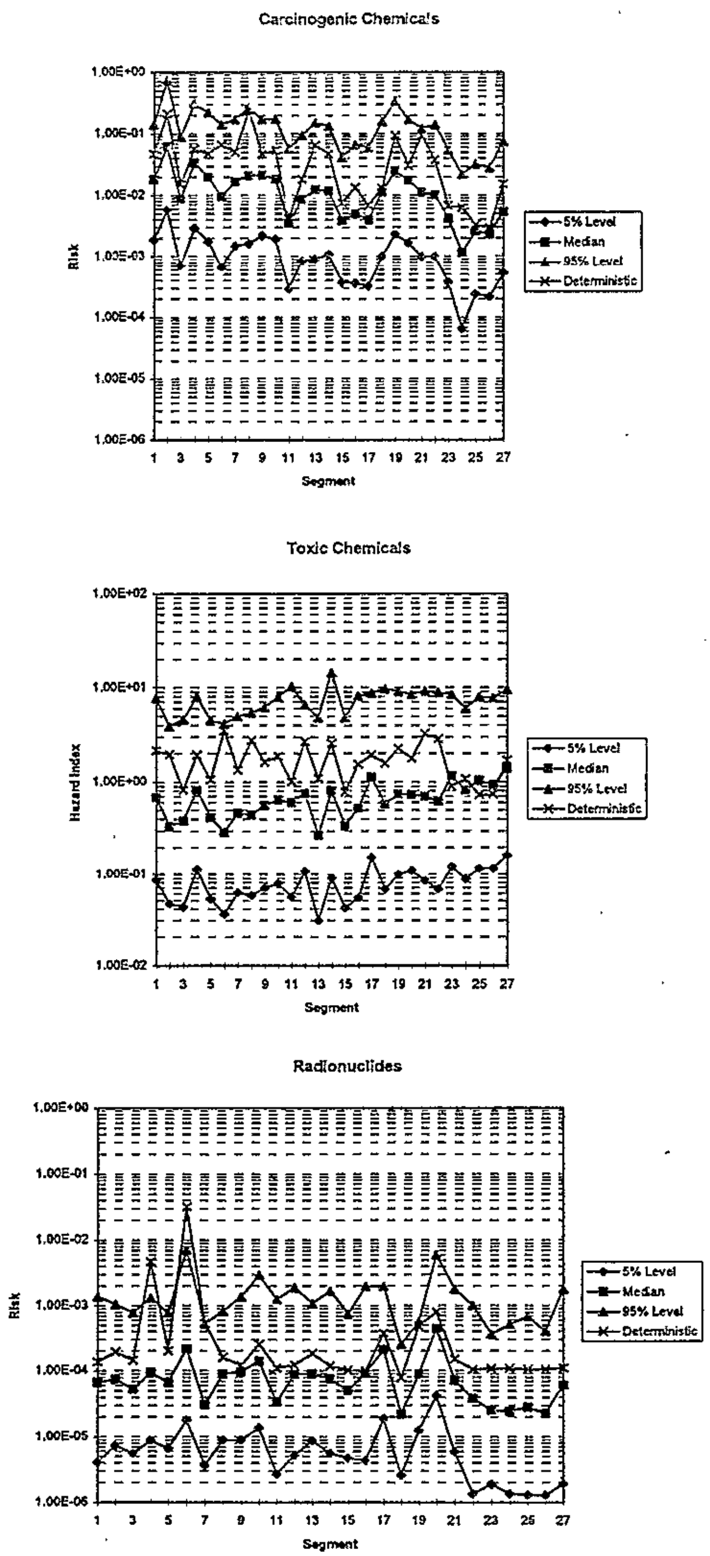


Figure E.8. Human Health Risk Estimate for the Resident Scenario

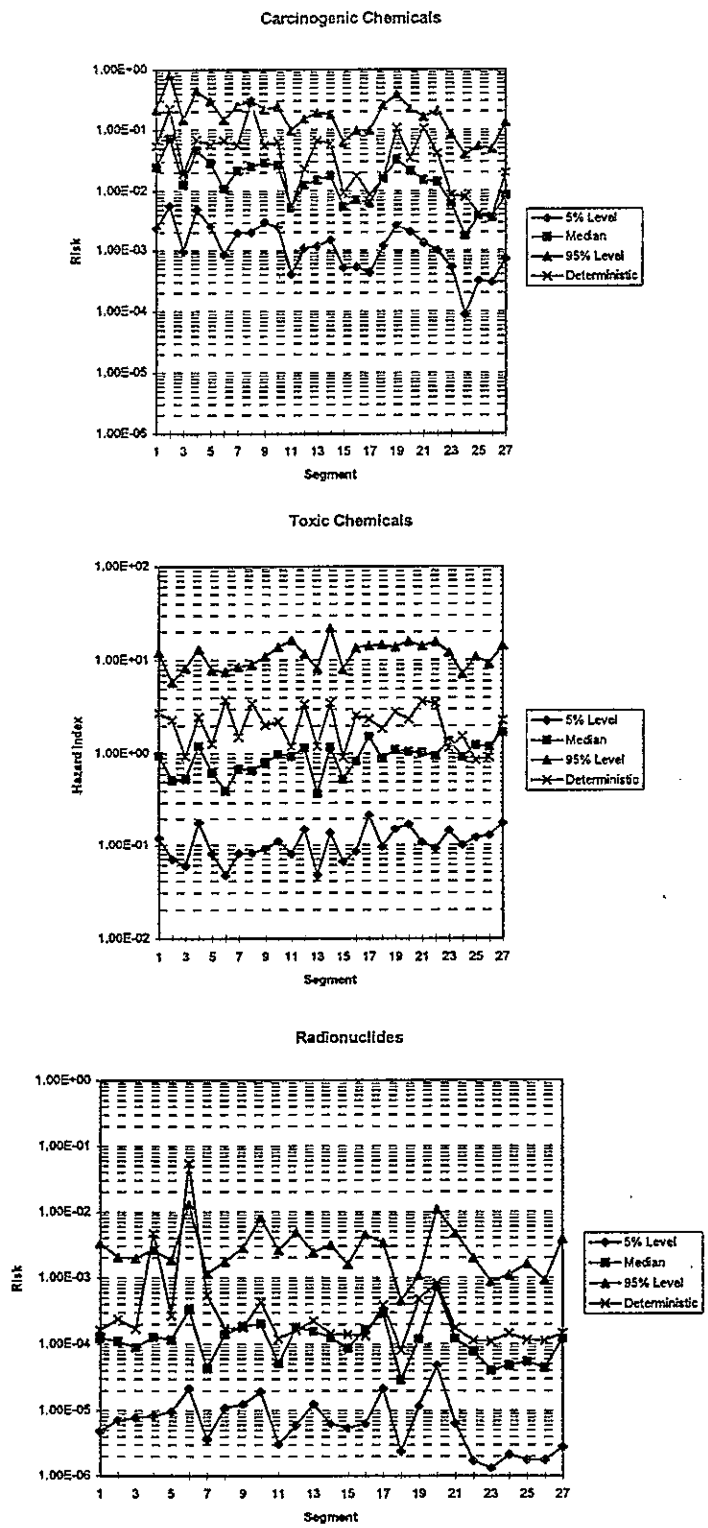


Figure E.9. Human Health Risk Estimate for the Agricultural Resident Scenario

Both sets of results are provided. The results of the deterministic calculations are provided in the self-extracting, compressed file "determ.exe." Additional details for each of these cases are provided in the self-extracting, compressed file, "det_dtl.exe." The results of the stochastic calculations are provided in self-extracting, compressed file, "stochast.exe." Additional details for each of these cases are provided in the self-extracting, compressed file, "stoc_dtl.exe." The values found in these various files were used to make the summary spreadsheet, "results.xls."

The contents of the diskette are:

Filename:	File description
determ.exe	Compressed, self-extracting file containing all of the calculational results of the HUMAN code runs for the deterministic simulations
det_dtl.exe	Compressed, self-extracting file containing secondary output from the deterministic runs, providing additional detail on the pathways and sources of exposure for each location and for each contaminant
stochast.exe	Compressed, self-extracting file containing all of the calculational results of the HUMAN code runs for the stochastic simulations
stoc_dtl.exe	Compressed, self-extracting file containing secondary output from the stochastic runs, providing additional detail on the pathways and sources of exposure for each location and for each contaminant
results.xls	Microsoft Excel 5.0 file of the numerical results as well as the graphical displays of those results (Figures E.1-E.9) by scenario

Computer Code for the Statistical Analysis of Downstream/Upstream Comparisons and the Results

As described in Section 5.2, the human risk results at Hanford-influenced locations were compared with those estimated for an upstream and, therefore, presumably minimally contaminated location (Segment 1). Graphical summaries of the results of the statistical evaluation are provided in Section 5.2.4 (Figures 5.36 and 5.37) for the Ranger and Native American Subsistence Resident scenarios, respectively. Summaries for the other scenarios (Figures E.10-E.18) are provided here.

Because the distributions hold more information than can be easily used, means of comparing the entire upstream and downstream distributions were developed. These techniques were based on detailed statistical approaches called the Mann-Whitney U Test and the Kruskal-Wallis One-Way Anova Test (Gibbons 1971).

A computer code to implement the Kruskal-Wallis and Mann-Whitney statistical tests (RISKS) was prepared. The RISKS code was developed under quality assurance controls. Documentation of the code

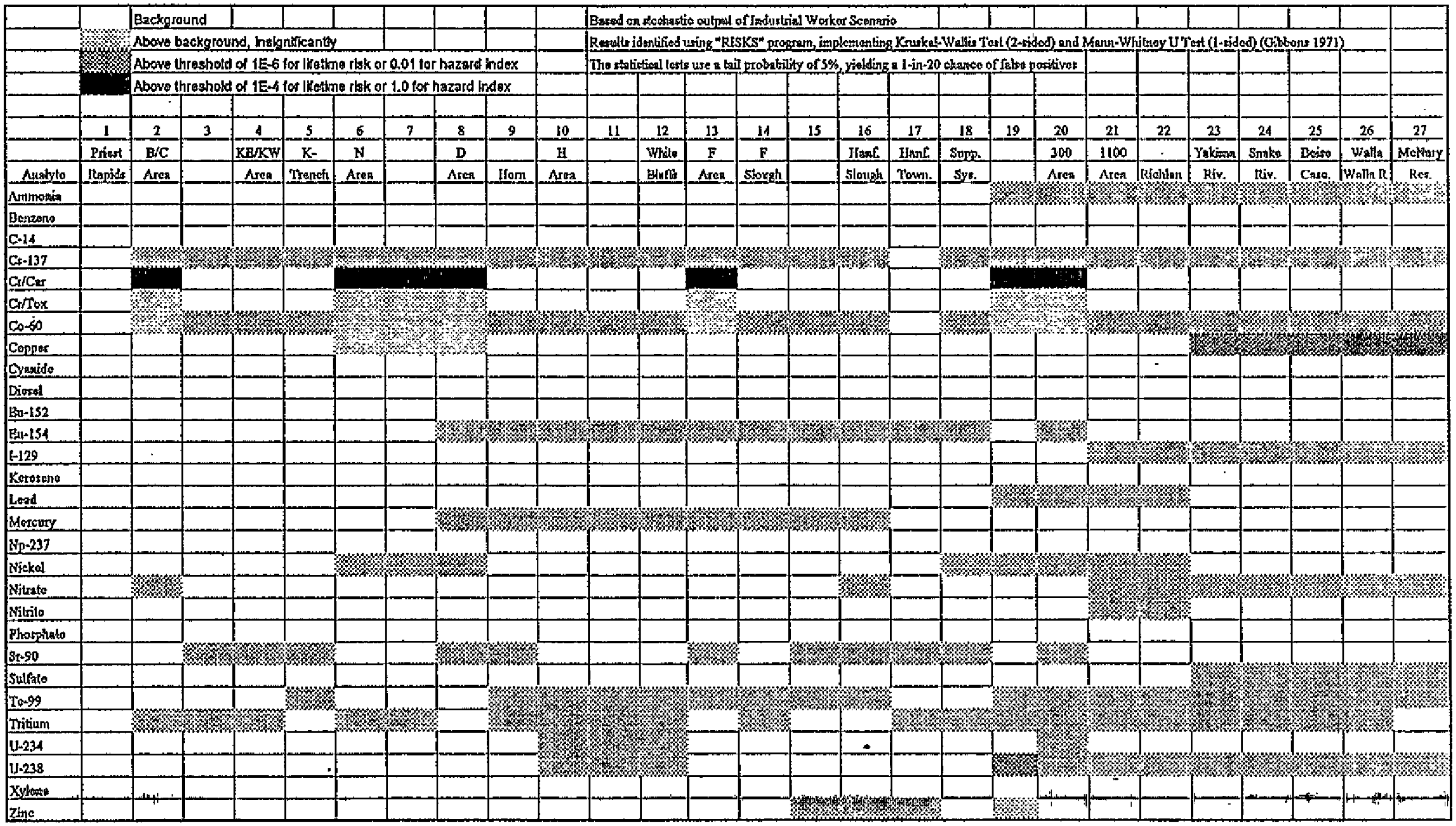


Figure E.10. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Industrial Worker Scenario

Background
Above background, insignificantly
Above threshold of 1E-6 for lifetime risk or 0.01 for hazard index
Above threshold of 1E-4 for lifetime risk or 1.0 for hazard index

Based on stochastic output of Fish Hatchery Worker Scenario
Results identified using "RISKS" program, implementing Kruskal-Wallis Test (2-sided) and Mann-Whitney U Test (1-sided) (Gibbons 1971)
The statistical tests use a tail probability of 5%, yielding a 1-in-20 chance of false positives

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Priest	B/C		KE/KW	K-	N		D		H		White	F	F		Hanf.	Hanf.	Supp.		300	1100		Yakima	Snake	Boise	Walla	McNary
Analyte	Rapids	Area		Area	Trench	Area		Area	Horn	Area		Bluffs	Area	Slough		Slough	Town.	Sys.		Area	Area	Richlan	Riv.	Riv.	Casc.	Walla R	Res.
Ammonia																											
Benzene																											
C-14																											
Cs-137																											
Cr/Car																											
Cr/Tox																											
Co-60																											
Copper																											
Cyanide																											
Diesel																											
Eu-152																											
Eu-154																											
I-129																											
Kerosene																											
Lead																											
Mercury																											
Np-237																											
Nickel																											
Nitrate																											
Nitrite																											
Phosphate																											
Sr-90																											
Sulfate																											
Tc-99																											
Tritium																											
U-234																											
U-238																											
Xylene																											
Zinc																											

Figure E.11. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Fish Hatchery Worker Scenario

Background
Above background, insignificantly
Above threshold of 1E-6 for lifetime risk or 0.01 for hazard index
Above threshold of 1E-4 for lifetime risk or 1.0 for hazard index

Based on stochastic output of Avid Recreational Visitor Scenario
Results identified using "RISKS" program, implementing Kruskal-Wallis Test (2-sided) and Mann-Whitney U Test (1-sided) (Gibbons 1971)
The statistical tests use a tail probability of 5%, yielding a 1-in-20 chance of false positives

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Priest	B/C		KE/KW	K-	N		D		H		White	F	F		Hanf.	Hanf.	Supp.		300	1100		Yakima	Snake	Boise	Walla	McNary
Analyte	Rapids	Area		Area	Trench	Area		Area	Horn	Area		Bluffs	Area	Slough		Slough	Town.	Sys.		Area	Area	Richlan	Riv.	Riv.	Casc.	Walla R	Res.
Ammonia																											
Benzene																											
C-14																											
Cs-137																											
Cr/Car																											
Cr/Tox																											
Co-60																											
Copper																											
Cyanide																											
Diesel																											
Eu-152																											
Eu-154																											
I-129																											
Kerosene																											
Lead																											
Mercury																											
Np-237																											
Nickel																											
Nitrate																											
Nitrite																											
Phosphate																											
Sr-90																											
Sulfate																											
Tc-99																											
Tritium																											
U-234																											
U-238																											
Xylene																											
Zinc																											

Figure E.12. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Avid Recreational Visitor Scenario

Background
Above background, insignificantly
Above threshold of 1E-6 for lifetime risk or 0.01 for hazard index
Above threshold of 1E-4 for lifetime risk or 1.0 for hazard index

Based on stochastic output of Casual Recreational Visitor Scenario
Results identified using "RISKS" program, implementing Kruskal-Wallis Test (2-sided) and Mann-Whitney U Test (1-sided) (Gibbons 1971)
The statistical tests use a tail probability of 5%, yielding a 1-in-20 chance of false positives

Analyte	1 Priest Rapids	2 B/C Area	3	4 KE/KW Area	5 K-Trench	6 N Area	7	8 D Area	9 Horn	10 H Area	11	12 White Bluffs	13 F Area	14 F Slough	15	16 Hanf. Slough	17 Hanf. Town.	18 Supp. Sys.	19	20 300 Area	21 1100 Area	22 Richlan	23 Yakima Riv.	24 Snake Riv.	25 Boise Casc.	26 Walla Walla R.	27 McNary Res.
Ammonia																											
Benzene																											
C-14																											
Cs-137																											
Cr/Car																											
Cr/Tox																											
Co-60																											
Copper																											
Cyanide																											
Diesel																											
Eu-152																											
Eu-154																											
I-129																											
Kerosene																											
Lead																											
Mercury																											
Np-237																											
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Phosphate																											
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Sulfate																											
Tc-99																											
Tritium																											
U-234																											
U-238																											
Xylene																											
Zinc																											

Figure E.13. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Casual Recreational Visitor Scenario

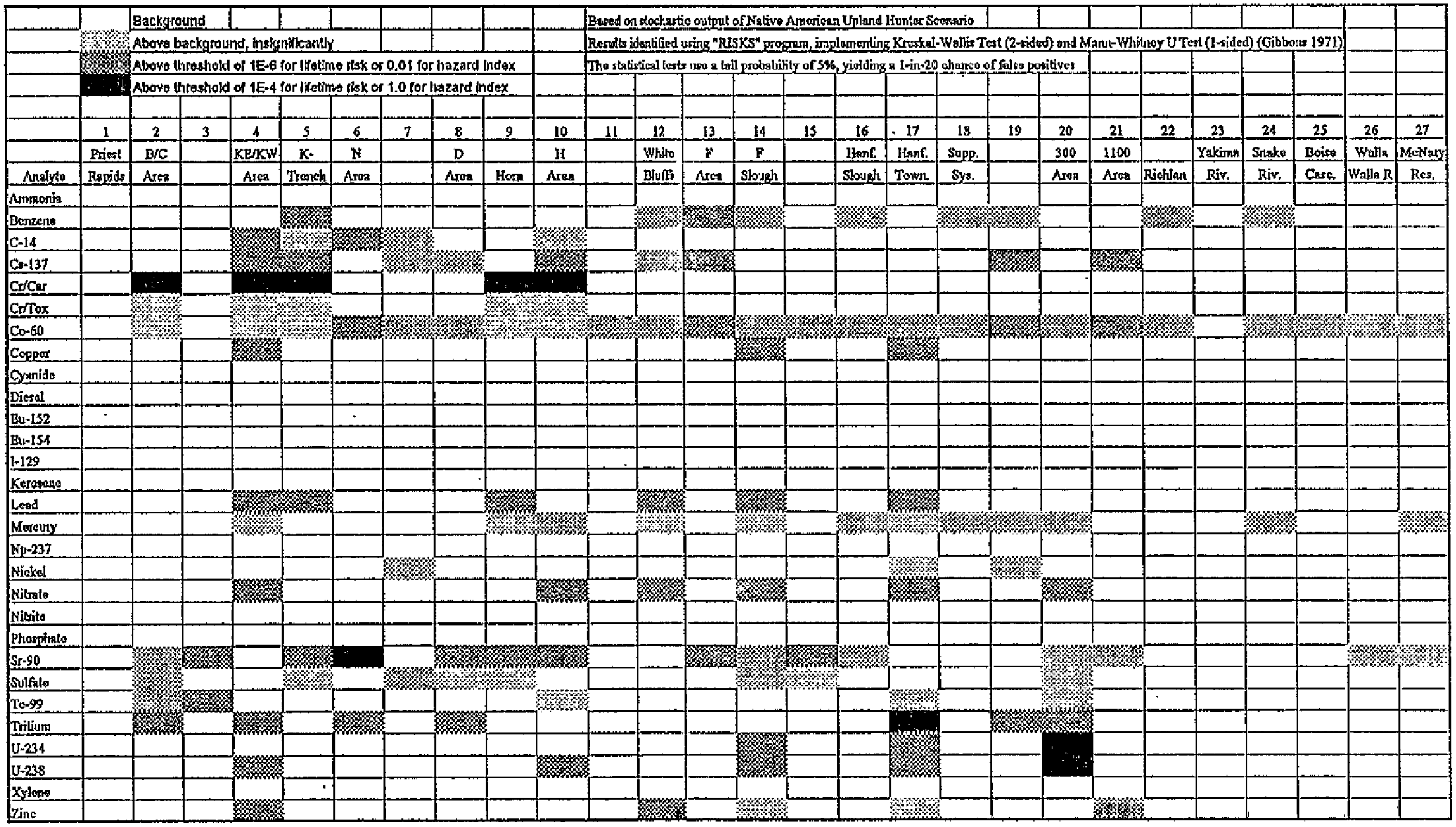


Figure E.14. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Native American Upland Hunter Scenario

Background

Above background, insignificantly

Above threshold of 1E-6 for lifetime risk or 0.01 for hazard index

Above threshold of 1E-4 for lifetime risk or 1.0 for hazard index

Based on stochastic output of Native American Hunter/Fisher Scenario

Results identified using "RISKS" program, implementing Kruskal-Wallis Test (2-sided) and Mann-Whitney U Test (1-sided) (Gibbons 1971)

The statistical tests use a tail probability of 5%, yielding a 1-in-20 chance of false positives

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Priest	B/C		KE/KW	K-	N		D		H		White	F	F		Hanf.	Hanf.	Supp.		300	1100		Yakima	Snake	Boise	Walla	McNary
Analyte	Rapids	Area		Area	Trench	Area		Area	Horn	Area		Bluffs	Area	Slough		Slough	Town.	Sys.		Area	Area	Richlan	Riv.	Riv.	Casc.	Walla R	Res.
Ammonia																											
Benzene																											
C-14																											
Cs-137																											
Cr/Car																											
Cr/Tox																											
Co-60																											
Copper																											
Cyanide																											
Diesel																											
Eu-152																											
Eu-154																											
I-129																											
Kerosene																											
Lead																											
Mercury																											
Np-237																											
Nickel																											
Nitrate																											
Nitrite																											
Phosphate																											
Sr-90																											
Sulfate																											
Tc-99																											
Tritium																											
U-234																											
U-238																											
Xylene																											
Zinc																											

Figure E.15. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Native American Hunter/Fisher Scenario

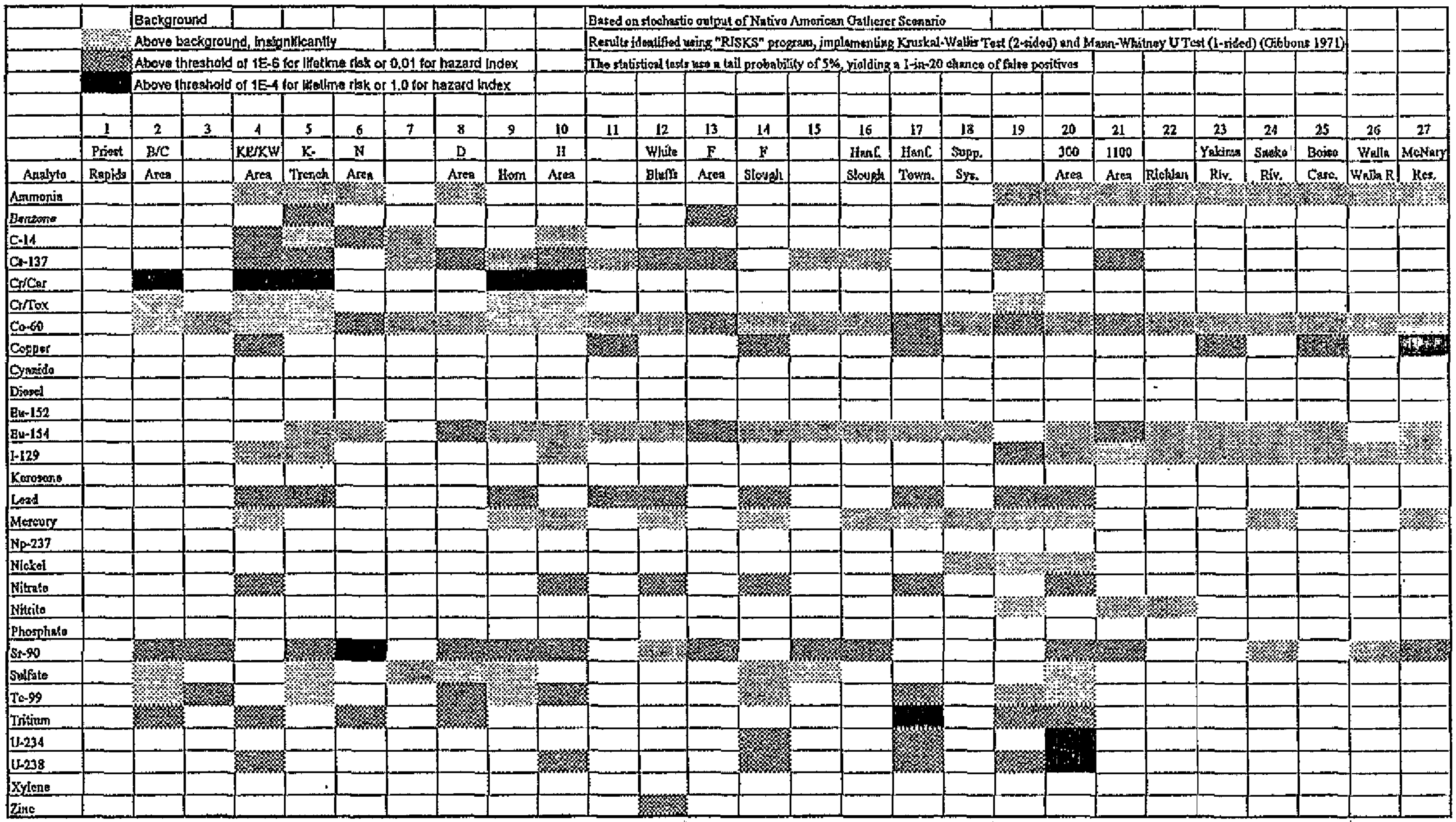


Figure E.16. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Native American Gatherer Scenario

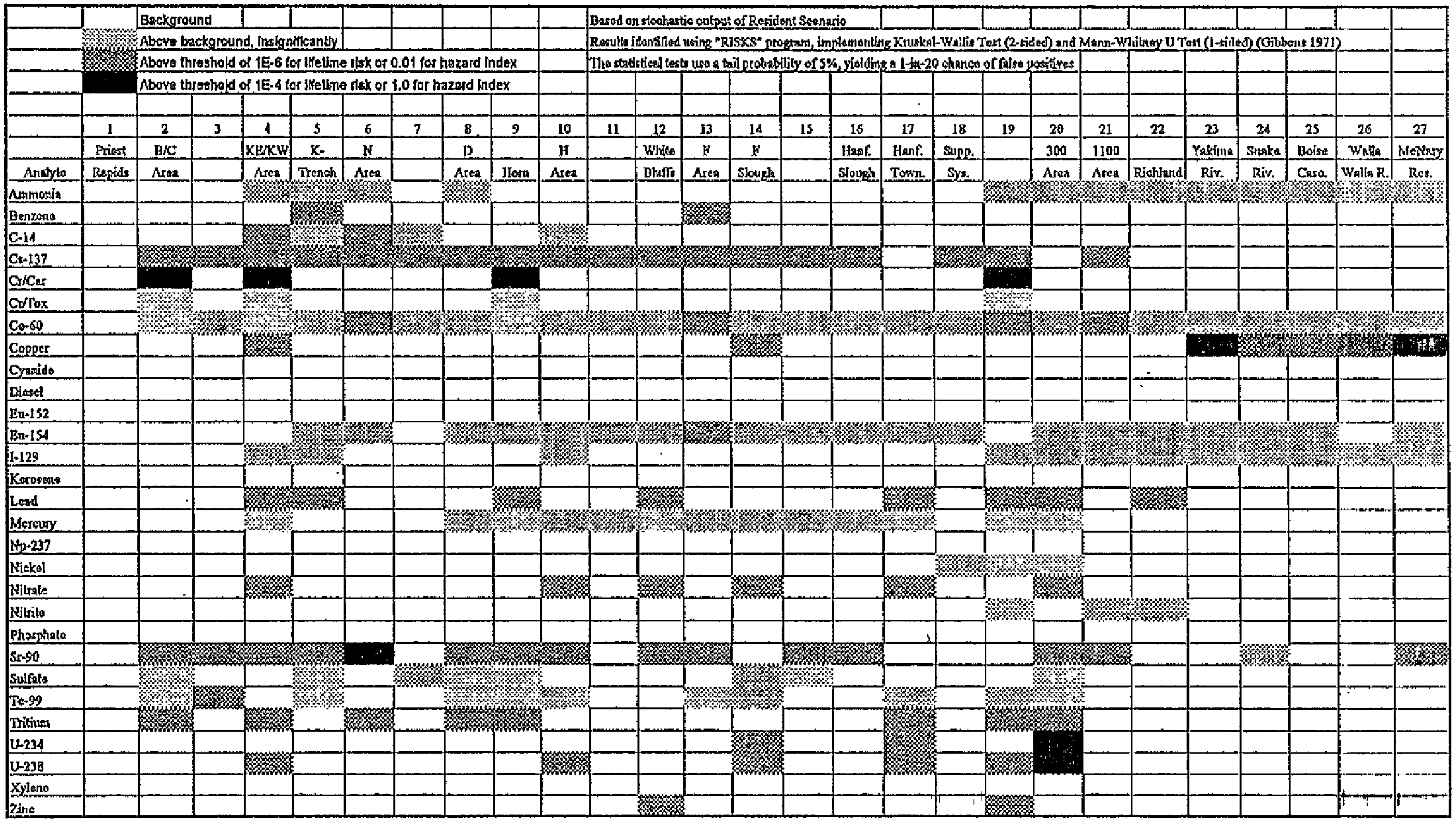


Figure E.17. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Resident Scenario

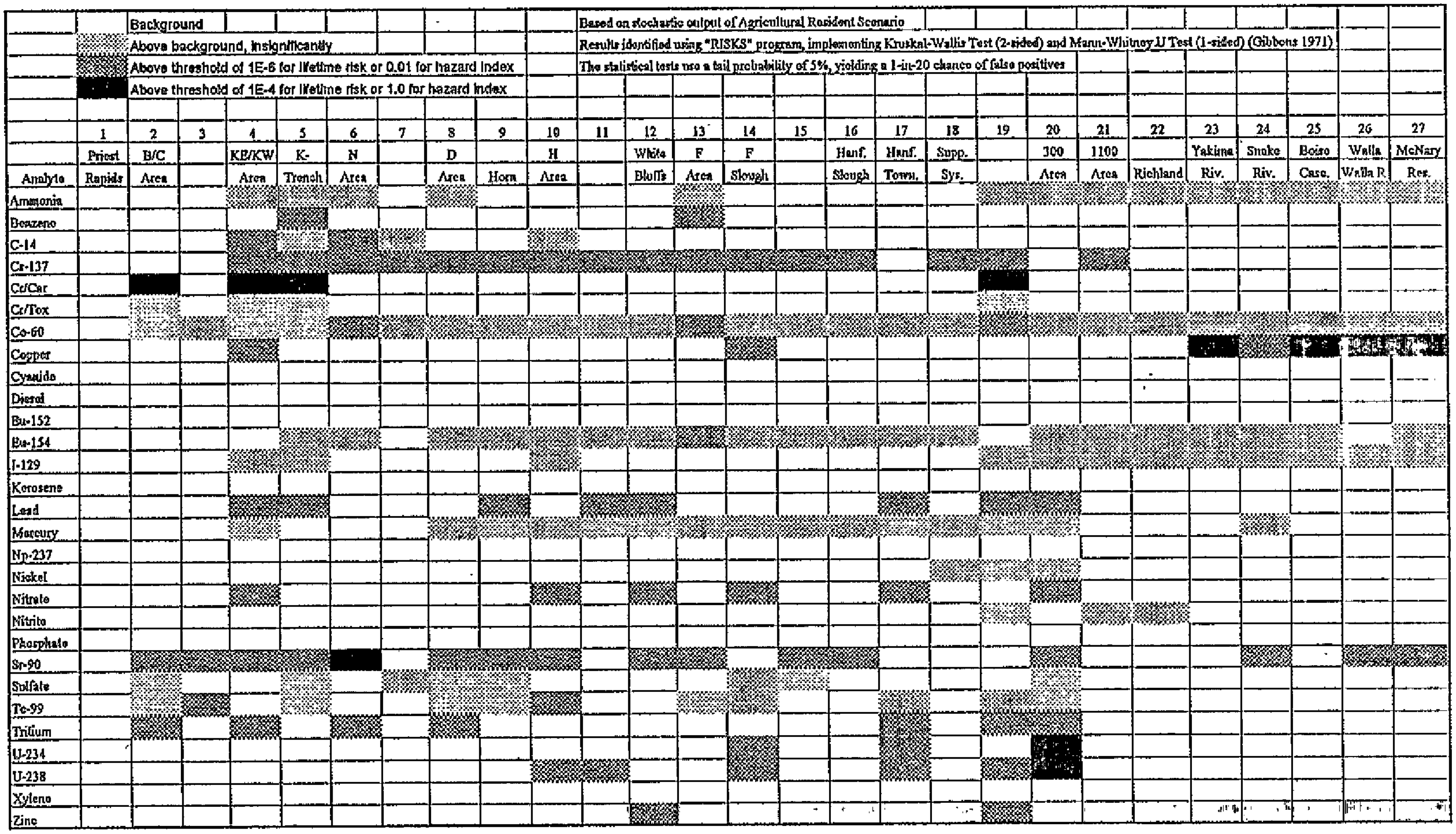


Figure E.18. Statistical Evaluation of the Differences Between a Segment Not Affected by Hanford Site Operations and Downstream Segments Affected by Hanford Site Operations for the Agricultural Resident Scenario requirements, development specifications, development testing, and user's manual are available in the project records. An executable copy of the RISKS code is available on diskette with this report.

The RISKS code used as input the output of the HUMAN code described earlier in this appendix. However, these files are so large as to make their distribution impossible. They may be reproduced using the HUMAN code and the input files provided. The input files used to make the calculations reported in Section 5.2 are provided on diskette. A summary of the results of the downstream/upstream comparisons is provided in the Microsoft Excel file (updown.xls).

The contents of the diskette are:

Filename:	File description
riskcode.exe	Compressed, self-extracting, executable RISKS code
riskkey.exe	Eleven compressed, self-extracting, input files used to control the RISKS code for each scenario
riskrpt.exe	Eleven compressed, self-extracting, output files containing the results of the downstream/upstream comparison calculations
updown.xls	EXCEL 5.0 file of the numerical results of the RISKS calculations as well as the graphical displays of those results (Figures 5.5-5.32) for each contaminant for the Ranger and Native American Subsistence Resident scenarios

Scenario Additivity

The scenarios presented in Section 5.1 and evaluated in Section 5.2 do not address all possible activities that could occur at Hanford. The scenarios were selected to provide a broad range of information, not to specify actual risk to real individuals. Generally speaking, the several residential scenarios should cover most foreseeable exposures. However, for those interested in compound lifestyles, such as might occur with a resident of the downstream City of Richland who is also an avid recreational visitor, a simplistic approximation is provided to allow additional evaluations.

The process of creating a compound scenario involves selecting the base scenario (that which forms the basic lifestyle of the individual) and adding to it a fraction or multiple of the additional scenario. The river segments applicable for each scenario need also to be defined.

For example, consider the hypothetical case of the risk from radionuclides to a near-river resident of the City of Richland (Resident Scenario, Segment 21) who occasionally visits the Wahluke Slope Wildlife Refuge Area (Segment 13) for recreational purposes. The median estimate for the lifetime risk from radionuclides to the Richland resident can be found in the radionuclides portion of Figure E.8 to be about $4.4x10^{-4}$. The median lifetime risk to a casual visitor to the Wahluke Slope recreation area in the vicinity of F-Reactor (Segment 13) is found in the radionuclides portion of Figure E.4 to be about $1x10^{-5}$. The joint risk is the sum of these two values, about $4.5x10^{-4}$. The additional activities that the individual enjoys on the Hanford Site add about 2 percent to her/his lifetime risk. The simple addition works because the time spent on site is so small in the Casual Recreational Visitor Scenario that adjustments to the residential portion of the scenario are not significant.

For a more complex example, consider the hypothetical case of the heavy metal risk (as measured using the hazard index) to a traditional Native American subsistence resident who might permanently live north of the 300 Area (Segment 19) but regularly fishes near the influx of the Yakima River at Columbia Point (Segment 22). In this case, the underlying assumption of the Native American Subsistence Resident Scenario is 365 days/year at Segment 19, and 150 days/year at Segment 22. These fractions need to be adjusted to make a reasonable total number of days per year. If we assume that the individual fishes 75 days/year, then the total risk from the Native American Subsistence Resident Scenario can be reduced by a factor of (365-75)/365, and the total risk from the Native American Hunter/Fisher Scenario can be reduced by a factor of (150-75)/150. The hazard index in Segment 19, assuming full-time occupancy, for the Native American Subsistence Resident Scenario is found in the toxic chemical portion of Figure 5.6 to be about 4.3. The hazard index in Segment 22 for 100 percent of the Hunter/Fisher scenario is found in the toxic chemical portion of Figure E.6 to be about 2.7. Thus, the overall hazard index for this combined lifestyle would be

$$(365\text{-}75)/365 * 4.3 + (150\text{-}75)/150 * 2.7 = 4.77$$

There is very little overall change in the average hazard index for the subsistence resident achieved by combining these two activities in this way. The net increase results because, while ingestion of foods from Segment 19 is assumed to be reduced, they are increased by foods caught by the individual fishing at Segment 22. Note, too, that the bulk of the overall hazard index results from Segments 19 and 22 are caused by the intake of copper and lead, which are not significantly above background. This level of detail can be found by decompressing the file, nasubs_d.dtl, from the diskette of results (compressed in the det_dtl.exe file) and viewing it with a text editor.

Other combinations of scenarios can be evaluated in a similar fashion. Those wishing more detail are advised to adapt one of the input files provided and run the HUMAN code.

Appendix I-F

Comments and Responses on the Contaminants, Data, Species, and Scenarios Draft Reports

Appendix I-F
Comments and Responses on the Contaminants, Data, Species, and Scenarios Draft Reports

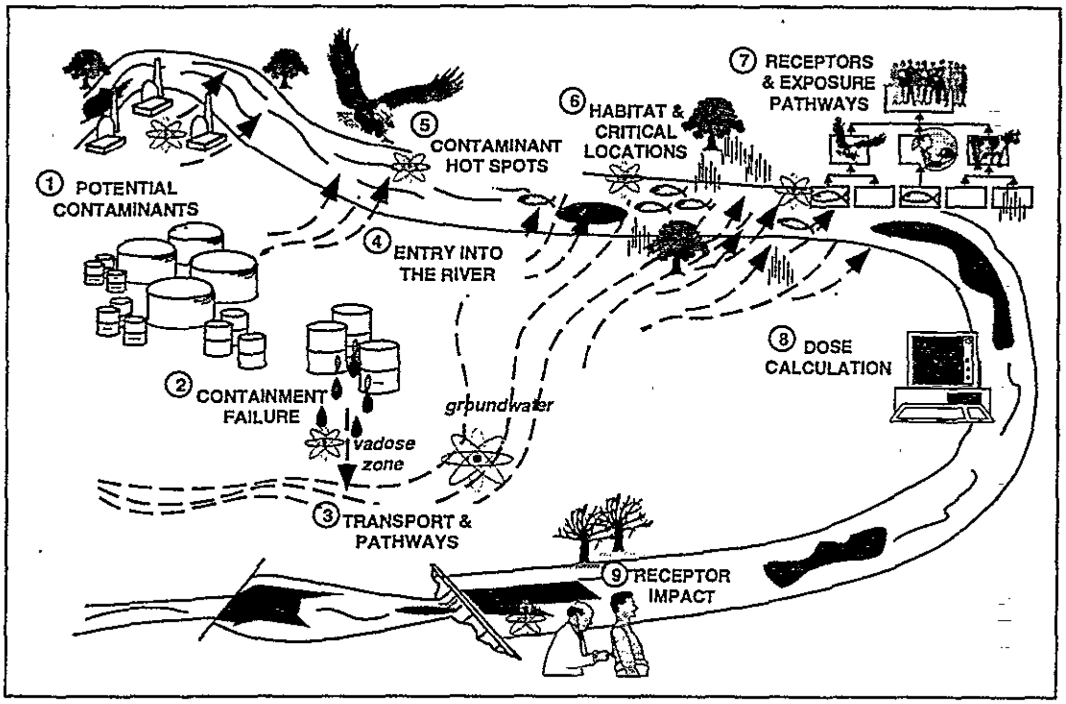
A series of reports on the selection of contaminants, data, species, and scenarios for use in the screening assessment were published as draft reports. The comments received on those draft reports were taken into consideration in the final selection of contaminants, data, species, and scenarios to be used in the screening assessment. The sections on contaminants, data, species, and scenarios in this report now reflect the changes that resulted from the comments.

For each draft report, there are two tables. Because of the need to respond to each comment and because numerous comments were the same, the responses are on a separate table from the comments. The comments table is a compilation of the comments with a notation to indicate the applicable response. The response table provides the responses with notations as to which comments are being addressed.

The comments and response tables are on a diskette (Word Perfect 5.1 for DOS) included in this report. The file names are:

con-com.wp5	=	comments on the draft contaminants report
con-resp.wp5	=	responses to the comments on the draft contaminants report
sce-com.wp5	=	comments on the draft scenarios report
sce-resp.wp5	=	responses to the comments on the draft scenarios report
spe-com.wp5	=	comments on the draft species report
spe-resp.wp5	=	responses to the comments on the draft species report
dat-com.wp5	=	comments on the draft data report
dat-resp.wp5	=	responses to the comments on the draft data report.

Part II



Requirements for the Columbia River Comprehensive Impact Assessment

Disclaimer

Publication of Part II of this document is being performed as a public service by the U. S. Department of Energy and in conformance with Milestone M-15-80 of the Hanford Federal Facility Agreement and Consent Order, referred to as the Tri-Party Agreement. Its publication does not constitute endorsement of the opinions, conclusions, or recommendations contained therein by the U. S. Department of Energy. The U. S. Department of Energy is required by Tri-Party Agreement Milestones M-15-80A, M-15-80B, and M-15-80-T01 to respond to and develop recommendations concerning Part II. More information regarding Tri-Party Agreement requirements and U. S. Department of Energy required responses can be found in the text.

Summary

As the screening assessment documented in Part I was being conducted, the assessment specified in Part II was developed by the Columbia River Comprehensive Impact Assessment Team (CRCIA Team). Active participants on the CRCIA Team have been representatives from the Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, Yakama Indian Nation, Hanford Advisory Board, Oregon State Department of Energy, Tri-Party agencies, and Hanford contractors. The CRCIA Team developed Part II to explicitly require any future assessment of Hanford impact on the Columbia River to embody, at a minimum, the methods, characteristics, and controls described in Part II. Those analyses involving the Columbia River which adhere to the spirit and substance of these requirements are far more likely to be acceptable to the governments and institutions which authored this section and far more meaningful in guiding cleanup decisions.

This is the only composite assessment of how effective the cleanup of the Hanford Site will be as expressed in terms of impact to the Columbia River. Other analyses address only some of the elements of the needed assessment. This is a composite assessment because, in part, all potentially harmful radioactive and chemical materials within the Hanford Site boundary (those planned by the U.S. Department of Energy, DOE, to exist at the completion of cleanup) are included in a single evaluation of impact resulting from potential exposure. The purpose of the Columbia River Comprehensive Impact Assessment (CRCIA) is to assess the effects of Hanford-derived materials and contaminants on the Columbia River environment, river dependent life, and users of river resources for as long as these contaminants remain intrinsically hazardous. This purpose is envisioned to be carried out by developing a suite of integrated analysis tools, which would be used for each revision of DOE's intended waste disposal plans defining the Hanford Site's final end state. As such, CRCIA becomes a major, critical part of the Hanford Site's final baseline risk assessment. CRCIA is also seen as a tool with which effectiveness can be estimated for each of the alternatives considered in strategic planning exercises, environmental impact statements, and the various projects' studies. This assessment was defined and this part of the document was prepared by the CRCIA Team (not DOE or its contractors) under a new public involvement paradigm described later in this summary, in Section 4.0 below, and in Appendix II-D.

In facing the question of what constitutes a comprehensive assessment, a serious problem soon became apparent: How can the assessment include all of the factors significant to potential river impact while keeping the effort to a manageable size which can be funded? Using expert judgment to "assume the assessment down-to-size" was rejected as an acceptable solution to this problem. Instead, a principle (specified as a

> **HOW TO USE THIS DOCUMENT**
>
> **Part II of this document consists of this narrative section and specification sections, Appendixes II-A, II-B, II-C, and II-D. The specification sections enumerate the technical and management requirements for conducting the assessment. The appendixes are for the analysts who will perform the technical work. This narrative section supplements the specification sections with general guidance and non-technical explanations of the requirements. As may be seen in this section's table of contents, organization of the narrative and the appendixes are parallel aside from the introductory topics in the narrative section. While each section is complete in its own right, the reader may find it useful to study the narrative and appendixes in parallel, turning from one to the other as interest dictates.**

requirement in Part II) was borrowed from other industries which routinely deal with large, complex problems yet have only limited resources. This principle requires the study's planning process be based upon sensitivity analyses and parametric analyses which sort the dominating factors from the smaller contributors to impact. Consequently, for any given level of resources allocated to this assessment, the biggest contributors to potential river impact will always be addressed. The challenge for analyst and manager alike is not to arbitrarily discard parts of the assessment to cut it down to size but rather to ensure that no factor is left out which would dominate the study results. Care has been taken in developing Part II to be fiscally responsible in defining the requirements for the technical work that must be conducted regardless of speculations on probable funding availability or limits presumed to exist in analytical methods, data collection techniques, or related technologies. Every effort has been made to ensure that the assessment will always focus on major contributors in such a way as to avoid obfuscation by the enormous number of smaller considerations.

Since the screening assessment in Part I of this document was scoped to be a less-than-comprehensive, limited-resource effort focused on identifying the most significant existing effects on the Columbia River, the comprehensive assessment in Part II subsumes the screening assessment in identifying both existing and future effects from the composite of all Hanford activities. In spite of the care in developing this document, it is recognized that it can and should be improved upon, especially in view of inevitable changes in waste disposal plans and experience gained in conducting this and similar assessments. It is intended that this be a living document with changes controlled by the authoring institutions.

Part II defines a new paradigm for predecisional participation by those affected by Hanford cleanup decisions. The CRCIA Team developed the requirements in Part II as well as the approach and structure for conducting and managing future assessment work. Appendix II-D describes this new paradigm and the associated management requirements. It is recognized that some time may be needed to make the adaptations in existing Hanford practices this new paradigm calls for. An implementation period is anticipated during which special attention will be given to working within existing policies and procedures while adaptations are being made.

Following the Introduction and the discussion of Principles and General Requirements, Part II is divided into four key sections: *WHAT* is to be analyzed, *HOW WELL* must the results represent actual and future impact to the Columbia River, technically *HOW* is the assessment to be performed, and what is the *MANAGEMENT* structure for the analysis work. Explanations and descriptions of these four areas are found below. Lists of the technical requirements parallel this structure in Appendixes II-A, II-B, II-C, and II-D. The parallel sections/appendixes are:

- Section 1.0/Appendix II-A, <u>What the Assessment Must Include</u>. These sections specify *WHAT* factors must be included in assessing river impact. They include the extent of Hanford Site activities and materials to be addressed, transport mechanisms and travel times, and contaminant introduction into the river. The requirements also address the distribution of the contaminants within the Columbia River as well as identification of habitat or other water uptake locations. The requirements specify potential species, ecosystems, human populations, and cultures that could be affected by

Hanford-derived contaminants in the Columbia River. This section also includes probable scenarios for the time frame of interest in which substantive change occurs to the river or ecosystem and cultural dependency on the river.

- Section 2.0/Appendix II-B, How Good the Impact Assessment Results Must Be. Requirements in these sections prescribe how complete the assessment results must be and *HOW GOOD* the analysis must be to produce the needed results.

- Section 3.0/Appendix II-C, Analytical Approach and Methods. Given the factors specified in the first two sections (1.0 and 2.0), these sections stipulate *HOW* the technical analyses are to be planned to ensure no dominant contributor is overlooked. Analytical methods, modeling requirements, data quality, uncertainty, and verification requirements are among the specifications included. While these requirements avoid specifying what tasks must be done or in what sequence work is to be performed, it is clear that this section must heavily influence how the assessment work is to be defined and the preparatory work which must precede the start of the analysis.

- Section 4.0/Appendix II-D, Conducting and Managing the Assessment. *MANAGEMENT* requirements are addressed in these sections to include methods to determine funding prioritization, sequence of technical work, the roles of peer reviewers, integration with Hanford Site strategic planning and other analyses, and support of environmental impact statement preparations. These sections also address the continuing involvement and authority of affected people and groups.

Contents

Figures

Introduction

The Columbia River system is the center of the regional ecosystem and has supported indigenous cultures for over 10,000 years. The river is a dynamic, living entity consisting of many linked aquatic and terrestrial habitats with many overlapping spatial and temporal scales. The part of the Columbia River which flows through the Hanford Site is known as the Hanford Reach and constitutes the last free flowing, non-tidal segment of river in the United States. The Hanford Reach section of the Columbia River, and a small distance downstream, has been designated by the Washington State Department of Ecology (Ecology) as a Class A (excellent) surface water body. This designation requires all industrial surface water uses to be compatible with other uses, including drinking water, wildlife, and recreation.

The Hanford Reach is also known for its exceptionally high biodiversity of plants and animals. It features several habitats which are rare or are in decline along the Columbia River. These features include riparian habitats, White Bluffs, upland shrub-steppe communities, and wetlands. After flowing nearly 80 kilometers (50 miles) through the Hanford Site, the Columbia River continues for another 500 kilometers (300 miles) past Washington and Oregon communities to the Pacific coast, flowing through Oregon's most heavily populated urban area and important agricultural, commercial, and recreational areas. Nearly one million Oregonians, somewhat fewer Washingtonians and several Native American tribes live directly downriver from the Hanford Site. They rely on the Columbia River for commerce, fisheries, irrigation, recreation, and transportation.

Authority

The authority underpinning these requirements for a comprehensive assessment of Hanford impact on the Columbia River is DOE's need for acceptance of cleanup decisions and this assessment's results by the affected people. DOE is providing only publications services for Part II of this document. It is not issued as an expression of DOE's endorsement. Like DOE, the other Tri-Party agencies, Ecology and the U.S. Environmental Protection Agency (EPA), are members of the CRCIA Team which originated these requirements. However, these requirements have been promulgated by the CRCIA Team, not by the Tri-Party agencies, even though preparation of these requirements is the subject of Tri-Party Agreement (TPA) commitments (milestone M-15-80).

Background

The CRCIA Team first met in August 1995 for the purpose of forming with DOE a steering force to define the requirements for a fully comprehensive assessment of the Hanford Site's effect on river-dependent life. Additionally, the CRCIA Team has acted as an advisory body for the screening assessment, which the Tri-Party agencies initiated in 1993 as the original comprehensive assessment of river impact. This effort was recognized in the TPA in January 1994 by including milestones for the comprehensive assessment, now the screening assessment. Dates for these milestones have since been modified, in part because the scope and priorities of CRCIA have been controversial with respect to what constitutes a comprehensive assessment. This contention has essentially disappeared, primarily because of the effectiveness of the CRCIA Team as a new predecisional paradigm in allowing the guidance of the screening assessment to rest in the hands of technical representatives of key socio-economic groups affected by Hanford's cleanup decisions. Development of these requirements has been the key condition in settling the controversy over comprehensiveness.

Those represented by the CRCIA Team are the Confederated Tribes of the Umatilla Reservation, Nez Perce Tribe, Yakama Indian Nation, Hanford Advisory Board, Oregon Department of Energy, DOE and their Hanford contractors, Ecology, and EPA.

How These Requirements Were Developed

Working to define a common ground on which the Tri-Party agencies and all participants could comfortably stand, the CRCIA Team developed the requirements through weekly facilitated workshops. Most participants had suggestions, criticisms, issues and concerns about previous, similar analyses. These were elicited from the participants in a systematic structure which, with some reorganization, became the framework for Part II of this document. The CRCIA Team had neither the expertise to design an analysis of this significance nor was it appropriate to preempt the performing contractor from designing the most effective approach. Therefore, the participants' issues and concerns were translated into the requirements to be met in designing and performing the analysis. DOE opted only for the role of a participant in these workshops rather than to develop the document directly or through their contractors. The CRCIA Team provided its own facilitator and clerical support from among its members. DOE provided publication services. Thus, CRCIA Team defined requirements are provided in this document. These requirements are not a DOE negotiated position, even though DOE and their contractors were active contributors to the effort. The CRCIA Team strove for completeness. Judgments on relative importance of the issues and requirements were not allowed pending formal work to define which considerations dominate the assessment and which contribute little.

WHAT IS DOE's COMMITMENT
TO CRCIA AND THESE REQUIREMENTS?

DOE is pursuing follow-on work based on the "Requirements for a Comprehensive Assessment." As part of completing TPA Milestones M-15-80A, M-15-80B, and M-15-80B-T01, DOE is working with the CRCIA Team to identify specific work tasks which 1) are necessary for a comprehensive assessment, 2) are prioritized and address the most dominant risk factors first, and 3) can be performed within budget guidelines dictated. Agreed to tasks will be included in the multi-year work plan packages for FY 1998 and beyond.

Problem Statement

The previous assessments of Hanford impact on the Columbia River were performed to provide information for specific projects and were not comprehensive. Here is a partial list of examples of why previous assessments were not comprehensive:

- Previous assessments have not addressed the Hanford Site in its post-cleanup end state as a single, composite source of potential contamination. This is partly because the source term data used was drawn from lists of known inventories of materials and wastes in their existing states. The planned end states of the wastes has not been reflected in the data used.

- A composite source term has not been used which combines the effects of all chemical and nuclear materials and wastes within the geographical boundaries of the Hanford Site.

- Predictive cumulative effects of Hanford's multiple contaminant sources have not been addressed.

- The time frame considered for potential effects to occur has been inconsistent with (1) the point at which planned waste containment devices can be expected to be breached allowing contaminant migration to the Columbia River and (2) the period during which potential contaminants remain intrinsically dangerous.

- River-borne contaminant impact on human health has not considered the full suite of potential health effects or all human exposure scenarios. For example, previous assessments have only considered incremental cancer risk and hazard quotients.

- The cultural impact on potentially affected people has not been evaluated.

- Ecological effects have not been adequately considered.

- Existing environmental regulations are, as the only guidance, inadequate because they are generally not site specific and because they do not adequately consider protection of the affected peoples. Only a site-specific assessment of risk can meet these needs.

If the assessment prescribed in Part II is performed so as to eliminate prior inadequacies, it should satisfy the need for a final Hanford Site risk assessment in so far as potential impact to the Columbia River is concerned.

Purpose of the Assessment

The purpose of CRCIA is to assess the effects of Hanford-derived materials and contaminants on the Columbia River environment, river-dependent life, and users of river resources.

For CRCIA to be comprehensive, representatives of the major community groups (CRCIA Team members who are other than the Tri-Party agencies) on the CRCIA Team have agreed that the following objectives must be achieved if the results and conclusions are to be acceptable by all concerned:

- Estimate, with useful certainty, river-related human health and ecological risks for the time period that the Hanford materials and contaminants remain intrinsically hazardous

- Evaluate the sustainability of the river ecosystem, the interrelated cultural quality-of-life, and the viability of socio-economic entities for the time period that Hanford materials and contaminants remain intrinsically hazardous

- Provide results that are useful for decision making on Hanford waste management, environmental restoration, and remediation

Relationship to the Screening Assessment

The requirements specified in Part II strive to be comprehensive for any assessment of Hanford impact on the Columbia River. Since the screening assessment in Part I was conceived and evolved from a Tri-Party-Agreement commitment to determine only the current state of the Columbia River as a basis for decisions on interim remedial actions, the screening assessment must be regarded as only an initial subset of any comprehensive assessment. The screening assessment was conducted simultaneously with the development of these requirements. While every effort was made to revise the screening assessment as individual requirements stabilized in the comprehensive definition, time and funding constraints made it impractical to achieve complete accord. To the extent that the screening assessment meets the comprehensive requirements, its data and results will be used to avoid unnecessary duplication of effort.

Uses and Users

WHAT IS A REQUIREMENT?

Use of the term "requirement" as used throughout Part II of this document is meant as a minimal constraint on the choices to be made in defining, planning, and conducting this assessment.

The requirements herein are prescribed in the following three forms:

1. **Guiding principles and general requirements common to all aspects of the assessment. These requirements are found primarily in the narrative section.**
2. **Conceptual descriptions of requirements with actual or hypothetical examples. These statements are typically found as a statement of purpose at the beginning of each requirements section in the appendixes. Explanations are usually included in the narrative section as well. It is intended that the analysts add specific instances as applications become apparent in the course of the assessment. Direction may be included for the analysts to identify the remaining instances of these requirements.**
3. **Explicitly stated requirements make up the preponderance of the appendixes.**

When conducted in accordance with the requirements in Part II, the results from a comprehensive assessment of the Columbia River will provide a sound basis for essentially two types of decision-making. The first is the group of decisions which, taken together, define how well the Hanford Site is cleaned up and how permanent the selected containment methods are expected to be. To provide a reliable basis for this class of decisions, the requirements must realistically specify how to calculate the effects on the species of interest. In turn, scenarios must be applicable for both individuals and socio-economic groups postulated to be affected. The users of the assessment results in this decision-making group include DOE, Ecology, EPA, other technical, management, and public groups directly involved in the Hanford cleanup and disposal decision-making process.

The second group of decisions includes those made in response to Hanford conditions by the people and groups affected by the cleanup decisions. The assessment results are intended to objectively reflect the effect of Hanford's potential contamination assuming the approved cleanup and waste containment plan is accurately defined, effectively implemented, kept current with technical and funding decisions, and CRCIA is updated as cleanup decisions change. This group of users is extensive. It includes the communities and individuals who depend on the Columbia River for drinking water, agriculture and irrigation, sustenance/sport/commercial fishing, transportation or its support activities such as dredging, hydroelectric power generation, and recreation.

The CRCIA Board, as defined in Appendix II-D, must seek advice and recommendations from these groups in planning and directing the assessment. Periodic reports of findings will be made available to these groups. Special attention will be given to the timing of cleanup and disposal decisions making results available which are relevant to those decisions.

Avoiding Duplication of Other Work

Some elements of the assessment prescribed may have been performed, or are being performed, in other studies. Such efforts will be sought out and used in lieu of redoing the work if the studies were performed in an acceptable manner as defined in Part II. The CRCIA Team became aware of some efforts underway at the time of this writing which appear to be similar to CRCIA. Upon inquiry, however, each effort was found to be fundamentally lacking in one or more facets, much as discussed in the Problem Statement section above. Efforts will be undertaken with those performing those studies to try to find an accommodation of CRCIA needs. Several smaller studies involving the Columbia River also are underway or planned which are of more limited scope and focus on a specific problem. They are, by design, less than comprehensive. To the degree that these and similar limited scope studies in the future meet CRCIA requirements, their findings and conclusions can be used in CRCIA assessments.

CRCIA efforts also will be integrated with other Hanford Site activities. Examples of special interest are strategic planning documents and products such as environmental impact statements and budget planning documents. CRCIA is a tool with which effectiveness can be estimated for each alternative considered in strategic planning exercises and project studies.

About the Appendixes

The requirements in the appendixes were developed from the issues and concerns held by the constituencies of the CRCIA Team members. As such, the appendixes are not complete from the standpoint of comprising the total guidance needed for the assessment. The CRCIA Team members are generally conversant with technical work but had little or no direct experience in designing an analytical effort like CRCIA. It is, therefore, left to the analysts to not only design and conduct the assessment to meet the requirements in Part II but to also grasp the spirit and intent of each subject area and flesh out the requirements as needed to be consistent with the CRCIA Team's intent as well as adhering to good technical practice.

Four appendixes have been structured to organize these issues and concerns into technical and management requirements. Generally, a hierarchical pattern has been followed in which the requirements at any given level comprise a subset of a higher level parent requirement for that subject area. Figure 1 provides an example of this hierarchical organization. The reader will notice many of the requirement statements to be conceptual in nature while others are quite explicit. Some of these conceptually described requirements do not yet have lower level requirements and, therefore, may appear to contradict the hierarchical pattern. Nevertheless, the intent should be sufficiently clear to support the analysts' implementation. Questions may always be referred to the CRCIA Board for clarification.

This initial publication of Part II purposely truncates most of the lower level requirements because of insufficient time to develop an orderly presentation reasonably free of error and redundancy. Therefore, the reader may not find many instances of the complete requirements hierarchy depicted in Figure 1. However the temporarily missing requirements should be available by this draft's publication date for those who would like to request a copy.

A-1.0 Hanford Materials and Contaminants (Sources and Inventories)
- [overview and conceptual requirements]
1.1 Radioisotopes and Chemicals (existing)
(1) [source term scoping criteria]
1.2 Materials and Contaminant Inventories (includes future receipts)
(1) source term scoping criteria
(a) [explicit requirement]
(b) [explicit requirement]
(c) [explicit requirement]
(2) composite source term criteria
- [illustrative requirement]
- [illustrative requirement]
- [illustrative requirement]
to be completed by analysts
(a) facilities to be included
- [illustrative requirement]
- [illustrative requirement]
(b) special nuclear materials
(c) uncontained contaminants
(d) contaminants in river locations
- [illustrative requirement]
(3)
(n)
1.3 Inventory Measurements and Investigations
A-2.0 Containment Failure and Contaminant Release

Figure 1. Typical Requirements Hierarchy

Principles and General Requirements

Several requirements recurred in so many of the sections that it became obvious they constituted overarching considerations. These have been consolidated into Principles and General Requirements.

Principles

- Dominance. This is the principle that in virtually all things a relatively small number of factors dominates the outcome. It is of the utmost importance that this assessment not leave out any factors which dominate the results. Yet the magnitude of work and cost of the analysis must be responsibly managed. Sensitivity analyses, parametric analyses, and related methods will be used to identify and rank order the factors which dominate the outcome of this assessment. These factors may be physical attributes of the Hanford Site or waste disposal, or they may be technical characteristics and challenges within the study itself. Assumptions framed through expert judgment (in lieu of repeatable analyses) will not be used to identify dominant factors or discard smaller contributors. The resulting understanding of relative importance will be used to focus technical emphasis, management oversight, and assessment planning, as well as Hanford Site budget estimates and funding allocation for the CRCIA. This principle and its implementation while managing uncertainty is discussed more fully in Appendix II-C, Analytical Approach and Methods

- Uncertainty. The relative uncertainty inherent in assessment results will be quantified and used in the technical definition of the assessment as well as in the study's management and allocation of resources. The level of uncertainty which can be tolerated in using the study results as a basis for cleanup decisions will be a guiding requirement. Uncertainty will be uniformly managed across the various study tasks. Methods such as "Value of Information" (from decision theory) will be used to determine the usefulness of spending more effort to reduce uncertainty. It also will be recognized that uncertainty and the dominance principle are coupled. This is more fully addressed in Appendix II-C.

Care must be taken by the analysts not to dismiss an effect which may be important from a cultural perspective simply because popular analytical approaches may discard such effects.

- Fidelity of Assessment Results. In the same sense that a high-fidelity sound system faithfully reproduces the original musical performance with clarity and discernible differences among instruments, this assessment must be capable of detecting an impact and resultant effect which is or will be significant to the people affected by the cleanup and waste disposal decisions made at Hanford (see Figure 2). In this context, fidelity in this assessment includes the concepts of accuracy, resolution of information in both time and location, and statistical significance. Perhaps the primary consideration is that assessment results have enough fidelity to distinguish among cleanup and disposal alternatives in the Hanford Site decision-making process. Care must be taken by the analysts not to dismiss an effect which may be important from a cultural perspective simply because popular analytical approaches may discard such effects. This principle imposes a difficult challenge on those who do the technical design of the

ORIGINAL MUSICAL PERFORMANCE	ACTUAL HANFORD CONDITIONS
DIGITAL RECORDING PLAYBACK	CRCIA ANALYSIS
HIGH FIDELITY SOUND REPRODUCTION	HIGHLY REPRESENTATIVE RESULTS

Figure 2. Fidelity

assessment. An appreciation of cultural and socio-economic values of the river-dependent people is requisite to an acceptable assessment.

- Preeminent Principles. Of all the requirements and guidance imposed by Part II of this document, by far the most important are dominance, uncertainty, and fidelity. Each is highly dependent upon the other two. Together they outweigh all other considerations by a wide margin in technically designing the assessment, in making budget decisions, and in making day-to-day technical and management choices.

- Use of Expert Judgment. Experienced, knowledgeable analysts are expected to exercise their skills and judgment with the highest professionalism in planning and conducting this assessment. Substituting expert judgment for analytical quantification should, however, be avoided unless there is convincing rationale to the contrary. Clearly, time, available resources and significance of the matter at hand must guide the analysts. The bases in making such choices are credibility and replication. Pivotal matters in the assessment must be able to be replicated by qualified professionals outside of the Hanford community. The assessment cannot be placed in a position of disrepute because results cannot be verified.

- Development and Use of Assumptions. Adherence to the requirements in Part II should eliminate the need to make arbitrary assumptions to conduct the assessment. If, however, it becomes apparent that assumptions are needed, CRCIA Board approval must be sought before implementation of the candidate assumptions. Those with merit will likely result in a revision to Part II of this document. The analyst must document all assumptions.

- Integration of Tasks Within the Assessment. As the assessment is subdivided into work tasks, care will be exercised to ensure consistency and compatibility in the application of requirements, use of data, seamlessness of modeling, management of uncertainty, and related factors bearing on overall assessment quality.

- Integration With Other Site Efforts. Two primary areas require continuous management integration aside from the assessment tasks. First, the assessment must remain integrated with cleanup and waste disposal decisions including related environmental impact statements, records of decision, conceptual design contract awards, planning bases for budget submittals, strategic planning, and Hanford Site project requirements documents. Second, integration must be achieved and maintained with other related analytical efforts, especially other studies involving the Columbia River. Any analyses involving the river or river corridor are expected to comply with the applicable portion of the requirements of Part II. Information from other studies may be used in this assessment only if those studies meet the requirements in Part II.

- Use of Other Study Results. While assessment efforts should not duplicate work appropriately done elsewhere, data which do not meet the requirements in Part II are not acceptable without convincing justification. This assessment will, however, use the Hanford Site disposition baseline for definition of disposal methods and, if available, estimates of containment performance. Composite source term information compiled elsewhere may be used if it meets CRCIA requirements.

- Research and Development of Analysis Methods. Several of the important objectives of this assessment lie beyond conventional analytical practices. Projecting mutagenic and cultural effects are examples. Modification of existing methods and development of new techniques will be needed. Design and planning of the assessment must include preliminary research and development (R&D) tasks to assure that proper analytical tools and technical information will be available as needed.

- CRCIA Phased Approach. While the CRCIA Team strove to capture the requirements for this assessment independent of any given definition or sequence of work tasks, a phased pattern seems to emerge. What may be thought of as the core set of calculations (such as contaminant inventory compilation, modeling, and exposure calculation) is described in Section 1.0. The elements of this core process received a high percentage of the CRCIA Team's attention. The screening assessment (Part I) represents the first phase of work in performing CRCIA and used some elements of this core process in assessing the current state of the Columbia River.

  The next phase of work will center on designing and planning (including budget estimates and schedules) the work necessary to respond to the comprehensive requirements in Part II. This planning phase also may include some of the preparatory tasks requisite to the core process. Following the planning phase, the remaining preliminary tasks and analytical tools preparation will likely require a level of effort large enough to become recognized as the next phase of the assessment.

  The first effort to produce useable assessment results constitutes the first phase following completion of the preparatory tasks. It will be complete when the core process has produced impact assessment results for each of the prescribed scenarios based upon the aggregate set of Hanford waste closure end states. Figure 4 graphically depicts this phase. The figure also shows each subsequent phase as being initiated by a planned or actual change in the Hanford post-cleanup end state. Performance of these iterative phases will be aligned with the timetable for key cleanup decisions, annual updates of strategic planning products, Hanford Site budget submittals, and 5-10 year plan revisions.

General Requirements

- Columbia River Area to be Assessed. The geographic section of the Columbia River to be assessed begins at the Priest Rapids Dam and proceeds downstream to the river's mouth at Astoria, Oregon. It includes the riparian zone on either side of the Columbia River and irrigation water drawn from the river. It also includes the aquatic and terrestrial life which depends on the river for biological, social, or economic reasons. It is stressed that the water ingested from the Hanford Reach area includes undiluted, or only somewhat diluted, groundwater found in seeps and springs in the riparian zone as well as groundwater upwellings in the river bottom where aquatic life habitat is found.

- Time Period of Potential Impact. The time period for which the impact to and through the Columbia River is to be assessed begins with the federal government's acquisition of Hanford lands in 1943. It continues through the period during which the radioactive and chemical materials remain intrinsically harmful, including radioactive decay daughter products and chemical reaction products. The current regulatory horizon (about 30-50 years) is inconsistent with the long term hazard from Hanford Site wastes and materials. The assessment must be guided by the materials' period of intrinsic hazard rather than the regulatory period.

  It is beyond the scope of CRCIA to make estimates of past injury or damages. Nevertheless, to the extent that past Hanford events have resulted in present day cumulative effects or conditions which bear on future river related impact, these past events must be understood and taken into account in this assessment.

- Radioactive and Chemical Materials. Calculations involving radioactive and hazardous materials data will include radioactive decay daughter products and chemical compounds/properties estimated to occur with time and after reaction with other chemicals, soils, and river chemistry.

- Impact Comparison Baseline. "Impact" as used throughout this assessment is to mean and will be compared with conditions existing prior to the federal government's construction of the Hanford Site complex. Generally, this pre-Hanford state will be equated with today's conditions upstream from Hanford to the Priest Rapids Dam. However, it is recognized that some elements of this ecosystem baseline must refer to conditions above the dam in order to capture meaningful information.

- CRCIA Standards. Contaminant concentrations and doses prescribed in regulations can be used in the assessment for general information and guidance. However, caution must be exercised because few, if any, current regulations were written with the spectrum of effects in mind that are of interest in this assessment such as mutagenic effects, teratogenic effects, and cultural effects. Elevated levels of contaminants will not be ignored because they lie below regulatory levels or because of the absence of accepted research linking such contaminant levels to adverse effects. The assessment analysts must develop criteria for elevated levels which should be of concern based on considerations such as naturally occurring background levels of the contaminants, the presence of multiple contaminants and multiple exposure pathways, general environmental cleanup experience, the body of regulatory experience, and historical environmental events such as Chernobyl. Other considerations include health physics accepted practice, international standards such as those of the International Commission on Radiological

Protection, cause and effect correlations from the medical community, and new developments in ecology, toxicology, and risk assessment. In addition to the need for criteria for elevated contaminant levels, criteria also must be developed for the aggregate tolerable contaminant load in groundwater and total plume size, both based on the presence of multiple contaminants.

- Required Results. A primary result of the assessment is the actual or projected dose level from Hanford derived contaminants for each receptor and each dominant contaminant as it varies with time throughout the time period of interest. Receptor resultant impact will also be determined. These determinations must be made for individual dominant contaminants as well as multiple contaminants which, when assessed in combinations occurring at the same time, result in elevated toxicity levels above CRCIA standards criteria (see Standards, above). Analysts might expect to find suspiciously high levels of some contaminants for which biological effects are not well established. Any such findings must be retained and reported. From the concerns expressed by CRCIA Team members, some potential effects have been defined (see Appendix II-A, Section 9.0) which must be evaluated to determine the potential for their existence and their severity.

- Assessment Control. The aggregate of the requirements in Part II of this document makes indispensable a relentless, intense attention to control of the conduct of the assessment. Sensibly applying, and maintaining, the delicate balance among the principles of dominance, management of uncertainty, and fidelity require thoughtful conceptualization and planning of the assessment as well as continual reassessment and rebalancing of the on-going effort. The burden of this effort rests primarily on the performing contractor, particularly the assessment project manager. As described in Appendix II-D, final decision authority rests with the CRCIA Board, which will remain actively involved in managing the assessment. However, the DOE project manager, designated in Appendix II-D by the Board as the CRCIA Executive Administrator, shares the responsibility of ensuring the assessment meets the letter and intent of these requirements.

- Assessment Frequency. The description of recurring CRCIA assessments for each successive revision of DOE's planned site end state is found in Section 1.0 and is illustrated in Figure 4. Additional iterations of the assessment will be needed, however, in response to such developments as results from atmospheric studies which suggest new environmental scenarios, significant changes in data from Hanford studies, new information which causes changes in CRCIA models and related tools, and advances in ecology and toxicology.

- Required Continuation of Columbia River Monitoring. Much of the basis for detecting trends in river changes, so important to realistic assessment results, comes from monitoring current groundwater and river conditions. It is essential that the monitoring program be continued and periodically refocused to the findings and needs of this assessment.

1.0 What the Assessment Must Include

This section discusses what must be considered and included in the assessment. The next section, 2.0, prescribes assessment fidelity, describing the care and depth with which each factor must be treated to achieve the needed thoroughness in assessment results. Both sections are subdivided according to the framework of assessment tasks or modules shown in Figure 3.

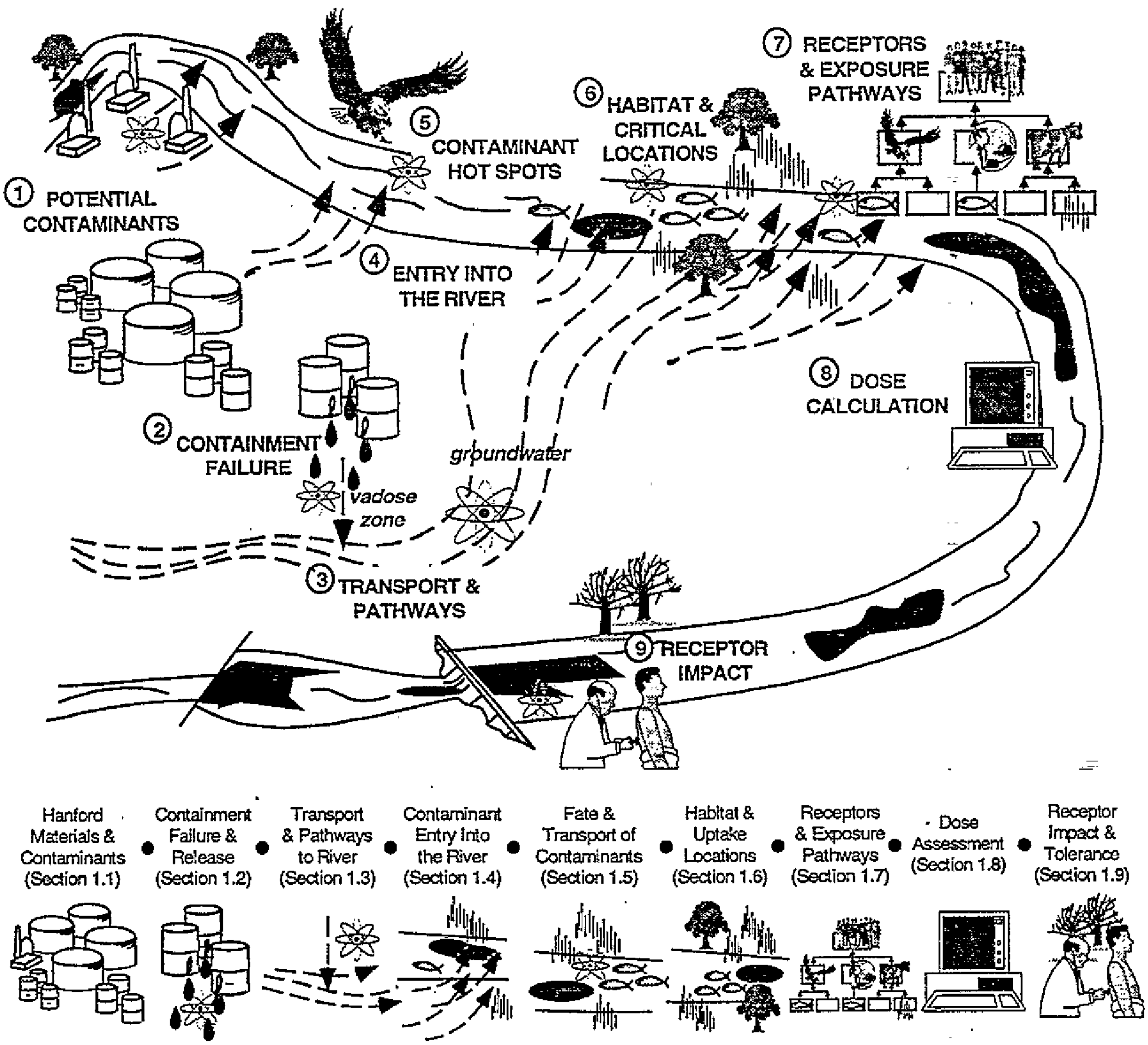


Figure 3. Analysis Modules Comprising the Assessment with Icons as Guides to Related Discussions

The following discussion of these modules, as well as the specific requirements in Appendices II-A, II-B, II-C, and II-D, is based on the conduct of the assessment in accordance with the concept shown in Figure 4. Any given execution of the assessment process addresses each of the modules shown in Figure 3, maintaining their respective dependencies on one another for valid information. A successive execution of this assessment process is required for each of the socio-economic and climate change scenarios in described Subsection 1.10 below (also see Appendix II-A, Section 10.0) beginning with the scenario describing today's conditions. It is stressed that the frame of reference is the Hanford Site set of permanent disposal methods planned and approved for the aggregate of all radioactive and chemical materials within the Hanford Site boundary, that is, the Hanford Site post-cleanup end state. This assessment should not make assumptions or otherwise develop this Hanford Site baseline for waste disposal. However, some effort may be needed to compile US Ecology, Seimens, and Washington Public Power Supply System data. If interim disposal is planned with no defined permanent disposition, the assessment will regard the interim method as permanent disposal. As the disposal planning baseline changes during the course of the multi-year cleanup effort, the assessment process in Figure 3 must be repeated for each scenario to determine the impact of the planned disposals on the affected people. Figure 4 graphically summarizes this assessment concept. The right sector of Figure 4 represents the modules shown in Figure 3. Calculations in each module are performed for each scenario shown in the left sector of Figure 4. Assessing risk for all scenarios in this fashion constitutes one execution or one iteration of the assessment process. The assessment process is executed for each composite set of Hanford Site-wide waste disposal decisions as shown in the top sector of Figure 4. As that decision set is revised, another execution iteration must be performed. It seems apparent that this assessment should be used to support the decision-making process and as a strategic planning tool. In this context, the assessment process becomes a powerful effectiveness measure for Hanford Site cleanup and overall risk reduction.

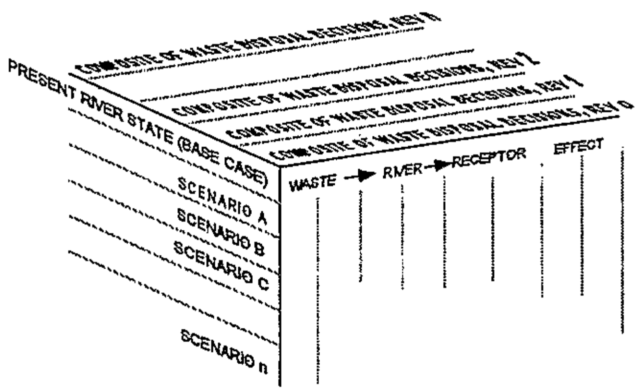


Figure 4. Assessment Concept

> **CRCIA is complete when the effects on people and other receptors have been estimated for each scenario and for the Hanford Site composite set of waste disposal decisions as each revision in the planned final end state emerges.**

1.1 Hanford Materials and Contaminants (Sources and Inventories)

CRCIA addresses all radioactive and chemical materials and wastes within the Hanford Site boundaries. It will include in its source term information on any potentially harmful chemicals introduced or released as a consequence of remediation work or Hanford operations, including new Hanford Site missions. These combined sources of potential future contamination, called the composite source term, include but are not limited to the sources documented in the DOE approved Hanford Site listings of special nuclear materials, waste sites, waste discharges, and related data bases and documentation. It is important that the assessment use the same source term data as used in DOE's development of the Hanford Site-wide approved remediation and disposal solutions. Failing to maintain this consistency introduces mismatches with DOE's planning base which may jeopardize the relevance of the assessment's results. If disagreements develop on the usability of DOE's source term information, guidance must be requested from the CRCIA Board. Completeness of the source term information provided for this assessment must be verified to the satisfaction of the CRCIA Board.

Since the primary pathway through which contaminants are reaching the Columbia River is the groundwater underlying the Hanford Site, it is crucial to this assessment's results to understand the contaminant burden potentially to be introduced into Hanford's groundwater from all sources. The assessment must include source term information from the Supply System facility, the US Ecology low level waste site, and the Seimens nuclear fuel facility. While these entities are responsible for contaminants originating from their operations, DOE is responsible to determine the cumulative groundwater contaminant load in estimating effects. Chemical and nuclear materials and waste historical background information related to the organizations referenced will be sought.

Materials and wastes continue to arrive at Hanford. These become a part of the composite source term. Information must be obtained to estimate the extent of future shipments to Hanford and their intended disposition. Assessment results will be updated as estimates of future inbound shipments are changed. Permitted discharges to the groundwater and the river must be included in the composite source term.

The composite source term will also include estimates of those contaminants which have already escaped containment or are in an indeterminate state, such as buried solid waste. If DOE's approved planning includes remediation work to recover uncontained contaminants, this assessment will treat them as contained materials in their post-remediation state. However, if recovery is not planned, contaminants will be treated as part of the source term already in, or moving to, the ground water (see Subsection 1.3 below and Appendix II-A, Section 3.0 for transport requirements).

As an aid in the source term definition effort, especially for estimating uncontained contaminants, the analysts are encouraged to consider chemical mass balance estimating methods. Calculations using known reactor operations data and chemical processing information can be of help in estimating undocumented waste discharges. This approach is also useful as an aid in validating source term information (see Appendix II-C, Section 3.0).

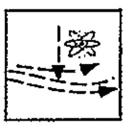
Analysis work throughout the assessment will use source term information as available from DOE's characterization work as well as the radioactive decay daughter products commensurate with the long time periods needed for loss of containment, transport to the river, and uptake from the river into and through the pathways to the receptors. Similarly, assessment analyses will include reasonably expected chemical compound breakdown and recombinations into new substances typical with the irrigation, soils, river chemistry, and prevailing agricultural chemicals in the section of the Columbia River being assessed.

1.2 Containment Failure and Contaminant Release

A reasonable paraphrase of a primary goal of the Hanford cleanup project is to retrieve, as necessary, and contain radioactive and chemical materials for a period deemed sufficient to assure safety for the people and organisms who might otherwise be adversely affected by exposure to these materials. Determining the period of containment and rate of contaminant escape are the subjects of the requirements in this section.

To maintain the assessment's consistency with the data supporting the Hanford Site waste disposal decisions, the assessment will use the same period of containment and the same estimated leakage rate as used in the disposal decision process, for example, as used in environmental impact statements. The decision documents usually include strategic planning products, budget proposals, and 5-10 year plans. If information is not available from these preferred sources, performance assessment calculations will be made as a part of this assessment's analysis effort.

Leakage rate will vary with time as containment deterioration worsens and surrounding soils become more saturated. Since these factors influence eventual contaminant concentrations and effects, it is important that these rate estimates be obtained with good levels of certainty as discussed in Appendix II-C, Section 2.0.



1.3 Transport Mechanisms and Pathways to the Columbia River

This section addresses requirements concerning two different but related matters. One issue is transport of contaminants downward through the soil to the groundwater beneath the containment device or, if the wastes were not contained, the point of free discharge at the surface. The soil above the groundwater is called the vadose zone. The other issue is the movement of the contaminated groundwater toward the Columbia River. In both cases, travel times, contaminant type, amounts, and concentrations are of great interest. Each will change over a wide range as time passes and as different climate and river characteristics change.

It is to be noted that while groundwater is considered the primary pathway by which contaminants reach the Columbia River, other pathways are not to be omitted unless their contribution can be shown to be negligible in accordance with the dominance principle. The assessment is to determine the impact sustained from river and riparian zone contamination regardless of the contaminant pathway to the Columbia River. Section 1.4 addresses the transition of groundwater into river water. That sub-section points out the importance to the assessment of realizing that in the riparian zone bordering the river contamination can potentially reach wildlife and people in undiluted groundwater.

Assessment requirements for vadose zone information include both vertical transport times and estimates of contaminants which have been free within the vadose zone since their initial discharge during reactor operations and chemical processing. In both vadose zone and groundwater contaminant migration estimates, the analyst will consider the likelihood of mobility changes resulting from chemical modification of the contaminant such that its solubility and sorption characteristics are altered.

Airborne contaminant migration to the Columbia River will also be considered, including airborne deposition on agricultural land which, in turn, is washed into the river by irrigation. Similarly, contaminants from direct discharges to the river will be included.

CRCIA requirements for groundwater movement information include travel times, contaminant presence, quantities, and concentrations. Correlations must be made between the locations of groundwater paths and geographical locations of potential contaminants in surface or vadose containments so the composite groundwater chemistry effects on migration can be estimated.

With regard to groundwater total contaminant load, contributions will be included from the Supply System facility, the US Ecology low level waste site, and the Siemens nuclear fuel facility, even though these entities are environmentally responsible for contaminants from their facilities.

Use of the Hanford Site consolidated groundwater model is encouraged provided that model is consistent with CRCIA requirements. It is especially important that the groundwater modeling for this assessment be responsive to the principles of balanced management of dominance, uncertainty, and fidelity, as well as being seamlessly compatible with other CRCIA modeling such as groundwater-to-river water transition models for the riparian zone and contaminant entry into the Columbia River.

1.4 Contaminant Entry into the Columbia River

The requirements in this subject area are especially challenging, principally because of two general considerations. First, in reality, the groundwater enters the Columbia River in a most irregular, heterogeneous fashion which will be difficult to legitimately generalize with most modeling techniques. Yet failure to explicitly recognize the actual entry locations, volumes, and rates results in omission of critical habitat linkages to undiluted, or slightly diluted, potentially contaminated groundwater. An example is the upwelling in the river bottom of groundwater through known salmon spawning beds. River bottom surveys to identify areas of upwelling seem unavoidable. Similarly, surveys of the riparian zone for points where the groundwater comes to the surface is important. In view of these considerations, any modeling assumptions implying an instantaneous, homogeneous entry of groundwater into the main body of the Columbia River are unacceptable for defining local impact.

The second consideration making this a difficult segment of the assessment is that groundwater enters the riparian zones where a large percentage of the river-dependent terrestrial life obtains its water. It is important to understand the relationships between groundwater aquifers beneath the Hanford Site and seeps, springs, wetlands, and free standing surface water in the riparian zone. A spatial description of each plume or point of discharge is also necessary. Overlapping plumes must be evaluated.

The dynamics of river flow patterns, storm run-off, dam operations, and river bank and riparian zone erosion add yet another dimension of difficulty to this assessment task. Field work will likely be needed to provide necessary information. Some approximations will have to be made. Managing the assessment in accordance with the principles of dominance, balanced uncertainty, and fidelity will be especially important in designing and conducting this work.

1.5 Fate and Transport of Columbia River-Borne Contaminants

Requirements in this section address the modeling of how the contaminants mix in the main body of river water. That is, the locations of deposits (fate) of sediments and dissolved contaminants must be determined as well as their redistribution when transported by storms or seasonal river changes in flow. Generalizations which assume instantaneous, homogeneous mixing and dilution, while simplifying the assessment task, are not acceptable because they mask potential linkages between contaminant hot spots and critical river locations such as aquatic habitats, and extractions of water for drinking or irrigation. The mixing of groundwater, potentially carrying contaminants, into the main body of the Columbia River is known to be slow and is not complete for perhaps tens of miles downstream of the point of introduction.

These requirements deal primarily with two methods of contaminant transport in the main body of Columbia River water. One is mixing of river water and groundwater potentially contaminated with dissolved radionuclides and chemicals. The other is suspended solids, mostly sediments, some of which have a great affinity for contaminants. Suspended sediment is continually settling, especially where flow rates are low. Sediment settles in holes and quiet water regions of the Columbia River, such as in sloughs and behind large rocks on the river floor. Runoff from storms and seasonal weather changes alters quiet water, sometimes dramatically, and resuspends the sediments, carrying them downstream to more permanent settling spots, perhaps behind dams (especially McNary Dam) or in areas periodically dredged for shipping.

Dissolved contaminants may remain at worrisome concentrations far enough downstream from the point of groundwater influx to encounter municipal water intakes or irrigation water systems. Even at dilute levels, mechanics such as irrigation, water treatment equipment, and hydroelectric turbines provide opportunities for reconcentration of dissolved contaminants. Such opportunities will be identified and evaluated for significance. Locations conducive to sediment accumulation and ecosystem habitats will be evaluated.

For either dissolved contaminants or sediments, little can be realistically concluded about these potential problems without knowledge of the river's flow characteristics, especially groundwater influx points (addressed in the previous section), turbulent regions and quiet areas. Columbia River bottom topological mapping surveys will almost certainly be required, as will seasonal changes.

Requirements in this section also deal with chemical recombinations between potential contaminants and the prevailing river chemistry in the area being evaluated. Some synergism of Hanford and off-site contaminants may occur in the Columbia River, causing a greater cumulative impact.

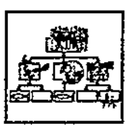
1.6 Critical Habitat and Uptake Locations

This section specifies the requirements for identifying the important locations of plant and animal habitat, for both aquatic and river-dependent terrestrial life, where uptake of contaminants is probable because of the river's deposits discussed in the previous section. Identification of other critical locations, such as municipal water intakes, is also required.

Critical locations are defined, for these purposes, as those places where the entry of contaminants into the food chain and other exposure pathways are most likely to occur. This section is especially important to the assessment as the analysis performed here links the contaminant hot spots to the biological/social/economic webs developed in the sections to follow.

The requirements for this subject area in Appendix II-A, Section 6.0 contain references to the species of interest having been selected and available to help guide the search for habitat and critical locations. Without doubt, a number of the key species can be identified simply on the basis of interest from societal groups and proximity to Hanford and the Columbia River. However, the identification of critical locations is very likely to show that certain aquatic and dependent terrestrial species are potentially in harm's way because of their position in the ecosystem web. If it is found that their exposure and ensuing impact is likely to be severe, those species may be added to the species-of-interest list. Selection of the species of interest is the subject of the next section. The search for critical locations should not depend solely on a predetermined set of species to be evaluated.

A point emphasized in these requirements is the necessary search and discovery of habitat located at points of upwelling of undiluted groundwater in the Columbia River. Discovery of active salmon spawning beds in gravels through which chrome-laden groundwater is entering the Columbia River is an example. Similarly, seeps and springs carrying undiluted groundwater to the surface and through the riparian zone into the Columbia River need to be identified if those areas contain important habitat or species.



1.7 Receptors and Exposure Pathways

This section contains those requirements dealing with the development of exposure web models which realistically define the pathways or mechanisms by which receptors of interest become exposed to contaminants.

Receptors, as defined for this assessment, include humans and human population groups as do other assessments. CRCIA, however, goes further to include as a candidate receptor any species, resource, or environmental function occupying a key juncture in the ecosystem web which, if lost, produces a significant loss or impact to the ecosystem, including potential impact to humans. Selecting all such candidates for the receptors-of-interest list is likely to be impossible until the model of the ecosystem web is complete or the habitat for the candidate species (or its supporting food chain) is found to coincide with a contamination hot spot as discussed above.

CRCIA also includes as receptors those humans and groups projected to suffer any other adverse health effects including but not limited to cancer. It is also important to include as species those which by virtue of different cultural life styles may be susceptible to exposures and effects not otherwise encountered. Native Americans and other ethnic or minority life styles, such as migrant farm workers, are in this category. Also included as candidate receptors are river-dependent economic groups such as irrigation supported agriculture, commercial fishing, hydroelectric workers, and river transportation industries (barges and support services like dredging operations).

Another important requirement is that receptor in this assessment will include the culture of the affected peoples. If Native Americans, for example, must relocate to avoid untenable exposure from contaminants, this would be considered a serious impact to their culture and their quality of life. If the economy of the Tri-Cities (Richland, Pasco, and Kennewick, Washington) is impacted (for example, by bad water) so as to adversely affect the quality of life of the residents, CRCIA would regard the Tri-Cities culture as a receptor.

Given this perspective, this section requires that both the process for selection of receptors be defined as well as development of models of the related physical, biological, social, cultural, and economic webs of dependency on the Columbia River through which contaminants might reach, and expose the selected receptors over time.

1.8 Dose Assessment

With the selection of receptors to be evaluated and the exposure pathway models developed which relate the receptors to potential sources of contamination, the requirements in this section address the calculation of the dose estimated to be sustained by the receptors. The intent in this section is only to determine dose, that is, level of exposure. Identification of the effects or impact from having received that dose is the subject of the next section.

As a general rule, accepted risk assessment practices will guide the analyst in making dose calculations. However, the CRCIA Team expressed several concerns about these accepted practices to which the analysts must be responsive. For example, unless specific predator and prey feeding habits for a species are unknown and unknowable, calculations must not be overgeneralized. An example is categorizing animals only by weight and ignoring distinctions in diet, activity patterns, and habitat. Similarly, Native American scenarios will be developed and used as will specialized exposure scenarios for other groups such as farm workers. Aside from the conceptual requirements the reader will find in this section, explicit requirements remain to be developed by the analysts and discussed with the CRCIA Board.

A major point of concern in this area is the exposure which may be sustained in short as well as over long time periods by one or multiple generations. Determining mutagenic effects, which is of great interest, will likely be impossible unless dose calculations are performed with this effect in mind. The analysts will note in this regard that several of the candidate receptors are members of small gene pools which may tend to magnify mutagenic effects.

1.9 Receptor Impact and Tolerance Assessment

The requirements in this section address the effects or impact expected to be sustained by the species of interest resulting from the exposure calculated in the previous section. Tolerance assessment refers to some impact threshold below which effects can be tolerated with no unacceptable or irreversible effect. Above such a threshold, unacceptable harm may occur to the species, group, or culture under study. Without an understanding of both the impact of the dose received and the level of tolerance to that impact, useful conclusions will be difficult to draw.

Tolerance assessment is one of the key objectives of CRCIA, that is (from the Statement of Purpose): Evaluate the sustainability of the Columbia River ecosystem, the interrelated quality-of-life, and the viability of socio-economic entities for the period that Hanford materials and contaminants remain intrinsically hazardous.

As pointed out earlier, care must be taken by the analyst not to dismiss as unimportant an effect which may be important from a cultural perspective simply because popular analytical approaches disregard such effects. The seriousness of respecting cultural values can best be illustrated by pointing out that, when in dispute, these matters are settled only through government-to-government negotiations between the sovereign nations of the Native Americans and the U.S. Government.

Appendix II- A, Section 9.0 requires evaluation of a number of potential adverse effects to determine if dose levels are expected to be sufficiently high to cause them. However, the analyst is cautioned not to regard this list as exhaustive. The analyst should also expect that unanticipated effects will be identified, or at least inferred, by elevated exposure levels of certain contaminants. The discussion in the Principles and General Requirements section also provides guidance in this matter.

1.10 Assessment Scenarios: Columbia River, Climate, Geological, and Political Changes

As discussed in Section 1.0 above, the assessment addressed in Sections 1.1 through 1.9 is to be performed for each of several scenarios. Most of the foregoing requirements were written from the perspective of the conditions observed today and accepted as normal. However, the Columbia River, climate, area geology, and even the regional cultural and political conditions change, and especially in view of the protracted time scale for which Hanford contaminants remain dangerous, these scenario changes should be expected to be major. The requirements in this section specify that the assessment be performed for changes which can reasonably be expected to occur.

Appendix II-A, Section 10.0 lists scenarios in categories generally expected to change pivotal factors in the assessment from what is seen today as normal. For example, a climate change which substantially increases the rainfall in the Hanford area would presumably make a dramatic change in the volume of contaminants reaching the Columbia River as well as the time necessary for them to reach the river. In another example, on a time scale of several hundred or thousands of years, the present dams on the Columbia River would likely be removed, would deteriorate and fail, or at least would have to have major desilting dredging performed. Any of these probabilities would remobilize large accumulations of contaminants in the sediments. Also considering the time scale involved, entirely new governments and/or political structures are inevitable, bringing with them potentially major changes affecting the materials and wastes at Hanford.

In view of the speculative nature of these scenarios and the expense of modifying the assessment for each, a recommended study set of the most credible scenarios must be winnowed from a broader list of candidate scenarios and proposed to the CRCIA Board for approval.

1.11 Hanford Site Disposition Baseline

As Figure 4 in Section 1.0 above shows, CRCIA is to be performed maintaining as great a consistency as possible with each set of Hanford Site-wide cleanup/disposal decisions and with each subsequent revision. In other words, whatever may be the collection of DOE documents which, at any given time, constitutes what may be considered to be the approved Hanford Site post-cleanup end state, there will be a corresponding CRCIA assessment of resultant impact. Because the various documents might be based on different assumptions, a comparison with those used in CRCIA is essential.

In the event no officially recognized end state plan exists for the overall Site, the CRCIA analysts will develop, with DOE's recommendations, the most credible surrogate end state information available. CRCIA Board approval of such surrogate information is essential.

It is particularly important that the analysts use the estimates of containment durability (time to failure and leakage rates) found in approved end state plan documents. However, transport time through the vadose zone to the Columbia River and dose levels will all be calculated in accordance with CRCIA requirements.

2.0 How Good the Impact Assessment Results Must Be

This section consists of requirements which specify the fidelity of the assessment results. Fidelity, as discussed above in the section on Principles and General Requirements, is used in this assessment in the same sense it is used in high fidelity sound reproduction, that is, it expresses the degree to which the reproduction (the assessment in this case) faithfully represents the actual performance (reality), overcoming any intrusion of factors which introduce distorting noise or bias.

Appendix II-B lists these requirements in four subject areas: (1) achieving sufficient assessment sensitivity to detect any potential adverse effects/impact, (2) ensuring seamless consistency across all models and calculation modules, (3) selecting the study set of factors and the specific fidelity requirements for the candidate factors discussed in Appendix II-A, Sections 1.0 through 9.0, and (4) ensuring software characteristics meet assessment needs.

2.1 Fidelity of Detecting Harmful Effects

These requirements specify that the assessment must be designed and conducted well enough that if an adverse effect is occurring or will occur, the assessment will identify or predict it. Deciding what constitutes an impact is discussed in the Principles and General Requirements section. It should also be kept in mind who the users of the assessment results are expected to be and for what purposes would they use the results (see Introduction).

Applying such a qualitative concept as fidelity to modeling and calculation tasks requires the use of what one regards as important. Relative importance, or value, is rooted in one's culture and lifestyle. What is seen as an impact to which the assessment must be sensitive is very much a matter of who the affected peoples are and what is important to them. Especially for this reason the CRCIA Board's guidance or approval must be sought in matters of this kind.

Two general factors will be frequent threats to needed fidelity. One is the fineness of definition in determining the timing of contaminant releases, groundwater migration rates, food chain and other pathway assimilation rates, and eventually, the duration and intensity of the exposures — especially combinations of exposures. The second factor is that it may be difficult to resolve the large geographic area being assessed into elements that are fine enough to detect contamination hot spots and the degree to which they coincide with critical uptake locations such as municipal water intakes and favored habitat. These are particularly critical considerations to the assessment and must be dealt with effectively.

In keeping with the principle of dominance (see Principles and General Requirements above), resources may not always be sufficient to support enough assessment work to include all the factors necessary to detect all impact for all the selected receptors of interest. Difficult choices may have to be made between assessing all potential impact or all receptors of interest. The CRCIA Board must make these decisions. However, the analysts will develop and use trade study methods to define the choices to be presented to the Board.

2.2 Model Integration and Consistency

These requirements are aimed at ensuring the insightful integration of the many assessment models and calculations such that overall fidelity is not degraded. For example, unless uncertainty is managed with consistency across all models, detection of important effects may be needlessly masked by the error band surrounding the final results. As discussed in Section 1.0 above (see Figure 3), the assessment task modules, especially those involving modeling and calculations, are highly dependent on one another. If output of one module is inadequate to properly enable the next module to function, fidelity will be lost to the overall assessment results. Seamlessness must be achieved across module boundaries. For instance, mass and momentum must be conserved between vadose zone models and groundwater models. This is an illustration of why the analysts must be cautious in accepting results and tools from other studies.

2.3 Selecting Factors for Assessment: The Study Set

This section deals with the fidelity requirements which apply to respective modules of the assessment addressed in Appendix II-A and Sections 1.0-1.9 above. Topics include:

- Screening candidate contaminants to identify those having the most dominant effects
- Development and use of transport models to preserve the needed sensitivity to timing and location (see Section 2.1 above)
- Search, discovery, and modeling of the most important habitat and uptake locations
- Receptor selection and exposure pathway web modeling
- Chemical and radiological dose calculation for single and multiple contaminants
- Selecting dominant effects

2.4 Assessment Software Requirements

This section contains the requirements to be observed in using commercial modeling software and in developing unique software for this assessment. The section specifies that software specifications will be prepared, that software verification and validation be performed, and that a software quality assurance plan be prepared and implemented.

2.5 Assurance of Assessment Quality

A concept of assessment quality will be developed which includes the principles of fidelity, management of uncertainty, dominance, the development of CRCIA standards, and required results. These topics have all been addressed previously. In addition, workable concepts for the management and reconciliation of work scope and funding must be developed in keeping with the principle of dominance yet ensuring that the most important assessment work is accomplished to high professional standards. Particular attention will be directed to validation of all models used in the assessment.

An assessment quality assurance plan will be prepared which defines how quality is to be infused into the assessment and maintained. The CRCIA Board must approve the quality assurance plan.

3.0 Analytical Approach and Methods

The requirements in this section address the matters of concern related to how the assessment is to be designed and technically conducted. Management of the assessment is discussed in Section 4.0. The requirements in this section are provided in Appendix II-C. They are categorized into seven groups: (1) ensuring that the factors contributing most to actual exposures/effects are always considered in any assessment task, (2) ensuring that assessment uncertainty is always known, quantified, consistent among all assessment tasks, and responsive to the needs of those who will use the results, especially Hanford decision-makers, (3) ensuring that the assessment be designed as a single, integrated set of seamless tasks which together form a logical, robust architecture for long term use of the assessment tools, (4) developing and implementing meaningful data quality criteria which draw upon the best features of the data quality objective process, (5) selecting and using assessment methods which capitalize on the progress made in the risk assessment field but are not subject to its limitations, (6) verifying assessment models and results, and (7) identifying new development efforts needed in assessment methods.

3.1 Identification and Management of Dominant Factors

Ensuring that the assessment effort is always focused on the most important contributors to contamination impact is the subject of this section. This is the first principle defined in the Principles and General Requirements section. Often project efforts are prioritized in terms of a chronological sequence of tasks or favored alternative solutions; funding and staff skills are allocated accordingly. The requirements in Part II reject such approaches. Rather, it is required that methods be developed to identify the dominant factors in this assessment based upon sensitivity study methods, parametric analysis methods, or related techniques. While it is clear that smaller contributors to impact must be set aside, it is critical that the methods be adequate to preclude leaving out any major contributor. If useful, analysts are encouraged to visit advanced design organizations in other industries where such methods are more commonly found than in nuclear or environmental fields.

3.2 Identification and Management of Uncertainty

Appendix II-C, Section 2.0 provides the requirements in this subject area. Uncertainties exist, for example, in how well the Hanford cleanup methods will contain the wastes, in our capability to forecast changes in climate, cultural, and economic scenarios, and in how well this assessment will be conceived, designed, funded, and technically executed. Uncertainty is addressed as a principle (see the Principles and General Requirements) because its management is pivotal to credible results and economy of resources required.

Allocation of the maximum acceptable level of uncertainty in the assessment's results is an approach often used, that is, each of the assessment's models and calculation tasks would be allocated ceiling values of uncertainty based upon the acceptable level of the results. Inability of any task to meet its allocation would then suggest a reallocation of either allowable uncertainty or funding to the more difficult tasks.

Other methods should be considered such as those in the National Council on Radiation Protection and Measurements Commentary No. 14 (National Council on Radiation Protection and Measurements. 1996. *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination*. NCRP Commentary No. 14, Bethesda, Maryland).

Uncertainty is highly dependent upon the dominant factors discussed above. For example, if offending levels of uncertainty reside among factors of little significance, then their uncertainty is also insignificant.

Methods will be developed to identify and manage uncertainty consistently across all of the assessment tasks. The CRCIA Board will approve the methods planned to be used.

3.3 Analytical Architecture and Integration

A simple example of an architecture for this assessment is shown in Figures 3 and 4 of Section 1.0. That architecture was developed only to organize an approach for capturing and communicating the requirements in Part II of this document. That architecture may not be the approach preferred by the analysts. It is essential, however, that an approach be conceived and understood by all those involved in this assessment. The CRCIA Board will review the recommended architecture for the assessment.

The fundamental concept preferred in developing this architecture is to identify all the assessment's necessary functions and arrange them in hierarchical form, partitioning upper level functions into subfunctions to the extent necessary to assure clarity and completeness. Dependencies among functions must be defined to assure the right information is generated for the right recipients. Such an architecture is not only useful in planning and sequencing assessment tasks, but it defines the necessary conditions for compatibly integrating all the assessment's tasks.

3.4 Data Quality

Development of data quality criteria for the assessment is essential. For example, it seems unlikely that there could be much success in managing uncertainty as discussed in Section 3.2 without control of data quality. Data quality requirements are found in Appendix II-C, Section 4.0. Like many areas in Part II of this document, Appendix II-C, Section 4.0 provides little more than a conceptual framework for data quality requirements. It is left to the analysts to complete the definition of the assessment's data quality requirements for the CRCIA Board's approval. The best practices from the data quality objective process should form the basis for CRCIA data quality criteria. Criteria will include identification of data gaps, data verification and validation, data acquisition, and data quality management.

3.5 Assessment Methods

Some assume the CRCIA analysis is a risk assessment in the same sense as the practices that have emerged in response to EPA's environmental literature. The analyst is cautioned against this conclusion. It has been stressed many times in this document that the CRCIA Team believes conventional risk assessments to be inadequate, especially with respect to cultural considerations (see Problem Statement in the Introduction section). If the analysts' intellectual perspective on this analysis is that of a conventional risk assessor, much of the needed innovation is unlikely to emerge. By all means, the experience accumulated in the risk assessment field should be drawn upon, and so should it be with radionuclide and chemical migration performance assessments methods, parametric and sensitivity analyses, mutagenic investigation methods, and many more. The requirements in this section reflect the concern expressed by several members of the CRCIA Team that the methods essential to this assessment's management of dominance, uncertainty, fidelity, and cultural impact would simply be ignored in favor of another conventional risk assessment. The analysts must design this assessment to take advantage of the best current practices but be limited by none of the popular approaches. The CRCIA Board will be kept informed and must approve the assessment approaches and design alternatives under consideration.

3.6 Verification

In discussing the required fidelity of the assessment to faithfully reflect reality without distortion (Section 2.0), the requirements for model validation were mentioned as one element of assuring the assessment's quality. A quality assurance plan was specified as a requirement in that section. Planning in response to the requirements in this section will be included in that plan. The requirements in this section address the need to be able to verify all the elements of the assessment. Among those matters to be addressed in this area are: (1) use of peer reviews, (2) field data collected especially for verification purposes, (3) use of historical and ongoing monitoring data, (4) results of climatic trending studies, (5) medical research of toxicity correlations.

3.7 Analysis Research and Development Needs

Research and development efforts will be identified to extend existing analytical methods and develop new techniques as needed to meet the requirements of this assessment. Advancing of the state-of-the-art is preferable, in most cases, to abandoning key objectives of this assessment. However, financial sponsorship of such development work will be sought from national grant programs and other sources. Use of CRCIA funding for these purposes will be considered only as a last resort.

Development of the R&D needs will be done as an integral part of the assessment planning and design effort. To the extent that assessment funds are needed for R&D, the CRCIA Board will approve the R&D candidates along with the assessment design.

3.8 CRCIA Standards, Regulations, and Guidelines

See "Standards" in the section on Principles and General Requirements.

4.0 Conducting and Managing the Assessment

This section is a brief summary of the requirements for conducting and managing the assessment found in Appendix II-D.

Paramount among the features of the management structure specified is the new public involvement paradigm this approach represents. Day-to-day management of the assessment work is carried out by a board composed of representatives from the people and socio-economic groups which, if the potential river contamination materializes, will be affected by Hanford's cleanup and disposal decisions. As a result, for the first time, cleanup effectiveness is assessed under the management of the people who are potentially affected. This effectiveness assessment is done objectively in a spirit of service and teamwork with DOE and its contractors in support of effective cleanup decision making which protects the people, ecosystems, and cultures dependent on the Columbia River.

Appendix II-D requirements address the management and CRCIA decision roles to be performed by those affected groups who accept the invitation to be represented on the Board. Since the Columbia River corridor to be assessed extends to the estuary at the Pacific Ocean, the representatives on the Board may become numerous. For practical day-to-day management purposes, the requirements provide for a hands-on Executive Board, consisting of those more closely related to the Hanford Site. Several sovereign governments will be represented on the Board. Participation does not abrogate any sovereign rights.

Funding would be provided by DOE through the Congressional appropriations process. Competition for scarce cleanup resources is on a merit basis. This means allocation of funding for assessment work would be expected to be in proportion to the value returned to the cleanup effort by the assessment's results. CRCIA deliverables are estimates of contaminant levels reaching receptors in and through the Columbia River, the sources of those contaminants within the Hanford Site, and the effects on the receptors resulting from exposure to the contaminants.

In collaboration with the Board, DOE would appoint an experienced Project Manager whom the Board would establish as the Executive Administrator and advocate of CRCIA. DOE would provide routine support services such as conference rooms, subcontracting services, clerical support and publishing services. While a DOE contractor would perform virtually all the assessment work through a senior manager dedicated to CRCIA, Board members are expected to perform significant management tasks such as developing CRCIA budget proposals, some of the higher level resource loaded schedules, and evaluating assessment technical problems and choices. Board members also are expected to review preliminary technical results and present progress reports to DOE, Hanford Site project leaders, and constituent stakeholder groups. Because most of the Board members are not likely to have technical experience, the Board may, from time to time, hire the independent technical expertise needed.

The Board is actively accountable to its constituencies through periodic progress reviews and an outreach program. The Board also is accountable to DOE and its contractors for providing technical results from the assessment needed to support cleanup decision making.

Realizing that this paradigm introduces a new way of doing business at Hanford, an implementation period is to be planned which allows — for an interim period — conduct of assessment work under existing practices with the CRCIA Team acting in its current advisory role.

Appendix II-A

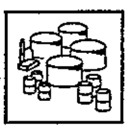
What the Assessment Must Include

Appendix II-A
What the Assessment Must Include

The Columbia River Comprehensive Impact Assessment (CRCIA) examines the process of exposure and harmful effects of Hanford-derived contaminants in the Columbia River to humans, ecosystems, and cultures. The requirements in this appendix define what factors must be included in assessing river impact in order to understand this process. These factors, compiled for each segment of the exposure process and variant scenarios (Section 1.0 through 10.0), constitute the all-inclusive set of candidates to be considered in the assessment. They are winnowed to a manageable study set as discussed in Appendix II-B.

An acceptable comprehensive assessment must examine Hanford Site materials and contaminants, their containment and eventual release, and their transport and entry into the Columbia River. The assessment must also examine potential receptors, their exposure to Hanford-derived contaminants in the Columbia River, and impact resulting from the estimated levels of exposure. The assessment must either include the specified candidate factors, or, if a factor is not included, the assessment must contain an evaluation that explains why the factor was not included.

The factors required to understand the process of exposure and harmful effects (described in Sections 1.0 to 9.0 of this appendix) are based on current environmental conditions and the disposition baseline for Hanford Site radioactive and hazardous materials (described in Section 11.0 of this appendix). Variations from the current conditions are described in Section 10.0 of this appendix. The extent to which each factor is to be assessed, that is, how well the analysis is to be performed, is defined in Appendix II-B. How the assessment should be conducted is defined in Appendix II-C. How the assessment should be managed is defined in Appendix II-D.



1.0 Hanford Materials and Contaminants (Sources and Inventories)

The requirements in this section call for all contamination sources within the boundaries of the Hanford Site to be considered in a composite source term for assessing impact to the Columbia River. The impact of the entire inventory of radioactive and hazardous materials is required. This includes materials which are not contained, such as those contaminating the vadose zone of the Hanford Site. It also includes materials managed by entities other than the U.S. Department of Energy (DOE), such as US Ecology Incorporated and the Siemens Nuclear Fuels. The inventory shall include estimates of future materials whether imported to the Hanford Site or generated on the site. This section requires the analyst to show that the list of potential contaminants used in the assessment is complete. This section also requires the analyst to rank all candidate contaminants in accordance with CRCIA criteria developed to screen contaminants by their potential contribution to harmful effects. The ranking will enable the assessment effort to always focus on the dominant contaminants regardless of the level of resources allocated to CRCIA (see Appendix II-B).

An overview of the requirements in this section is:

(A1.0-1) All existing and potential contaminants and contaminant sources must be identified, characterized, and ranked for significance of potential impact. The characterization shall include atomic or molecular composition, mass, and location. It also shall include reactivity, solubility, and mobility. Materials shall be defined clearly enough to support tracing their movement through the media along their pathway to the Columbia River.

(A1.0-2) A composite source term shall be established that captures all potentially harmful radioactive and hazardous materials and contaminants on or near the Hanford Site.

(A1.0-3) A method to demonstrate and document completeness of the list of inventory sources and compositions used in the assessment shall be developed.

Approximately three and a half additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

2.0 Containment Failure and Contaminant Release

The requirements in this section call for assessment of potential contamination of the Columbia River expected to result from eventual containment failure. Radionuclides and hazardous chemicals are contained during disposal operations by some form of engineered containment. Over time, all containments will eventually allow leaks into the surrounding soil, air or water as containment fails. The analyst must determine when containment failure is projected to occur. The analyst also must determine the rate at which contaminants are projected to be released when containment fails.

An overview of the requirements in this section is:

(A2.0-1) A projected time of containment failure shall be determined based on the method of containment selected in the approved disposal plan. If the disposal plan includes defensible estimates of containment durability, these will be used.

(A2.0-2) The projected rates of release (progression of containment deterioration) shall be determined based on the approved disposal plan.

A2.0-3) Determination of release rates shall consider external migration rates in adjacent soils.

(A2.0-4) Candidate containment failure scenarios that span the range of possibilities shall be established.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

3.0 Transport Mechanisms and Pathways to the Columbia River

The requirements in this section call for transport of Hanford-derived contaminants to the Columbia River to be assessed. Existing transport models will be used to the extent that they satisfy the following requirements. An overview of the requirements in this section is:

(A3.0-1) Contaminant transport through the vadose zone to groundwater shall be assessed.

(A3.0-2) Contaminant transport through the groundwater to the Columbia River shall be assessed.

(A3.0-3) Transport characteristics of geologic formations, such as the Hanford formation and Ringold Formation, shall be established to the degree needed to support the assessment.

(A3.0-4) All other pathways of Hanford-derived contaminants to the Columbia River shall be considered. This shall include but is not limited to atmospheric releases, direct discharges, and transport of contaminants to the Columbia River by contaminated humans, plants, and animals.

(A3.0-5) Migration rates to and concentrations in the Columbia River of all contaminants shall be determined including estimates of holdup periods in travel time calculations.

(A3.0-6) Uncertainty in travel times and contaminant concentrations at the point of introduction to the Columbia River shall be assessed.

(A3.0-7) Transport of contaminants through all potentially dominant pathways from the source term to the Columbia River shall be assessed. See Principles and General Requirements and Appendix II-B for definition of "dominant."

(A3.0-8) Chemical forms and physical characteristics of radionuclides, such as solubility and soption rates, shall be considered to the extent that migration rates are affected. This consideration shall include probable modifications of the original contaminants' characteristics as contact is made with soils, groundwater chemistry, and other contaminants.

(A3.0-9) Decay of radionuclides during transport shall be evaluated.

Approximately three additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

4.0 Contaminant Entry into the Columbia River

The requirements in this section call for the determination of the entry locations and flux of contaminants as they enter the river.

Model and geological/hydrological description requirements must be established for introduction of Hanford-derived contaminants into the Columbia River through groundwater. The rates and locations of contaminant influx to the river must support investigations to determine potential contaminant distribution in the river. (Section 5.0 of this appendix).

Currently, the Hanford Site groundwater discharges into the Columbia River through seeps, springs, river bottom (for example, gravel substrate), and potentially as surface water during storms. Contaminants in dissolved, colloidal, and particulate form, enter the river through these paths.

Contaminated groundwater mixes with surface water. The groundwater contamination concentrations are eventually diluted to bulk river concentrations. Mixing begins in porous river bottom and is complete at a currently unspecified distance downstream from each given entry point.

Some of these contaminants can compromise the health of the river ecosystem. For example, early life stages of fish are susceptible to the toxic effects of hexavalent chromium which enters the gravel substrate of the Columbia River bottom. Section 6.0 of this appendix addresses the mapping of habitat critical locations to contaminant concentrations.

Groundwater influx, though difficult to quantify, must be defined. If generalizations are used instead of field data, potentially high concentrations in critical locations may be missed. Groundwater influx locations must be identified, the groundwater at those locations characterized, and the groundwater and expected contaminant loading quantified. The relationship between groundwater influx and river flow (for example, dam operations) must be established. The hydraulic conductivity at a given location greatly affects the amount and concentration of contaminant entering the river at that location.

An overview of the requirements in this section is:

(A4.0-1) Groundwater and surface water interactions shall be evaluated.

(A4.0-2) The interface with the Columbia River, including seeps, springs, and sub-surface influx into the river, shall be evaluated to support the assessment of biota exposures in the riparian zone and near the river bottom as required in Section 8.0 of this appendix.

(A4.0-3) The groundwater interface with the Columbia River, seeps, springs, and sub-surface influx shall be evaluated to support assessment of contaminant distribution in the river.

(A4.0-4) Valid interfaces shall be defined between groundwater transport assessment and the assessment of groundwater introduction into the Columbia River.

Approximately three additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

5.0 Fate and Transport of Columbia River-Borne Contaminants

The requirements in this section describe how the assessment must represent the way the contaminant distribution in the river evolves. The Columbia River redistributes contaminants to habitat where the contaminants may injure humans, ecosystems, and eventually cultures. It transports a large amount of water and a much smaller but significant amount of suspended solids (sediment). Some contaminants concentrate on the sediment particles, making them primary dose contributors in some situations.

Suspended sediment is continually settling, especially where flow rates are low. Sediment settles in holes and quiet water regions of the river, such as in sloughs and behind large rocks. Sediment settled on the river bottom can also be resuspended and carried downstream. Dissolved contaminants are carried by the river without settling out. Contaminants that dissolve out of the sediment are carried with the river water.

As slowly flowing groundwater approaches the river channel, it passes through the river bottom into the main body of the river. Contaminant concentration varies as it approaches and passes through the river bottom. Lateral mixing into the main body of the river is slow and not complete for perhaps tens of miles below the point of introduction into the river. Higher contaminant concentrations, resulting from high groundwater concentrations, persist along river streamlines emanating from contaminated groundwater influx points, until the mixing with the less contaminated river water is complete. The concern is redistribution of contaminants to critical locations where they may contact humans, plants, and animals at harmful concentrations and periods of time. Critical locations are defined in Section 6.0 of this appendix.

An overview of the requirements in this section is:

(A5.0-1) The fate assessment of river-borne contaminants (locations of sediment deposits) shall support exposure and dose assessment.

(A5.0-2) The transport assessment of river-borne contaminants shall support exposure and dose assessment.

(A5.0-3) Hot spots (contaminant concentrations) in the Columbia River which result from slow mixing of high concentration contamination sources with river water and suspended solids shall be assessed.

(A5.0-4) All Hanford contamination in the Columbia River environment that has the potential to significantly contribute to habitat or drinking water contamination shall be evaluated.

Approximately five additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

6.0 Critical Habitat and Uptake Locations

The requirements in this section call for identifying candidate locations of plant and animal life where contaminants are likely to enter exposure pathway webs. This includes habitats of both aquatic and river-dependent terrestrial life. The requirements also call for other critical locations, such as municipal water intakes, to be identified.

An overview of the requirements in this section is:

(A6.0-1) Candidate habitat locations within the study area shall be identified.

(A6.0-2) Cleanup impact on critical locations shall be assessed. See Section 11.0 of this appendix.

(A6.0-3) The spatial representation scheme shall support realistic representation of exposure to contaminants that occur at critical locations.

(A6.0-4) Any habitats within the study area that are considered high priority or sensitive by the State of Washington shall be accounted for. Habitats critical to the well being of plant and animal species that are classified as threatened, endangered, or sensitive by the State of Washington, the State of Oregon, the Federal Government, and/or the Indian Nations shall be evaluated.

(A6.0-5) Suspect areas with unknown characteristics shall be evaluated.

(A6.0-6) All available sources of information shall be cataloged and included in databases to the extent needed to meet assessment objectives.

Approximately two additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

7.0 Receptors and Exposure Pathways

The requirements in this section call for the identification of candidate receptors from which the receptors of concern (the study set) will be selected (see Appendix II-B). The requirements in this section also call for definition of the pathways through which receptor exposure potentially could occur. Examples of ways receptors may be exposed to contaminants include ingestion, inhalation, dermal exposure, or external radiation exposure.

The requirements in this section suggest some candidate receptors. Additional candidates will be identified upon determination of their criticality to other species because of their essential position in the web of ecosystem relationships.

An overview of the requirements in this section is:

(A7.0-1) An all-inclusive, internally consistent set of receptors shall be identified to include river-dependent humans, plants, animals, and groups whose activities bring them into contact with river corridor resources. These activities include but are not limited to sustenance, recreational, commercial, religious, and cultural practices. The term receptor also includes the culture of affected population groups (for example, the Yakama Indian Nation and Hispanic migrant farm workers) as well as the economic viability of commercial groups (for example, agriculture and river barge transportation). This requirement includes those candidate receptors who come into contact with river resources even though they may be a considerable distance from the river corridor under study. Examples include those coming into contact with commercially marketed fish, wide-ranging animals that drink at the river, water fowl, distributed municipal water, irrigation water, wind-blown sediments, and hydroelectric parts or equipment.

(A7.0-2) All interactions with river resources that may lead to contaminated habitat, food, or receptors and that contribute to exposure levels shall be evaluated.

(A7.0-3) All humans, animals, and plants that use habitat in the study area shall be considered as candidate receptors.

(A7.0-4) Pathway webs shall be developed which capture the relationships of the candidate receptors to river resources. Different relationship webs may be needed for each type of potential impact such as health effects, economic effects, and cultural practices. All such webs are expected to embody many of the river ecosystem relationships.

(A7.0-5) Intrusion scenarios which result in potential contaminant transport into the river corridor shall be evaluated for both humans and biota.

(A7.0-6) Exposure mechanisms related to airborne contaminants shall be evaluated for both humans and biota.

Approximately three additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

8.0 Dose Assessment

The requirements in this section address the calculation of the dose which results from potential exposure of the receptors to Hanford-derived contaminants.

Dose in individual biota is the presence over time of toxicant concentrations or energy deposition rates in the tissues of a selected receptor. The dose characterization needed varies with receptor role. If a particular biota category is of interest only as a contaminant carrier, simple mass uptake adequately characterizes dose. However, additional properties are needed to define the impact resulting from that dose. Contaminant uptake events that affect economic or socio-cultural groups must be identified.

Doses from past exposures can be obtained by sampling and measuring the receptors. Future doses must be estimated based on exposure models.

Dose calculations shall be made for each of the selected receptors of concern. The receptors of concern comprise a set selected from the candidate receptors (see Section 7.0 of this appendix). The requirements that describe the process to select receptors of concern are in Appendix II-B. After the receptors of concern set is developed, changes will probably seldom be needed. However, dose calculations may be constrained in some fiscal years to only a portion of the receptors of concern by CRCIA resource limitations. If dose calculations cannot be made for all receptors of concern, a subset will be defined using the requirements of dominance (see the Principles and General Requirements and section Appendix II-B).

An overview of the requirements in this section is:

(A8.0-1) Radiation and chemical doses shall be calculated for each of the receptors of concern for all contaminants in the dominant contaminants set.

(A8.0-2) Dose calculation scenarios will be defined for each receptor group having different activities in relationship to river resources and potential exposure. Examples include different scenarios for fishery and related river workers, farm workers where irrigation water is used, Native Americans, Tri-Cities residents, and metropolitan area industrial and office workers. Age and gender shall be considered in establishing absorption or uptake rates.

Approximately six additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

9.0 Receptor Impact and Tolerance Assessment

The requirements in this section translate receptor dose into adverse effects. Both current and future dose and effects from Hanford-derived contaminants must be assessed.

An overview of the requirements in this section is:

(A9.0-1) Acute health effects shall be assessed.

(A9.0-2) Chronic health effects including delayed health effects and cumulative effects from multiple exposures shall be assessed.

(A9.0-3) The full range of genetic effects shall be assessed in all affected populations.

(A9.0-4) The impact to community, tribal, and other populations' quality of life shall be assessed. This includes impact to jobs, housing, produce markets, and recreational opportunities.

(A9.0-5) The impact to tribal quality of life shall be assessed, including but not limited to:

(a) Restrictions on access to ancestral lands and heritage resources

(b) Interruption of transfer of educational and spiritual knowledge within the community and between generations

(c) Protection of cultural and religious values and sacred landscapes

(d) Degree of effort being expended to preserve or restore culturally important sites and resources within the study area

(e) Sustainable economic and environmental practices

(f) Access to open spaces

(g) Visual and aesthetic impact to landscape

(h) Trust in governing institutions

(i) Cost of avoiding exposure and illness

Approximately six additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

10.0 Assessment Scenarios: Columbia River, Climate, Geological, and Political Changes

Sections 1.0 through 9.0 of this appendix define requirements to comprehensively assess potentially adverse effects of Hanford-derived contaminants in the Columbia River. These requirements are to be applied to:

- Current or normal conditions
- Hypothetical but probable or credible scenarios

The requirements in this section specify the development of candidate scenarios that span all possibilities. Appendix II-B provides the requirements for winnowing these candidates to the most credible study set.

The normal scenario assumed in the preceding sections is defined by parameters that change either very slowly or unpredictably and constitute present-day expectations. While the preceding sections are based on a normal scenario, future scenarios must also be considered. Because all the possible combinations of scenarios would lead to an unworkable number of assessment cases, the number of scenarios must be limited. The set of scenarios to be included in the assessment are those that involve the largest impact of Hanford contaminants to the Columbia River.

An overview of the requirements in this section is:

(A10.0-1) A set of scenarios that depict the maximum impact from Hanford shall be defined.

(A10.0-2) Credible scenarios with parameters that depict increased consequences from Hanford contaminants shall be evaluated to establish a set of scenarios for use in a comprehensive assessment.

(A10.0-3) The limited set of scenarios to be evaluated shall include waste containment performance corresponding to the current Hanford Site disposition baseline for cleanup. See Section 11.0 in this appendix.

(A10.0-4) The limited set of scenarios to be evaluated include potential demographic changes for the river corridor area under study.

(A10.0-5) Scenarios to be assessed shall include but are not limited to:

(a) Scenarios that depict the groundwater recharge rate in a way that the maximum impact from Hanford is assessed. Examples are climate change, future site uses including irrigated agriculture, and river channel changes.

(b) Scenarios that depict contaminant dilution by groundwater or Columbia River water in a way that the maximum impact from Hanford is assessed. Examples are flood and drought scenarios, upgradient injection or extraction, disposition of present or new dams, and geologic events.

(c) Scenarios that depict enhanced remobilization of sediment in a way that the maximum impact from Hanford is assessed. Examples are future dredging, disposition of present or new dams, and river channel changes.

(d) Scenarios that depict potential changes in receptors. Examples are future Hanford land use scenarios, Hanford Site accident scenarios, transportation accident scenarios, demographic scenarios, economic scenarios, institutional evolution scenarios, and cultural evolution scenarios.

(A10.0-6) Scenarios to be evaluated include but are not limited to:

(a) Scenarios that involve increased inventories of dangerous materials at Hanford. An example is a projected future plutonium repository.

(b) Scenarios that depict the impact of newly introduced foreign species. An example is the introduction of Northern Pike.

(c) Scenarios that depict loss of institutional control over the Hanford Site after various time periods. The full range of probable times for loss of institutional control shall be evaluated.

(d) Scenarios that depict loss of cleanup funding

(e) Scenarios that depict the future production of plutonium and other new missions for the Hanford Site

(f) Scenarios that depict ecosystem changes

Approximately two additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

11.0 Hanford Site Disposition Baseline

The requirements in this section call for the Columbia River impact assessment to be consistent with the current definition of the Hanford Site after all cleanup and waste disposal actions are complete and institutional controls cease. Because this may be a very long period of time, an assessment is also needed for the transition period when operations are in process.

As the strategic planning changes which defines the Hanford Site post-operations end state, the assessment must be updated.

An overview of the requirements in this section is:

(A11.0-1) A complete disposition baseline shall be documented for purposes of the assessment.

(A11.0-2) The assessment shall be consistent with the current revisions of the Hanford disposition baseline.

(A11.0-3) The impact from actual and proposed remedial actions shall be assessed for compatibility with target, end-state conditions.

(A11.0-4) The retrieveability of new waste forms that are part of either interim or permanent remedies and which affect the Columbia River shall be assessed.

Appendix II-B

How Good the Impact Assessment Results Must Be

Appendix II-B
How Good the Impact Assessment Results Must Be

The requirements in this appendix call for the assessment to be performed in accordance with the principles of fidelity, dominance, and management of uncertainty as specified in the Principles and General Requirements section. As used here, fidelity carries the same meaning that it does in high fidelity sound reproduction. It expresses the faithfulness of reproduction of the actual performance without adding distorting noise or bias which may obscure the more delicate but crucial sounds. To be useful for addressing public and regulator concerns, the assessment results must have acceptable fidelity, in other words, an acceptably low level of error, distortion, and bias. Idealized Hanford impact simulations must be shown to capture the essential factors of the actual situation. Fidelity also must encompass the lowest impact levels of concern to stakeholders and regulators.

Applying the principle of dominance requires the selection of the largest contributors to contaminant impact from among the demonstrably complete set of candidates specified in Appendix II-A. All potentially harmful Hanford-derived materials and contaminants must be included as candidates. This appendix specifies that the most dominant must be selected as contaminants of concern.

Consistent treatment of uncertainty throughout the assessment is indispensable to controlling quality or how good the impact assessment must be. For example, inattention to uncertainty of some field data collection effort may relegate all the assessment's data to unacceptably poor levels. Fidelity of assessment results could become so poor because of uncertainties in just one area of the assessment that actual impact to some receptors may be obscured.

An overview of the requirements in this appendix is:

(B0.0-1) Impact assessment fidelity shall be adequate for the assessment uses and users, either those directing the Hanford cleanup effort or those affected by its results. See "Uses and Users" in the Principles and General Requirements section.

(B0.0-2) The impact assessment shall provide the range of impact values which bracket uncertain impact with high probability. For example, it may be decided that the results must be able to show that, with 95 percent certainty, 99 percent of all impact has been identified.

(B0.0-3) An explicit, documented definition and validation of model structure and parameters shall be established and maintained current with model and parameter revisions.

(B0.0-4) Overall assessment uncertainty objectives shall be consistent with the applicable definition of the post-cleanup Hanford Site end state.

(B0.0-5) Projected assessment quality shall be acceptable to the Columbia River Comprehensive Impact Assessment (CRCIA) Board. See Appendix II-D.

1.0 Fidelity of Detecting Harmful Effects

The requirements in this section call for the assessment calculations to represent actual conditions. Decisions on the acceptability of generalizations or deviations from reality must be made with an understanding and a concern for the people potentially affected by Hanford derived contaminants. Their cultural perspective and values are the only moral measures of the acceptable fidelity. Fidelity must be treated as a serious factor which requires major investments of time to gather information about the ecosystems and population groups in the study area.

One fidelity concern is identification of the periods of highest exposure, which correspond to the periods when peak contaminant concentrations reach the Columbia River. The evaluation of the ability of models with to predict peak exposure levels is particularly important.

An overview of the requirements in this section is:

(B1.0-1) Assessment fidelity shall be sufficient to enable impact assessment at a level determined by the needs of affected ecosystems and cultural groups.

(B1.0-2) Exposures and, therefore, effects vary with time over very long periods. The time at which high exposures occur is less important than the peak concentrations encountered, except to the extent that simultaneously arriving contaminants combine in their effects on receptors.

(B1.0-3) Temporal peak width shall be accurate enough to support estimates of multi-generational exposure.

(B1.0-4) The effect of uncertainty in the relative timing of peaks shall be considered in evaluating the uncertainty of combined (total) peak exposures. The timing of contaminant concentration peaks and their period (temporal width) shall be accurate enough in relation to each other that they adequately approximate total dose to an unspecified maximally exposed receptor generation, including the effect of individual contaminant peaks overlapping in time. See Appendix II-C, Section 2.0.

(B1.0-5) Uncertainty in peak exposure level shall be quantified and managed to enable detection of impact relative to the criteria developed in response to the requirements specified in "CRCIA Standards" in the Principles and General Requirements section.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

2.0 Model Integration and Consistency

The requirements in this section call for the overall assessment to conform to established physical laws and sound practice. This will help maintain the required consistency among all the subtasks and models in the assessment; for example, across geographical subdivisions.

An overview of the requirements in this section is:

(B2.0-1) Consistency shall be maintained between boundary conditions of partitioned sub-region analyses, supporting valid and seamless integration into the overall assessment.

(B2.0-2) Consistency shall be maintained at interfaces between models used in the assessment. Before models are designed or selected, interfaces must be defined in terms of the output data characteristics required from one model to enable the receiving model to function with consistency, for example, in uncertainty, and fidelity.

(B2.0-3) Mass and momentum shall be conserved across the study area. This includes but is not limited to between calculations of partitioned sub-regions of the Hanford Site and river corridor downstream.

(B2.0-4) Integration of model equations for all exposure process and harmful effects steps shall be validated before committing resources to their use.

(B2.0-5) Consistency and seamless integration are especially important requirements which also apply to the use of data from other studies and analyses.

3.0 Selecting Factors for Assessment: The Study Set

The requirements in this section parallel the sections in Appendix II-A. The purpose of Appendix II-A is to ensure that no relevant factor is overlooked. This appendix requires that for any level of CRCIA effort, the assessment always considers the most important factors. These requirements call for the narrowing of the candidate factors specified in Appendix II-A to those which dominate potential impact to the receptors, that is from a demonstrably complete candidate set to the dominate study set.

An overview of the requirements in this section is:

(B3.0-1) The impact assessment shall be designed so that the dominant threats to humans, cultures, and the Columbia River ecosystem are assessed and so that assessment resources and time are focused on correctly assessing the most severe threats.

(B3.0-2) The dominant sources of harmful effects, both existing and projected, shall be evaluated.

(B3.0-3) The assessment shall provide estimates of peak concentrations and the duration of contaminant pulses at all Columbia River locations of importance to the Hanford ecosystem and human users.

3.1 Hanford Materials and Contaminants

The requirements in this section assure that all Hanford radioactive materials and chemicals that could have an unacceptable impact are assessed. A suggested way to do this is to estimate the likely impact of contaminants and inventories with successive, iteratively refined models of the contaminant-transport-exposure-impact process.

Three additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

3.2 Containment Failure and Release

The requirements in this section call for selection of the dominant containment failure scenarios from among the candidates defined in Appendix II-A, Section 2.0. Radioactive materials and hazardous chemicals are expected to be contained after disposal following cleanup operations. They also are expected to slowly leak into the surrounding ground, water, and air when the containments eventually fail. Selection of the containment failure scenarios will be based upon credible probability of occurrence and the extent of resulting impact. To preserve CRCIA relevancy to cleanup decisions, containment performance information should come from only one source, the U.S. Department of Energy's (DOE's) approved disposal engineering plans. Only if no such documentation exists will alternate sources of information be used. This could include DOE performance requirements, or generally accepted performance estimates for the selected disposal method.

Two additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

3.3 Transport Mechanism and Pathways to the Columbia River

The requirements in this section call for selection of the transport mechanisms and pathways to the Columbia River from among the candidates defined in Appendix II-A, Section 3.0. Physical transport mechanisms are involved in the movement of contaminants from an inventory in a contaminated region or breached containment to the Columbia River. Selection of the level of detail in modeling or in choosing from among alternative mechanisms and pathways will be done using the principles of dominance, fidelity, and management of uncertainty. Pathways accounting for 95 percent of the receptors' dose shall be included for each of the scenarios in Appendix II-A, Section 10. Uncertainties may be large. If so, it may be desirable to determine the cost effectiveness of research efforts to reduce uncertainty to a level comparable with other calculations and modeling in the assessment.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

3.4 Contaminant Entry into the Columbia River

The requirements in this section call for field data and the selection of the interface models which describe the manner and locations where contaminants enter the Columbia River. Candidates were identified in Appendix II-A, Section 4.0. While groundwater may be perceived to be the most probable pathway and entry mechanism, some scenarios may suggest other pathways to be more dominant and will require attention to other entry methods and locations. Applying the principles of dominance and fidelity to this selection process may depend on considerations such as habitat and drinking water uptake locations.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

3.5 Fate and Transport of Columbia River-Borne Contaminants

The requirements in this section call for selection of the dominant, most credible mechanisms of contaminant concentration upon initial entry into the Columbia River. The requirements also address the rate and pattern of mixing with bulk river water, reconcentration of diluted contaminants, and redistribution of contaminated sediments. Candidate mechanisms were developed in response to the requirements in

Appendix II-A, Section 5.0. Examples of situations these requirements examine include reconcentration of contaminants in soils through years of using weakly contaminated irrigation water, reconcentration of contaminants on hydroelectric equipment which is exposed for years to large volumes of water, and the redistribution of contaminated sediments by dredging or the eventual removal of dams. Rates and patterns of mixing with bulk river water also require insightful selection from among candidate scenarios such as patterns of dam operations and cyclical river flow rates.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

3.6 Critical Habitat and Uptake Locations

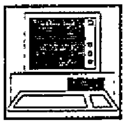
The requirements in this section call for selection of dominant uptake mechanisms and locations which result in the largest contributions to receptor dose. Candidate ecosystem habitat locations and requirements to identify candidate critical uptake locations such as drinking water uptake were addressed in Appendix II-A, Section 6.0. The selections specified in this section define the interface between distributed contaminants and the biotic exposure webs, such as food chains. Matching locations of concentrated contaminants with critical uptake is key to the assessment.

Two additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

3.7 Receptors and Exposure Pathways

The requirements in this section address selection of the receptors of concern (the receptor study set) from among the candidates identified in Appendix II-A, Section 7.0. Selections must also be made from among the candidate exposure pathways such that the chosen exposure models (the pathway study set), regardless of depth of detail, always represent the most important pathways to the potentially highest impacted receptors. In addition to the candidate receptors required to be considered for selection in Appendix II-A, Section 7.0, this section also requires selection of candidate receptors if they occupy crucial positions in food chains, cultural webs, economic networks, or any other receptor dependency web. If resource allocations to CRCIA are highly constrained, tradeoffs may have to be made between assessing more receptors or a broader spectrum of contaminants, for example. In any case, the most highly impacted receptors and the most dominant exposure pathways must be selected — a balance achievable only through interative executions of rough order-of-magnitude calculations prior to commitment of significant resources.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.



3.8 Dose Assessment

The requirements in this section address how well the dose characterization and quantification requirements in Appendix II-A, Section 8.0, must be implemented. Dose assessment provides the basis for assessing the impact because doses correlate with impact. Dose characterization approximates and simplifies dose. The dose as characterized must represent the actual or impeding dose to an acceptable degree of approximation. For example, dose is characterized in part by the selected Contaminants of Concern. Dominant contaminants are selected on the basis of their contributions to dose. Simplifying approximations must be applied similarly to other factors determining dose. Dose characterization must be statistical. Dose distribution across population groups must be assessed. Because of their disproportionate contribution to impact, the dose to the most highly exposed members of a population group is important. The tails of the distributions on the side of high dose are of particular importance to values, such as equity.

3.9 Receptor Impact and Tolerance Assessment

The requirements in this section call for selection of the dominant adverse effects from among the candidates required to be considered in Appendix II-A, Section 9.0. This section also requires the adverse effects selected for evaluation (the study set) be assessed with sufficient fidelity to reveal actual conditions. Project scope limitations will constrain these choices. Unexpected potential adverse effects discovered in the course of the assessment must be identified and either included for assessment or shown to be less than the least dominant impact previously selected.

3.10 Assessment Scenarios: River, Climate, Geological, and Political Changes

The requirements in this section call for selection of the dominant scenarios from among the candidates required to be considered in Appendix II-A, Section 10.0. Dominant scenarios are chosen based on both the severity of their effects on impact and the likelihood of their occurrence. Scenarios provide stakeholders and decision makers a measure of the effectiveness of cleanup solutions.

4.0 Assessment Software Requirements

The requirements in this section call for software characteristics that meet assessment needs. The requirements in this section are:

(B4.0-1) Software shall be designed, implemented, or procured on the basis of explicit requirements.

(B4.0-2) Model representation of dominant contaminants and pathways shall include all elements necessary to describe dominant elements of dose.

(B4.0-3) Verification and validation shall be performed on software.

(B4.0-4) A Quality Assurance Plan shall be established before any software is developed or procured.

(B4.0-5) A Software Test Plan shall be established during software requirements phase.

(B4.0-6) Software reviews (walk-throughs) shall be held for each software module. Reviews shall include verification of software interfaces.

(B4.0-7) Formal technical reviews shall be held at the end of the software requirements phase, the software design phase, and for analysis software integration prior to calculating assessment results.

(B4.0-8) Software design quality shall be evaluated and reviewed for acceptability by qualified independent reviewers approved by the CRCIA Board.

(B4.0-9) Software testing requirements shall be established during the software requirements phase.

5.0 Assurance of Assessment Quality

A concept and implementation approach to control the quality of the assessment during execution of the work shall be developed. This approach together with descriptions of the quality assurance work tasks to be done shall be published in a brief quality assurance plan. Required topics to be addressed in the plan follow and include confirmation that factors included in the assessment are the most dominant, confirmation of consistent treatment of uncertainty, and ensuring acceptable fidelity in the assessment results.

An additional page of explicit, detailed requirement for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

Appendix II-C

Analytical Approach and Methods

Appendix II-C
Analytical Approach and Methods

The requirements in this appendix specify that the Columbia River Comprehensive Impact Assessment (CRCIA) analysis process is to be designed and technically conducted so as to objectively reveal probable adverse effects. Appendix II-A, in contrast, addressed the factors to be considered in the exposure process and determination of its impact. The analysis process performance needed is driven by the quality requirements for the assessment results specified in Appendix II-B. The analysis must effectively cut through the complexity of the exposure process and the consequent adverse effects to quantify the essential, or dominant, contributors to the impact. A comprehensive impact assessment can only be realized if the analysis process performs this function. Contaminants and effects are quantitatively related by modeling.

An overview of the requirements in this appendix is:

(C0.0-1) The analysis process design shall possess the capability to assess all impact, or threats of impact, listed in this document or discovered through the efforts of analysts and the CRCIA Board.

(C0.0-2) The analysis process shall identify, select, and organize the dominant sources of impact, and the dominant pathways and pathway characteristics from the sources to their adverse effects.

(C0.0-3) Models of the exposure process and consequent impact shall be validated.

(C0.0-4) The capacity to evaluate and respond to timeliness and quality tradeoffs shall be designed into the assessment process.

(C0.0-5) The assessment process shall manage uncertainty to achieve balanced uncertainty reduction as well as integration with management of dominant factors.

(C0.0-6) The architecture and integration features of the analysis process shall be specified prior to commitment of the major funding.

(C0.0-7) The assessment process shall incorporate a well defined data quality management process.

(C0.0-8) Assessment methods that are consistent with and integrate with other impact assessment requirements shall be adopted or developed and verified.

(C0.0-9) The assessment process shall manage verification.

(C0.0-10) Analysis research and development needs shall be identified.

(C0.0-11) Standards will be compiled especially for CRCIA as discussed in the General Requirements Section.

1.0 Identification and Management of Dominant Factors

The requirements in this section call for the assessment to always evaluate those factors having the greatest contribution to receptor exposure and consequent impact. A comprehensive assessment must describe the dominant effects and relationships involved. By focusing on dominant factors, simplified approximations can be used in models without compromising their validity. However, representing behavior in terms of dominant factors is a two-edged sword. The representation problem is intractable without limiting the representation to dominant factors. But, failing to include a major contributor distorts the answer, perhaps seriously. While less important factors must be excluded to conserve resources, all important factors must be included for validity. Failure to distinguish between important and unimportant factors is not acceptable. Distinguishing between the two is the subject of this section.

In model formulation an iterative search for dominant process features must be done. For example, in searching through the possible factors influencing an impact to identify the essential (dominant) set, indirect, as well as direct, effects must be considered. Dependencies among receptors may affect the dominant set. For example, a receptor of concern's dependency on other receptors may cause effects on them to be propagated to the receptor of concern. Relatively small effects on several receptors of no apparent interest may be cumulative in a receptor of interest. For example, predator/prey relationships in the food web may lead to substantial cumulative dose in a receptor of concern. If such chains of effects contribute significantly to the total impact, they must be carefully preserved in representing the progression of adverse effects. Impact may also be manifested through dynamic instabilities. For example, non-linear dynamics or positive feedback can cause sudden, unexpected population collapse in a threatened ecosystem.

By definition, a set of dominant factors accounts for the bulk of the related impact, to any required degree of completeness. Any set of factors that fails to account for the impact to the required degree of completeness is not a dominant set. The most influential factors must be included in the dominant set, both for effective simplification and to meet completeness requirements. Dominant factors can take the form of pathways, relationships, contributors to, or elements of, dose or effects.

An additional page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

Conceptualization of the technical approach to the assessment must account for, if not begin with, the selection of methods and criteria with which to select the study set (dominant factors) from the candidate set (all-inclusive factors) in each module of the assessment process. For any given iteration of the assessment, all the assessment modules (see Figure C-1 below) will be included. However, the depth of detail will vary, that is, the number of factors making up the study set from each module will differ depending on their significance to the assessment end result. The study set selection methods must determine the depth of detail in each module such that a balance in significance is struck across all modules. This becomes a key in technical direction to each module's technical leader. It also becomes key in recommending budget allocations for the modules to the CRCIA management. It should be expected that the study set size and resource allocation for each module will have to be reviewed periodically as new information and modeling provide new insight to the significant contributors to the assessment final result. It is likely to be found that the study set selection methods involve an iterative series of sensitivity studies using first coarse, then progressively better approximations (models) of exposure and impact.

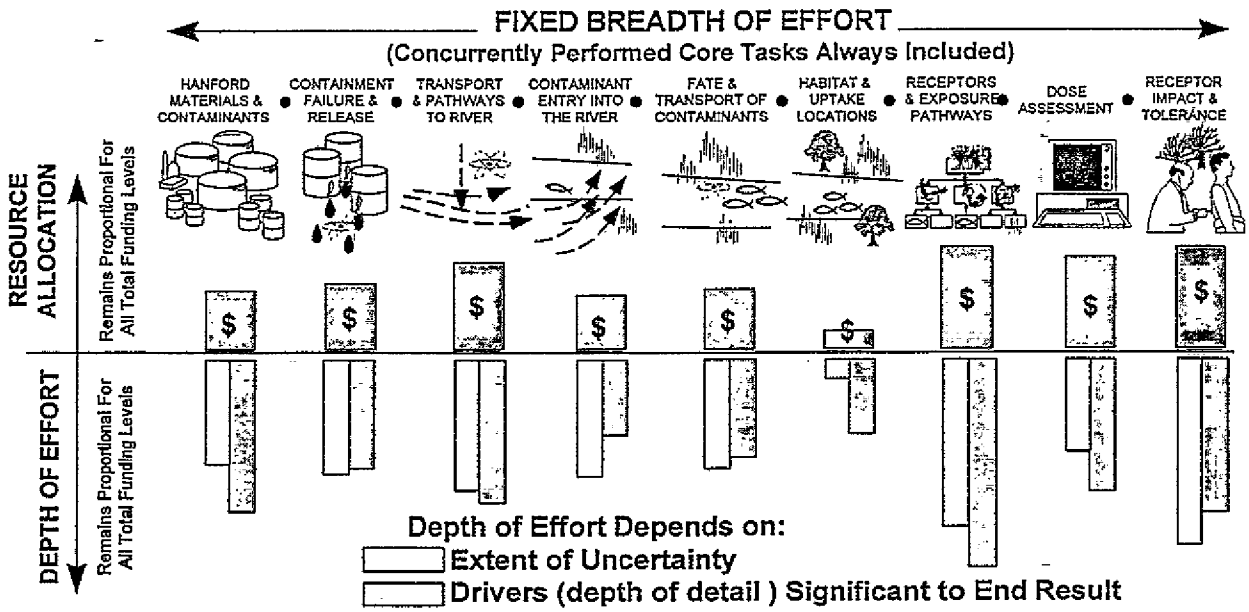


Figure C-1. Management of Dominance and Uncertainty

The sources of uncertainty and their extent of contribution to the overall uncertainty of the assessment's end result also vary across the nine assessment modules. To conceptualize the technical approach to the assessment, methods must also be selected to estimate the extent of uncertainty contribution. Because technical effort and resource allocation should be made such that overall uncertainty of results is reduced, it is necessary to reduce the uncertainty from the largest contributors. Figure C-1 depicts this relationship graphically. Further, uncertainty and dominance are coupled. For example, some given factor may be very uncertain but of little consequence to the assessment results. Therefore, the technical approach must include methods which can estimate these combined effects and balance the depth of effort across the modules such that both the most important factors and the degree of uncertainty receive appropriate resources and investigative efforts.

2.0 Identification and Management of Uncertainty

The requirements in this section call for uncertainties to be identified, quantified, and managed. An appropriate level of allowed uncertainty which considers both needs and costs is to be established through interaction by analysts and the CRCIA Board. The uncertainty, or probability distribution, of exposures and biological damage depends many factors. Examples include:

Scenario Uncertainty:

(a) Climate (recharge rate) uncertainty
(b) Socio-economic evolution
(c) Ecosystem evolution

Performance Uncertainty:

(a) Performance of the cleanup approach causing the exposure
(b) Technological uncertainty—maturity of technology and application experience
(c) Institutional performance uncertainty

Analysis Uncertainty:

(a) Data/parameter uncertainty
(b) Model uncertainty

Management involves reducing those uncertainties that reduce overall impact uncertainty the most for the available money. An iterative approach, starting from a coarse initial analysis and progressing through ever more refined analyses, with uncertainty reduction at each step, is normally used. Dominant uncertainties, uncertainties that are the largest contributors to overall impact uncertainty, are addressed. Irreducible uncertainty is reached when reducing the largest sources of uncertainty is beyond the available time and resources.

Note that dominance among uncertainties is closely related to dominance as discussed in the previous section and should be treated in a unified process using, for example, the methods in National Council on Radiation Protection and Measurements (NCRP) Commentary No. 14 (1996).

Two additional pages of explicit, detailed requirements for this section have been identified from stakeholder concerns, issues, and experience. They do not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. They should be separately available by this draft's publication date for those who would like to request a copy. They will be included in the final document.

3.0 Analytical Architecture and Integration

The requirements in this section call for the assessment process to have an architecture that:

(a) Supports iterative refinement of analysis products

(b) Uses resources well, performing up-front scoping analyses to ensure purposeful and efficient execution of main-line tasks

(c) Proceeds along a well-defined path to the final product

(d) Is well integrated, using pre-defined intermediate analytical products effectively

3.1 Functional Definition of the Analysis Process

The requirements in this section call for a complete functional definition of the assessment process to be done prior to assessment planning. They also call for major intermediate assessment products to be defined, and the functions needed to produce the products to be identified.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

3.2 Internal Interfaces of the Analysis Process

The requirements in this section call for the input information categories, intermediate products, and final assessment products to be well defined during design of the assessment process.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

4.0 Data Quality

The requirements in this section call for data quality, data gaps, data acquisition, and verification and validation to be managed in a balanced way and consistent with other requirements.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

5.0 Assessment Methods

The requirements in this section describe the characteristics the analysis methods and procedures used in the assessment must have.

(1) Assessment methods shall estimate the likelihood and severity of all the effects to be assessed.

(2) Assessment methods shall satisfy the quality requirements in Appendix II-B.

(3) Risk assessment methods shall be capable of detecting impact levels that affect the sustainability, robustness, and viability of the Columbia River ecosystem or stakeholder cultures.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

6.0 Verification

The requirements in this section call for the assessment process design to be properly verified before it is implemented.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

7.0 Analysis Research and Development Needs

The requirements in this section call for research and development needs for new or modified analytical methods to be promptly identified. They also call for research and development expenditures and efforts to focus on areas that make the most difference in assessment quality and assessment process performance.

Research to determine relative importance of factors which influence adverse effects will be an important part of identifying dominant assessment factors. The benefits of such research include assessment completeness and uncertainty reduction.

It is expected that, because of the delays and expense such development efforts entail, every effort will be made to incorporate the requirements for this assessment into previously planned and scheduled research efforts.

An additional half page of explicit, detailed requirements for this section has been identified from stakeholder concerns, issues, and experience. It does not appear in this draft due to insufficient time to develop an orderly presentation reasonably free of error or redundancy. It should be separately available by this draft's publication date for those who would like to request a copy. It will be included in the final document.

8.0 CRCIA Standards, Regulations, and Guidelines

The requirements in this section identify the standards to be used in the analytical process (see "Standards" in the section on Principles and General Requirements.)

(1) The applicability of federal, State of Washington and State of Oregon laws and guidelines shall be evaluated and reported to the CRCIA Board.

(2) Analysis methods shall be compatible with pertinent State of Washington and Oregon water regulations. Regulations such as Washington's Clean Water Act, Surface Drinking Water Act, and Model Toxins Control Act must be evaluated for applicability and relevance. The evaluation must be approved by the CRCIA Board.

(3) The most stringent applicable standards shall be identified and applied. For example, salmon related standards shall be applied in regions where salmon are affected. This means an analytical sensitivity below 11 parts per billion of chromium (the concentration at which injury to juvenile salmon occurs) in salmon reads shall be achieved rather than 50 parts per billion as required by the clean water (human) standard.

Appendix II-D

Conducting and Managing the Assessment

Appendix II-D
Conducting and Managing the Assessment

The requirements in this section define how the assessment process is to be managed (see Figure II-D.1). They establish:

- Authority for direction of the assessment and the stakeholder roles in the directive process.
- Role of the sponsoring organization, including administration and funding.
- Responsibilities.
- Assessment planning, budget preparation, and resource allocation.
- Progress reporting to stakeholders.
- Oversight and review.
- Integration with waste disposal decision-making.
- Implementation.
- Control of changes in assessment results, planning, and budgets, as well as changes to the requirements in this document (Part II).

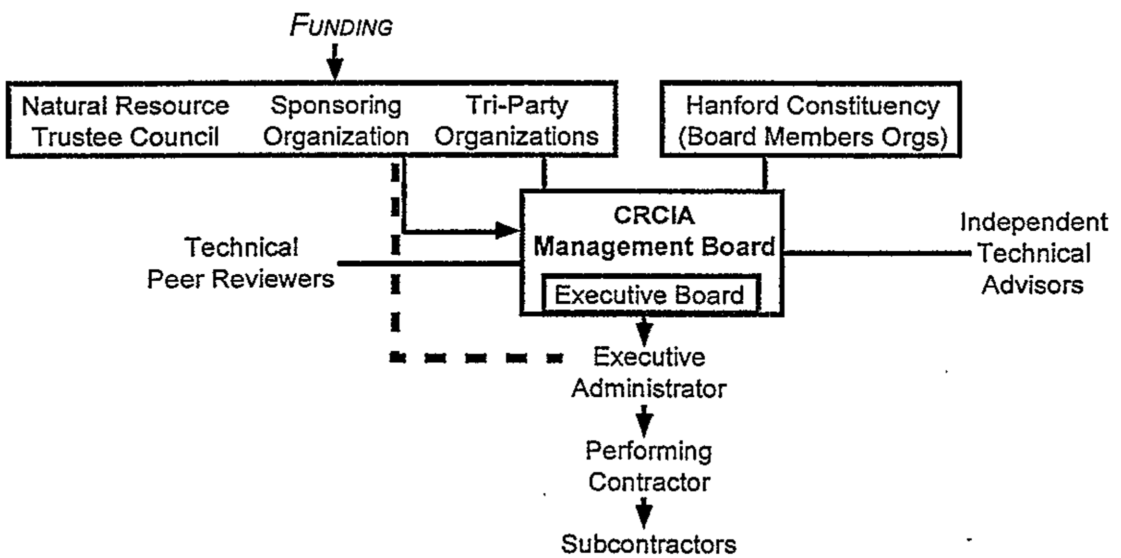


Figure D.1. Management of the Columbia River Comprehensive Impact Assessment

1.0 Project Direction and Stakeholder Steering Roles

A group representing the people affected by the cleanup and waste disposal decisions at Hanford, the Columbia River Comprehensive Impact Assessment (CRCIA) Board, will serve as the steering authority for the conduct of the assessment. This document, supplemented by a Board Charter, establishes and empowers the CRCIA Board. The Board manages the conduct of the assessment under the auspices of the Tri-Party Agreement and the Natural Resource Trustee Council. The requirements in this section are:

(D1.0-1) Membership of the CRCIA Board will be sought to represent:

(a) General citizenry affected by Hanford
(b) Persons who use the Columbia River for sustenance, commerce, or recreation
(c) Affected Tribal governments
(d) Tri-Party Agreement agencies
(e) Federal and state regulators of Hanford
(f) Federal, state, and local public health agencies
(g) Hanford Natural Resource Trustee Council
(h) Fish and wildlife agencies
(i) Representatives of the affected local, state, and federal governments

Participation on the CRCIA Board does not abrogate the sovereignty of Indian Nations, state or local governments, nor does it preclude separate action.

(D1.0-2) The decision authority established for the CRCIA Board applies solely to the conduct of the impact assessment. Unless specific individuals are invited to make personal recommendations, involvement of assessment personnel in other Hanford Site decision-making activities is limited to the presentation of assessment results. Assessment results will not include judgments on the acceptability of river conditions (as opposed to portraying regulatory standards) or suggested disposal solutions. Personal recommendations must be clearly understood to be only the views of the individual and do not represent the Board or the assessment project.

(D1.0-3) Within the Board, an Executive Board will be established. The Executive Board will conduct the hands-on management of the assessment while the full Board will establish policy and provide executive oversight of the on-going assessment activities. The full Board will meet at regular intervals as needed, monthly, for example. The Executive Board, however, will need to meet more frequently, perhaps weekly, and for longer sessions, such as a half or full business day. Additional meetings will be convened as needed.

(D1.0-4) The Executive Board will be composed of representatives of the Tri-Party Agreement agencies, the governments of the states of Washington and Oregon, the Hanford Advisory Board, and the sovereign governments of the Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, and Yakama Indian Nation. This participation is essential.

Reimbursement for time and expenses may be a condition for some members' participation. The Board is authorized to make funds available from the funding authorized to CRCIA from the sponsoring organization.

(D1.0-5) Among the responsibilities of the CRCIA Board is planning the conduct of the assessment and preparing the annual budget proposal. Both the sponsor's administrative staff and the performing contractor will assist as requested. The CRCIA Board will present and defend each CRCIA budget proposal to the sponsor's budget decision-making body and to higher authority as warranted. Definition and planning of the assessment's technical work is to be accomplished by the performing contractor under the guidance of the CRCIA Board.

(D1.0-6) The CRCIA Board may, through the sponsoring organization, hire independent experts to advise or perform intermittent special technical tasks for the Board. Similarly, the Board will need independent peer review services which, like the technical advisors, will be acquired through the contracting capabilities of the sponsoring organization or performing organization. The experience of these advisors and peer reviewers should be from outside the Hanford and U.S. Department of Energy (DOE) community to the extent feasible considering the degree of familiarity with Hanford Site cleanup the Board feels to be essential.

(D1.0-7) The meetings and all other business of the CRCIA Board will be open to the public. However, in view of the broad based public representation comprising the Board, it is expected that input from the public will usually be made through the appropriate representative.

(D1.0-8) The CRCIA Board will prepare a Charter to formalize its existence, responsibilities and operations.

2.0 Roles of the Sponsoring Organization

The sponsoring organization is that group which funds and advocates accomplishing the assessment, most probably, but not necessarily, DOE's Richland Operations Office. The organization serving as the sponsor and funding agent of this assessment will defer to the CRCIA Board to manage the conduct of the assessment. The requirements in this section are:

(D2.0-1) The sponsoring organization will keep the CRCIA Board informed of the need for funding information and budget requests. While the Board will represent the assessment project in budget reviews and related resource allocation activities, the sponsoring organization is expected to provide fair and impartial advocacy of the assessment project's needs in day-to-day funds management activities.

(D2.0-2) The sponsoring organization will provide a senior, well qualified manager to serve as project manager within the sponsoring organization and as executive administrator within assessment activities. This person must have sufficient stature and respect within the sponsoring organization to enable authority to be delegated to him or her to act for and, in all but sensitive policy areas and funding matters, to commit the sponsoring organization to the agreements reached in

Board deliberations. In all matters, the executive administrator will reflect and advocate the Board's consensus positions and sentiments. The sponsoring organization will also provide reasonable staff support to the executive administrator.

(D2.0-3) The CRCIA project will rely upon the sponsoring organization to provide:

(a) General administrative services

(b) Meeting support services, including minutes, conference rooms, and audio/visual equipment

(c) Procurement and subcontracting services, including contract management of the contractor performing the assessment analytical work

(d) Payroll and/or expense reimbursement services for those Executive Board members whose participation is not possible without financial support

(e) Publishing services, including controlled document distribution and support

(f) Liaison and support services with other project managers and senior DOE officials to ensure integration of the CRCIA with other Hanford Site activities and decision-making

3.0 Performing Organization and Subcontractors

(D3.0-1) The sponsoring organization in collaboration with the CRCIA Board will select and contract with the most highly qualified company available to perform the assessment. Subcontractors will also be selected in collaboration with the CRCIA Board. In all cases, contractor selection will be made so as to avoid a conflict-of-interest.

(D3.0-2) The performing organization will be responsive to the CRCIA Board's direction through the sponsoring organization and appropriate contract provisions.

(D3.0-3) The performing contractor is responsible to ensure that the Board acts in all matters with a grasp of the relevant technical considerations.

4.0 Conflict of Interest

(D4.0-1) Potential or perceived conflict-of-interest will be acted upon by the Board as appropriate.

5.0 Relationship with Hanford Site Decision-Making

(D5.0-1) In accordance with the stated purpose for performing this assessment, it is expected that the results and conclusions will be used by Hanford Site decision-makers to:

(a) Help determine the manner in which remediation and waste disposition should be done

(b) Validate the waste disposition decisions already made or justify a revision in planned actions

(c) Provide advice and recommendations to people down river from Hanford

(D5.0-2) In view of the intended uses of assessment results, the CRCIA Board must plan and schedule the key milestones in the assessment to yield timely information for the Hanford Site decision making process. The Executive Administrator will keep the Board advised of:

(a) Budget preparation, review, and allocation schedules
(b) Hanford Environmental Impact Statement and Record of Decision schedules
(c) Key strategic planning activities
(d) Formulation efforts for other key decision documents at both the Site and project levels

(D5.0-3) The Board will consider the use of such devices as a newsletter, flash reports, and similar tools to both advise Hanford project managers of significant CRCIA developments and also to encourage informal networking between the assessment project and the decision makers.

(D5.0-4) The Board must constantly strive to have assessment results available which reveal the overall Hanford Site performance for each officially approved waste disposal baseline. This applies whether the expression of that baseline occurs in formal strategic planning documentation, in environmental impact statements, or in budget proposal planning assumptions.

6.0 Management and Progress Reviews

(D6.0-1) The CRCIA Board will, with support from the sponsoring organization and performing contractor, develop and maintain a resource loaded project work plan spanning the life of the project. Currency of the work plan, progress, and problem resolution responsibilities will be reviewed regularly, perhaps monthly, by the Executive Board and reported to the full CRCIA Board.

(D6.0-2) The CRCIA Board is responsible for the allocation of the funding provided as well as the financial state of the assessment project. The Board may appoint one of its members to serve as Financial Manager. The project work plan will be the basis for preparation of budget proposals and reports. Financial information available through the existing cost reporting systems of the sponsoring organization and performing contractor will be used as appropriate.

(D6.0-3) The Board will ensure that resources and budgets are allocated in accordance with the results of the required sensitivity studies which are intended to identify and rank order the factors contributing most to impact to the river (See Appendix C, Section 2.0). This approach will require that funding is allocated to the evaluation of the most dominant drivers first. This requirement is the cornerstone of financial management for the project and for defining and revising work plans.

(D6.0-4) At the Board's discretion, gates should be defined at key junctures in the work plan schedule. The gates should define conditions to be met during the assessment which measure work progress and keep subtasks in harmony with one another. Gates also improve financial management within the project. Reporting the extent to which gate conditions are being met should be included in management reviews.

(D6.0-5) After completion of any given work plan, literature searches will be done. This is to determine if technical work done in the past meets the needs of the work plan and the requirements of this document. If so, the results may be used in lieu of performing the work again in the CRCIA project.

(D6.0-6) The CRCIA Board will receive a progress report presentation from the sponsoring organization and performing contractor on a regular basis, perhaps monthly. Observers, especially representatives of the sponsoring organization and Tri-Party Agreement agencies, may be invited to participate.

(D6.0-7) The Executive Administrator and performing contractor will provide a written quarterly progress report to the Board for approval and transmission to the Tri-Party Agreement agencies and sponsoring organization.

(D6.0-8) Periodic reviews of progress and findings will be made by the Board with the organizations represented on CRCIA Board.

7.0 Public Outreach

The CRCIA Board will remain mindful of its burden to responsibly represent the public who, through Hanford's impact on the Columbia River, are affected by the cleanup program's waste disposal decisions. The structure of the CRCIA management approach is designed to enable the public's meaningful involvement in directing the assessment. However, this will be achieved only to the extent that each Board member aggressively develops and maintains a rapport with the constituency to which he or she is accountable. The requirements in this section are:

(D7.0-1) The CRCIA Board will develop a public outreach plan that shall include but not be limited to the following:

(a) Regularly provides assessment reports to interested parties informing them of the emerging insights into the present and future states of the Columbia River together with the causes of any projected impact

(b) Provides innovative opportunities for meaningful and effective public participation in assessment project reviews

8.0 Technical Oversight

(D8.0-1) At the discretion of the Board, periodic technical reviews will be made by independent, qualified experts. These reviews may be of the assessment project in general, of the technical approach(es) planned, or of the results obtained. Peer review comments and recommendations will be made available to anyone who requests them. The experience of the reviewers should be from outside the Hanford and DOE community to the extent feasible considering the degree of familiarity with Site cleanup the Board feels to be essential.

9.0 Implementation

The management approach prescribed for CRCIA defines a new paradigm for predecisional participation by affected people. Realizing that it will take time to adapt the supporting infrastructure, the CRCIA Board will work cooperatively with existing policies and practices while helping to develop more effective processes. Throughout the implementation period, the Board will entertain suggestions to revise and update requirements in this document. However, the basic approach and structure is considered sound. The requirements in this section are:

(D9.0-1) Throughout the conduct of the Screening Assessment and preparation of these requirements, the CRCIA Board functioned as a stakeholder advisory team. It has been composed of the Tri-Party Agreement agencies, the governments of the states of Washington and Oregon, the Hanford Advisory Board, and the sovereign governments of the Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, and Yakama Indian Nation. Implementation of these requirements broadens the membership of the Board and changes its role to management of the assessment effort.

(D9.0-2) The existing CRCIA Team will determine when the full CRCIA Board should be formed. Probably the existing team will remain unchanged while preliminary assessment tasks are being performed. The other provisions of this appendix will be implemented on the date(s) established by the existing team or on the date this document is published as revision zero.

10.0 Control of Changes to the Assessment Project

The CRCIA Board or the Executive Board acting in the Board's behalf is the only approval authority for changes in the assessment's work plans, budget allocations, findings, or for changes to the requirements in this document, Part II. The requirements in this section are:

(D10.0-1) Upon initial release in its final form, Part II of this document will be controlled by the CRCIA Team. It will be released as revision zero (Rev. 0). Subsequent revisions distributed by interim correspondence can be approved only by the CRCIA Board or the Executive Board acting in the Board's behalf.

(D10.0-2) The assessment project work plan, after its initial preparation and approval by the Board, will be revised only upon approval by the Board. However, it is expected that the Board will provide the performing contractor moderate discretionary authority to make operational deviations in keeping with the provisions and spirit of this document and the work plan.

(D10.0-3) Results from the assessment will be released only after review and approval by the Board. Findings of subsequent technical work indicating a need to update these conclusions will be approved by the Board prior to release and prior to revising earlier assessment results.

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