TABLE E-16. Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1-Hour Average Concentration (g/m^3)
103.632	121.920	0.84920E-07
109.728	121.920	0.23430E-07
115.824	121.920	0.90110E-07
121.920	121.920	0.25260E-07
128.016	121.920	0.33810E-07
134.112	121.920	0.69710E-07
140.208	121.920	0.32610E-07
146.304	121.920	0.70900E-08
152.400	121.920	0.29370E-07
158.496	121.920	0.48230E-07
164.592	121.920	0.38920E-07
170.688	121.920	0.18190E-07
176.784	121.920	0.55900E-08
182.880	121.920	0.75800E-08
188.976	121.920	0.16270E-07
195.072	121.920	0.24800E-07
195.072	115.824	0.30650E-07
195.072	109.728	0.12580E-07
195.072	103.632	0.59300E-08
195.072	97.536	0.26860E-07
195.072	91.440	0.33090E-07
195.072	85.344	0.10110E-07
195.072	79.248	0.11460E-07
195.072	73.152	0.36010E-07
195.072	67.056	0.24690E-07
195.072	60.960	0.35600E-08
188.976	60.960	0.39600E-08
182.880	60.960	0.44300E-08
176.784	60.960	0.49900E-08
170.688	60.960	0.56600E-08
164.592	60.960	0.64800E-08
158.496	60.960	0.74700E-08
152.400	60.960	0.87100E-08
146.304	60.960	0.10270E-07
146.304	54.864	0.91820E-07
146.304	48.768	0.15660E-07

TABLE B-18. Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1-Hour Average Concentration (g/m^3)
146.304	42.672	0.81140E-07
146.304	36.576	0.29800E-07
146.304	30.480	0.48830E-07
146.304	24.384	0.61430E-07
146.304	18.288	0.95200E-08
146.304	12.192	0.57720E-07
146.304	6.096	0.45820E-07
146.304	0.000	0.70900E-08
140.208	0.000	0.32610E-07
134.112	0.000	0.69710E-07
128.016	0.000	0.33810E-07
121.920	0.000	0.25260E-07
115.824	0.000	0.90100E-07
109.728	0.000	0.23430E-07
103.632	0.000	0.84910E-07
97.536	0.000	0.46250E-07
91.440	0.000	0.92330E-07
85.344	0.000	0.38270E-07
79.248	0.000	0.12115E-06
73.152	0.000	0.14940E-07
67.056	0.000	0.12115E-06
60.096	0.000	0.38300E-07
54.864	0.000	0.92330E-07
48.768	0.000	0.46280E-07
42.672	0.000	0.84910E-07
36.576	0.000	0.23430E-07
30.480	0.000	0.90100E-07
24.384	0.000	0.25260E-07
18.288	0.000	0.33810E-07
12.192	0.000	0.69700E-07
6.096	0.000	0.32610E-07

TABLE B-17. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

X Coordinate (m)	Y Coordinate (m)	1-Hour Average Concentration (g/m^3)
0.000	0.000	0.44300E-06
0.000	6.096	0.28640E-05
0.000	12.192	0.36070E-05
0.000	18.288	0.59400E-06
0.000	24.384	0.38390E-05
0.000	30.480	0.30510E-05
0.000	36.576	0.18620E-05
0.000	42.672	0.50710E-05
0.000	48.768	0.97900E-06
0.000	54.864	0.57390E-05
0.000	60.960	0.64200E-06
0.000	67.056	0.57390E-05
0.000	73.152	0.98000E-06
0.000	79.248	0.50710E-05
0.000	85.344	0.18630E-05
0.000	91.440	0.30510E-05
0.000	97.536	0.38400E-05
0.000	103.632	0.59400E-06
0.000	109.728	0.36070E-05
0.000	115.824	0.28640E-05
0.000	121.920	0.44400E-06
6.096	121.920	0.20370E-05
12.192	121.920	0.43570E-05
18.288	121.920	0.21140E-05
24.384	121.920	0.15780E-05
30.480	121.920	0.56310E-05
36.576	121.920	0.14650E-05
42.672	121.920	0.53060E-05
48.768	121.920	0.28920E-05
54.864	121.920	0.57700E-05
60.960	121.920	0.23930E-05
67.056	121.920	0.75710E-05
73.152	121.920	0.93300E-06
79.248	121.920	0.75720E-05
85.344	121.920	0.23930E-05
91.440	121.920	0.57720E-05
97.536	121.920	0.28920E-05

TABLE B-17. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1-Hour Average Concentration (g/m^3)
103.632	121.920	0.53070E-05
109.728	121.920	0.14640E-05
115.824	121.920	0.56320E-05
121.920	121.920	0.15790E-05
128.016	121.920	0.21130E-05
134.112	121.920	0.43570E-05
140.208	121.920	0.20380E-05
146.304	121.920	0.44300E-06
152.400	121.920	0.18360E-05
158.496	121.920	0.30140E-05
164.592	121.920	0.24330E-05
170.688	121.920	0.11370E-05
176.784	121.920	0.34900E-06
182.880	121.920	0.47400E-06
188.976	121.920	0.10170E-05
195.072	121.920	0.15500E-05
195.072	115.824	0.19160E-05
195.072	109.728	0.78700E-06
195.072	103.632	0.37100E-06
195.072	97.536	0.16790E-05
195.072	91.440	0.20680E-05
195.072	85.344	0.63200E-06
195.072	79.248	0.71700E-06
195.072	73.152	0.22510E-05
195.072	67.056	0.15430E-05
195.072	60.960	0.22200E-06
188.976	60.960	0.24700E-06
182.880	60.960	0.27700E-06
176.784	60.960	0.31200E-06
170.688	60.960	0.35400E-06
164.592	60.960	0.40500E-06
158.496	60.960	0.46700E-06
152.400	60.960	0.54400E-06
146.304	60.960	0.64200E-06
146.304	54.864	0.57390E-05
146.304	48.768	0.97900E-06

TABLE B-17. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1-Hour Average Concentration (g/m^3)
146.304	42.672	0.50710E-05
146.304	36.576	0.18620E-05
146.304	30.480	0.30520E-05
146.304	24.384	0.38390E-05
146.304	18.288	0.59500E-06
146.304	12.192	0.36070E-05
146.304	6.096	0.23640E-05
146.304	0.000	0.44300E-06
140.208	0.000	0.20380E-05
134.112	0.000	0.43570E-05
128.016	0.000	0.21130E-05
121.920	0.000	0.15790E-05
115.824	0.000	0.56310E-05
109.728	0.000	0.14640E-05
103.632	0.000	0.53070E-05
97.536	0.000	0.28900E-05
91.440	0.000	0.57710E-05
85.344	0.000	0.23920E-05
79.248	0.000	0.75720E-05
73.152	0.000	0.93400E-06
67.056	0.000	0.75720E-05
60.096	0.000	0.23940E-05
54.864	0.000	0.57710E-05
48.768	0.000	0.28920E-05
42.672	0.000	0.53070E-05
36.576	0.000	0.14640E-05
30.480	0.000	0.56310E-05
24.384	0.000	0.15790E-05
18.288	0.000	0.21130E-05
12.192	0.000	0.43570E-05
6.096	0.000	0.20380E-05

TABLE B-18. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

X Coordinate (m)	Y Coordinate (m)	1 Hour Average Concentration (g/m^3)
0.000	0.000	0.15960E-05
0.000	6.096	0.10312E-04
0.000	12.192	0.12987E-04
0.000	18.288	0.21400E-05
0.000	24.384	0.13820E-04
0.000	30.480	0.10985E-04
0.000	36.576	0.67030E-05
0.000	42.672	0.18254E-04
0.000	48.768	0.35230E-05
0.000	54.864	0.20659E-04
0.000	60.960	0.23110E-05
0.000	67.056	0.20659E-04
0.000	73.152	0.35260E-05
0.000	79.248	0.18254E-04
0.000	85.344	0.67070E-05
0.000	91.440	0.10985E-04
0.000	97.536	0.13824E-04
0.000	103.632	0.21400E-05
0.000	109.728	0.12985E-04
0.000	115.824	0.10312E-04
0.000	121.920	0.15970E-05
6.096	121.920	0.73340E-05
12.192	121.920	0.15684E-04
18.288	121.920	0.76110E-05
24.384	121.920	0.56800E-05
30.480	121.920	0.20273E-04
36.576	121.920	0.52750E-05
42.672	121.920	0.19100E-04
48.768	121.920	0.10411E-04
54.864	121.920	0.20770E-04
60.960	121.920	0.86160E-05
67.056	121.920	0.27256E-04
73.152	121.920	0.33590E-05
79.248	121.920	0.27261E-04
85.344	121.920	0.86160E-05
91.440	121.920	0.20778E-04
97.536	121.920	0.10411E-04

TABLE B-18. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1 Hour Average Concentration (g/m^3)
103.632	121.920	0.19106E-04
109.728	121.920	0.52710E-05
115.824	121.920	0.20274E-04
121.920	121.920	0.56830E-05
128.016	121.920	0.76080E-05
134.112	121.920	0.15684E-04
140.208	121.920	0.73360E-05
146.304	121.920	0.15960E-05
152.400	121.920	0.66080E-05
158.496	121.920	0.10851E-04
164.592	121.920	0.87580E-05
170.688	121.920	0.40930E-05
176.784	121.920	0.12570E-05
182.880	121.920	0.17060E-05
188.976	121.920	0.36610E-05
195.072	121.920	0.55800E-05
195.072	115.824	0.68970E-05
195.072	109.728	0.28320E-05
195.072	103.632	0.13350E-05
195.072	97.536	0.60440E-05
195.072	91.440	0.74460E-05
195.072	85.344	0.22750E-05
195.072	79.248	0.25790E-05
195.072	73.152	0.81030E-05
195.072	67.056	0.55540E-05
195.072	60.960	0.80000E-06
188.976	60.960	0.89100E-06
182.880	60.960	0.99700E-06
176.784	60.960	0.11240E-05
170.688	60.960	0.12740E-05
164.592	60.960	0.14580E-05
158.496	60.960	0.16810E-05
152.400	60.960	0.19600E-05
146.304	60.960	0.23100E-05
146.304	54.864	0.20659E-04
146.304	48.768	0.35250E-05

TABLE B-18. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	1 Hour Average Concentration (g/m^3)
146.304	42.672	0.18256E-04
146.304	36.576	0.67040E-05
146.304	30.480	0.10988E-04
146.304	24.384	0.13821E-04
146.304	18.288	0.21410E-05
146.304	12.192	0.12987E-04
146.304	6.096	0.10310E-04
146.304	0.000	0.15960E-05
140.208	0.000	0.73360E-05
134.112	0.000	0.15684E-04
128.016	0.000	0.76080E-05
121.920	0.000	0.56830E-05
115.824	0.000	0.20273E-04
109.728	0.000	0.52710E-05
103.632	0.000	0.19104E-04
97.536	0.000	0.10406E-04
91.440	0.000	0.20775E-04
85.344	0.000	0.86120E-05
79.248	0.000	0.27258E-04
73.152	0.000	0.33610E-05
67.056	0.000	0.27258E-04
60.096	0.000	0.86190E-05
54.864	0.000	0.20775E-04
48.768	0.000	0.10412E-04
42.672	0.000	0.19104E-04
36.576	0.000	0.52720E-05
30.480	0.000	0.20273E-04
24.384	0.000	0.56830E-05
18.288	0.000	0.76080E-05
12.192	0.000	0.15684E-04
6.096	0.000	0.73360E-05

TABLE B-19. Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
0.000	0.000	0.49630E-08
0.000	6.096	0.32081E-07
0.000	12.192	0.40404E-07
0.000	18.288	0.66570E-08
0.000	24.384	0.42994E-07
0.000	30.480	0.34174E-07
0.000	36.576	0.20853E-07
0.000	42.672	0.56791E-07
0.000	48.768	0.10962E-07
0.000	54.864	0.64274E-07
0.000	60.960	0.71890E-08
0.000	67.056	0.64274E-07
0.000	73.152	0.10969E-07
0.000	79.248	0.56791E-07
0.000	85.344	0.20867E-07
0.000	91.440	0.34174E-07
0.000	97.536	0.43008E-07
0.000	103.632	0.66570E-08
0.000	109.728	0.40397E-07
0.000	115.824	0.32081E-07
0.000	121.920	0.49700E-08
6.096	121.920	0.22820E-07
12.192	121.920	0.48790E-07
18.288	121.920	0.23681E-07
24.384	121.920	0.17675E-07
30.480	121.920	0.63070E-07
36.576	121.920	0.16408E-07
42.672	121.920	0.59423E-07
48.768	121.920	0.32389E-07
54.864	121.920	0.64617E-07
60.960	121.920	0.26803E-07
67.056	121.920	0.84798E-07
73.152	121.920	0.10451E-07
79.248	121.920	0.84812E-07
85.344	121.920	0.26803E-07
91.440	121.920	0.64645E-07
97.536	121.920	0.32389E-07

TABLE B-19. Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at *Receptor Locations* (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m³)
103.632	121.920	0.59444E-07
109.728	121.920	0.16401E-07
115.824	121.920	0.63077E-07
121.920	121.920	0.17682E-07
128.016	121.920	0.23667E-07
134.112	121.920	0.48797E-07
140.208	121.920	0.22827E-07
146.304	121.920	0.49630E-08
152.400	121.920	0.20559E-07
158.496	121.920	0.33761E-07
164.592	121.920	0.27244E-07
170.688	121.920	0.12733E-07
176.784	121.920	0.39130E-08
182.880	121.920	0.53060E-08
188.976	121.920	0.11389E-07
195.072	121.920	0.17360E-07
195.072	115.824	0.21455E-07
195.072	109.728	0.88060E-08
195.072	103.632	0.41510E-08
195.072	97.536	0.18802E-07
195.072	91.440	0.23163E-07
195.072	85.344	0.70770E-08
195.072	79.248	0.80220E-08
195.072	73.152	0.25207E-07
195.072	67.056	0.17283E-07
195.072	60.960	0.24920E-08
188.976	60.960	0.27720E-08
182.880	60.960	0.31010E-08
176.784	60.960	0.34930E-08
170.688	60.960	0.39620E-08
164.592	60.960	0.45360E-08
158.496	60.960	0.52290E-08
152.400	60.960	0.60970E-08
146.304	60.960	0.71890E-08
146.304	54.864	0.64274E-07
146.304	48.768	0.10962E-07

TABLE B-19. Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
146.304	42.672	0.56798E-07
146.304	36.576	0.20860E-07
146.304	30.480	0.34181E-07
146.304	24.384	0.43001E-07
146.304	18.288	0.66640E-08
146.304	12.192	0.40404E-07
146.304	6.096	0.32074E-07
146.304	0.000	0.49630E-08
140.208	0.000	0.22827E-07
134.112	0.000	0.48797E-07
128.016	0.000	0.23667E-07
121.920	0.000	0.17682E-07
115.824	0.000	0.63070E-07
109.728	0.000	0.16401E-07
103.632	0.000	0.59437E-07
97.536	0.000	0.32375E-07
91.440	0.000	0.64631E-07
85.344	0.000	0.26789E-07
79.248	0.000	0.84805E-07
73.152	0.000	0.10458E-07
67.056	0.000	0.84805E-07
60.096	0.000	0.26810E-07
54.864	0.000	0.64631E-07
48.768	0.000	0.32396E-07
42.672	0.000	0.59437E-07
36.576	0.000	0.16401E-07
30.480	0.000	0.63070E-07
24.384	0.000	0.17682E-07
18.288	0.000	0.23667E-07
12.192	0.000	0.48790E-07
6.096	0.000	0.22827E-07

TABLE B-20. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
0.000	0.000	0.31010E-06
0.000	6.096	0.20048E-05
0.000	12.192	0.25249E-05
0.000	18.288	0.41580E-06
0.000	24.384	0.26873E-05
0.000	30.480	0.21357E-05
0.000	36.576	0.13034E-05
0.000	42.672	0.35497E-05
0.000	48.768	0.68530E-06
0.000	54.864	0.40173E-05
0.000	60.960	0.44940E-06
0.000	67.056	0.40173E-05
0.000	73.152	0.68600E-06
0.000	79.248	0.35497E-05
0.000	85.344	0.13041E-05
0.000	91.440	0.21357E-05
0.000	97.536	0.26880E-05
0.000	103.632	0.41580E-06
0.000	109.728	0.25249E-05
0.000	115.824	0.20048E-05
0.000	121.920	0.31080E-06
6.096	121.920	0.14259E-05
12.192	121.920	0.30499E-05
18.288	121.920	0.14798E-05
24.384	121.920	0.11046E-05
30.480	121.920	0.39417E-05
36.576	121.920	0.10255E-05
42.672	121.920	0.37142E-05
48.768	121.920	0.20244E-05
54.864	121.920	0.40390E-05
60.960	121.920	0.16751E-05
67.056	121.920	0.52997E-05
73.152	121.920	0.65310E-06
79.248	121.920	0.53004E-05
85.344	121.920	0.16751E-05
91.440	121.920	0.40404E-05
97.536	121.920	0.20244E-05

TABLE B-20. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
103.632	121.920	0.37149E-05
109.728	121.920	0.10248E-05
115.824	121.920	0.39424E-05
121.920	121.920	0.11053E-05
128.016	121.920	0.14791E-05
134.112	121.920	0.30499E-05
140.208	121.920	0.14266E-05
146.304	121.920	0.31010E-06
152.400	121.920	0.12852E-05
158.496	121.920	0.21098E-05
164.592	121.920	0.17031E-05
170.688	121.920	0.79590E-06
176.784	121.920	0.24430E-06
182.880	121.920	0.33180E-06
188.976	121.920	0.71190E-06
195.072	121.920	0.10850E-05
195.072	115.824	0.13412E-05
195.072	109.728	0.55030E-06
195.072	103.632	0.25970E-06
195.072	97.536	0.11753E-05
195.072	91.440	0.14476E-05
195.072	85.344	0.44240E-06
195.072	79.248	0.50190E-06
195.072	73.152	0.15757E-05
195.072	67.056	0.10801E-05
195.072	60.960	0.15540E-06
188.976	60.960	0.17290E-06
182.880	60.960	0.19390E-06
176.784	60.960	0.21840E-06
170.688	60.960	0.24780E-06
164.592	60.960	0.28350E-06
158.496	60.960	0.32690E-06
152.400	60.960	0.38080E-06
146.304	60.9[illegible]	0.44940E-06
146.304	54.864	0.40173E-05
146.304	48.768	0.68[illegible]

TABLE B-20. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m³)
146.304	42.672	0.35497E-05
146.304	36.576	0.13034E-05
146.304	30.480	0.21364E-05
146.304	24.384	0.26873E-05
146.304	18.288	0.41650E-06
146.304	12.192	0.25249E-05
146.304	6.096	0.20048E-05
146.304	0.000	0.31010E-06
140.208	0.000	0.14266E-05
134.112	0.000	0.30499E-05
128.016	0.000	0.14791E-05
121.920	0.000	0.11053E-05
115.824	0.000	0.39417E-05
109.728	0.000	0.10248E-05
103.632	0.000	0.37149E-05
97.536	0.000	0.20230E-05
91.440	0.000	0.40397E-05
85.344	0.000	0.16744E-05
79.248	0.000	0.53004E-05
73.152	0.000	0.65380E-06
67.056	0.000	0.53004E-05
60.096	0.000	0.16758E-05
54.864	0.000	0.40397E-05
48.768	0.000	0.20244E-05
42.672	0.000	0.37149E-05
36.576	0.000	0.10248E-05
30.480	0.000	0.39417E-05
24.384	0.000	0.11053E-05
18.288	0.000	0.14791E-05
12.192	0.000	0.30499E-05
6.096	0.000	0.14266E-05

TABLE B-21. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
0.000	0.000	0.11172E-05
0.000	6.096	0.72184E-05
0.000	12.192	0.90909E-05
0.000	18.288	0.14980E-05
0.000	24.384	0.96740E-05
0.000	30.480	0.76895E-05
0.000	36.576	0.46921E-05
0.000	42.672	0.12779E-04
0.000	48.768	0.24661E-05
0.000	54.864	0.14461E-04
0.000	60.960	0.16177E-05
0.000	67.056	0.14461E-04
0.000	73.152	0.24682E-05
0.000	79.248	0.12778E-04
0.000	85.344	0.46949E-05
0.000	91.440	0.76895E-05
0.000	97.536	0.96768E-05
0.000	103.632	0.14980E-05
0.000	109.728	0.90895E-05
0.000	115.824	0.72184E-05
0.000	121.920	0.11179E-05
6.096	121.920	0.51336E-05
12.192	121.920	0.10979E-04
18.288	121.920	0.53277E-05
24.384	121.920	0.39760E-05
30.480	121.920	0.14191E-04
36.576	121.920	0.36925E-05
42.672	121.920	0.13370E-04
48.768	121.920	0.72877E-05
54.864	121.920	0.14539E-04
60.960	121.920	0.60312E-05
67.056	121.920	0.19079E-04
73.152	121.920	0.23513E-05
79.248	121.920	0.19083E-04
85.344	121.920	0.60312E-05
91.440	121.920	0.14545E-04
97.536	121.920	0.72877E-05

TABLE B-21. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
103.632	121.920	0.13374E-04
109.728	121.920	0.36897E-05
115.824	121.920	0.14192E-04
121.920	121.920	0.39781E-05
128.016	121.920	0.53256E-05
134.112	121.920	0.10979E-04
140.208	121.920	0.51352E-05
146.304	121.920	0.11172E-05
152.400	121.920	0.46256E-05
158.496	121.920	0.75957E-05
164.592	121.920	0.61306E-05
170.688	121.920	0.28651E-05
176.784	121.920	0.87990E-06
182.880	121.920	0.11942E-05
188.976	121.920	0.25627E-05
195.072	121.920	0.39060E-05
195.072	115.824	0.48279E-05
195.072	109.728	0.19824E-05
195.072	103.632	0.93450E-06
195.072	97.536	0.42308E-05
195.072	91.440	0.52122E-05
195.072	85.344	0.15925E-05
195.072	79.248	0.18053E-05
195.072	73.152	0.56721E-05
195.072	67.056	0.38878E-05
195.072	60.960	0.56000E-06
188.976	60.960	0.62370E-06
182.880	60.960	0.69790E-06
176.784	60.960	0.78680E-06
170.688	60.960	0.89180E-06
164.592	60.960	0.10206E-05
158.496	60.960	0.11767E-05
152.400	60.960	0.13720E-05
146.304	60.960	0.16170E-05
146.304	54.864	0.14461E-04
146.304	48.768	0.24675E-05

TABLE B-21. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction (continued)

X Coordinate (m)	Y Coordinate (m)	8-Hour Average Concentration (g/m^3)
146.304	42.672	0.12779E-04
146.304	36.576	0.46928E-05
146.304	30.480	0.76916E-05
146.304	24.384	0.96747E-05
146.304	18.288	0.14987E-05
146.304	12.192	0.90909E-05
146.304	6.096	0.72170E-05
146.304	0.000	0.11172E-05
140.208	0.000	0.51352E-05
134.112	0.000	0.10979E-04
128.016	0.000	0.53256E-05
121.920	0.000	0.39781E-05
115.824	0.000	0.14191E-04
109.728	0.000	0.36897E-05
103.632	0.000	0.13373E-04
97.536	0.000	0.72842E-05
91.440	0.000	0.14543E-04
85.344	0.000	0.60284E-05
79.248	0.000	0.19081E-04
73.152	0.000	0.23527E-05
67.056	0.000	0.19081E-04
60.096	0.000	0.60333E-05
54.864	0.000	0.14543E-04
48.768	0.000	0.72884E-05
42.672	0.000	0.13373E-04
36.576	0.000	0.36904E-05
30.480	0.000	0.14191E-04
24.384	0.000	0.39781E-05
18.288	0.000	0.53256E-05
12.192	0.000	0.10979E-04
6.096	0.000	0.51352E-05

Appendix C

RiskFocus

November 13, 1990

Captain Alan Holck
AFOEHL/EHT
Brooks Air Force Base, TX 78235-5501

Dear Captain Holck:

Enclosed please find a trip report for the Johnston Island site visit conducted on October 10-11, 1990. Please note the questions and needs expressed at the end of the report. This information is important to the successful completion of the project. Some of the information (e.g., location of fish sampling stations 4 and 6) will be easily obtained by us in a phone conversation with Roger DiRosa of FWS.

Yours truly,

Scott R. Baker, Ph.D.
Deputy Director

Attachment

Trip Report for Visit to Johnston Island

October 10-11, 1990

Background for the Trip and its Objectives

The RiskFocus Division of Versar is conducting a baseline risk assessment for the Occupational and Environmental Hygiene Laboratory for the Herbicide Orange (HO) storage site at Johnston Island. This risk assessment is part of the site investigation/remediation process related to EPA's regulations on the cleanup of hazardous waste and is being performed in the context of DoD's Installation Restoration Program. A major objective of the risk assessment is to determine the potential for human exposure to contaminants at the HO storage site (using the existing information on site characterization) and the potential human health risk that is the consequence of exposure. In this regard, the site was visited as part of the "investigation" phase of the study, during which several points of information to support the objectives of the study were identified and obtained (to the extent possible). The information to be obtained during the site visit included the following:

- The nature of morbidity (related to the known health effects of HO) among long-term residents of the island, particularly those who participated in the HO leak containment, dedrumming, and drum crushing operations;

- The sampling strategy used by personnel of the Fish and Wildlife Service to determine the levels of dioxin, 2,4,-D and 2,4,5,-T in water, sediments, and biota;

- The need for and possible arrangement for additional sampling and monitoring;

- The relation of site to other activities on the island that might present confounding factors on the risk from exposure to the HO site (e.g., potential for exposure to dioxin from the JACADS operation as it impacts the dioxin risk potential from exposure to the HO site);

- Background information on the potential for contamination of seawater with dioxin at the HO site (e.g., design and construction of the seawall surrounding the site), and

- Based on the physical layout of the island, activities of its residents, and prevailing meteorology, preliminary impressions about the potential for exposure to contaminants at the HO site.

The knowledge gained from the site visit in relation to these points of information is presented in the following descriptions. Recommendations for additional data collection activities, based on site-visit observations and the objectives of the baseline risk assessment, are presented in text in context with specific observations that are being made.

The Nature of Morbidity Among Long-term Residents of the Island

In accordance with the objectives of the study, it is important to determine if current long-term residents on the island are at risk from exposure to contaminants at the HO site. This includes, in particular, residents who participated in the HO removal activities in 1977 and who are still on the island (estimated to be 16 individuals). It does not include residents who are on the island for short durations (one year or less) because short-term exposure to low levels of potential contaminants at the HO site are not presumed to result in a health risk from a toxicological perspective. It also does not include residents who have resided on the island in the past and who are not currently residing there. Current and future exposure for these latter individuals is presumed to be zero; therefore, their attendant current and future risk is presumed to be zero.

The staff of the medical unit indicated that limb injuries (sprains, bruises) constitute most of the health complaints on the island. Dr. Patrick, a physician currently assigned to JI, estimated that fewer than 50% of the residents smoke, although he did not have enumerative statistics on smoking incidence. He also observed that, to his knowledge, few residents have clinically diagnosed allergies (respiratory, dermal, and other immunologic responses from plants, food, dust, pollen, and in particular chemical exposure). In part, this may be the result of the relatively pollution-free atmosphere over the island, the lack of extensive pollen-bearing plant life on the island, and the relatively constant winds that promote high air exchange around the atoll. Three or four cases of breast cancer have occurred over the years, in addition to one melanoma (which was present prior to residence on the island but which metastasized while on the island), and one case of lung cancer in a smoker. Any hematological workups that were needed were done at the Straub Clinic on Oahu.

As a matter of due course, a more aggressive occupational medicine program should be instituted on the island, including medical monitoring, to determine if the island's hazards, including the HO site, are impacting the health of its long-term civilian residents.

Sixteen (16) individuals who are still on the island worked at the HO site. A list of these individuals was provided. Their medical histories should be examined for HO-related illnesses.

Sampling Strategy Used to Determine the Levels of HO Constituents in Water, Sediments, and Biota

Because the island is a National Wildlife Refuge, personnel of the U.S. Fish and Wildlife Service were present to manage the animal life on land and in the surrounding waters. Their activities center around identification, enumeration, and further characterization of biota in the island environment, and in assisting Federal departments in the sampling and analysis of biological and environmental samples for evidence of chemical contamination. In that context, the FWS staff were drawing fish and sediment samples to support the JACADS monitoring program for dioxin. Samples of fish and sediment are being drawn on a semiannual basis from the area surrounding the HO site. Although a degree of order and record keeping are maintained by FWS staff in their sampling regimen, there is no scientifically-based, systematic collection scheme (i.e., sampling method, frequency, location, and fish-type) in place with an objective of monitoring the potential migration and bioaccumulation of contaminants in the aquatic environment. Sampling parameters are left to the discretion of FWS staff. Reports of tissue and sediment analyses being conducted by Radian Corporation have been made available. The most recent analytical results were provided by FWS staff during the site visit. FWS staff are embarking on a sample collection and monitoring program to support the JACADS activity. This will be centered on the coral reef downrange of the HO site and presents a potential for collaboration with sampling needs for the HO site investigation (see below).

Need for and Possible Arrangement for Additional Sampling and Monitoring

A potential protocol for future aquatic sampling was discussed at length with FWS staff on the island. The stated objective is to determine the possible link between HO site contamination, sediment/water/fish contamination, and human consumption of contaminated fish (by catching them off the west wharf near the HO site). The sampling plan should be responsive to this objective and was conceived as presented below for further consideration:

The physical layout of the area consists of, on land, the HO site and west wharf, and, in water, a seawall, reef, and intermediate area between the seawall and reef. To draw links between the HO site and the potential human consumption of contaminated fish caught at the fishing wharf, samples should be taken at the following locations:

- *Snails (a representative of filter feeders) and sediment (to determine if HO site contaminants are leaching from site to sediment or seawater) immediately off the HO site;*

- *Goat fish (representative of an intermediate aquatic trophic level) and sediment in the intermediate area off the HO site;*

- *Herbivores and predatory fish (representative of a higher trophic level) and sediment at the reef off the HO site;*

- *Sediment at the reef off the fishing wharf;*

- *Sediment at the intermediate area off the fishing wharf;*

- *Sediment at the seawall off the fishing wharf; and*

- *Fish that are caught by individuals fishing off the wharf.*

There is some question as to whether or not fish migrate between waters off the wharf area and waters off the HO site, and whether fish at the reef come inland as potential catch. The fish tagging and tracking effort that would be required to address this issue is a costly and labor-intensive undertaking. The above plan circumvents the need for such an elaborate activity by drawing links between HO site contamination and actual catch.

Dr. Phillip LaBelle of the Woods Hole Oceanographic Institute will be embarking on a sampling regimen related to the JACADS operation to monitor the existence of furans, dioxins, and PCB's in sediments and fish at the reef and west camera stand. This presents an opportunity for the Air Force to collaborate on any need for further sampling with that being conducted by Dr. LaBelle for the Aberdeen Proving Ground. The JACADS monitoring program will begin shortly so that timely decisions on the need for additional sampling related to the HO site are needed. It is anticipated that, as long as stack monitors at the JACADS incinerators do not detect these chemicals at the stack, no JACADS-related chemicals will appear in biota off the west end of the island.

Well-placed locations for drawing *a few* water samples should be ascertained. As a substitute for taking extensive water samples, it may be sufficient to place current meters in the water to gain additional knowledge of present-day current patterns. This, in combination with existing empirical information on currents in the Atoll in general, may provide information on the potential role of currents in the distribution of HO site contaminants and further information on the land/water/fish/sediment interfaces.

There is a need to get as accurate information as possible on consumption (frequency and quantity) of fish caught off the west end of the island, as well as the dioxin levels in those fish.

With regard to air monitoring, there is a distinct aroma of formulation constituents in the area of the transformer west of the HO site. Based on dioxin levels at selected locations within the site as determined in the 1986 soil characterization study, it is plausible that dioxin and other HO formulation ingredients (2,4-D, 2,4,5-T, emulsifiers, pH buffers, detergents, stabilizers, etc.) as cocontaminants may be volatilizing from the site. Since fire-training, burn-pit, and possibly other activities occur in this downwind area, the air as a potential source of personnel exposure to HO-site derived chemicals should be monitored for 2,4,-D and 2,4,5-T and in particular 2,3,7,8-dioxin that may be volatilizing from the HO site. Tomato plant bioassays provide only crude estimates of the presence of dioxin according to the severity of epinastic growth. This bioassay is not sufficient for human exposure estimation.

Activities on the Island as Potential Confounders to Risks from the HO Site

There is a potential for a confounding effect presented by two possible carcinogen-generating sources on the island other than the HO site:

- The JACADS facility is located upwind of the HO site and activities west of the site. The potential for dioxin release from JACADS is unknown. For purposes of the baseline risk assessment related to the HO site, it will be assumed that the potential for JACADS to pose a confounding influence in air or water media is negligible. Nevertheless, should there be airborne dioxin, furan, or other carcinogenic releases from the JACADS incinerators and dioxin releases from the HO site, any concentrations at locations west of the HO site would have to be apportioned between the two sources by air dispersion modeling (requiring knowledge of the source term). The reliability of results presented by modeling may be questionable enough to warrant additional monitoring. Currently, monitoring for dioxin related to the JACADS operation is being conducted only at the stack; downrange (Hi-Vol) samplers are monitoring for criteria pollutants and not for organics.

- The current fire training area is located immediately downrange of the HO site. Since this is a combustion operation (probably fueled by a petroleum-based product), there is a possibility that the area is contaminated with PAH's (i.e., carcinogens) including benzpyrenes and dioxin. Soil analyses of this area as presented in the 1986 soil characterization study reveal levels of 15 and 24 ppt in the fire training area. This may impact health risks associated with the HO site through both air and water media in ways that are difficult to predict with existing data.

Potential for Contamination of Seawater with Chemicals at the HO Site

Some aquatic and sediment samples have contained dioxin to varying degrees. If continuing monitoring of sediments and fish reveals contamination, particularly if the levels that are not diminishing with time, the possibility that the HO site as a source of dioxin in water must be explored. The seawall risers surrounding the HO site are lined with an impervious tough material near to the top of the seawall as it adjoins the ground of the HO site. There are two potential sources of migration of contaminants at the site to the surrounding aquatic environment:

- Backwash of contaminated soil over the seawall on those rare meteorological occasions when seawater is able to climb over the wall;

- Possible confluence between the groundwater aquifer under the site with the sea. The groundwater aquifer under the HO site has not been characterized. To ascertain if groundwater is a potential source of fugitive escape, the following prudent protocol should be conducted:

  - At hot cells on the HO site, bore holes into the water table;

- If groundwater is contaminated, characterize both the aquifer and the contaminant plume;

- Determine if the plume is (or is predicted to) reach the seawater;

- Determine the frequency of topsoil being washed out to sea;

- Estimate wind erosion and sea deposition of topsoil from the site; and

- Determine levels of dioxin in sediments and biota (see above: Need for and Possible Arrangement for Additional Sampling and Monitoring).

Preliminary impressions about the potential for exposure to contaminants at the HO site based on the physical layout of the island, activities of its residents, and prevailing meteorological features

Because the HO site is at the western edge of the island in the presence of prevailing easterly winds, there is not much potential for exposure via the air. There is also not much potential for confounding effects from the JACADS facility due to design and safety features of that facility; any JACADS releases will be acute episodic with health consequences (if any) that are different from those posed by HO-site contaminants. The fire training area poses a more plausible source of confounding synergistic or potentiative exposure because of its proximity to the HO site (i.e., the possibility that personnel working around the fire training area might receive exposures from the HO site) and the probable similarity in mode of action of contaminants from the HO site and the fire training area. The health status of islanders is a complete unknown (smoking histories, morbidity). As a result it will be difficult to select likely sensitive individuals. In accordance with HHEM procedures, risk will be determined for the MEI (most exposed individual) and MEAP (most exposed actual person). Considering the air and water as transport media for HO-derived dioxin and other HO-site contaminants (i.e., the only potential sources of exposure), water poses a greater risk because of fish contamination and human consumption.

Followup Information Needed

In order to conduct a thorough analysis for the baseline risk assessment, we would like to obtain answers to the following questions:

- *What is the formulation composition of HO (chemicals and % wt)?* This will help us determine the range of contaminants present at the site. Presumably the maker (Dow Chemical) of HO would have this information. It may be more readily available in Air Force files than by starting with a cold call to Dow.

- *How much time (frequency and time interval per occurrence) do people spend downwind of the HO site (at the burn pit and the fire training area)?* Someone (who?) on JI would have to provide estimates.

- *Where would we be able to obtain automated meteorological data (data tape or disk) for the island?*

- *Who designed the seawall?* We would like to find out the principle of seawall operation, water dynamics through the seawall, and the likelihood of leakage of water through it.

- *Can you help us locate Colonel Nay (?) at Tyndall AFB?* He was the base engineer during the time of the HO removal operation. He may be able to provide information on the location of specific operations (e.g., burning of dunnage, use of ash for fill).

- *Can you help us obtain a copy of JACADS EIS Second Supplemental for Storage and Ultimate Disposal of the European Chemicals (first and/or second versions)?*

- *What are stations 4 and 6 identifying locations from which fish are being sampled?*

- *Can you please furnish the following documents cited in the Holmes and Narver Preliminary Assessment of Johnston Atoll (October 1989):*

  - Channell, R.E.. and T.L. Stoddart, April 1984, *Herbicide Orange Monitoring Program: Interim Report, January 1980-December 1982*, ESL-TR-83-56, ESL, AFESC, Tyndall AFB, Florida.

  - Rhodes, 2 Lt., Albert N., January 2, 1985, *Johnston Island Fish Samples*, Letter to USAF OEHL/EC.

  - Casanova, J.N., January 1986, *JI Survey Sampling and Analysis Project*, EG&G/Idaho, Inc., Idaho Falls, Idaho.

  - Casanova, J.N., March 1986, *Johnston Island Survey Sampling and Analysis Project Addendum I*, EG&G/Idaho, Inc., Idaho Falls, Idaho.

July 15, 2004

Honorable Anthony J. Principi
Secretary
Department of Veterans Affairs
Washington, DC 20420

Dear Mr. Secretary:

Thank you for your reply to my letter concerning the exposure of veterans who served on Johnston Atoll between 1971 and 1977. I am puzzled at your conclusion that there is not enough evidence to concede exposure of these veterans to Agent Orange.

Johnston Island, the largest of the islands comprising Johnston Atoll, is less than 2 miles long and less than a half mile wide. Approximately 113,400 kg of Agent Orange accidentally spilled in 1972 during redrumming after the Air Force brought approximately 5.18 million liters of unused Agent Orange from Vietnam to Johnston Island. In addition, 49,000 gallons per year of Agent Orange are estimated to have leaked from drums at the Johnston Island storage site. Dioxin contamination was attributed to soil transport (wind transport or surface water runoff).

Given the very small size of Johnston Island, and the wind transport and water runoff of contaminated soil, I am at a loss as to how it would be possible for a servicemember assigned to Johnston Island to avoid exposure to Agent Orange. I am enclosing copies of selected pages from "An Ecological Assessment of Johnston Atoll" which provided some of the information referenced in this letter.

I am requesting that you reconsider your decision concerning the likelihood that all veterans who served on Johnston Island during 1971 – 1977 were exposed to Agent Orange and dioxin. I also note that as late as 1994, the most toxic dioxin isomer (TCDD) with concentrations as high as 901.00 was still present at 28% of the soil samples tested at the Agent Orange storage site on Johnston Island. It is also possible that servicemembers who were stationed at the Agent Orange site as late as 1994 (such as those assigned to guard the area) were exposed to TCDD.

Kindly provide me with a response to this request by September 1, 2004. If you have any questions about this request or need further information, please contact Mary Ellen Mc Carthy, Democratic Staff Director, Subcommittee on Benefits at 202-225-9756. Thank you for your cooperation in this matter.

Sincerely,

LANE EVANS
Ranking Democratic Member

Department of Veterans Affairs

Report

REPORT TO TO SECRETARY OF THE DEPARTMENT OF VETERANS AFFAIRS

ON THE ASSOCIATION BETWEEN ADVERSE HEALTH EFFECTS

AND EXPOSURE TO AGENT ORANGE

CLASSIFIED

CONFIDENTIAL STATUS (1)

As Reported by Special Assistant

Admiral E.R. Zumwalt, Jr.

May 5, 1990

WARNING

NOT FOR PUBLICATION AND

RELEASE TO THE GENERAL PUBLIC

I. INTRODUCTION

On October 6, 1989 I was appointed as special assistant to Secretary Derwinski of the Department of Veterans Affairs to assist the Secretary in determining whether it is at least as likely as not that there is a statistical association between exposure to Agent Orange and a specific adverse health effect.

As special assistant, I was entrusted with evaluating the numerous data relevant to the statistical association between exposure to Agent Orange and the specific adverse health effects manifested by veterans who saw active duty in Vietnam. Such evaluations were made in accordance with the standards set forth in Public Law 98-542, the Veterans' Dioxin and Radiation Exposure Compensation Standards Act and 38 C.F.R. 1.17, regulations of the Department of Veterans Affairs concerning the evaluation of studies relating to health effects of dioxin and radiation exposure.

Consistent with my responsibilities as special assistant, I reviewed and evaluated the work of the Scientific Council of the Veterans' Advisory Committee on Environmental Hazards and commissioned independent scientific experts to assist me in evaluating the validity of numerous human and animal studies on the effects of exposure to Agent Orange and/or exposure to herbicides containing 2,3,7,8 tetrachlorodibenzo-para-dioxin (TCDD or dioxin). In addition, I reviewed and evaluated the protocol and standards employed by government sponsored studies to *assess* such studies' credibility, fairness and consistency with generally accepted scientific practices.

After reviewing the scientific literature related to the health effects of Vietnam Veterans exposed to Agent Orange as well as other studies concerning the health hazards of civilian exposure to dioxin contaminants, I conclude that there is adequate evidence for the Secretary to reasonably conclude that it is at least as likely as not that there is a relationship between exposure to Agent Orange and the following health problems: non—Hodgkin's lymphoma, chloracne and other skin disorders, lip cancer, bone cancer, soft tissue sarcoma, birth defects, skin cancer, porphyria cutanea tarda and other liver disorders, Hodgkin's disease, hematopoietic diseases, multiple myeloma, neurological defects, auto—immune diseases and disorders, leukemia, lung cancer, kidney cancer, malignant melanoma, pancreatic cancer, stomach cancer, colon cancer, nasal/pharyngeal/esophageal cancers, prostate cancer, testicular cancer, liver cancer, brain cancer, psychosocial effects and gastrointestinal diseases.

I further conclude that the Veterans' Advisory Committee on Environmental Hazards has not acted with impartiality in its review and assessment of the scientific evidence related to the association of adverse health effects and exposure to Agent Orange.

In addition to providing evidence in support of the conclusions stated above, this report provides the Secretary with a review of the scientific, political and legal efforts that have occurred over the last decade to establish that Vietnam Veterans who have been exposed to Agent Orange are in fact entitled to compensation for various illnesses as service-related injuries.

II. AGENT ORANGE USAGE IN VIETNAM

Agent Orange was a 50:50 mixture of 2,4-D and 2,4,5-T. The latter component, 2,4,5-T, was found to contain the contaminant TCDD or 2,3,7, 8-tetrachlorodibenzo-para-dioxin (i.e. dioxin), which is regarded as one of the most toxic chemicals known to man.[1]

From 1962 to 1971 the United States military sprayed the herbicide Agent Orange to accomplish the following objectives: 1) defoliate jungle terrain to improve observation and prevent enemy ambush; 2) destroy food crops; and 3) clear Vegetation around military installations, landing zones, fire *base* camps, and trails [2]

Unlike civilian applications of the components contained in Agent Orange which are diluted in oil and water, Agent Orange was sprayed undiluted in Vietnam. Military applications were sprayed at the rate of approximately 3 gallons per acre and contained approximately 12 pounds of 2,4-D and 13.8 pounds of 2,4,5-T.[3]

Although the military dispensed Agent Orange in concentrations 6 to 25 times the manufacturer's suggested rate, "at that time the Department of Defense (DOD) did not consider herbicide orange toxic or dangerous to humans and took few precautions to prevent exposure to it."' Yet, evidence readily suggests that at the time of its use experts knew that Agent Orange was harmful to military personnel.[5]

The bulk of Agent Orange herbicides used in Vietnam were reportedly sprayed from "Operation Ranch Hand" fixed wing aircraft. Smaller quantities were applied from helicopters, trucks, riverboats, and by hand. Although voluminous records of Ranch Hand missions are contained in computer records, otherwise known as the HERBS and Service HERBs tapes, a significant, if not major source of exposure for ground forces was from non— recorded, non Ranch Hand operations.[6]

Widespread use of Agent Orange coincided with the massive buildup of U.S. military personnel in Vietnam, reaching a peak in 1969 and eventually stopping in 1971. [7] Thus, according to an official of the then Veterans Administration, it was "theoretically possible that about 4.2 million American soldiers could have made transient or significant contact with the herbicides because of [the Ranch Hand Operation]." [8]

A. REASONS FOR PHASE OUT

Beginning as early as 1968, scientists, health officials, politicians and the military itself began to express concerns about the potential toxicity of Agent Orange and its contaminant dioxin to humans. For instance, in February 1969 The Bionetics Research Council Committee ("BRC') in a report commissioned by the United States Department of Agriculture found that 2,4,5-T showed a "significant potential to increase birth defects." [9] Within four months after the BRC report, Vietnamese newspapers began reporting significant increases in human birth defects ostensibly due to exposure to Agent Orange.[10]

By October, 1969, the National Institute of Health confirmed that 2,4,5—T could cause malformations and stillbirths in mice, thereby prompting the Department of Defense to announce a partial curtailment of its Agent Orange spraying.[11]

By April 15, 1970, the public outcry and mounting scientific evidence caused the Surgeon General of the United States to issue a warning that the use of 2,4,5-T might be hazardous to "our health". [12]

On the same day, the Secretaries of Agriculture, Health Education and Welfare, and the Interior, stirred by the publication of studies that indicated 2,4,5-T was a teratogen (i.e. caused birth defects), jointly announced the suspension of its use around lakes, ponds, ditch banks, recreation areas and homes and *crops* intended for human consumption.[13] The Department of Defense simultaneously announced its suspension of all uses of Agent Orange.[14]

B. HEALTH STUDIES

As Agent Orange concerns grew, numerous independent studies were conducted between 1974 and 1983 to determine if a link exists between certain cancerous diseases, such as non-Hodgkin's lymphoma and soft-tissue sarcomas, and exposure to the chemical components found in Agent Orange. These studies suggested just such a link.

In 1974, for example, Dr. Lennart Hardell began a study which eventually demonstrated a statistically significant correlation between exposure to pesticides containing dioxin and the development of soft tissue sarcomas.[15]

In 1974, Axelson and Sundell reported a two—fold increase of cancer in a cohort study of Swedish railway workers exposed to a variety of herbicides containing dioxin contaminants.[16]

By 1976, the Occupational Safety and Health Administration, established rigorous exposure criteria for workers working with 2,4,5-T. [17]

In 1977 the International Agency for Research on Cancer (IARC), while cautioning that the overall data was inconclusive, reported numerous anomalies and increased mortality rates in animals and humans exposed to 2,4-D or 2,4,5-T.[18]

In 1978, the Environmental Protection Agency issued an emergency suspension of the spraying of 2,4,5-T in national forests after finding "a statistically significant increase in the frequency of miscarriages" among women living near forests sprayed with 2,4,5-T.[19]

In 1980, another provocative mortality study of workers involved in an accident at an industrial plant which manufactured dioxin compounds suggested that exposure to these compounds resulted in excessive deaths from neoplasms of the lymphatic and hematopoietic tissues. [20]

On September 22, 1980, the U.S. Interagency Work Group to Study the Long-term Health Effects of Phenoxy Herbicides and Contaminants concluded "that despite the studies' limitations, they do show a correlation between exposure to phenoxy acid herbicides and an increased risk of developing soft-tissue tumors or malignant lymphomas."[21]

To be sure, there remain skeptics who insist that the studies failed in one respect or another to establish a scientifically acceptable correlation.[22] Yet, it can fairly be said that the general attitude both within and outside the scientific community was, and continues to be increasing concern over the mounting evidence of a connection between certain cancer illnesses and exposure to dioxins.

III. VETERANS' DIOXIN AND RADIATION EXPOSURE COMPENSATION STANDARDS ACT OF 1984

With the increasing volume of scientific literature giving credence to the belief of many Vietnam Veterans that exposure to Agent Orange during their military service was related to their contraction of several debilitating diseases -- particularly non-Hodgkin's lymphoma, soft tissue sarcoma ("STS") (malignant tumors that form in muscle fat, or fibrous connective tissue) and porphyria cutanea tarda ("PCT") (deficiencies in liver enzymes) --Vietnam Veterans rightfully sought disability compensation from the Veterans Administration ("VA").

The VA determined, however, that the vast majority of claimants were not entitled to compensation since they did not have service connected illnesses. [23] As a consequence, Congress attempted to alter dramatically the process governing Agent Orange disability claims through passage of the Veterans' Dioxin and Radiation Exposure Compensation Standards Act of 1984 (hereinafter the "Dioxin Standards Act") [24] To ensure that the VA provided disability compensation to veterans exposed to herbicides containing dioxin while serving in Vietnam,[25] Congress authorized the VA to conduct rulemaking to determine those diseases that were entitled to compensation as a result of a service-related exposure to Agent Orange.[26]

In promulgating such rules, the Dioxin Standards Act required the VA to appoint a Veterans' Advisory Committee on Environmental Hazards (the "Advisory Committee") -- composed of experts in dioxin, experts in epidemiology, and interested members of the public -- to review the scientific literature on dioxin and submit periodic recommendations and evaluations to the Administrator of the [27] Such experts were directed to evaluate the scientific evidence pursuant to regulations promulgated by the VA, and thereafter to submit recommendations and evaluations to the Administrator of the VA on whether "sound scientific or medical evidence" indicated a connection to exposure to Agent Orange and the manifestation of various diseases.[28]

In recognition of the uncertain state of scientific evidence and the inability to make an absolute causal connection between exposures to herbicides containing dioxin and affliction with various rare cancer diseases.[29] Congress mandated that the VA Administrator resolve any doubt in favor of the veteran seeking compensation. As stated in the Dioxin Standards Act:

> It has always been the policy of the Veterans Administration and is the policy of the United States, with respect to individual claims for service connection of diseases and disabilities, that when, after consideration of all the evidence and material of record, there is an approximate balance of positive and negative evidence regarding the merits of an issue material to the determination of a claim,

the benefit of the doubt in resolving each such issue shall be given to the claimant. [30]

A. NEHMER V. U.S. VETERANS ADMINISTRATION

Despite Congressional intent to give the veteran the benefit of the doubt, and in direct opposition to the stated purpose of the Dioxin Standards Act to provide disability compensation to Vietnam Veterans suffering with cancer who were exposed to Agent Orange, the VA continued to deny compensation improperly to over 31,000 veterans with just such claims. In fact, in promulgating the rules specified by Dioxin Standards Act, the VA not only confounded the intent of the Congress, but directly contradicted its- own established practice of granting compensable service-connection status for diseases on the lesser showing of a statistical association, promulgating instead the more stringent requirement that compensation depends on establishing a cause and effect relationship.[31]

Mounting a challenge to the regulations, Veterans groups prosecuted a successful legal action which found that the VA had "both imposed an impermissibly demanding test for granting service connection for various diseases and refused to give the veterans the benefit of the doubt in meeting the demanding standard." Nehmer v. U.S. Veterans Administration, 712 F. supplement 1404, 1423 (1989) (Emphasis in original) As a result, the court invalidated the VA's Dioxin regulation which denied service connection for all diseases other than chloracne; ordered the VA to amend its rules; and further ordered that the Advisory Committee reassess its recommendations in light of the court's order.[32]

Thus, on October 2, 1989, the VA amended 38 C.F.R. Part 1, which among other things set forth various factors for the Secretary and the Advisory Committee to consider in determining whether it is "at least as likely as not" that a scientific study shows a "significant statistical association" between a particular exposure to herbicides containing dioxin and a specific adverse health effect.[33] Equally important, the regulation permits the Secretary to disregard the findings of the Advisory Committee, as well as the standards set forth at 38C.F.R. § 1.17 (d) and determine in his own judgment that the scientific and medical evidence supports the existence of a "significant statistical association" between a particular exposure and a specific disease 38 C.F.R. § 1.17 (f).

The Secretary recently exercised his discretionary authority under this rule when he found a significant statistical association between exposure to Agent Orange and non-Hodgkin's lymphoma, notwithstanding the failure of his own Advisory Committee to recommend such action in the face of overwhelming scientific data.[34]

B. THE WORK OF THE VETERANS' ADVISORY COMMITTEE ON ENVIRONMENTAL HAZARDS

To assess the validity and competency of the work of the Advisory Committee, I asked several impartial scientists to review the Advisory Committee transcripts. Without exception, the experts who reviewed the work of the Advisory Committee disagreed with its findings and further questioned the validity of the Advisory Committee's review of studies on non-Hodgkin's lymphomas.

For instance, a distinguished group at the Fred Hutchinson Cancer Research Institute in Seattle, Washington, upon reviewing the Advisory Committee transcripts, concluded "that it is at least, as likely as not that there is a significant association *(as* defined by the Secretary of Veterans Affairs) between (exposure to phenoxy acid herbicides and non-Hodgkin's lymphoma.)" 35 This same group further asserts that the Committee's work was "not sensible" and "rather unsatisfactory" in its review and classification of the various studies it reviewed. Additionally, these scientists regarded Dr. Lathrop's views as "less than objective" and felt that the possibility exists that "his extreme views (e.g., in respect to the role of dose--response testing) may have unduly affected the Committee's work." Finally, the Hutchinson scientists argue that the issue of chemical-specific effects, in which animal studies have been sufficient to demonstrate the carcinogenicity of dioxin, is an important factor "not well considered by the Committee." (Emphasis in original)

A second reviewer of the Committee's work, Dr. Robert Hartzman (considered one of the U.S. Navy's top medical researchers), effectively confirms the views of the Hutchinson group. Dr. Hartzman states that "the preponderance of evidence from the papers reviewed [by the Advisory Committee) weighs heavily in favor of an effect of Agent Orange on increased risk for non-Hodgkin's lymphoma."[36] Dr. Hartzman also attests that: An inadequate process is being used to evaluate scientific publications for use in public policy. The process uses scientific words like 'significant at the 5% level' and a committee of scientists to produce a decision about a series of publications. But in reality, the Committee was so tied by the process, that a decision which should have been based on scientific data was reduced to vague impressions... Actually, if the reading of the rules of valid negative found in the transcript is correct ('a valid negative must be significant at the p=.05 level' that is statistically significant on the negative side) none of the papers reviewed are valid negatives. [37]

A third reviewing team, Dr. Jeanne Hager Stellman, PhD (Physical Chemistry) and Steven D. Stellman, PhD (Physical Chemistry), also echo the sentiments expressed by the Hutchinson Group and Dr. Hartzman on the validity of the Committee's proceedings and conclusions. In fact, the Stellmans' detailed annotated bibliography and assessment of numerous cancer studies relevant to herbicide exposure presents a stunning indictment of the Advisory Committee's scientific interpretation and policy judgments regarding the link between Agent Orange and Vietnam Veterans. [38]

A fourth reviewer, a distinguished scientist intimately associated with government sponsored studies on the effects of exposure to Agent Orange, states the same conclusions reached by the other reviewers:

> The work of the Veterans' Advisory Committee on Environmental Hazards, as documented in their November 2, 1989 transcript, has little or no scientific merit, and should not serve as a basis for compensation or regulatory decisions of any sort...

> My analysis of the NHL articles reviewed by the committee reveals striking patterns which indicate to me that it is much more likely than not that a statistical association exists between NHL and herbicide exposure.

As these various reviewers suggest, the Advisory Committee's conclusions on the relationship between exposure to Agent Orange and non-Hodgkin's lymphoma were woefully understated in light of the clear evidence demonstrating a significant statistical association between NHL and exposure to phenoxy acid herbicides such as Agent Orange.

Perhaps more significant than the Committee's failure to sake such obvious findings is the distressing conclusion of the independent reviewers that the Committee's process is so flawed as to be useless to the Secretary in making any determination on the effects of Agent Orange. From a mere reading of Committee transcripts, these reviewers detected overt bias in the Committee's evaluation of certain studies. In fact, some members of the Advisory Committee and other VA officials have, even before reviewing the evidence, publicly denied the existence of a correlation between exposure to dioxins and adverse health effects.[40] This blatant lack of impartiality lends credence to the suspicion that certain individuals may have been unduly influenced in their evaluation of various studies. Furthermore, such bias among Advisory committee members suggests that the Secretary should, in accordance with the Dioxin Standards Act, appoint new personnel to the Advisory Committee.

III. THE CDC STUDIES

Were the faulty conclusions, flawed methodology and noticeable bias of the Advisory Committee an isolated problem, correcting the misdirection would be more manageable. But, experience with other governmental agencies responsible for specifically analyzing and studying the effects of exposure to Agent Orange strongly hints at a discernible pattern, if not outright governmental collaboration, to deny compensation to Vietnam Veterans for disabilities associated with exposure to dioxin .

A case in point is the Centers for Disease control ("CDC"). As concerns grew following the first studies of human exposure to Agent Orange, Congress commissioned a large scale epidemiological study to determine the potential health effects for Vietnam Veterans exposed to Agent Orange. Initially, this study was to be conducted by the VA itself. When evidence surfaced, however, of the VA's foot-dragging in commencing the study (and initial disavowal of any potential harm from exposure to Agent Orange), Congress transferred the responsibility for the study to the CDC in 1983. [41]

Unfortunately, as hearings before the Human Resources and Intergovernmental Relations Subcommittee on July 11, 1989 revealed, the design, implementation and conclusions of the CDC study were so ill conceived as to suggest that political pressures once again interfered with the kind of professional, unbiased review Congress had sought to obtain.[42]

The Agent Orange validation study, for example, a study of the long-term health effects of exposures to herbicides in Vietnam, was supposedly conducted to determine if exposure could, in fact, be estimated.[43] After four years and approximately $63 million in federal funds, the CDC concluded that an Agent Orange exposure study could not be done based on military records. [44] This conclusion was based on the results of blood tests of 646 Vietnam Veterans which ostensibly demonstrated that no association existed between serum dioxin levels and military-based estimates of the likelihood of exposure to Agent Orange.[45] Inexplicably, the CDC then used these "negative" findings to conclude that not only could an exposure study not even be done, but that the "study" which was never even conducted proves that Vietnam Veterans were never exposed to harmful doses of Agent Orange.

Even more disturbing, when the protocol for this "study" and the blood test procedures were examined further, there appeared to be a purposeful effort to sabotage any chance of a meaningful Agent Orange exposure analysis. For, the original protocol for the Agent Orange exposure study understandably called for subject veterans to be tracked by company level location.[46] By tracking company level units of 200 men, rather than battalions of 1,000 men, the location of men in relation to herbicide applications would be known with greater precision, thereby decreasing the probability that study-subjects would be misclassified as having been or not been exposed to Agent Orange.

However, in 1985 the CDC abruptly changed the protocol to have battalions, rather than companies, serve as the basis for cohort selection and unit location. [47] By the CDC's own admission, changing the protocol to track veterans on the broader batta1ion basis effectively diluted the study for the simple reason that many of the 1,000 men in a battalion were probably not exposed to Agent Orange. Why then did the CDC change the protocol in 1985?

According to Dr. Vernon Houk, Director of the Center for Environmental Health and Injury control, the department within the CDC responsible for conducting the Agent Orange study, the protocol was changed because the CDC concluded that company-specific records were unreliable and contained too many gaps of information. As a result, military records could simply not be used to assess exposure.[48]

Richard Christian, the former director of the Environmental Study Group of the Department of Defense ("ESG") testified that not only was this conclusion false, but that he had personally informed the CDC that adequate military records existed to identify company-specific movements as well as spray locations.[49] Furthermore, in a February 1985 report to the Congressional Office of Technology Assessment, the CDC reported that in analyzing 21 of 50 detailed computer HERBs tapes developed by the ESG on company movements that it was possible to correlate the exposure data to areas sprayed with Agent Orange with consistent results.[50] Indeed, a peer reviewed study sponsored by the American Legion conclusively demonstrated that such computerized data could be used to establish a reliable exposure classification system essential to any valid epidemiologic study of Vietnam Veterans.[51]

In addition to altering the protocol from company units to battalions, the CDC further diluted the study by changing the protocol on the length of time study subjects were to have served in Vietnam. Whereas the original protocol required subjects to have served a minimum of 9 months in combat companies, the CDC reduced the minimum to 6 months. Furthermore, the CDC eliminated from consideration all veterans who served more than one tour in Vietnam. Finally, while the original protocol called only for subjects who served in Vietnam from 1967 to

1968, the years that Agent Orange spraying was at its height, the CDC added an additional 6 months to this time period. The net effect of these various changes was seriously to dilute the possibility that study subjects would have been exposed to Agent Orange, which in turn would impair any epidemiological study's ability to detect increases in disease rate.[52]

Although the above referenced problems cast serious suspicion on the work of the CDC, perhaps its most controversial action was to determine unilaterally that blood tests taken more than 20 years after a veteran's service in Vietnam were the only valid means of determining a veteran's exposure to Agent Orange. In addition, Dr. Houk further "assumed" that the half-life for dioxin in the blood was seven years. [53] When the underlying data for Houk's assumptions were recently reviewed, however, 11 percent of the blood tests were invalid (i.e. study subjects had higher values of dioxin in their blood in 1987 than in 1982 even though the subjects had no known subsequent exposure to dioxin) and the half lives of dioxin in the remaining study subjects ranged from a low of 2 to a high of 740 years! [54] Yet despite this tremendous variance in the data and the high incidence of false results, Houk and the CDC concluded, rather remarkably, that a large scale exposure study was simply not possible since "negative" blood tests appeared to "confirm" that study subjects were not even exposed to Agent Orange.

Such conclusions are especially suspect given the fact that scientists have consistently cautioned against the use of blood tests as the sole basis for exposure classification. Although blood and adipose tissue tests can be used to confirm that Vietnam veterans were heavily exposed to Agent Orange and the contaminant dioxin[55], even the CDC's own researchers have unequivocally stated that "much more has to be learned about the kinetics of dioxin metabolism and half-life before current levels can be used to fully explain historic levels of exposure."[56]

While the CDC's changes in protocol have been "justified", however unreasonably, on the basis of "scientific" explanations[57], what cannot be justified is the evidence of political interference in the design, implementation and drafting of results of the CDC study by Administration officials rather than CDC scientists. As early as 1986, the Subcommittee on Oversight and Investigations of the Committee on Energy and Commerce documented how untutored officials of the Office of Management and Budget (0MB) interfered with and second-guessed the professional judgments of agency scientists and multidisciplinary panels of outside peer review experts effectively to alter or forestall CDC research on the effects of Agent Orange, primarily on the grounds that "enough" dioxin research had already been done.[58] These Agent Orange Hearings revealed additional examples of political interference in the CDC~s Agent Orange projects by members of the White House Agent Orange Working Group.[59]

Dr. Philip Landrigan, the former Director of the Environmental Hazards branch at the CDC, upon discovering the various irregularities in CDC procedures concluded that the errors were so egregious as to warrant an independent investigation not only of the methodology employed by the CDC in its validation study, but also a specific inquiry into what actually transpired at the Center for Environmental Health of the CDC.[60]

With these suspicions in mind, it should come as no surprise that those familiar with the CDC~s work found little credence in the conclusions reached by the CDC in its recently released Selected Cancers Study. Even though the CDC has previously stated that it believes exposure to

Agent Orange is impossible to assess, it found no difficultly in reporting to the *press* upon the release of the Selected Cancers Study that exposure to Agent Orange does not cause cancer. This conclusion was reached despite the fact that the CDC made no effort to determine, through military records or blood/adipose tissue tests, if study subjects were, indeed, exposed to dioxins; nor did the CDC attempt to verify exposure to Agent Orange of those study subjects who actually contracted cancerous diseases. In fact, according to scientists who have made preliminary reviews of the CDC's findings, the statistical power of any one cancer grouping, with the exception of non-Hodgkin's lymphoma, was so low as to make any conclusion virtually impossible.

IV. RANCH HAND STUDY

Unfortunately, political interference in government sponsored studies associated with Agent Orange has been the norm, not the exception. In fact, there appears to have been a systematic effort to suppress critical data or alter results to meet preconceived notions of what alleged scientific studies were meant to find.[61] As recently as March 9, 1990 Senator Daschle disclosed compelling evidence of additional political interference in the Air Force Ranch Hand study, a separate government sponsored study meant to examine the correlation between exposure to Agent Orange and harmful health effects among Air Force veterans who participated in Agent Orange spraying missions under Operation Ranch Hand. As Senator Daschle explained:

> In January 1984, the scientists in charge of the Ranch Hand Study issued a draft baseline morbidity report that described some very serious health problems in the Ranch Hand veterans and stated that the Ranch Handers, by a ratio of five to one, were generally less well than the veterans in the control group. The opening sentence of the draft report's conclusion was clearly stated: "It is incorrect to interpret this baseline study as 'negative.'
>
> After the Ranch Hand Advisory Committee, which operates under the White House Agent Orange Working Group of the Domestic Policy Council, got its hands on the document, the final report was changed in some very important ways. Most notably, the table and exposition explaining that the Ranch Handers were generally less well than the controls was omitted, and the final conclusion was altered substantially. The statement that the baseline study was not negative was completely omitted and the study was described as "reassuring." [62]

By altering the study's conclusion, opponents of Agent Orange compensation were able to point to "irrefutable proof" that Agent Orange is not a health problem: if those veterans most heavily exposed to Agent Orange did not manifest any serious health problems, they argued, then it could safely be deduced that no veteran allegedly exposed to Agent Orange in smaller doses could have health problems. Yet, when Senator Daschle questioned Air Force scientists on why discrepancies existed between an Air Force draft of the Ranch Hand Study and the final report actually released to the press, the answers suggested not merely disagreements in data evaluation, but the perpetration of fraudulent conclusions. In a word, the major premise was badly flawed.

For example, in 1987 Ranch Hand scientists confirmed to Senator Daschle that an unpublished birth defects report shows that birth defects among Ranch Hand children are double those of children in the control group and not "minor" as originally reported in l984.[63]

This increase in birth defects takes on added significance when one considers that the original CDC birth defects study, which found no increase in birth defects, merely examined birth defects as reported on birth certificates, rather than as reported by the child's parent or physician. The CDC never recorded hidden birth defects, such as internal organ malformations and other disabilities that only became apparent as the child developed. Consequently, it is very likely that the CDC's negative findings on birth defects were also vastly understated.[64]

In addition to elevated birth defects, Ranch Handers also showed a significant increase in skin cancers unrelated to overexposure to the sun as originally suggested in the 1984 report. Air Force scientists also admitted that Air Force and White House Management representatives were involved in scientific decisions in spite of the study's protocol which prohibited such involvement.[65]

On February 23, 1990, the Air Force released a follow-up morbidity report on the Ranch Handers. That report, "1987 Follow-up Examination Results," described statistically significant increases in health problems among Ranch Handers including: all cancers--skin and systemic combined, both verified and suspected; skin cancers alone; hereditary and degenerative neurological diseases and other problems. The Air Force-concluded, however, that these and other problems cannot necessarily be related to Agent Orange/dioxin exposure, as they do not always show a "dose-response" relationship--particularly since the exposure index used in the data analysis "is not a good measure of actual dioxin exposure." [66]

With this conclusion, the Air Force for the first time officially acknowledged that the conclusions reached in its original 1984 Ranch Hand study are not simply moot, but that the Ranch Hand study is not, at this date, an Agent Orange study at all since dioxin exposure could not be determined reliably in the first place. In other words, the Air Force could just as easily have concluded that the health problems associated with the Ranch Handers were not necessarily related to eating beer nuts.

For the Air Force to have made the statement in 1990 of no evidence of a link between exposure to Agent Orange and the cancer problems experienced by Ranch Handers is, as Senator Daschle notes, "patently false."[67]. Although not yet conclusive, what the Ranch Hand and CDC studies demonstrate is that there is evidence of a link between health problems and dioxin exposures which may become definitive when a new and reliable exposure index is used to evaluate the data.

As stated by Dr. James Clary, one of the scientists who prepared the final Ranch Hand report:

> The current literature on dioxin and non-Hodgkin's lymphoma and soft tissue sarcoma can be characterized by the following:

> 1. It underestimates (reduced risk estimates) the effect of dioxins on human tissue systems. As additional studies are completed we can expect to see even stronger correlations of dioxin exposure and NHL/STS.
>
> 2. Previous studies were not sensitive enough to detect small, but statistically significant increases in NHL/STS. As time progresses, and additional evidence is forthcoming, it will be increasingly difficult for anyone to deny the relationship between dioxin exposure and NHL/STS

V. INDEPENDENT STUDIES

Shamefully, the deception, fraud and political interference that has characterized government sponsored studies on the health effects of exposure to Agent Orange and/or dioxin has not escaped studies ostensibly conducted by independent reviewers, a factor that has only further compounded the erroneous conclusions reached by the government.

For instance, recent litigation against the Monsanto Corporation revealed conclusive evidence that studies conducted by Monsanto employees to examine the health effects of exposure to dioxin were fraudulent. These same fraudulent studies have been repeatedly cited by government officials to deny the existence of a relationship between health problems and exposure to Agent Orange. According to court papers:

Zack and Gaffey, two Monsanto employees, published a mortality study purporting to compare the cancer death rate amongst the Nitro workers who were exposed to Dioxin in the 1949 explosion with the cancer death rate of unexposed workers. The published study concluded that the death rate of the exposed worker was exactly the same as the death rate as the unexposed worker. However, Zack and Gaffey deliberately and knowingly omitted 5 deaths from the exposed group and took 4 workers who had been exposed and put these workers in the unexposed group, serving, of course, to decrease the death rate in the exposed group and increase the death rate in the unexposed group. The exposed group, in fact, had 18 cancer deaths instead of the reported 9 deaths (P1 Ex 1464), with the result that the death rate in the exposed group was 65% higher than expected (emphasis in original) [69]. Similarly, recent evidence also suggests that another study heavily relied upon by those opposed to Agent Orange compensation to deny the existence of a link between dioxin and health effects was falsified. Three epidemiologic studies and several case report studies about an 1953 industrial accident in which workers at a BASF plant were exposed to dioxins concluded that exposure to TCDD did not cause human malignancies.[70] A reanalysis of the data that comprised the studies, all of which was supplied by the BASF company itself, revealed that some workers suffering from chloracne (an acknowledged evidence of exposure to dioxin) had actually been placed in the low--exposed or non--exposed cohort groups. Additionally, 20 plant supervisory personnel, not believed to have been exposed, were placed in the exposed group.

When the 20 supervisory personnel were removed from the exposed group, thereby negating any dilution effect, the reanalysis revealed statistically significant increases in cancers of the respiratory organs (lungs, trachea, etc.) and

When the 20 supervisory personnel were removed from the exposed group, thereby negating any dilution effect, the reanalysis revealed statistically significant increases in cancers of the respiratory organs (lungs, trachea, etc.) and cancers of the digestive tract.[71] According to the scientist who conducted this study, "(t)his analysis adds further evidence to an association between dioxin exposure and human malignancy."[72]

Recent evidence also reveals that Dow Chemical, a manufacturer of Agent Orange was aware as early as 1964 that TCDD was a byproduct of the manufacturing process. According to Dow' s then medical director, Dr. Benjamin Holder, extreme exposure to dioxins could result in "general organ toxicity" as well as "psychopathological" and "other systemic" problems. [73] In fact, a recent expert witness who reviewed Dow Chemical corporate documents on behalf of a plaintiff injured by exposure to dioxin who successfully sued Dow[74] states unequivocally that "the manufacturers of the chlorphenoxy herbicides have known for many years about the adverse effects of these materials on humans who were exposed to them."[75]

VI. CURRENT SCIENCE ON HEALTH EFFECTS OF HERBICIDES AND DIOXIN

Despite its poor record in carrying out its responsibility to ascertain the health effects of exposure to Agent Orange, the CDC has been candid in some of its findings. As early as 1983, for instance, the CDC stated in the protocol of its proposed Agent Orange Studies "(t) hat the herbicide contaminant TCDD is considered to be one of the most toxic components known. Thus any interpretation of abnormal findings related to 2,4,5-T must take into consideration the presence of varying or undetermined amounts of TCCD." [76]

In 1987, after first being leaked by the New York Times, a VA mortality study was released indicating a 110 percent higher rate of non-Hodgkin's lymphoma in Marines who served in heavily sprayed areas as compared with those who served in areas that were not sprayed. [77] The study also found a 58 percent higher rate of lung cancer among the same comparative groups. [78]

Also in 1987, a second VA study found a suggestive eight-fold increase in soft tissue sarcoma among veterans most likely to have been exposed to Agent Orange.[79]

A proportionate mortality study of deaths in pulp and paper mill workers in New Hampshire from 1975 to 1985 showed that one or more of the exposures experienced by such workers (dioxin is a byproduct of pulp and paper production) posed a "significant risk" for cancers of the digestive tract and lymphopoietic tissues. [80]

Another case control study of farmers in Hancock County, Ohio, showed a "statistically significant" rise in Hodgkin's disease and non-Hodgkin's lymphoma. Although the study speculates that exposure to phenoxy herbicides may be the cause of such elevated cancers, the study recognizes that, given the size of its cohort, the only credible conclusion that can be drawn is that it "adds to the growing body of reports linking farming and malignant lymphoma, particularly NHL." [81]

A study of disease and non-battle injuries among U.S. Marines in Vietnam from 1965 to 1972 showed a significantly higher rate of first hospitalizations for Marines stationed in Vietnam as opposed to Marines stationed elsewhere, particularly for neoplasms, diseases of the blood and blood forming organs and diseases of the circulatory and respiratory systems.[82] Of particular significance is the fact that the rate of first hospitalization for disease and non-battle injuries among Vietnam personnel rose steadily, reaching a peak in 1969, while the rate of non-Vietnam personnel remained relatively constant.[83] This rise in hospitalization for non-combat injuries coincides exactly with the increased use of Agent Orange, reaching a peak in 1969, and declining thereafter until its elimination in 1971.

In a recently published article entitled "2,4-D, 2,4,5-T, and 2,3,7,8-TCDD: An Overview", the authors acknowledge that at least three weaknesses in research related to dioxins are sufficient to cast doubt on the validity of any study. [84] The authors report that while the data on soft tissue sarcoma and phenoxy acids are too inconsistent to allow for any comment at this time, there is evidence of a strong association between STS and the suspect chemicals in 2 of the 8 studies analyzed in their article. Furthermore, the birth defect studies analyzed "suggest that adverse reproductive effects can be caused by (dioxin). [85]

Recent studies in Vietnam continue to show statistically significant reproductive anomalies and birth defects among women, and children of women presumably exposed to Agent Orange spraying.[86]

In the December 1, 1989, issue of *Cancer,* a study of the cancer risks among Missouri farmers found elevated levels of lip and bone cancer as well as nasal cavity and sinuses, prostrate, non-Hodgkin’s lymphoma and multiple myeloma. Smaller elevations, but elevations nonetheless, were found for cancers of the rectum, liver, malignant melanoma, kidney and leukemia. According to the authors, evidence of the cause for the elevated risks for these illnesses "may be strongest for a role of agricultural chemicals, including herbicides, insecticides and fertilizers." [87]

Both the U.S. Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC) have concluded that dioxin is a "probable human carcinogen." [88]

In a work entitled "Carcinogenic Effects of Pesticides" to be issued by the National Cancer Institute Division of Cancer Etiology, researchers conclude that while confirmatory data is lacking there is ample evidence to suggest that NHL, STS, colon, nasal and nasopharyngeal cancer can result from exposure to phenoxy herbicides .

A just released case control study of the health risks of exposure to dioxins confirmed previous findings that exposure to phenoxyacetic acids or chlorophenols entails a statistically significant increased risk (i.e. 1.80) for soft tissue sarcoma.[89]

As recently as February 28, 1990 an additional study found that farmers exposed to various herbicides containing 2,4-D may experience elevated risks for certain cancers, particularly cancers of the stomach, connective tissue, skin, brain, prostate, and lymphatic and hematopoietic systems."[90]

This week a scientific task force, after reviewing the scientific literature related to the potential human health effects associated with exposure to phenoxyacetic acid herbicides and/or their associated contaminants (chlorinated dioxins) concluded that it is at least as likely as not that exposure to Agent Orange is linked to the following diseases: non-Hodgkin's lymphoma, soft tissue sarcoma, skin disorders/chloracne, subclinical hepatotoxic effects (including secondary coproporphyrinuria and chronic hepatic porphyria), porphyria cutanea tarda, reproductive and developmental effects, neurologic effects and Hodgkin's disease.[91]

On the same day that this scientific task force reported a statistically significant linkage between exposure to the dioxins in Agent Orange and various cancers and other illnesses, the Environmental Protection Agency reported that the cancer risk posed by the release of such a "potent carcinogen" as dioxin in the production of white paper products is "high enough to require tighter controls on paper mills."[92]

CONCLUSIONS

As many of the studies associated with Agent Orange and dioxins attest, science is only at the threshold of understanding the full dimension of harmful toxic effects from environmental agents on various components of the human immune system. [93] In fact, a whole new discipline-immunotoxicology - has developed to explore further the effects of environmental chemicals on human health and to relate animal test results to humans.[94]

Immunotoxicology has established, however, at a minimum that at least three classes of undesirable effects are likely occur when the immune system is disturbed by environmental exposure to chemicals such as dioxin, including: 1) immunodeficiency or suppression; 2) alteration of the host defense mechanism against mutagens and carcinogens (one theory is that the immune system detects cells altered by mutagens or other carcinogenic trigger and destroys these cells. Thus, an impaired immune system may not detect and destroy a newly forming cancer); and 3) hypersensitivity or allergy to the chemical antagonist. Because of dioxin's ability to be both an immunosuppressant and a carcinogen, as early as 1978 immunologists were suggesting that "(a) gents such as TCDD may be far more dangerous than those possessing only one of these properties."[95]

While scientists are not in agreement, some immunotoxicologists argue that one molecule of a carcinogenic agent, like dioxin in the right place and at the right time can cause the human immune system to turn on itself, manifesting such breakdowns in the form of cancer. Indeed, even some courts have accepted this theory of causation in matters specifically related to exposure to dioxin.[96]

With additional evidence from Vietnam suggesting that Agent Orange contaminants have the ability to migrate away from actual spray locations via river channels and the food chain, the opportunity for a Vietnam Veteran to have been exposed to dioxin contaminant molecules increases significantly.[97]

It cannot be seriously disputed that any large population exposed to chemical agents, such as Vietnam Veterans exposed to Agent Orange, is likely to find among its members a number who will develop malignancies and other mutagenic effects as a result of being exposed to harmful agents.

To be sure, decisions today with regard to the seriousness of Agent Orange health effects must be made while the science of immunotoxicology is in its infancy. After having evaluated and considered all of the known evidence on Agent Orange and dioxin contaminants, it is evident to me that enough is known about the current trends in the study of dioxins, and their linkage with certain cancers upon exposure, to give the exposed Vietnam Veteran the benefit of the doubt.

This benefit of the doubt takes on added credence given two separate means for determining exposure to Agent Orange - 1) HERBs and Service HERBs tapes establishing troop location for comparison with recorded Ranch Hand spraying missions; and 2) blood testing from living Veterans, to ascertain elevated dioxin levels. The inexplicable unwillingness of the CDC to utilize this data has had the effect of masking the real increase in the rate of cancers among the truly exposed. There is, in my opinion, no doubt that had either of these methods been used, statistically significant increased rates of cancer would have been detected among the Veterans for whom exposure can still be verified.

Since science is now able to conclude with as great a likelihood as not that dioxins are carcinogenic directly and indirectly through immunosuppression, and since a large proportion of those exposed to dioxin can be so ascertained, I am of the view that the compensation issue for service-related illnesses associated with exposure to Agent Orange should be resolved in favor of Vietnam Veterans in one of the two following ways:

COMPENSATION FOR SERVICE RELATED ILLNESSES

Alternative 1:

Any Vietnam Veteran, or Vietnam Veteran's child who has a birth defect, should be presumed to have a service-connected health effect if that person suffers from the type of health effects consistent with dioxin exposure and the Veteran' s health or service record establishes 1) abnormally high TCDD in blood tests; or 2) the veteran's presence within 20 kilometers and 30 days of a known sprayed area (as shown by HERBs tapes and corresponding company records); or 3) the Veteran' s presence at fire base perimeters or brown water operations where there is reason believe Agent Orange have occurred.

Under this alternative compensation would not be provided for those veterans whose exposure came from TCDD by way of the food chain; silt runoff from sprayed areas into unsprayed waterways; some unrecorded U.S. or allied Agent Orange sprayings; inaccurately recorded sprayings; or sprayings whose wind drift was greater than 20 kilometers. Predictably, problems generated by the foregoing oversights, the mass of data to be analyzed as claims were filed, and the known loss of many service records would invalidate many veterans' legitimate claims

Alternative 2:

Any Vietnam Veteran or child of a Vietnam Veteran who experiences a TCDD-like health effect shall be presumed to have a service-connected disability. This alternative is admittedly broader than the first, and would provide benefits for some veterans who were not exposed to Agent Orange and whose disabilities are not presumably truly service-connected. Nevertheless, it is the only alternative that will not unfairly preclude receipt of benefits by a TCDD exposed Vietnam Veteran.

Furthermore, this alternative is consistent with the Secretary's decision regarding the service-connection of non- Hodgkin's lymphoma, as well as legal precedent with respect to other diseases presumed by the Department of Veterans Affairs to be connected to one or more factors related to military service (i.e. veterans exposed to atomic radiation and POW's with spastic colon).

PRESUMPTIONS OF AGENT ORANGE RELATED HEALTH EFFECTS

I have also given considerable thought to which health effects are to be presumed likelier than not to be related to TCDD exposure and therefore service-connected. Any such determination must be made in light of: 1) the review of the scientific literature, including animal studies where human data does not exist or has been manipulated; 2) the inappropriate processes of the Veterans Advisory Committee on Environmental Hazards; 3) the past political manipulations of Ranch Hand and CDC studies; and 4) the recent discoveries of manipulation by scientists hired by chemical manufacturers of dioxin contaminants to evaluate the potentially best epidemiological data concerning TCDD's effects on humans.

My evaluation of the evidence has been made with just such considerations in mind. Additionally, I have conferred with several experts in the field. After evaluating all the evidence and material of record, I am convinced that there is better than "an approximate balance of positive and negative evidence" on a series of Agent Orange related health effects.

It can, in my judgment, be concluded, with a very high degree of confidence, that it is at least as likely as not that the following are caused in humans by exposure to TCDD: non-Hodgkin' s lymphoma, chloracne and other skin disorders, lip cancer, bone cancer, soft tissue sarcoma, birth defects, skin cancer, lung cancer, porphyria cutanea tarda and other liver disorders, Hodgkin's disease, hematopoietic diseases, multiple myeloma, neurological defects and auto-immune diseases and disorders.

In addition, I am most comfortable in concluding that it is at least as likely as not that liver cancer, nasal/pharyngeal/esophageal cancers, leukemia, malignant melanoma, kidney cancer, testicular cancer, pancreatic cancer, stomach cancer, prostate cancer, colon cancer, brain cancer, psychosocial effects, and gastrointestinal disease are service-connected.

I have separated the two foregoing subsets subjectively only because there is somewhat more data to support the former than the latter. Nonetheless, immunological and toxicological theory supports both subsets and fully justifies, in my view, the inclusion of both subsets of the foregoing health effects in determining a service-connected injury.

Such a resolution of the embarrassingly prolonged Agent Orange controversy would be on the order of decisions to compensate U.S. soldiers who contracted cancer after exposure to radiation from atomic tests and U.S. soldiers involved, without their knowledge, in LSD experiments. With the scientific basis now available for it to be stated with confidence that it is at least as likely as not that various health effects are related to wartime exposure to Agent Orange, there is the opportunity finally to right a significant national wrong committed against our Vietnam Veterans.

RECOMENDATIONS

1. That the Secretary undertakes a prompt reevaluation of the compensation decision impacting on Vietnam Veterans exposed to Agent Orange in light of accumulating scientific evidence that discredits earlier "findings" of an insufficient linkage between dioxin contaminants in Agent Orange and rare disease, such as cancer illnesses.

2. To the extent that the Secretary deems it necessary to use the Veterans' Advisory Committee on Environmental Hazards to assist in his reevaluation, the current members should be dismissed-having demonstrated a disturbing bias in their review to date of the scientific literature related to Agent Orange and dioxin-and new members should be appointed in accordance with Section G of the Veterans' Dioxin and Radiation Exposure Compensation Standards Act, including persons with recognized scientific and medical expertise in fields pertinent to understanding the health effects of exposure to dioxin. The Committee meeting currently scheduled for May 16th and May 17th should be cancelled.

3. That the Secretary in making his decision regarding Agent Orange compensation for Vietnam Veterans do so on the basis of his independent evaluation of the existing scientific and medical evidence on the health effects of exposure to dioxins, as cataloged and discussed in this Report, and in full recognition that the standard to be applied-as mandated by both Congress and the courts-requires the resolution of doubts as to a number of cancers linked to dioxins in favor of the Vietnam Veterans.

FOOTNOTES

[1] See CDC Protocol for Epidemiologic Studies on the Health of Vietnam Veterans (November, 1983), p. 4 (The CDC Protocol also contains a literature review as of 1983 of the health effects on animals and humans exposed to herbicides and dioxin, pp. 63-78. The literature review documents health problems such as chloracne, immunological suppression, neurological and psychological effects, reproductive problems such as birth defects, carcinogenic effects such as soft tissue sarcomas, lymphomas and thyroid tumors, and various gastrointestinal disorders) ; See also General Accounting Office, "Report by the Comptroller General: Health Effects of Exposure to Herbicide Orange in South Vietnam Should Be Resolved," GAO-CED-79-22 at 2 (April 6, 1979) (hereinafter GAO Report, 1979)

Dioxin is a family of chemicals (75 in all) that does not occur naturally, nor is it intentionally manufactured by any industry. The most toxic dioxin is called 2,3,7,8-TCDD. Dioxins are produced as byproducts of the manufacture of some herbicides (for example, 2,4,5-T), wood preservatives made from trichlorophenals, and some germicides. Dioxins are also produced by the manufacture of pulp and paper, by the combustion of wood in the presence of chlorine, by fires involving chlorinated benzenes and biphenyls (e.g. PCBs), by the exhaust of automobiles burning leaded fuel, and by municipal solid waste incinerators

[2] See Bruce Myers, "Soldier of Orange: The Administrative, Diplomatic, Legislative and Litigatory Impact of Herbicide Agent Orange in South Vietnam," 8 B. C. Env't. Aff. L. Rev. 159, 162 (1979)

[3] See GAO Report, 1979 at 2, 3 n.1; See also Myers, 8 B.C. Environment Affairs L. Rev, at 162 In contrast, civilian applications of 2,4,5-T varied from 1 to 4 pounds per acre

[4] General Accounting Office, 'Ground Troops in South Vietnam Were in Areas Sprayed with Herbicide Orange," FPCD 80-23, p.1 (November 16, 1979)

[5] Letter from Dr. James R. Clary to Senator Tom Daschle (September 9, 1988). Dr. Clary is a former government scientist with the Chemical Weapons. Branch, BW/CW Division, Air Force Armament Development Laboratory, Eglin APE, Florida Dr. Clary was instrumental in designing the specifications for the **A/A** 45y-l spray tank (ADO 42) and was also the scientist who prepared the final report on Ranch Hand: Herbicide Operations in SEA, July 1979. According to Dr. Clary:

> When we (military scientists) initiated the herbicide program in the 1960's, we were aware of the potential for damage due to dioxin contamination in the herbicide. We were even aware that the 'military[6] formulation had a higher dioxin concentration than the 'civilian' version due to the lower cost and speed of manufacture. However, because the material was to be used on the 'enemy', none of us were overly concerned. We never considered a scenario in which. our own personnel would become contaminated with the herbicide. And, if we had, we would have expected our own government to give assistance to veterans so contaminated.

See also notes 13, 73-75 and accompanying text infra for additional information of the manufacturer's awareness of the toxicity of Agent Orange

[6] Combat units, such as the 'Brown Water Navy,' frequently conducted "unofficial" sprayings of Agent Orange obtained from out of channel, and thus unrecorded sources. Additionally, as Commander, U.S. Naval Forces, Vietnam, I was aware that Agent Orange issued to Allied forces was frequently used on unrecorded missions

[7] GAO Report 1979, supra note 1, at 29. See also note 82 and accompanying text infra for a discussion of the correlation between the spraying of Agent Orange and the hospitalization of Vietnam soldiers for disease and non-battle related injuries

[8] House Committee on Veteran's Affairs, 95th Cong., 2d Session, Herbicide "Agent Orange" Hearings before the Subcommittee on Medical Facilities and Benefits, (Oct. 11, 1978) (Statement of Maj. Sen. Garth Dettinger USAF, Deputy Surgeon General USAF at 12)

[9] Myers at 166

[10] Id   While birth defects did significantly increase in Saigon, critics contend that Saigon was not an area where the preponderance of defoliation missions were flown and argue that such increases were due primarily to the influx of U.S. medical personnel who kept better records of birth defects. Subsequent studies in Vietnam confirm the incidence of increased birth defects among civilian populations exposed to Agent Orange. See e.g. Phuong, et. al. "An Estimate of Reproductive Abnormalities in Women Inhabiting Herbicide Sprayed and Non-herbicide Sprayed Areas in the South of Vietnam, 152-1981 18 Chemospere 843-846 (1989) (significant statistical difference between hydatidiform mole and congenital malformations between populations potentially exposed and not exposed to TCDD); Phuong, et al, "An Estimate of Differences Among Women Giving Birth to Deformed Babies and Among Those with Hydatidiform Mole Seen at the OB-GYN Hospital of Ho Chi Minh City in the South of Vietnam," 18 Chemosphere 801-803 (1989) (statistically significant connection between frequency of the occurrence of congenital abnormalities and of hydatidiform moles and a history of phenoxyherbicide exposure); Huong, et al, "An Estimate of the Incidence of birth Defects, Hydatidiform Mole and Fetal Death in Utero Between 1952 and 1985 at the OB-GYN Hospital of Ho Chi Minh City, Republic of Vietnam," 18 Chemosphere 805-810 (l989) (sharp increase in the rate of fetal death in utero, hydatidiform mole (with or without choriocarcinoma) and congenital malformations from the pre 1965-1975 period, suggesting possible association to phenoxyherbicide exposure)

[11] Myers at 167

[12] Id

[13] Id Although Dow Chemical Company, the primary manufacturer of 2,45-T and 2,4-D, denied this teratogenicity, Dow's own tests confirmed that when dioxin was present in quantities exceeding production specifications, birth defects did occur. See J. McCullough, Herbicides: Environmental Health Effects: Vietnam and the Geneva Protocol: Developments During 1979,

13, (1970) (Congressional Research Report No. UG 447, 70-303SP) Pressure from industry subsequently led to some relaxation of the limits placed on the 2,4,5-T and 2,4-D. The only current uses for these chemicals in the United States are on rice, pastures, rangelands and rights of way

[14] Id at 167 See also Dow Chemical v. Ruckelshaus, 477 F.2d 1317, 1319 (8th Cir. 1973) (Secretaries announcement quoted in the opinion)

[15] Hardell, L. and Sandstrom, A. "Case-control Study: Soft Tissue Sarcomas and Exposure to Phenoxyacetic Acids or Chlorophenols," 39 Brit. J. Cancer, 711-717 (1979). See also note 89 infra for the confirming results of follow-up studies by Hardell and others

[16] Axelson and Sundell, "Herbicide Exposure, Mortality and Tumor Incidence: An Epidemiological Investigation on Swedish Railroad Workers," 11 Work Environment Health 21-28 (1974)

[17] U.S. Occupational Safety and Health Administration (1976), Air Contaminants; U.S. Code, Federal Register 29, Part 1910.93 at p. 27

[18] With regard to 2,4-D, the IARC found the following anomalies: elevated levels of cancer in rats; acute and short—term oral toxicity in mice, rabbits, guinea pigs and rats-death, stiffness in the extremities, in coordination, stupor, myotonia, and other physical abnormalities; in monkeys, injections caused nausea, vomiting, lethargy, muscular in coordination and head droop, fatty degeneration of the liver, spleen, kidneys and heart; fetal anomaly increases in some species; post—birth death rates increased in some. species; higher mortality rates and morphological alterations in pheasant embryos and their chicks when spraying took place under simulated field conditions; higher mortality rates in rat pups in a 3 generation exposure; gene mutation after exposure to high concentrations; chromosomal aberrations when cultured human lymphocytes were exposed; increased frequency of aberrant metaphases (2 to 4 times) in mice exposed to toxic concentrations

In humans the IARC found that: a 23 year old farming student, a suicide, had 6 grams of 2,4-D in his body, acute congestion of all organs, severe degeneration of ganglion cells in the central nervous system; 3 cases of peripheral neuropathy in humans sprayed with 2,4-D with initial symptoms of nausea, vomiting, diarrhea, swelling and aching of feet and legs with latency, in individual cases, paresthesia in the extremities, pain in the legs, numbness and aching of fingers and toes, swelling in hand joints, flaccid parapheresis; similar case reports in agriculture workers sprayed by 2,4-D; workers associated with 2,4-D developed symptoms of somnolence, anorexia, gastralgia, increased salivation, a sweet taste in the mouth, a sensation of drunkenness, heaviness of the legs and hyperacusea, rapid fatigue, headache, loss of appetite, pains in the region of liver and stomach, weakness, vertigo, hypotension, bradycardia, dyspeptic symptoms, gastritis, liver dysfunction, changes in metabolic processes

With regard to 2,4,5-Vs effect on animals the IARC found: it can increase the frequency of cleft palates in some strains of mice; fetal growth retardation may also be observed; cystic kidneys were observed in two strains of mice; in purest available form, it induced some fetal effects and skeletal anomalies in rats as well as behavioral abnormalities, changes in thyroid activity and brain serotonin levels in the progeny; increases in intrauterine deaths and in malformations in rats; fetal death and teratogenic effects in Syrian golden hamsters; chromosomal abnormalities

The IARC reported in 1977 with respect to 2,4,5-T's effects on humans that: workers exposed at a factory in the USSR had skin lesions, acne, liver impairment, and neurasthenic syndrome; similar findings were reported by Jerasneh, et al (1973, 1974) in a factory in Czechoslovakia which in 1965-68 produced 76 cases of chloracne, 2 deaths from bronchogenic cancers. Some workers had porphyria cutanea tarda, urophryimuria, abnormal liver tests, severe neurasthenia, depression syndrome, peripheral neuropathy; in a 1975 accident in West Virginia, 228 people were affected. Symptoms included chloracne, melanosis, muscular aches and pains, fatigue, nervousness, intolerance to cold; 4 workers of 50 affected in a similar accident in the Netherlands in 1963 died within 2 years and at least 10 still had skin complaints 13 years later

[19] June 1979 Congressional Hearings before House Commerce Committee. Subcommittee on Oversight and Investigations, quoted in "Human Disease Linked to Dioxin: Congress Calls for 2,4,5-T Ban After Dramatic Herbicide Hearings", 28 Bioscience 454 (August 1979). This study, otherwise known as the Alsea Study, has been cited as showing the first correlation between 2,4,5-T (and presumably its TCDD contaminant) and teratogenic effects in humans

[20] Zack and Suskind, "The Mortality Experience of Workers Exposed to TCDD in a Trichlorophenol Process Accident," 22 Journal of Medicine 11-14 (1980)

[21] See U.S. Interagency Workgroup to Study the Long-Term Health Effects of Phenoxy Herbicides and Contaminants (September 22, 1980) (executive summary)

[22] See...e.g. "The Weight of the Evidence on the Human Carcinogenicity of 2,4-D" (January 1990) (This report, sponsored by the National Association of Wheat Growers Foundation and a grant from the Industry Task Force II on 2,4-D Research Data, an association of manufacturers and commercial formulators of 2,4-D, concluded that the toxicological data on 2,4-D does not provide a strong basis for predicting that 2,4-D is carcinogenic to humans. Nevertheless, the panel reviewing the evidence did conclude that "evidence indicates that it is possible that exposure to 2,4-D can cause cancer in humans.")

[23] By October 1, 1983, 9170 veterans filed claims for disabilities that they alleged were caused by exposure to Agent Orange. The VA denied compensation to 7709 claimants on the grounds that the claimed diseases were not service connected. Only one disease was deemed associated with service related exposure to Agent Orange, a skin condition known as chloracne. See House Report No. 98-592, reprinted in U.S. Code Cong. & Adm. News, 98th Cong. 2d Session, 1984, at 4452. See also Nehmer v. U.S. Veterans Administration, 712 F supplement 1404, 1407 (1989)

[24] Veterans' Dioxin and Radiation Exposure Compensation Standards Act, Pub. L. 98-542, Oct. 24, 1984, 98 Stat. 2727 (hereinafter the Dioxin Standards Act). In passing the Act Congress found that Vietnam Veterans were "deeply concerned about possible long term health effects of exposure to herbicides containing dioxin,"(Section 2 (1)), particularly since "(t) here is scientific

and medical uncertainty regarding such long-term adverse health effects." (Section 2 (2)) In responding to this uncertainty, Congress mandated that "thorough epidemiological studies of the health effects experienced by veterans in connection with exposure to herbicides containing dioxin" be conducted, (Section 2(4)), especially in light of the fact that "(t) here is some evidence that chloracne, porphyria cutanea tarda, and soft tissue sarcoma are associated with exposure to certain levels of dioxin as found in some herbicides." (Section 2 (5))

[25] Id at Section 3

[26] Id at Section 5

[27] Id at Section 6

[28] Id at Section 5

[29] See Nehmer v. U.S. Veterans Admin., 712 F. Supp. 1404, 1408. (N.D. Cal. (1989). wherein the court found after reviewing the legislative history of the Act "that Congress intended service connection to be granted on the basis of "increased risk of incidence" or a "significant correlation" between dioxin and various diseases," rather than on the basis of a casual relationship

[30] See Dioxin Standards Act at Section 2 (23).

[31] See e.g. 38 C.F.R. 3.310(b) (compensation granted for cardiovascular diseases incurred by veterans who suffered amputations of legs or feet); Nehmer at 1418

The significance of the distinction between a statistical association and a cause and effect relationship is in the burden of proof that the veteran must satisfy in order to be granted benefits. A statistical association "means that the observed coincidence in variations between exposure to the toxic substance and the adverse health effects is unlikely to be a chance occurrence or happenstance," whereas the cause and effect relationship "describes a much stronger relationship between exposure to a particular toxic substance and the development of a particular disease than ‘statistically significant association’ does." Nehmer, 712 F supplement at 1416

Thus, the regulation promulgated by the VA established an overly burdensome standard by incorporating the causal relationship test within the text of the regulation itself. 38 C.F.R. 1 3.311(d) ("Sound scientific and medical evidence does not establish a cause and effect relationship between dioxin exposure" and any diseases except some cases of chloracne) (emphasis added)

[32] Nehmer, 712 F supplement at 1423.

[33] 38 C.F.R. 1.17 (b) & (d) 38 C.F.R. 1.17 states:
(a) From time to time, the Secretary shall publish evaluations of scientific or medical studies relating to the adverse health effects of exposure to a herbicide containing 2,3,7,8 tetrachlorodibenzo-p-dioxin (dioxin) and/or exposure to ionizing radiation in the "Notices"

section of the Federal Register.

(b) Factors to be considered in evaluating scientific studies include:
(1) Whether the study's findings are statistically significant and replicable.
(2) Whether the study and its findings have withstood peer review.
(3) Whether the study methodology has been sufficiently described to permit replication of the study.
(4) Whether the study's findings are applicable to the veteran population of interest.
(5) The views of the appropriate panel of the Scientific Council of the Veteran' Advisory Committee on Environmental Hazards

(c) When the Secretary determines, based on the evaluation of scientific or medical studies and after receiving the advice of the Veteran's Advisory Committee on Environmental Hazards and applying the reasonable doubt doctrine as set forth in paragraph (d) (1) of this section, that a significant statistical association exists between any disease and exposure to a herbicide containing dioxin or exposure to ionizing radiation, 3.311a or 3.311b of this title, as appropriate, shall be amended to provide guidelines for the establishment of service connection.

(d) (1) For purposes of paragraph (c) of this section a "significant statistical association" shall be deemed to exist when the relative weights of valid positive and negative studies permit the conclusion that it is at least as likely as not that the purported relationship between a particular type of exposure and a specific adverse health effect exists.

(2) For purposes of this paragraph a valid study is one which:

(i) Had adequately described the study design and methods of data collection, verification and analysis;

(ii) Is reasonably free of biases, such as selection, observation and participation biases; however, if biases exist, the investigator has acknowledged them and so stated the study's conclusions that the biases do not intrude upon those conclusions; and

(iii) Has satisfactorily accounted for known confounding factors.

(3) For purposes of this paragraph a valid positive study is one which satisfies the criteria in paragraph (d) (2) of this section and whose findings are statistically significant at a probability level of .05 or less with proper accounting for multiple comparisons and subgroups analyses.

(4) For purposes of this paragraph a valid negative study is one which satisfies the criteria in paragraph (d) (2) of this section and has sufficient statistical power to detect an association between a particular type of exposure and a specific adverse health effect if such an association were to exist.

(e) For purposes of assessing the relative weights of valid positive and negative studies, other studies affecting epidemiological assessments including case series, correlation studies and studies with insufficient statistical power as well as key mechanistic and animal studies which are found to have particular relevance to an effect on human organ systems may also be considered.

(f) Notwithstanding the provisions of paragraph (d) of this section, a "significant statistical association" may be deemed to exist between a particular exposure and a specific disease if, in the Secretary's judgment, scientific and medical evidence on the whole supports such a decision.

[34] After reviewing numerous scientific studies, at least four of which were deemed to be valid positive in demonstrating the link between exposures to herbicides containing dioxin and non-Hodgkin's lymphoma, the Advisory Committee still concluded that:

> The Committee does not find the evidence sufficient at the present time to conclude that there is a significant statistical association between exposure to phenoxy acid herbicides and non-Hodgkin's lymphoma. However, the Committee cannot rule out such an association.

The Secretary should be interested to note that a new mortality study positively confirms that farmers exposed to herbicides containing 2,4-D have an increased risk of developing non-Hodgkin's lymphoma. See Blair, "Herbicides and Non-Hodgkin's Lymphoma: New Evidence from a Study of Saskatchewan Farmers," 82 Journal of the National Cancer Institute 575--582 (1990)

[35] Letter to Admiral Zumwalt from Dr. Robert W. Day, Director of the Fred Hutchinson Cancer Research Center of Seattle, Washington (Feb. 20, 1990)

[36] Letter to Admiral Zumwalt from Dr. R.J. Hartzman Capt. MC USN (March 7, 1990)

[37] Id at p.3

[38] See Stellman & Stellman, "A Selection of Papers with Commentaries Relevant to the Science Interpretation and Policy: Agent Orange and Vietnam Veterans,' (March 1, 1990). See also note 51 and accompanying text infra for additional discussion of the Stellmans' work.

[39] A copy of the anonymous reviewer's analysis can be made available for the Secretary's personal .inspection and review. In another paper, this same source stated: "I estimate that the Vietnam Veterans are experiencing a 40% to 50% increase in sarcomas and non--Hodgkin's lymphoma rates."

[40] For instance, Dr. Lawrence B. Hobson (Director, Office of Environmental Medicine, Veterans Health Services and Research Administration), claims that TCDD 'presents no threat from the exposures experienced by the veterans and the public at large," and virtually accuses scientists who find that such health effects do exist to be nothing more than witch doctors. See Hobson, 'Dioxin and Witchcraft" presented at the 5th International Symposium on Chlorinated Dioxins and Related Compounds (September 1985)

[41] See 135 Congressional Record, Statement of Senator Tom Daschle (November 21, 1989); See also Agent Orange Hearings at p.37

[42] Oversight Review of CDC's Agent Orange Study: Hearing Before the Human Resources and Intergovernmental Relations Subcommittee of the Committee on Government Overations House of Representatives, 101st Cong., 1st Sess. at p. 71 and 330 (1989) [hereinafter cited as Agent Orange Hearing]

[43] Id at 37; See also, Protocol for Epidemiologic Studies of the Health of Vietnam Veterans, Centers for Disease Control, Public Health Service, U.S. Department of Health and Human Services (November, 1983).

[44] Agent Orange Hearings at 13 (Statement of Dr. Vernon Houk)

[45] Id at 12-13

[46] Id at 4l

[47] Id at 38

[48] Agent Orange Hearing: Testimony of Dr. Vernon Houk at 38-40 and 69. Dr. Houk sports an unbounded skepticism for the health hazards of dioxin. He recently endorsed the lessening of the dioxin dumping standard in the State of Georgia at a rate 500 times more lenient than EPA recommended guidelines. See Letter from Dr. Vernon N. Houk to Leonard Ledbetteber, Commissioner Georgia Department of Natural Resources (November 27, 1989)

[49] Agent Orange Hearing, Testimony of Richard Cheristian at 41

[50] Interim Report, Agent Orange Study: Exposure Assessment: Procedures and Statistical Issues. See Also American Legion Magazine Special Issue, "Agent Orange" (1990) at p. 12

[51] Agent Orange Hearing 155-220 (Testimony of Steven and Jeanne Stellman); American Legion and Columbia University Vietnam Experience Study, Environmental Research (December, 1988)

[52] Agent Orange Hearing at 46-49. This "dilution effect" is considered the classic flaw in epidemiological study design most epidemiologists would try to optimize the chances of observing an effect by including, rather than excluding, the subjects who are most likely to have been exposed to the suspected disease causing agent. This statistical ability to observe an effect if one is present is generally referred to as the "statistical power" of a given study

When the CDC chose to generalize exposure to Agent Orange to groups of veterans who were less likely, rather than more likely, to be exposed, the power of the study was diluted. For example, if we assume that 1 out of every 5 men who served in Vietnam was exposed to Agent Orange any possible effects of the exposure will be diluted when the 4 non-exposed men are averaged in. If we assume further that exposure to Agent Orange caused a doubling of the incidence of cancers among the 20% of men exposed, the effect would largely be obscured since 80% of the group being studied would not have been sprayed with Agent Orange and would thus have a normal background rate of cancer. Consequently, only exceptionally large increases in the cancer rate would be discovered and or reach statistical significance in a study group so diluted from the outset. See Agent Orange Hearing at 149 (Testimony of John F. Sommer, Jr., Director National Veterans Affairs and Rehabilitation commission the American Legion). See also Agent Orange Legislation and Oversight: Hearing before the Committee on Veterans' Affairs, United States Senate, 100th Congress, (May 12, 1988) (Testimony of Dr. Joel Nichalek) at pp. 65, 66 and 668

[53] Agent Orange Hearing at 59 Dr. Houk's assumption was based on a study of only 36 former Ranch Handers (members of "Operation Ranch Hand," the Air Force herbicide defoliation program) who had volunteered blood samples in 1982 and 1987

[54] American Legion Magazine Reprint "Agent Orange" at 12 See also Agent Orange Hearing at p. 67 (testimony of Dr. Houk revealed that the senior-statistician on the Agent Orange project believed that the dioxin blood analysis was so flawed there is a substantial likelihood that there is no correlation between the exposure scores and the blood levels)

[55] See Kahn, "Dioxins and Dibenzofurans in Blood and Adipose Tissue of Agent Orange Exposed Vietnam Veterans and Matched Controls," 259 Journal of the American Medical Association 1661 (1988). This report found that "Vietnam veterans who were heavily exposed to Agent Orange exceeded matched control subjects in both blood, and adipose tissue levels of 2,3,7, 8-tetrachlorodibenzo-p-dioxin (TCDD) but not in the levels of the 12 other 2,3,7,8-substituted dioxins and dibenzofurans that were detected. Since only TCDD among these compounds was present in Agent Orange but all are present in the population of the industrialized world, it is likely that the elevated TCDD levels arose from wartime exposure."

[56] Patterson, "Levels of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Workers Exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin, 16 American Journal of Industrial Medicine 135, 144 (1989)

[57] See generallv, Agent Orange Hearing (Testimony of Dr. Vernon Houk) at 44--50

[58] OMB Review of CDC Research: Impact of the Paperwork Reduction Act; A Report Prepared for the Subcommittee on Oversight and Investigations of the Committee on Energy and Commerce, 99th Cong. 2nd Session (October 1986)

[59] See Agent Orange Nearing at 49-54 (Testimony of Dr. Vernon Houk)

[60] Agent Orange Hearing at 229 and 330

[61] See generally Agent Orange Hearing; Congressional Record, S 2550 (March 9, 1990); Congressional Record, (November 21, 1989) (Statements of Senator Thomas Daschle)

[62] See Congressional Record S 2550 (March 9, 1990)

[63] Congressional Record, (November 21, 1989) (Statement of Senator Thomas Daschle)

[64] The CDC birth defects study was confined to Vietnam Veterans located in the Atlanta, Georgia region. The study was not an Agent Orange birth defects study since no effort was made to determine whether the veterans had even been exposed to Agent Orange. See notes 10 and 18 supra for additional information on birth defects

[65] Congressional Record, S 2551 (March 9, 1990) (Statement of Senator Daschle)

[66] Wolfe, St. et al, Air Force Health Study and Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides (Feb. 1990) at p. vi

[67] Congressional Record 5 2551 (March 9, 1990). **See also** Letter from Maj. Gen. James G. Sanders, U.S.A.F. Deputy Surgeon General to Senator Thomas Daschle (February 23, 1990)

[68] Letter from Dr. James Clary to Senator Tom Daschle (September 9, 1988)

[69] Brief of Plaintiffs-appellees in Kemner. et. al. v. Monsanto Company, No. 5-88-0420 (5th Dist., Illinois Appellate Court) (Oct. 3, 1989) (as the facts were proven at trial, the appeal only considered appealable matters of law). Plaintiff's brief refers to Zack and Gaffey, "A Mortality Study of Workers Employed at the Monsanto Company Plant in Nitro, WV man Environmental Risks of Chlorinated Dioxins and Related Compounds (1983) pp. 575-591. It should be noted that the Advisory Committee classified this report as "negative" in evaluating compensation for NHL

The brief also states that another study of the workers exposed in the 1949 accident was also fraudulent (e.g. R.R. Suskind and V.S. Hertzberg, "Human Health Effects of 2,4,5-T and Its Toxic Contaminants," Journal of the American Medical Association, Vol. 251, No. 18 (1984) pgs. 2372-2380.) The study reported only 14 cancers in the exposed group and 6 cancers in the unexposed group. Trial records conclusively demonstrated, however, that there were 28 cancers in the group that had been exposed to dioxins, as opposed to only 2 cancers in the unexposed group

[70] See e.g. Thiess, Frentzel-Beyme, Link, "Mortality Study of Persons Exposed to Dioxin in a Trichlorophenol Process Accident that occurred in the BASF AG on November 17 , 1953", 3 American Journal of Industrial Medicine 179—189 (1982)

[71] Friedemann Rohleder, "Dioxins and Cancer Mortality Reanalysis of the BASF Cohort," presented at the 9th International Symposium on Chlorinated Dioxins and Related Compounds, Toronto, Ontario (Sept. 17-22, 1989). BASF recently published a study in an attempt to refute the allegations that the original studies related to the accident were fraudulent. See Zobier, Messerer & Huber, "Thirty Four Year Mortality Follow Up of BASF Employees, 62 Occupational Environmental Health 139-157, (Oct. 19, 1989). While the company states that "there was no significant increase in deaths from malignant neoplasms," the study does conclude that:

> There was, however, a significant excess for all cancers combined among the chloracne victims 20 or more years after initial exposure when an excess would be most likely to occur. In addition, there is the notable finding on one case of liver cancer without cirrhosis in a worker with an exceptionally high level of TCDD in the blood.

Id at 155 See also Id at 139 ("In general, our results do not appear to support a strong association between cancer mortality and TCDD, but they do suggest that some hazard may have been produced.) (emphasis added) and 149 ("Although TCDD blood levels were available for only 5 of the 10 subjects, the three highest levels were found in subjects with liver cancer, leucosis and Merkell-cell carcinoma of the skin.")

[72] Wanchinski, "New Analysis Links Dioxin to Cancer," New Scientist, (Oct. 28, 1989) p. 24

[73] See L. Casten, Patterns of Secrecy: Dioxin and Agent Orange (1990) (unpublished manuscript detailing the efforts of government and industry to obscure the serious health consequences of exposure to dioxin)

[74] Peteet v. Dow Chemical Co., 868 F.2d 1428 (5th Cir. 1989) cert...Denied 110 S. Ct. 328 (1989)

[75] Letter from Daniel Teitelbaum, M.D., P.C. to Admiral E.R. Zumwalt, Jr. (April 18, 1990). Dr Teitelbaum additionally states:

What I do think...may bear on the Agent Orange issue, is the fact that in review of Dow's 2,4-D documentation I found that there are significant concentrations of potentially carcinogenic materials present in 2,4-D which have never been made known to the EPA, FDA, or to any other agency. Thus, in addition to the problem of the TCDD which, more likely than not, was present in the 2,4,5-T component of Agent Orange, the finding of other dioxins and closely related furans and xanthones in the 2,4-D formulation was of compelling interest to me.

[76] CDC Protocol, see note 1 supra The CDC went on to state that a wide variety of health effects have been observed following the administration of TCDD to experimental animals including soft tissue sarcomas and lymphoma$_1$ nasal and nasopharyngeal cancers, birth defects, changes in thymus and lymphoid tissues, and other numerous cancers. Additionally, the CDC acknowledged the toxic effects of occupational exposure to dioxin, including evidence that exposure "may be associated with an increased risk of soft tissue sarcoma and lymphoma" and perhaps nasal and nasopharyngeal cancers.

[77] Breslin, et al, "Proportionate Mortality Study of U.S. Army and U.S. Marine Corps Veterans of the Vietnam War," Veterans Administration (1987)

[78] Id Some scientists, including the Advisory Committee have attempted to denigrate these significant findings on the basis that Army personnel did not show similar results. The explanation for this lack of comparative Army findings is directly attributable to the dilution effect caused by including logistics personnel as part of the Army study. Marines were studied as a separate group. The Marine's logistical support personnel (i.e. the Navy), were not included. Thus, the increased cancers among Marines were clearly associated with field exposure to Agent Orange

The Army study, on the other hand, combined field personnel with personnel on logistics assignments who were unlikely to have been exposed to Agent Orange. As a result, the Army findings were drastically diluted. Additionally, Army personnel generally engaged the enemy and returned to base, whereas Marines consistently remained in areas presumably sprayed by

Agent Orange to provide medical, health and engineering assistance to the local population. Such "pacification" efforts gave Marines additional opportunities to be exposed to dioxins.

[79] Kang, et al, "Soft-Tissue Sarcoma and Military Service in Vietnam: A Case Control Study," 79 Journal of the National Cancer Institute 693 (October, 1987). The increases were not statistically significant as reported. Nonetheless, the results are remarkable.

[80] E · Schwartz, "A Proportional Mortality Ratio of Pulp and Paper Mill Workers in New Hampshire," 45 British Journal of Industrial Medicine, 234-238 (1988)

[81] Dubrow, Paulson & Indian, "Farming and Malignant Lymphoma in Hancock county, Ohio," 45 British Journal of Industrial Medicine 25-28 (1988)

[82] Palinkas & Coben, "Disease and Non-Battle Injuries among U.S. Marines in Vietnam, 153 Military Medicine 150 (March, 1988)

[83] Id at 151 It should be noted that the year of greatest combat activity, as measured by the number of personnel wounded in action, 1968, had the smallest disease and non-battle injury vs. wounded in action ratio. Id at 152

[84] Lilienfeld and Gallo "2,4-D, 2,4,5-T and 2,3,7,8-TCDD An Overview," Epidemiologic Review, Vol. II (1989). Three major criteria must be considered in evaluating the numerous epidemiologic studies of phenoxy herbicides and 2,3,7,8-TCDD: 1) the accuracy of exposure assessment; 2) the studies' statistical power; and 3) the adequacy of follow-up. Problems in any one of the three areas leaves the study open to criticism and subject to manipulation.

For instance, in retrospective studies, various proxies of exposure to herbicides and 2,3,7,8,-TCDD have been used such as military service in Vietnam or residence in an area in which the herbicides were sprayed. The weakness in such an approach is that unless the proxy corresponds to exposure, the "exposed group" is diluted with the individuals who have NOT been exposed, thereby reducing the magnitude of the strength of the association. In fact, such reduction may be of such a degree as to preclude detection of any of a serum marker for 2,3,7,8-TCDD by Kahn may provide the means of identifying persons who have been exposed.

Furthermore, studies concerning Agent Orange have nearly all been conducted in the past decade. This 10 year latency period is generally thought to be insufficient for many cancers to be clinically detected.

[85] Id

[86] See note 10 supra. It should be noted that as early as 1977 information about Agent Orange's potential for genetic damage was known to the VA. For example, a "NOT FOR RELEASE" VA document expressly noted Agent Orange's "high toxicity" and "its effect on newborn, deformed children - similar to the thalidomide situation." See L. Casten, Patterns of Secrecy note 73 supra at Department of Veteran Affairs p.4. Similarly, in March of 1980, Senator Tom Daschle and Rep. David Bonior received an anonymous memorandum written on VA stationery which stated:

> Chemical agents 2,4,5-T and 2,4-D commonly known as Agent Orange and Agent Blue, are mutagenic and teratogenic. This means they intercept the genetic DNA message processed to an unborn fetus, thereby resulting in deformed children being born. Therefore, the veteran would appear to have no ill effects from the exposure but he would produce deformed children due to this breakage in his genetic chain.... . .Agent Orange is 150,000 times more toxic than organic arsenic.

Id. See also Wolfe & Lathrop, **"A** Medical Surveillance Program for Scientists Exposed to Dioxins and Furans," Human and Environmental Risks of Chlorinated Dioxins and Related Compounds, 707-716 (1983)

[87] Brownson, et. al. "Cancer Risks Among Missouri Farmers," 64 Cancer 2381, 2383 (December 1, 1989)

[88] Agency for Toxic Substances and Disease Registry, pp. 7, 61-68, 94 reprinted in Rachel's Hazardous Waste News # 173 (March 21, 1990)

[89] Eriksson, Hardell & Adami, "Exposure to Dioxins as a Risk Factor for Soft Tissue Sarcoma: A Population--Based Case--Control study," 82 Journal of the National Cancer Institute 486-490 (March 21 1990). It should be noted that in this study the median latency for phenoxyacetic acid and chlorophenols exposure was 29 and 31 years respectively, thereby suggesting that many of the veterans who are at risk have not yet manifested symptoms of STS

[90] Blair, "Herbicides and Non-Hodgkin's Lymphoma: New Evidence from a Study of Saskatchewan Farmers," 82 Journal of the National cancer

[91] Report of the Agent Orange Scientific Task Force of the American Legion, Vietnam Veterans of America, and the National Veterans Legal Services Project, reported by McAllister, "Viet Defoliant Linked to More Diseases, Washington Post, May 1, 1990 at AS, col. 4. The report also found that there are other disorders for which there is evidence suggesting an association with exposure to Agent Orange, but for which statistically significant evidence is not currently available. Those diseases include: leukemias, cancers of the kidney, testis, pancreas, stomach, prostate, colon hepatobiliary tract, and brain, psychosocial effects, immunological abnormalities, and gastrointestinal disorders

[92] Weisskopf, "EPA Seeking to Reduce Dioxin in White Paper: Cancer Risk Said to Justify Mill Restrictions," Washington Post, May 1, 1990 at **AS,** col. 1

[93] A recent report in the Washington Post suggests that there is an inherent uncertainty in trying to measure the dangers posed by the chemicals humans eat, drink and breathe. Since human experimentation is impossible to assess the effect of varied doses of a chemical on human health, scientists are ultimately required to speculate or guess as to the health effects of a given chemical to the human body. See Measuring Chemicals' Dangers: Too Much Guesswork?" Washington Post, March 23, 1990

[94] Silbergeld & Gaisewicz, "Dioxins and the Ah Receptor," 16 American Journal of Industrial Medicine 455, 468-69 (1989)

[95] Inadvertent Modification of the Immune Response — The Effect of Foods, Drugs, and Environmental Contaminants; Proceedings at the Fourth FDA symposium; U.S. Naval Academy (August 28-30, 1978), p. 78

[96] See Peteet V. Dow Chemical Co. , 868 F.2d 1428, 1433 (5th Cir. 1989) cert denied 110 S. Ct. 328 (1989)

[97] See e.g. Schecter, et al, "Levels of 2,3,7,8—TCDD in Silt Samples Collected Between 1985-86 From Rivers in the North and South of Vietnam," 19 Chemosphere 547-550 (1989) (suggestive findings that the predominant dioxin isomer in Agent Orange has moved into downstream rivers in the South of Vietnam); Olie, et al, "Chlorinated Dioxin and Dibenzofuran Levels in Food and Wildlife Samples in the North and South of Vietnam," 19 Chemosphere 493-496 (1989) (food and wildlife specimens in South Vietnam had a higher relative abundance of 2,3,7,8-TCDD suggesting contamination from Agent Orange); Schecter, et al, "Chlorinated Dioxin and Dibenzofuran Levels in Food Samples Collected Between 1985-87 in the North and South of Vietnam," 18 Chemosphere 627-634 (1989) (Agent Orange contaminants, specifically 2,3,7,8-TCDD found at relatively elevated levels in food and wildlife samples 15-25 years after environmental contamination with compound in South of Vietnam

Annex A Calculation of Ocean and Shore Activity

Estimating the amount of material deposited in the lagoon and onto JI is the goal. Dr. Leo Rahal (DTRA 2000a) modeled and predicted the deposition of plutonium from the explosion and fire from BLUEGILL PRIME and STARFISH using LE-1 as the center. The predicted plume covered areas of JI and the lagoon.

The first step is to take the BLUEGILL PRIME Deposition pattern (labeled Figure B-10 in DTRA 2000a) and reproduced here as Figure 19. (The units on Figure B-10 in the DTRA document are listed as ^{238}Pu, but that is a typographical error. It should be ^{239}Pu.)

The second step is to calculate the land area. The shoreline is estimated to be 100 yards from the launch site as the center of deposition pattern. The method is to take Figure 19 and enlarge it as Figure 20. The land area covered by the boundary of the Inner Line is broken into small geometrical units (squares, triangles, etc.) and then summed for the total area. The same approach is done for Middle Line and Outer Line areas. The calculations are shown in Table A-1.

Using the Inner Line, Middle Line, and Outer Line concentrations ($\mu Ci/m^2$) for Figure 19 and multiplying by the land area (m^2), it is possible to estimate the amount of plutonium deposited on JI as 0.236 Ci. Those calculations are shown in Table A-1.

With the land activity calculated, the next step was to calculate the total activity released by BLUEGILL PRIME. Multiplying each concentration (Inner, Middle, and Outer) by its corresponding area gives the total activity. The calculation is shown in the bottom of Table A-1 as 1.66 Ci.

The ratio is easily calculated as 14% of BLUEGILL PRIME was deposited on JI and 86% into the lagoon area. These estimates are unclassified and are used to determine percentages.

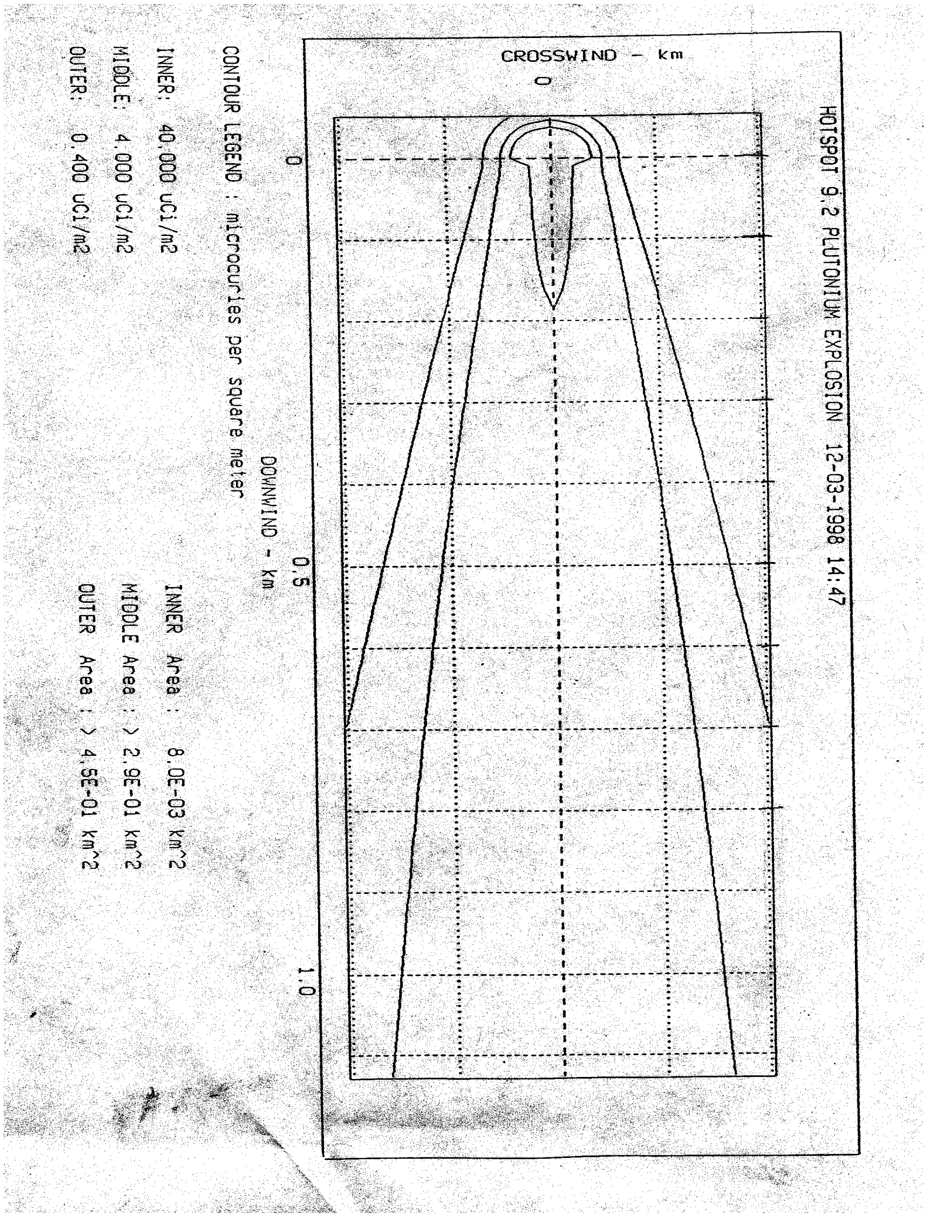


Figure 1 Estimated BLUEGILL PRIME Deposition Pattern

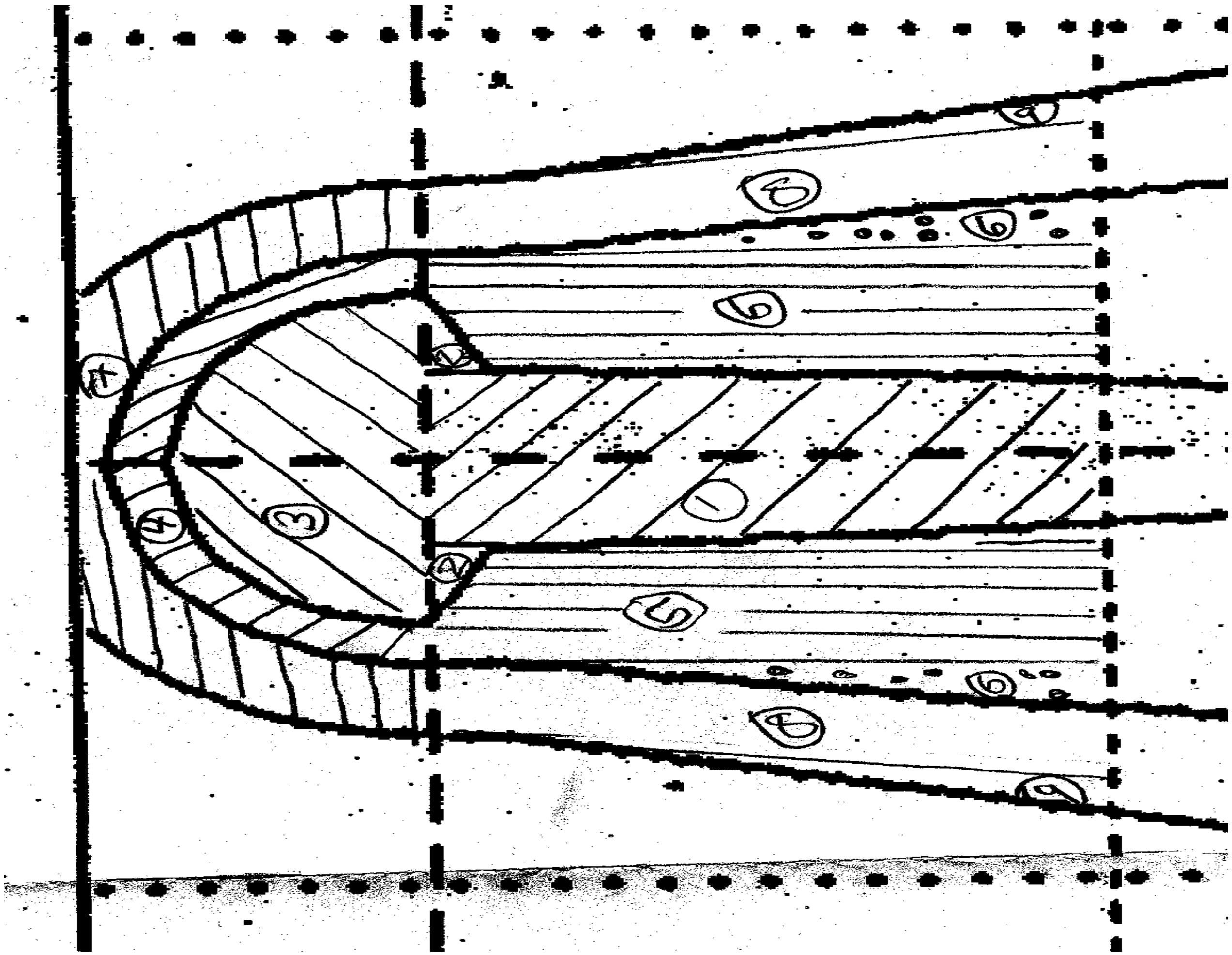


Table A-1 Calculation of Plutonium Percentage in Ocean and on JI from BLUEGILL PRIME

		Inner Line			Middle Line			Outer Line
Shape 1		Rectangle	Shape 4		Semi Circle	Shape 7		Semi Circle
	5.00E+00	wide at narrow end						
	6.00E+00	wide at wide end		7.00E+00	Outer Radius		9.00E+00	Outer Radius
	1.30E+01	Long		5.50E+00	Inner Radius		7.00E+00	Inner Radius
	7.80E+01	dots2		6.98E+00	Dots2		1.19E+01	Dots2
Shape 2		Two triangles on wings	Shape 5		Rectangle	Shape 8		Rectangle
	3.00E+00	wide		1.30E+01	Long		1.30E+01	long
	1.00E+00	high		7.00E+00	Wide		3.00E+00	Wide
	3.00E+00	dots2		1.82E+02	dots2		7.80E+01	dots2
Shape 3		Semi-Circle	Shape 6		Triangle (each side)	Shape 9		Triangle (each side)
	5.50E+00	Radius of circle		2.00E+00	Wide		1.00E+00	wide
	1.19E+01	dots2		1.30E+01	Long		1.30E+01	Long
				2.60E+01	Dots		1.30E+01	dots2
Conversion:	1.96E+02	dots2/10000m^2						
Total dots2	9.29E+01	dots2		2.15E+02	dots2		1.03E+02	dots2
Land Area	4.74E+03	m^2		1.10E+04	m^2		5.25E+03	m^2
Concentration	4.00E+01	μCi/m^2		4.00E+00	μCi/m^2		4.00E-01	μCi/m^2
Activity	1.90E+05	μCi		4.39E+04	μCi		2.10E+03	μCi
						Total Land Activity:	2.36E+05	μCi

Predicted Total		km^2	m^2	Total
Inner Line	4.00E+01 μCi/m^2	8.00E-03	8.00E+03	3.20E+05
Middle Line	4.00E+00 μCi/m^2	2.90E-01	2.90E+05	1.16E+06
Outer Line	4.00E-01 μCi/m^2	4.50E-01	4.50E+05	1.80E+05
			Total:	**1.66E+06** μCi of ^{239}Pu

The STARFISH event can be estimated in a similar manner at 88% into the ocean and 12% on JI using Figure 21.

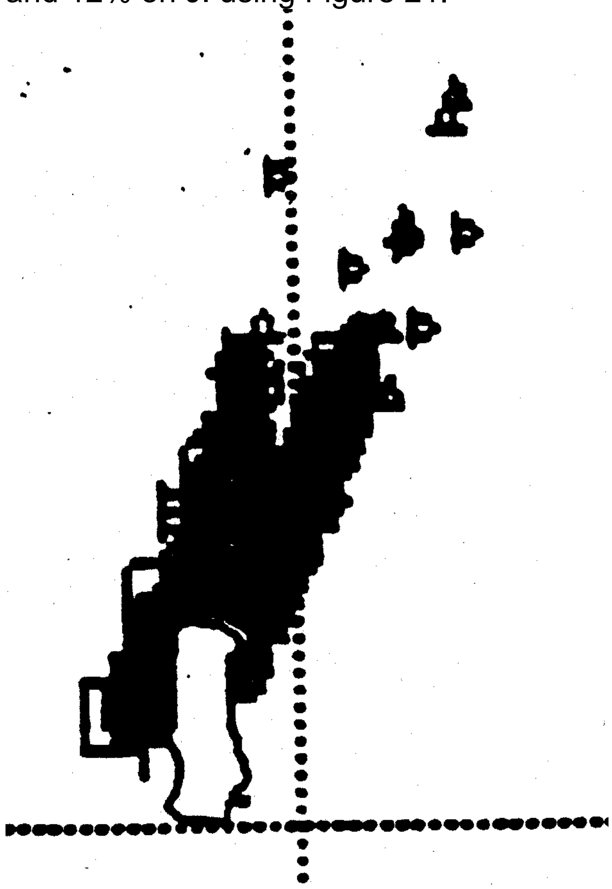


Figure 3 Estimated STARFISH Deposition Pattern over the Current Island Footprint

Now that the estimates for each deposition are completed, the next step is to take those estimates and multiply them by the amount of plutonium in the missiles. The International Atomic Energy Agency (IAEA) defines a "significant quantity" (SQ) as "The approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded." For plutonium, a SQ is 8 kg.

For this mass and the projected deposition percentages into the ocean and lagoon, the activity deposited into the ocean and on JI can be estimated, as shown in Table A-2.

Table A-2 Estimated Summary of Activity into the Ocean and onto JI			
Significant Quantity	8 kg		
Specific Activity of ^{239}Pu	6.13E-02 Ci/g		
(PHS 1970)			
	Activity	Ocean	Land
BLUEGILL PRIME	490 Ci	86%	14%
STARFISH	490 Ci	88%	12%
	Estimated Totals	853.3 Ci	127.5 Ci

The estimated activity of the "above" pile with an average activity of 200 pCi/g is shown below in Table A-3.

Table A-3 Estimated Activity in "Above" Pile			
Average Activity	200 pCi/g		
		2.00E-10 Ci/g	
Estimated Volume of Pile	45,000 m^3		
		4.50E+10 cm^3	
Density	1.25 g/cm^3		
Total Pile Activity	11 Ci		

It is then possible to estimate the percentage of the "above" pile to the predicted activity in the lagoon. The calculation is 11 Ci/853.3 Ci or 1.2%.

Annex B JA Plutonium Ratios

JA plutonium oxides consist of five isotopes: ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu. The plutonium in the environment at JA has a different isotopic mix than originally in the weapons because of radionuclide decay. There has also been substantial ingrowth of ^{241}Am (the decay product of ^{241}Pu), which emits a low energy photon suitable for measurement by direct gamma spectrometric methods. The chemical composition of the plutonium is most likely to be an oxide, as the bulk of the material released to the site surface was due to physical destruction of the warhead and subsequent burning on the launch pad. Plutonium metal is pyrophoric and burns/oxidizes rapidly when finely divided, such as after an explosion.

The isotopic mix used in derivation of cleanup levels for the JA RCA is shown in Table B-1. Because isotopic information is not available for the JA site, this distribution was derived from alternative non-classified sources. Specifically, data was obtained by the government laboratory responsible for the manufacture of the fissile components of the warhead. The isotopic composition of plutonium processes at the Rocky Flats Environmental Technology Site (RFETS) was age-decayed to provide the presumed present day isotopic composition of the weapons destroyed at JA (DOE 1996). ORNL, in conducting their research at JA, inferred a TRU-alpha activity by direct ratio to the measured ^{241}Am activity. In their work, a value of 6.51 was used (ORNL 1998). In comparison, the estimated 1999 activity presented in Table B-1 indicates a predicted ratio of TRU-alpha to ^{241}Am of 6.63. Table B-1 is taken from DTRA, 2000a. The 2% difference is negligible. Consequently, the method used to estimate the isotopic mix is reasonable.

Table B-1 Transuranics to Americium Ratio Calculations

(reproduced from DTRA 2000a)[a]

Nuclide & Principal Decay Mode	Half-Life, (years)	Initial Composition of RFETS Plutonium (% by Weight)	Initial Activity in RFETS Plutonium (Ci/g)[a]	Estimated Composition of Plutonium (% by Weight) 1999	Estimated Activity, 1999, (Ci/g)[b]
^{238}Pu (α)	8.77 x10^{1}	0.01	1.7 x 10^{-3}	0.01	1.3 x 10^{-3}
^{239}Pu (α)	2.41x10^{4}	94	5.8 x 10^{-2}	94	5.8 x 10^{-2}
^{240}Pu (α)	6.53 x10^{3}	5.8	1.3 x 10^{-2}	5.3	1.3 x 10^{-2}
^{241}Pu (β)	1.44 x10^{1}	0.36	3.7 x 10^{-1}	0.09	8.7 x 10^{-2}
^{242}Pu (α)	3.76 x10^{5}	0.03	1.2 x 10^{-6}	0.03	1.2 x 10^{-6}
^{241}Am (α)	4.32 x10^{2}		7.5 x 10^{-3}	0.5	1.6 x 10^{-2}
			Initial Activity		**1999 Activity**
Specific Alpha Activity, Ci/g of Pu:			8.0 x 10^{-2}		9.0 x 10^{-2}
Total Specific Pu Activity, Ci/g of Pu:			4.5 x 10^{-1}		1.8 x 10^{-1}
Predicted Activity Ratio of:					
$^{239/240}Pu/^{241}Am$:			9.47		4.44
Pu Alpha/^{241}Am :			10.7		5.63
Am + Pu Alpha Activity/^{241}Am			**11.7**		**6.63**
Total Pu /^{241}Am			60.0		11.3

[a]*Derived from data presented in "Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement" corrected to 1999 time frame (DOE 1996).*
[b]*Based on the specific activity of plutonium unassociated with other materials.*

Annex C Conversion from Volume Activity to Area Concentration for Concrete

The density of coral (since concrete does not contain plutonium) is used with the 13.5 pCi/g concentration to determine the total activity in that volume (thickness of 1 millimeter). Then that activity is projected onto a two-dimensional surface.

$$Density\left(g/_{cm^3} \right) \times Concentration\left(pCi/_{g} \right) = ActivityperVolume\left(pCi/_{cm^3} \right)$$

Table C-1 Activity/gram to Activity/cm^2 Conversions

1.25 g/cm^3		Density of coral
13.5 pCi/g		Project activity concentration
16.8 pCi/cm^3		Using equation above
168 pCi/cm^2		Projected volume onto a surface

The above calculations are for fixed contamination only. The unrestricted release standard, as stated in American National Standards Institute N13.12 (1987), is 20 disintegrations per minute/100cm^2 (dpm/100cm^2)(removable) or 200 dpm/100 cm^2 total.

Annex D Metal and Concrete Cost Estimates

Cost estimates are based on DTRA engineering staff input, experience with contractor performance and contractor cost proposals.

D-1 Option 1: Scrap Metal Dealer and Island Riprap or Reef Building for the Concrete

This option requires 2 different tasks: radiological survey of the concrete debris and the movement of the clean concrete to its final location. The detailed breakdown of the cost is shown in Table D-1.

Table D-1 Estimated Costs for Concrete Option 1

Subtask	Cost
Radiological Survey	$181,800
Dismantling of the Concrete	$74,000
Movement to Final Location	
Truck	$50,000
Barge	$80,000
Total Cost	**$385,800**

D-2 Option 2: Shipment to an Off-Island Radioactive Waste Facility

This option requires the radiological survey of the concrete to determine which pieces of concrete would require shipment offsite. The standard would be 168 pCi/cm^2 (fixed). The metal debris would be not surveyed since it is not cost effective or safe to survey by hand. The second task would be to dismantle the metal and concrete into sizes that would be small enough for placement in shipping containers. The third task would be to radiologically characterize the concrete and metal according to the final disposal site standards. The fourth task would be the shipping and disposal of the materials in a radioactive waste facility.

The amount shown for the concrete disposal is assuming the worst case (100% shipment). The summary cost table is shown below in Table D-2.

Table D-2 Estimated Costs for Metal and Concrete Option 2		
	Costs	
Subtask	Concrete Debris	Metal Debris
Survey Concrete	$181,800	
Dismantle the Piles and Equipment	$100,000	$900,000
Characterization	$100,000	$100,000
Placement of Piles in Shipping Containers	$200,000	$400,000
Transportation and Disposal	$0-395,500 (Dependent on the radiological survey results)	$4,500,000
Sub-Totals	$581,800-977,300	$5,900,000
Total Option Cost	$**6,481,800-6,877,300**	

D-3 Option 3: Landfill on JA

This option requires three tasks. The first is to dismantle the concrete and metal debris into manageable sizes. The second is movement of the concrete and metal debris into the LE-1 area for burial in place. The third task is the movement of covering coral. No assumptions are made at this time for the radioactive content of the covering coral. The estimated volume of coral to cover the debris piles at the stated design is 79,000 cubic meters. The estimated costs are shown in Table D-3.

Table D-3 Estimated Costs for Metal and Concrete Option 3		
	Costs	
Subtask	Concrete Debris	Metal Debris
Dismantle and Move the Debris	$100,000	$900,000
Move the Covering Coral Over the Debris	$420,000	
Sub-Total	$520,000	$1,320,000
Total Cost	$**1,420,000**	

Annex E Coral Attenuation Calculations

The attenuation of the americium gamma rays from the coral (calcium carbonate) is calculated according to Cember (1996).

The first step is to determine the chemical makeup of the shielding material ($CaC0_3$), the gamma energies of the isotope of concern (18, 30, and 60 keV for ^{241}Am), calculate the mass attenuation coefficient (MAC), and then the linear attenuation coefficient (LAC) for each element. The next step is to combine them all into the coral LAC. The linear attenuation coefficients allow attenuation calculations vs. coral depth for each gamma energy.

The equations, mathematics (Table E-1, 2, and 3) and resulting graph (Figure 22) are shown below for the 18, 30, and 60 keV gamma rays.

$MAC\ (\mathit{from\ U.S.\ Department\ of\ Health\ Education\ and\ Welfare}, 1970)$

Density ($element$), ρ (from Handbook of Radiaton Measurement and Protection, Brodsky)

Atomic Weights, A_w (from Handbook of Radiaton Measurement and Protection, Brodsky)

$$LAC(element) \equiv \frac{MAC(element)}{\rho(element)}$$

$$\text{Percent of Each Element in Coral Molecule} \equiv \%(element) = \frac{Each\ Element's\ Weight}{Total\ Coral\ Molecular\ Weight}$$

$$\text{Number of Atoms } {}^{1}\!/_{cm^3}\ (element\ in\ coral) \equiv N(element)$$

$$N(element) = \frac{6.02x10^{23}\ {}^{atoms}\!/_{mole}}{A_w\ (element)\ {}^{g}\!/_{mole}} \times \rho\ (coral)\ {}^{g}\!/_{cm^3} \times \%\ (element)$$

$$\text{Atomic Cross Section}(element) \equiv \frac{LAC(element)}{N(element)}$$

$$Coral\ LAC = \sum \left[Number(element\ in\ coral) \times \text{Atomic Cross section}(element)\right]$$

$$Radiation\ Intensity\ (with\ thickness\ x\ of\ coral) \equiv I_0 e^{-Coral\ LAC \cdot x}$$

Table E-1 Attenuation Calculations for the 18 keV Gamma Photon

Coral Chemical Formula is $CaCO_3$
For 18 keV gamma photon

	MAC	Density	Atomic Weight
	Cm^2/g	g/cm^3	
Ca	1.85E+01	1.55	40.08
C	5.57E-01	2.25	12.01
O	1.15E+00	1.14	15.99

Element	LAC	Number of Atoms/cm^3	Cross Section
Ca	2.86E+01	2.33E+22	1.22E-21
C	1.25E+00	1.12E+23	1.10E-23
O	1.31E+00	4.29E+22	3.05E-23

	% by Weight
Ca	4.01E-01
C	1.20E-01
O	4.79E-01
Sum	1

Density of Coral
1.25 g/cm^3

	Number of Atoms	Cross Section (cm^2)	Product	
Ca	7.53E+21	1.23E-21	9.25E+00	
C	7.53E+21	1.11E-23	8.36E-02	
O	2.26E+22	3.05E-23	6.89E-01	
		LAC	***1.00E+01***	cm^{-1}
		MAC	***8.02E+00***	cm^2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 18 keV gamma (Figure 22).

Table E-2 Attenuation Calculations for the 33 keV Gamma Photon

Coral Chemical Formula is $CaCO_3$

For 33 keV gamma photon

	MAC	Density	Atomic Weight	
	cm^2/g	(g/cm^3)		
Ca	3.28E+00	1.55	40.08	
C	2.36E-01	2.25	12.01	
O	3.35E-01	1.14	15.99	

Element	LAC	Number of Atoms/cm^3	Cross Section
Ca	5.08E+00	2.33E+22	2.18E-22
C	5.31E-01	1.13E+23	4.70E-24
O	3.82E-01	4.30E+22	8.89E-24

	% by Weight
Ca	0.400507
C	0.1200237
O	0.4794693
Sum	1

Density of Coral
1.25 g/cm^3

	Number of Atoms	Cross Section ($cm^{2)}$	Product
Ca	7.53E+21	2.18E-22	1.64E+00
C	7.53E+21	4.70E-24	3.54E-02
O	2.26E+22	8.89E-24	2.01E-01
		LAC	***1.88E+00*** cm^{-1}
		MAC	***1.50E+00*** cm^2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 30 keV gamma (Figure 22).

Table E-3 Attenuation Calculations for the 60 keV Gamma Photon

Coral Chemical Formula is CaCO3
For 60 keV gamma photon

	MAC	Density	Atomic Weight
	cm^2/g	(g/cm^3)	
Ca	6.23E-01	1.55	40.08
C	1.75E-01	2.25	12.01
O	1.89E-01	1.14	15.99

Element	LAC	Number of Atoms/cm3	Cross Section
Ca	9.66E-01	2.33E+22	4.14E-23
C	3.94E-01	1.13E+23	3.49E-24
O	2.15E-01	4.30E+22	5.01E-24

	% by Weight
Ca	0.401
C	0.120
O	0.479
Sum	1

Density of Coral
1.25 g/cm3

	Number of Atoms	Cross Section (cm^2)	Product	
Ca	7.53E+21	4.14E-23	3.12E-01	
C	7.53E+21	3.49E-24	2.63E-02	
O	2.26E+22	5.01E-24	1.13E-01	
		LAC	***4.51E-01***	cm-1
		MAC	***3.61E-01***	cm2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 60 keV gamma (Figure 22).

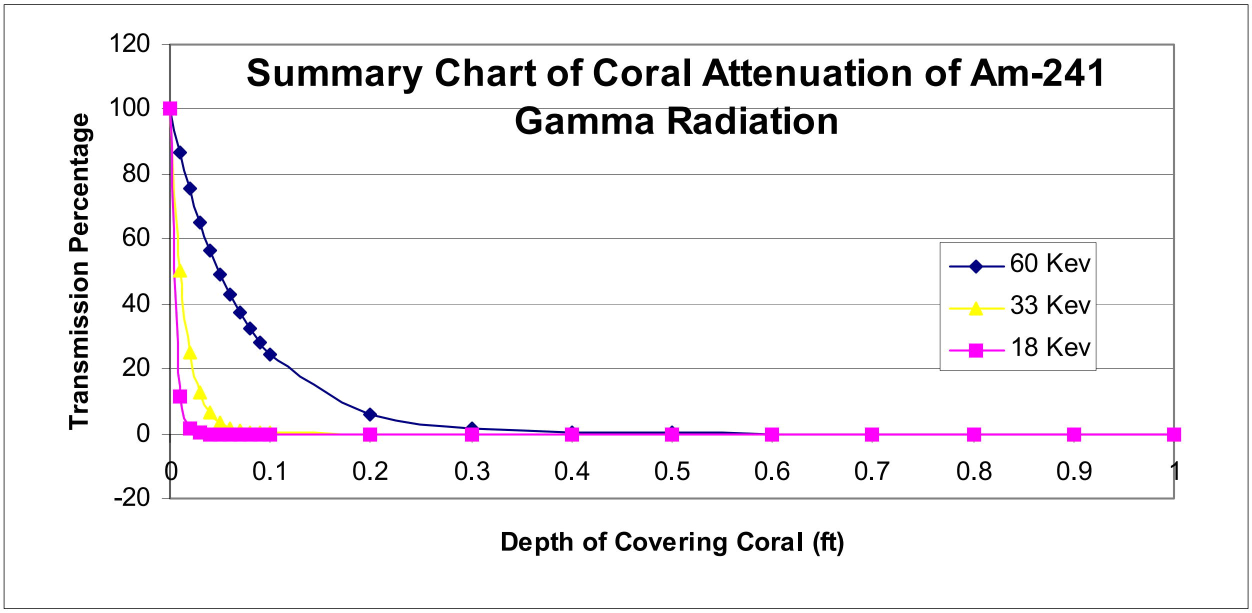


Figure 4 Gamma Attenuation of ^{241}Am: Transmission vs. Coral Depth

It is easy to see that radiological shielding does not mandate the coral cap thickness of 61 cm (2 ft). The coral cap thickness is based upon the expected burrowing depth of the birds.

Annex F "Above" Pile Cost Estimates

Cost estimates are based on estimates made by the DTRA engineering staff, experience with contractor performance and contractor cost proposals.

F-1 Option 1: Clean Cap

This option requires the same tasks as Option 3 for the metal and concrete debris. That cost estimate (Table D-3) serves as the base for the following cost estimates (Table F-1 to F-6).

Table F-1 Estimated Costs for Option 1 Clean Cap

	Costs
Subtask	
Dismantle and Move the Debris	$1,000,000
Move the "Above" Coral Over the Debris	$420,000
Move the Covering Coral Over the Debris	$420,000
Total Cost	$**1,840,000**

F-2 Option 2: Clean Cap and Geotextile Liner

The option uses Option 1 as a basis and then adds to cost and installation of the liner (Table F-2).

Table F-2 Estimated Costs for Option 2 Geotextile Liner and Clean Cap

Option 1 Cost	$1,840,000
Cost and Installation of Geotextile Liner	$60,000
Estimated Option Total	**$1,900,000**

F-3 Option 3: Clean Cap with Concrete Cap

The option uses Option 1 as a basis and then adds the concrete cap installation cost along with the cement transportation costs (Table F-3).

Table F-3 Estimated Costs for Option 3 Concrete Cap and Clean Cap

Option 1 Cost	$1,840,000
Cost and Installation of Concrete Cap	$420,000
Barge Cost	$80,000
Estimated Option Total	$**2,340,000**

F-4 Option 4: Clean Cap over a 6-sided Concrete Vault

The option uses Option 1 as a basis and then adds the concrete vault design and construction costs along with the cement transportation costs (Table F-4).

Table F-4 Estimated Costs for Option 4 Concrete Vault and Clean Cap	
Option 1 Cost	$1,840,000
Cost and Installation of Concrete Vault	$1,230,000
Barge Cost	$80,000
Estimated Option Total	$**3,150,000**

F-5 Option 5: Clean Cap over a Concrete Slurry

The option uses Option 1 as a basis and then adds the concrete slurry construction costs along with the cement transportation costs (Table F-5).

Table F-5 Estimated Costs for Option 5 Slurry Mix and Clean Cap	
Option 1 Cost	$1,840,000
Concrete Construction Cost	$1,566,000
Barge Cost	$80,000
Estimated Option Total	$**3,486,000**

F-6 Option 6: Clean Cap Covering a Vitrified "Above" Pile

The option uses Option 1 as a basis and then adds the vitrification capital and operation costs (Table F-6).

Table F-6 Estimated Costs for Option 6 Vitrifying the "Above" Pile and Clean Cap		
Option 1 Cost		$1,840,000
Vitrification Costs	Description	
Plant Acquisition Cost	12,000,000 per plant	$12,000,000
Operating Cost	$80-165/ton with 45,000 tons	$3,600,000-7,425,000
Maintenance Costs	400,000 per year	$800,000
Labor Cost	(Based on a 4 person crew operating 24 hours a day, 7 days a week with a throughput of 100 tons per day for 45,000 tons)	$2,430,000
Barge Cost		$80,000
Estimated Option Total		$**20,750,000-24,575,000**

F-7 Option 8: Shipment of Entire "Above" Pile

The costs include characterization, transportation and disposal (Table F-7).

Table F-7 Estimated Costs for Option 8 Shipment of Entire "Above" Pile Off-Island	
Subtask	
Metal and Concrete Debris Landfill cost	$142,000
Characterization of "Above" Pile for Shipment	$300,000
Transportation and Disposal for "Above" Pile (45,000 m^3 at $1,100/$m^3$	$49,500,000
Total Option Cost	$**49,942,000**

Annex G GROUNDWATER SURVEY

G-1 Introduction

This document summarizes the results of a groundwater investigation performed to verify whether plutonium has been mobilized significantly by groundwater at the JA Plutonium Cleanup Project.

A characterization of the plutonium oxide by Argonne National Laboratory indicates the plutonium and americium contamination of JA coral soil is primarily in the form of scattered particles. The majority of the activity (>99%) was associated with particles ranging from 43 to 0.4 μm in diameter. The study suggests that a possible mechanism for dispersal is complexation with calcium carbonate (the main constituent of coral sand), followed by adsorption onto the coral soil. This would lead to a greater dispersal of plutonium and americium than would be expected by physical transport of discrete particles alone (Wolf et al. 1995).

The contamination at JA is from TRU elements (elements of the actinide series including plutonium isotopes and ^{241}Am) from failed missile launches during the 1960s. ^{241}Am is the daughter product of ^{241}Pu, which has a 14.35-year half-life. The primary types of radiation associated with TRU are alpha radiation, characteristic x rays from ^{239}Pu, and 60-keV gamma radiation from ^{241}Am.

Because the TRU contamination at JA exists in a highly oxidized form, it is especially likely to be immobile in all media. This assumption was tested in the technical approach herein, which included three scenarios to detect TRU in water: (1) leaching tests in columns, (2) well installation and sampling immediately downgradient of the source, and (3) existing well sampling.

The primary area of investigation was around the RCA on JI, the largest of the islands comprising JA that contains a pile of remediated coral ("below" pile) that consists of approximately 120,000 metric tons and an area of residual radioactive material ("above" pile) of approximately 45,000 metric tons. The remediated coral is generally on the eastern side of the RCA. The residual radioactive material is on the western side of the RCA, next to a former missile launch pad (LE-1) (Figure 23).

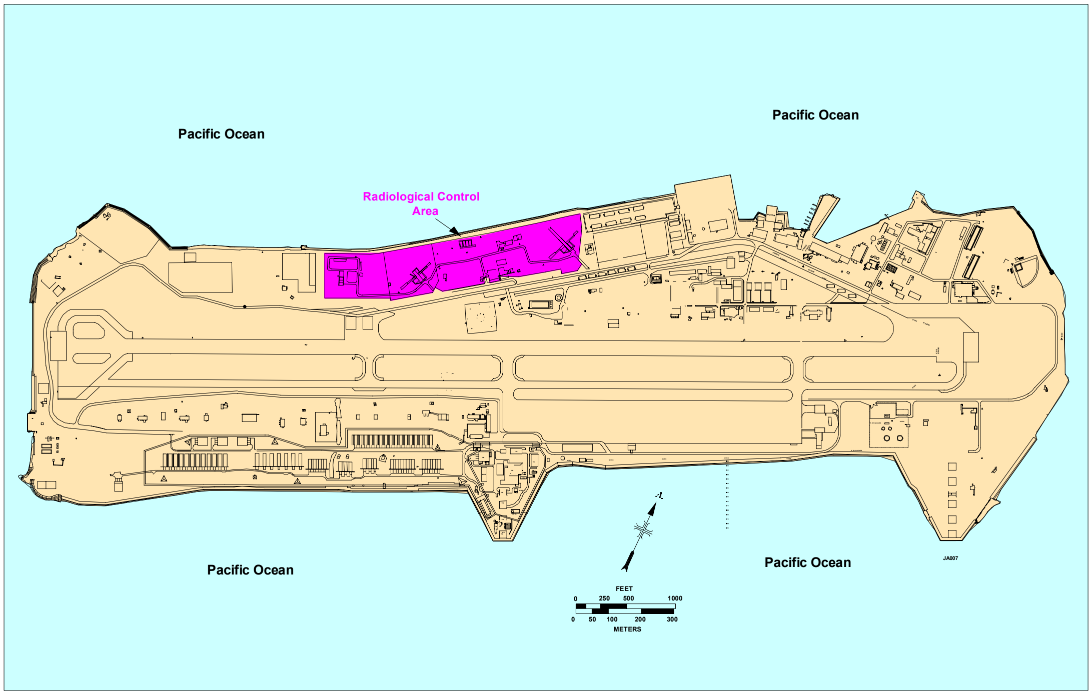


Figure 5 JI Map Showing the RCA.

Previous contractors have stated that the PuO_2 contaminant is relatively immobile in groundwater. However, recent studies of plutonium migration at other sites have given rise to the concern of plutonium transport at JI (EPA 1999a, Wolf et al. 1995).

The objective of this investigation was to provide independent data to determine whether plutonium migration is occurring at the JI site.

The groundwater investigation was conducted from May 17 to 31, 2000, and included field leachate testing, installing temporary monitoring wells along the shoreline between the RCA and the lagoon, and sampling existing monitoring wells at JI. Samples were analyzed for total TRU activity with radiochemistry in June and July 2000.

G-2 Contaminants of Concern

Contamination from the failed missile launches is from insoluble TRU present as dispersed activity (volume) and hot particles (point sources) (DNA 1991). The dispersed activity, particles approximately 10 μm in diameter with approximately 10 Bq of TRU activity, may be mobile within coral and could migrate due to precipitation runoff, tidal action, or in groundwater. The discrete hot particles, <45 μm in diameter and with activity >1,000 Bq, are relatively immobile unless affected by erosion, excavation, or physical means of disturbance (DNA 1991).

G-3 Applicable Guidelines

There are no site-specific guidelines for TRU in groundwater. The EPA has set a standard for radionuclides in drinking water of 15 pCi/L gross alpha for all alpha-emitting radionuclides, excluding radon and uranium (40 CFR, Part 141). Although the groundwater at JI is not considered drinking water, nor is it potable, this standard is used as a comparative measure in this report.

G-4 Environmental Setting—Groundwater at JI

A thin lens of brackish water underlying the original part of JI is encountered at depths of 1.2- 2.7 m (4 to 9 ft). Because of the high permeability of the soil and relatively low precipitation, there are no natural bodies of fresh water (DNA 1994). The hydraulic conductivity at the site ranges between 2.4 ft/d and 240 ft/d. The typical gradient toward the ocean is 0.001 ft/ft. Within the capture zone of the reverse osmosis (RO) unit wells, the gradient is 0.008 ft/ft.

The groundwater beneath the RCA is not a drinking water source. The source of potable water on JI is from groundwater supplied by upgradient wells and processed through an RO system housed in the Water Treatment Plant (Building 45). Examination of the island's potentiometric surface shows the RCA to be cross-gradient to the RO wells. Therefore, the RCA is not in the RO capture zone.

G-5 Leachate Testing Experimental Methods

A leachate column experiment designed to simulate natural conditions at JI was performed using contaminated and uncontaminated coral from the RCA. Clean material was also collected from an area south of the RCA for use in the test. Each column was filled with uncontaminated, crushed coral, representative of the sediment found at JI. As the columns were filled, a plutonium spike (approximately 1/5 the volume of the respective columns) was added to the center of the column. The material in the columns was manually compacted to represent natural conditions as closely as possible. A Field Instrument for the Detection of Low-Energy Radiation (FIDLER) detector was used to isolate particles from an area of residual radioactive material to prepare the spike material. Gamma count rates from the particles were integrated over 3-minute periods and are summarized in Table G-1. The purpose of gamma screening was to ensure that radioactive material was present in the soil columns. The actual activity of the material was determined after conducting the experiment and is shown in ORNL, 2000. It should be noted that one of the particles in Column 1 is a magnitude higher than any of the other particles used in the experiment.

Table G-1 Gamma Exposure Rates of Isolated Particles	
Particles	cpm [a]
Column 1	
1	55,808
2	64,607
3	27,338
4	23,048
5	20,632
6	19,987
7	17,847
Column 2	
8	185,260
9	20,860
[a]Counts taken in 3-min intervals.	

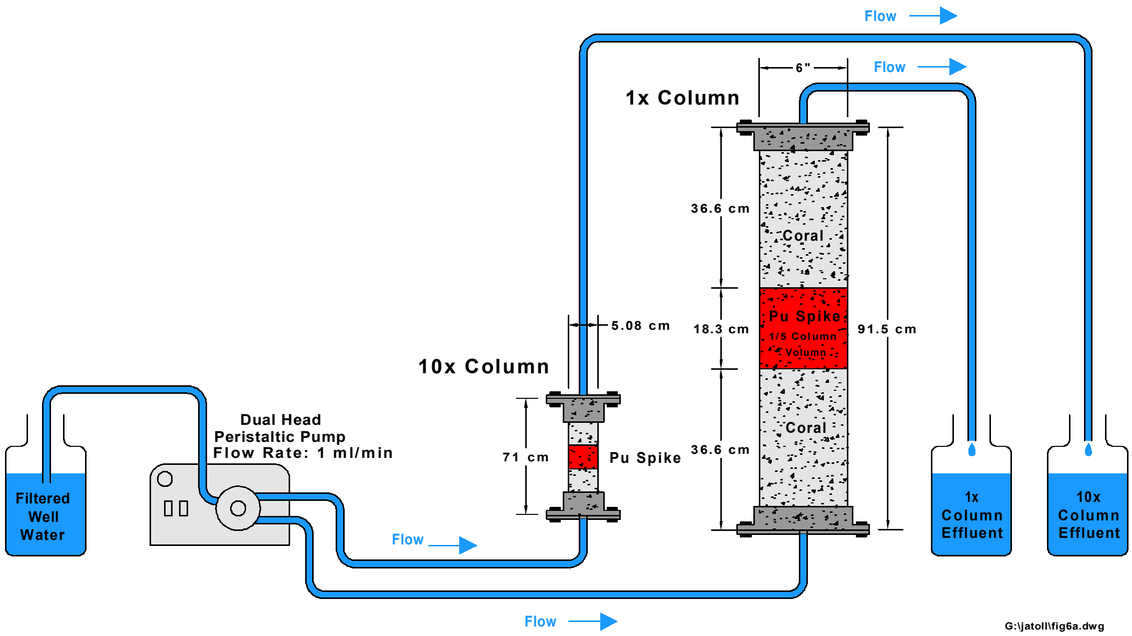
The extraction fluid used for leachate testing simulated the JI groundwater and was collected from a nearby existing well (SWMW09). Twelve gallons of water were collected for the test after purging 3 gallons. The groundwater extraction fluid was filtered using a 0.2-μm membrane filter. The filter and an aliquot of the filtered water were collected and submitted for analysis.

Because it is impossible in the leaching test to mimic natural conditions of velocity and gradient, the experiment used the lowest flow rate possible that could be regulated with certainty. This is considered an experimental limitation. To evaluate the possibility of colloidal transport, samples were analyzed in both filtered and unfiltered conditions.

Two columns were used in the leachate testing experiment (Figure 24 and 25). The first column was designed to simulate actual groundwater velocities as closely as possible. The second column was designed to be 1/10 the size of the first column and represents groundwater velocities 10 times natural conditions.

Johnston Atoll

SCHEMATIC OF LEACHATE COLUMN EXPERIMENT



Not to Scale
Conceptual Only

Figure 6 General Schematic Diagram of the Leachate Column Experiment

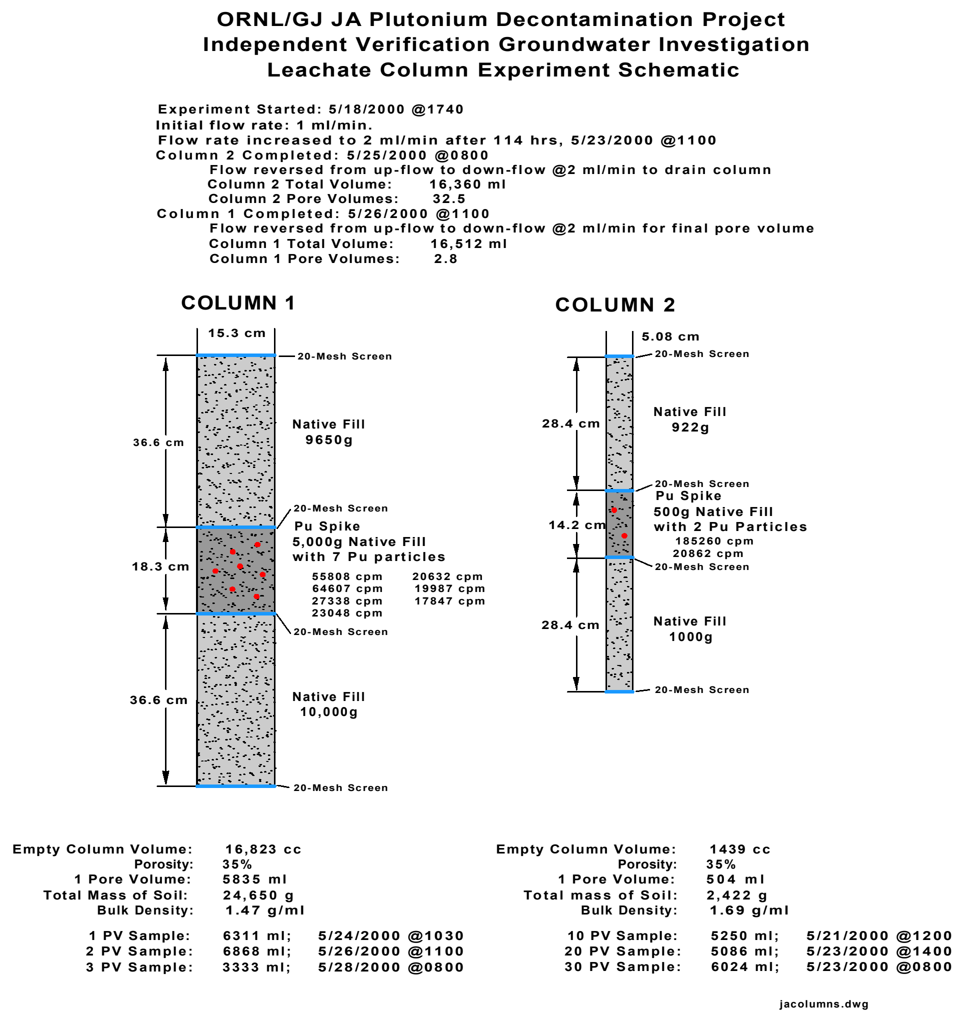


Figure 7 Detailed Diagram and Parameters of the Leachate Column Experiment

The large column was designed to be 3-ft long with a 6-in diameter (approximately 1,017 in^3) by assuming a flow rate of approximately 1 mL/min, a natural groundwater velocity of 1 ft/d, and a porosity of 0.35. Ten kg of clean material were placed in the large column. Next, a “20” mesh screen was placed below and above 5 kg of contaminated material to mark the position of the spike in the column. Finally, 9.65 kg of clean material was placed on top of the spike (Figure 25).

The dimensions for the smaller 10× column were 28-in long with a 2-in diameter (approximately 90 in^3). Again, a spike of contaminated material (500 g), marked by “20” mesh screen, was placed between two volumes of clean material (both approximately 1000 g) (Figure 25).

The resulting bulk density of column material (1.47 g/mL in the large column and 1.69 g/mL in the small column) was less than that found in natural conditions. This experimental limitation contributes a measure of conservatism to the test. The groundwater used as the extraction fluid for the test had a conductivity of 25.2 mS. The filtered water was pumped through the columns at a rate of 2 mL/min using a dual-head peristaltic pump. The column effluent was collected from each pore volume from the columns (ten pore volumes for the 10× column). Pore-volume effluents were collected in separate containers. One unfiltered composite water sample was taken from each of the containers. The remaining water was filtered using a 0.2-μm membrane filter. All groundwater and filter samples from the leachate test were scanned with a FIDLER (with no detection) before shipment. The filters and filtered and unfiltered water samples were submitted for TRU analysis by the described methods. After column testing was complete, the spike material was removed from the columns and was analyzed for TRU using DTRA's on-site gamma spectrometry. Results are presented in ORNL, 2000.

G-6 Methods of Installation and Sampling of Temporary Groundwater-Monitoring Wells

Field measurements of groundwater were collected at the RCA site to provide a quantitative measure of TRU concentrations within the groundwater immediately downgradient of the site and of the interface with ocean water.

Six temporary well locations (TW01 through TW06) were installed (Figure 26). The wells were located approximately 27 m (290 ft) apart, covering the shoreline area downgradient of the RCA in equidistant segments. The wells were located by using a Global Positioning System (GPS).

The well locations and their surrounding areas were scanned for the presence of TRU with a FIDLER before placement. No gamma measurements were detected above the background range of 1200 to 2300 counts per minute (cpm). Furthermore, all groundwater and filter samples were scanned with a FIDLER before shipment with no detection. The wells were installed using a 4-in. solid-stem auger; they were drilled to a depth of approximately 3.5 m (11.5 ft). The augers were removed and 5-ft sections of 3/4-in.-inside-diameter, flush-threaded, schedule 40 polyvinylchloride (PVC) casing and screen were installed.

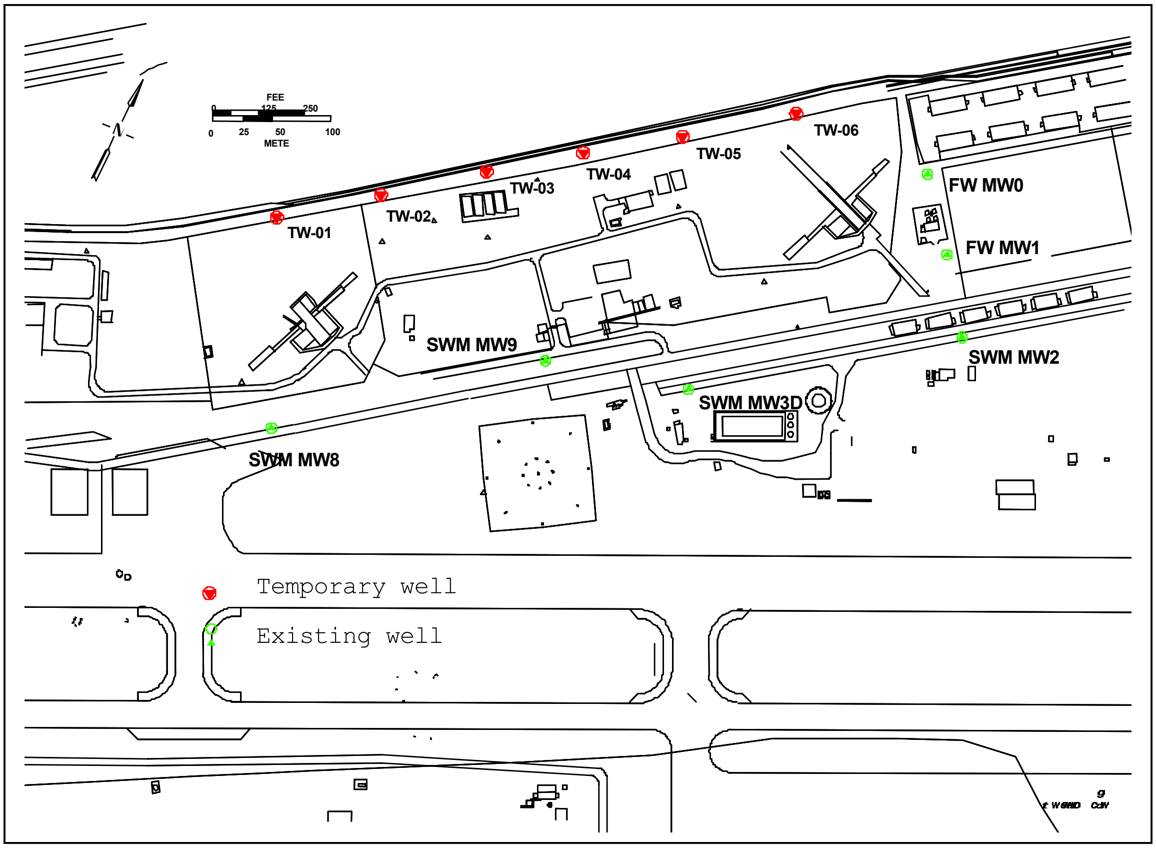


Figure 8 Locations of Permanent and Temporary Monitoring Wells

Most of the wells were installed to a depth of 3.2 m (10.5) ft. Drilling was difficult in some locations because larger coral cobbles exist at a depth of 1 m (3 to 4 ft) in the subsurface.

Field methods to install temporary monitoring wells and to sample groundwater were consistent with the general protocol defined in EPA 1992, EPA 1997, and ASTM D3370-82. The wells were installed using a Little Beaver manual driller. Soil cuttings were screened during installation for low-energy gamma rays associated with TRU contamination with a FIDLER. No elevated gamma ray count rates were detected. The temporary monitoring points were abandoned after sampling.

G-7 Methods of Sampling of Existing Groundwater-Monitoring Wells

Six existing groundwater-monitoring wells upgradient of the RCA were sampled for TRU (Figure 26). The wells were installed as part of the RCRA Facility Investigation in the early 1990s. The following existing wells were subject to sampling (Figure 26): FW MW 0, FW MW 1, SWM MW 2, SWM MW 3D, SWM MW 9, and SWM MW 8. It should be noted that the existing wells are all upgradient of the source (the RCA). However, they represent groundwater moving through the island and could have been subject to contamination from the events previously described.

The sampling of existing wells was consistent with the general protocol defined in EPA 1992, EPA 1997, and ASTM D3370-82.

G-8 Analytical Chemistry Methods

The water and filter samples from the leachate testing and well sampling were analyzed for TRU (^{241}Am, ^{244}Cm, ^{238}Pu, ^{239}Pu/^{240}Pu, and ^{242}Pu) as described below. The RC-19 RO6 procedure ("Determination of Americium, Curium, Plutonium, Neptunium, Thorium and Uranium in Water, Brine, Soil, Filters, and Organic Samples by Extraction Chromatography and Alpha Spectrometry") was used for analysis. This method was developed in large part by using articles by Horwitz et al. (1992, 1993 and 1995), who helped develop resins produced by Eichrom (Eichrom Industries method ACWO3 Rev. 1.4, "Americium, Plutonium and Uranium in Water"). To our knowledge, there is no EPA procedure for the separation of TRU.

Filtered and unfiltered water samples were collected in Nalgene bottles and were acidified with nitric acid in the field to a pH less than 2. There are no holding times or temperature requirements for the samples. Typically, 1.5 mL of 8-*M* nitric acid is added per liter of water to achieve a pH <2 and remain within the U.S. Department of Transportation (DOT) shipping regulations.

Aliquots of the samples were taken in the lab based on requested detection limits (1 pCi/L), interference in the sample, and/or approximate isotopic activities in the sample. Radioactive tracers are added to the samples (^{236}Pu for plutonium analysis and ^{243}Am for americium and curium analysis). Samples are stirred and oxidized to ensure that analytes and tracers are in the same oxidation states, and an iron hydroxide precipitation is done for the initial preconcentration.

This precipitate is dissolved in a nitrate solution for loading on Eichrom TEVA and TRU columns. Plutonium is fixed in the +4 oxidation state using ascorbic acid and sodium nitrite. The solution is loaded onto a TEVA column, which is stacked on top of a TRU column (the eluate from the TEVA column loads onto the TRU column). After rinsing the columns with additional nitrate solution, the columns are separated.

Purified plutonium is eluted from the TEVA column. Americium and curium are eluted from the TRU column. The purified isotopes are then precipitated from eluted solution using a cerium fluoride co-precipitation. The precipitate is then filtered from solution using a 0.1-μm polypropylene filter, which is mounted and counted by alpha spectrometry.

G-9 Gamma Scanning Methods

Gamma scans for health and safety and of drill cuttings were conducted using a FIDLER. Scan ranges in cpm were recorded in the sample logbook. Furthermore, all samples were scanned with the FIDLER. No readings were detected above the background range.

G-10 Quality Assurance/Quality Control (QA/QC) Methods

Table G-2 list types and numbers of field QC samples per sampling event set. The following QA/QC samples were taken or were included in the field-sampling effort. No trip blanks were taken because volatile organic compounds were not analyzed.

- Duplicate. One duplicate was analyzed every tenth sample. Results from duplicate samples were used to assess the precision of the sampling effort.
- Field blank. One field blank was collected per source per event. The field blank was prepared by collecting a sample of bottled water at the time of sampling. This bottled water was the same source as the water used in the final rinse during decontamination procedures. Deionized water was unavailable at the site.
- Equipment rinsate. One equipment rinsate was taken based on 10%/matrix per event. The equipment rinsate was taken by filling the decontaminated sampling equipment with deionized water and collecting a sample of the water.

Table G-2 Field QC for Groundwater Samples Per Sampling Event[a]

Type of sample	Number of samples
Lab duplicates	10%
Field blanks	One per event
Equipment rinsate	10%

[a]A sampling event is considered to be from the time the sampling personnel arrive at a site until these personnel leave for more than 24 hours.

Results of QA/QC are presented in ORNL, 2000.

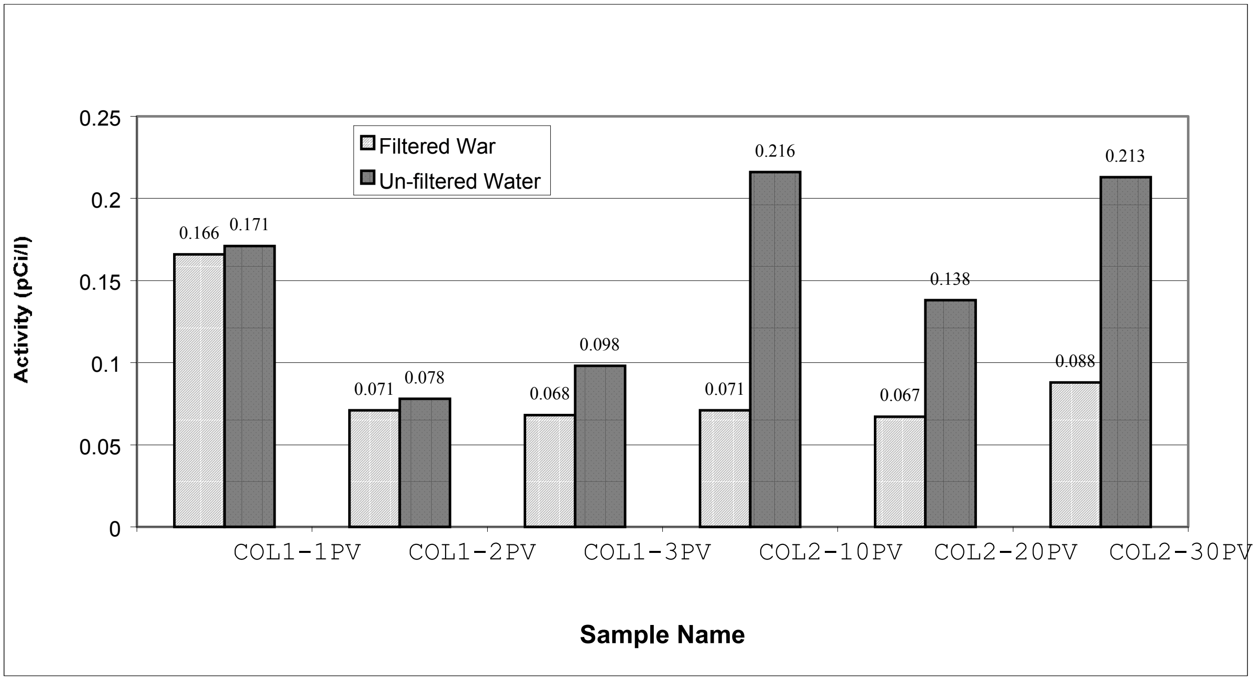


Figure 9 Graph of TRU Concentrations from JI Leachate Column Studies

G-11 Results

G-11.1 Leachate Testing Results

Total TRU in unfiltered groundwater from both columns ranged from 0.078 to 0.216 pCi/L (Figure 27). Total TRU concentrations in filtered samples of the same leachate ranged from 0.067 to 0.088 pCi/L (Figure 27). These results are far below the EPA drinking water standard of 15 pCi/L. Furthermore, most results were below the detection limits for TRU isotopes. Unfiltered groundwater leachate obviously contains particulates; however, TRU concentrations are negligible.

Specific activities in the spike material ranged as high as 13,750 pCi/g in Column 1 and 75,884 pCi/g in Column 2. It should be noted that specific activity in the native soils placed above and below the spiked material in the columns are comparable to background levels. If this material were to be considered mobile, these same high concentrations would be found in the unfiltered samples and associated filters.

G-11.2 Results of Sampling Temporary Wells

Figure 28 presents the results of sampling temporary wells (TWO1-TWO6). Samples were collected from depths where the conductivity was 52,800 or below (indicating the presence of brackish groundwater).

Total TRU concentrations in unfiltered groundwater from the temporary wells ranged from 0.047 to 0.181 pCi/L. Filtered samples had total TRU concentrations ranging from 0.03 to 0.072 pCi/L. Most isotopes were below the detection limits. The detections are miniscule in comparison to the 15-pCi/L guideline for drinking water.

G-11.3 Results of Sampling Existing Wells

Figure 28 presents the results of sampling existing wells (FW MW 0, FW MW 1, SWM MW 2, SWM MW 3D, SWM MW 9, and SWM MW 8). Total TRU concentrations in unfiltered groundwater from the temporary wells ranged from 0.039 to 0.16 pCi/L. Filtered samples had total TRU concentrations ranging from 0.01 to 0.059. Most isotopes were below the detection limits. The detections in water are miniscule in comparison to the 15 pCi/L guideline.

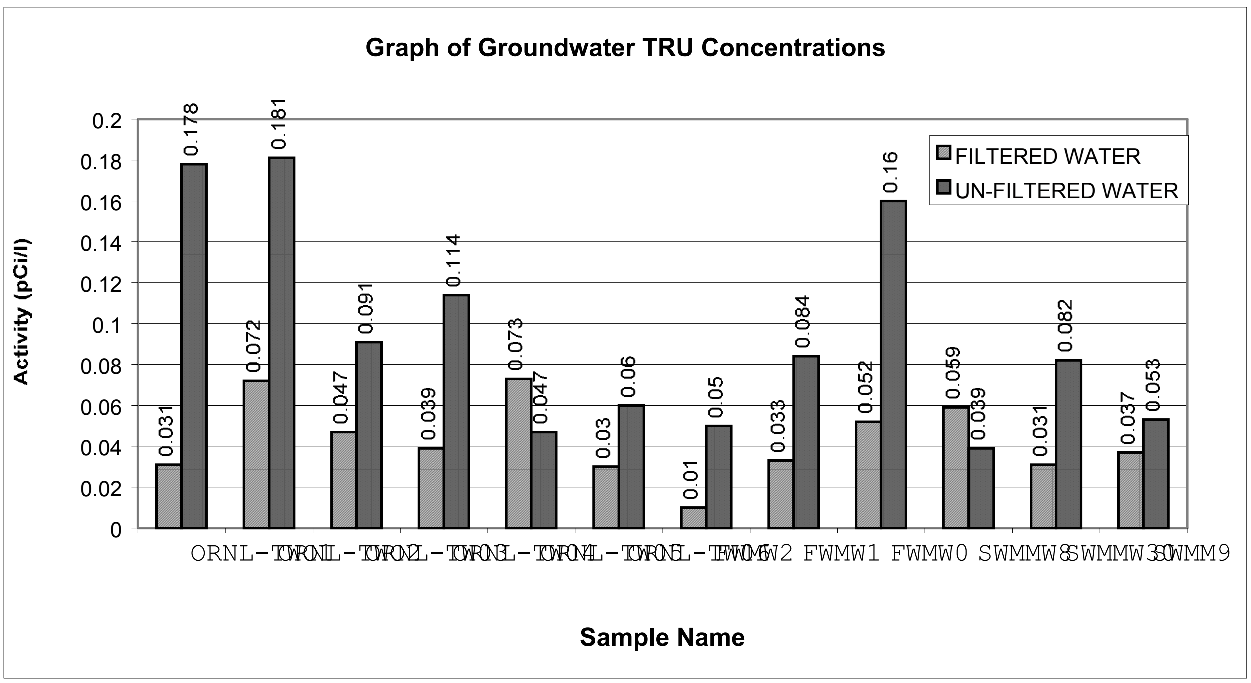


Figure 10 Graph of Groundwater Concentrations on JI

G-12 Discussion and Conclusions

The issue of TRU mobility in groundwater has been researched since the early 1970s. In general, TRUs, including plutonium, are relatively immobile in the environment (DOE 1980). Because the TRU contamination at JA consists in a highly oxidized form, it is especially likely to be immobile in all media. This assumption was tested in the technical approach herein, which included three scenarios to detect TRU in water: (1) existing well sampling, (2) well installation and sampling immediately downgradient of the source, and (3) leaching tests in columns. There were no significant detections of TRU isotopes in any of these waters. The highest concentration of total TRU isotopes in all 71 water samples was 0.181 pCi/L. This value is miniscule (1.2%) in comparison to the total alpha guideline in drinking water of 15 pCi/L. Furthermore, 180 out of 236 isotopic results were less than the minimum detectable activity (MDA). Finally, the conservative measures involved in the column testing favored the leaching or particulate movement of the spike consisting of elevated TRU material. However, no significant levels of TRU were found in the leachate or in the associated filters.

In regard to plutonium mobility, technical literature demonstrates that plutonium would not be mobile in the dissolved phase at JI. Hydrolyzable transuranic elements, such as plutonium, can only be maintained in solution by highly acidic solutions. Since coral sand is essentially pure calcium carbonate, acidic solutions are not possible in equilibrium with the soil. Thus, the particulate plutonium that is present at JI is not soluble when leached by rainwater or seawater. Even if plutonium were dissolved in an acid solution, once contacted with soil and diluted, the plutonium will be rapidly immobilized as a result of hydrolysis and subsequent precipitation on particle surfaces (Wildung and Garland 1980).

Numerous studies have also demonstrated that natural systems do not promote the mobility of plutonium. For example, freshwater studies have concurred that sediments appear to be the major reservoir for plutonium deposition. These studies concluded that even with contaminated sediments, transport of plutonium through biotic systems to man is insignificant (Emery and Klopfer 1976, Hakonson et al. 1976).

A study using soil from Nevada is also relevant, although it involved a nonmarine soil. The soil was calcareous (high in calcium carbonate) as is the soil (crushed coral) at JA. In this research, the authors attempted to leach plutonium from the soil by using HCl and NaOH to vary the pH of the extraction solution (Nishita and Hamilton 1981). Although these experiments are not an exact analog to using seawater or rainwater, there are useful similarities, such as their high ionic strength and pH. In these experiments, less than 1% of the plutonium could be leached under alkaline conditions in the same pH range as seawater. These data indicate the strength of plutonium sorption by calcareous soils.

Also, a monitoring program conducted from 1993 to 1995 at the Rocky Flats Plant concluded that plutonium was largely immobile in semiarid soils. Only 1 to 3% of the plutonium was released when large rainfall simulators were used to simulate very heavy rain. The plutonium that was released during the simulated rainfall, however, was found almost exclusively on suspended particulates (Litaor et al. 1998).

In summary, the technical literature provides ample precedent, based both on field studies and on plutonium's geochemical properties, to state with confidence that plutonium will not dissolve in the environment prevalent at JA.

Furthermore, the column studies demonstrate that neither particulate nor dissolved plutonium mobilize readily in JI groundwater because no elevated TRU concentrations were found in filters or in the filtered and unfiltered water samples. Therefore, in consideration of these tests, the DTRA believe that the TRU contamination at JI can be considered essentially insoluble in groundwater at the site.

Annex H LAGOON SURVEY - Sediment Sampling of the JA Lagoon

H-1 Summary

Plutonium oxide concentrations both in surface and sub-surface sediments of the JA lagoon were characterized, and comparison data were established for biological sampling. There were a total of 197 laboratory samples prepared and analyzed from 113 sediment cores (109 usable) taken from the atoll; 37 offshore of the RCA, 11 surrounding Sand Island, and 61 scattered across the rest of the atoll. 5 out of 197 laboratory samples had plutonium oxide concentrations above the soil cleanup level of 13.5 pCi/g, but only one was on the surface (0-7.6 cm depth (0-3 in depth)) with its activity at 14.9 pCi/g. The results show that the highest concentrations are at sediment depths between 15-30 cm (6-12 in). All elevated readings were collected from the area offshore of the RCA, as expected.

The area around Sand Island was of concern as well, since the Historical Site Assessment (HSA) identified recovered debris from the STARFISH event in this area. No readings above the soil cleanup level were detected from the 19 laboratory samples prepared from core collection sites around the perimeter of Sand Island.

The lagoon survey results show that the existing plutonium oxide in the lagoon is concentrated in rare spots and is no longer at the surface. The present hazard to lagoon biota is therefore considered minimal.

H-2 Historical Site Assessment

H-2.1 Background

The HSA conducted as part of the Johnston Atoll Radiological Survey (DTRA 2000a) established the most likely areas of contamination. Of the four aborted tests, only two would have contributed to the dispersal of radionuclides in the lagoon. Most of the debris and residual plutonium from the STARFISH event landed on JI, adjacent Sand Island, and in the water surrounding them. The BLUEGILL PRIME event and ensuing fire and smoke from the launch area, scattered radioactive material primarily downwind of the launch emplacement due to the predominant winds from the east and northeast.

H-2.2 Contaminants of Concern

The HSA established that the residual contaminant was WGP which consists of five alpha-emitting TRU isotopes as previously described.

H-3 Objectives of the Survey

The objectives of the plutonium oxide characterization survey for the JA lagoon were twofold.

1) Sediment characterization of lagoon plutonium oxide concentrations both at the surface and sub-surface.

2) Provide comparison data for biological sampling.

H-4 Sample Collection

H-4.1 Introduction and Overview

The DTRA contracted with the USACOE for the collection of the sediment cores. The USACOE then subcontracted with Arthur D. Little, Inc. (ADL) and Environet, Inc., who performed core collection with a team comprised of three personnel. Cores were collected between 15-20 November 2000 with an additional two days of mobilization and demobilization. The team collected 113 sediment cores during the 6 days, with an average core length of approximately 38 cm (11 in). For a map detailing the sample locations, see Appendix F of DTRA report 2001b.

Core collection was accomplished using two different methods. Method 1 (Section H.4.2) was used for the first 3½ days after which Method 2 (Section H.4.3) was used exclusively. Method 1 was unable to consistently recover the desired core length of 46 cm (18 in) of sediment per the Sampling and Analysis Plan (SAP). After consultation with the USFWS Manager and the USACOE, Method 2 was approved and utilized. All but 4 of the 113 sediment cores recovered provided sufficient volume to meet the objectives of the survey (to characterize lagoon plutonium oxide concentrations at both the surface and sub-surface and provide comparison data for biological sampling), and had laboratory samples prepared. The four cores which did not have laboratory samples prepared were FIDLER scanned with no detects and archived. Cores collected from both methods penetrated the sediment surface until refusal or to a maximum depth of 61 cm (24 in).

Both methods utilized a Raytheon Raychart 320 Satellite Differential Global Positioning System (SD-GPS) which uses the Wide Area Augmentation System for a differential correction. GPS coordinates were recorded for each core location.

Cores were marked clearly with pre-printed labels that denoted the core top. Field notes were taken for each sediment core and compiled into a Field Database, (see Appendix A of DTRA report 2001b). A Chain of Custody Record documented each day's collected cores as they were delivered from the collection team to the DTRA, which handled sample preparation and laboratory analysis.

H-4.2 Collection Method 1

The first method used a vessel equipped with a temporary davit and 12 volt electric winch for deploying and recovering the sample equipment. Sediment was collected with a modified Diedrich Drill split spoon sampler, deployed from the vessel.

Prior to each deployment, the core collection equipment was cleaned. The field team visually assessed the bottom topography from the vessel and avoided coral reefs by positioning the equipment over areas in the lagoon free of coral formations. The core unit was lowered on a cable guided by a scuba diver until it reached the bottom and the pneumatic vibratory motor was activated to allow the coring equipment to penetrate to a maximum depth of two feet or refusal. After retrieval of the equipment, the polycarbonate tube was removed from the coring equipment and covered with polyethylene caps on the top and bottom. Cores were stored upright on the vessel at ambient temperature conditions and kept in the shade.

H-4.3 Collection Method 2

A scuba diver using the 2-inch OD polycarbonate liner tube, collected each sediment core from an area free of coral formations. Each tube was manually pushed into the sediment until refusal or to a maximum depth of two feet. The top end was covered with a polyethylene cap to create a vacuum and the tube slowly withdrawn. When the bottom end of the collection tube was clear of the sediment surface, another cap was used to cover the bottom.

H-5 FIDLER Scanning

The purpose of scanning each core was to look for high activities before sample preparation and to detect isolated plutonium oxide particles that might be present.

H-5.1 Equipment

A single five-inch diameter Ludlum 2221 FIDLER was used to conduct the scanning. This instrument is designed expressly to detect the low energy gamma radiation emitted by ^{241}Am. A source and response check was conducted twice daily (before and after scanning) using a known ^{241}Am source for quality assurance. All quality assurance checks for each day of scanning were within the industry standard of 10% of the baseline limits and indicate the FIDLER functioned properly. The daily background level prior to scanning was established by averaging three, one-minute ambient air counts. For the FIDLER Source/Response Check results and the Daily FIDLER Background results, see Appendix B of DTRA report 2001b.

H-5.2 Scanning Procedure

All cores had excess water decanted into a centralized container prior to FIDLER scanning. This excess water was then scanned with the FIDLER and determined to be free of any radioactive material.

FIDLER scanning was conducted for all 113 cores over the entire length of the polycarbonate tube prior to extrusion. 10-second stationary readings were recorded in cpm for each core. The core length was the determining factor as to how many stationary readings were taken per core (DTRA report 2001b).

H-5.3 Scanning Results

FIDLER scanning results (DTRA Report 2001b, Appendix C) determined 2 out of 113 cores had readings greater than twice the background level. One core (station number 17) had an elevated reading in the bottom third. The other core (station number 32) contained two elevated readings, one at the top or surface and one in the middle. Because the FIDLER scan found an elevated reading in the middle section of the core, a sample was prepared and analyzed by the laboratory counting equipment. See Table H-1 for a summary of the results from these two cores.

Table H-1 Sediment Sampling Results for the Two High Cores

Station Number	Core Length (in)	Bkg (cpm)	FIDLER Scanning and Laboratory Results Determined by laboratory counting equipment		
			Bottom	**Middle**	**Top**
17	8.4	631	2795 cpm / 677.9 pCi/g		914 cpm / 14.9 pCi/g
32	21.6	638	676 cpm / 9.3 pCi/g	3002 cpm / 347.8 pCi/g	1743 cpm / 3.9 pCi/g

H-5.4 FIDLER Scanning Results and Sediment Sample Concentrations

Results from laboratory analysis of the five samples prepared from these two cores (station numbers 17 and 32) show three of the five samples were above the established soil cleanup level of 13.5 pCi/g. Both of these cores were collected offshore of the RCA. For a map of specific locations, see Appendix F of DTRA Report 2001b.

H-6 Sample Preparation for Laboratory Analysis

H-6.1 Introduction and Overview

DTRA prepared laboratory samples in accordance with guidance received from the EPA Region IX. Of the 113 sediment cores collected, 109 (four sediment cores did not provide sufficient volume to prepare a sample) were used to prepare 197 samples for analysis. Each sediment core was to have two laboratory samples prepared (109 cores X 2 = 218), one from the top three inches and one from the bottom three inches. However, all cores were not able to have a top and bottom sample prepared for laboratory analysis (N=197). One or more of three reasons apply:

1) not enough core volume was collected for laboratory analysis
2) only enough core collected for one sample to be prepared
3) a rock or piece of hard coral prevented laboratory analysis

H-6.2 Preparation Procedures

Cores were extruded from the top of the polycarbonate collection tube using a fitted plunger. Each core was pushed out to expose approximately the bottom three inches, cut and placed on an aluminum pie plate. The remaining core was pushed out of the collection tube, and the top three inches was cut and placed on a separate aluminum pie plate. One core (station number 32) as noted above, due to an elevated FIDLER scan reading, also had a middle aliquot prepared. Any remaining core was archived in a double-bagged plastic container.

Sample aliquots were dried in an oven at 400^{o} F for 6 hours and air-dried for 48 hours. Each sample was prepared as directed by EPA Region IX in accordance with paragraph 32.5.1 *Cone-and-Quarter Method,* as outlined in the American Society for Testing and

Materials (ASTM 1996) method E-300. Once coned and quartered, each sample was then put into a 100 milliliter (mL) centrifuge tube for laboratory analysis and weighed in grams. The sediment weight was recorded, along with the sample identification number on each centrifuge tube. Remaining sediment from this procedure was archived along with any of the remaining extruded core.

H-7 Laboratory Analysis

H-7.1 Instrumentation

The counting systems used for the sediment samples were custom designed by American Nuclear Systems (ANS). The laboratory analysis utilized four detector/counting chambers to do on-site quantitative gamma spectroscopy analysis. The systems count samples in 100 mL centrifuge tubes. A summary of the equipment used in the laboratory counting systems is provided below.

Gamma Spectroscopy MCA Counting System Description

MCA Detector	Pre-Amp Software Shield	Version	Materials
ANS, Quantum MCA	Harshaw NaI (TI) 5 x 8 inch well	Quantum MCA Gold/Pu, Ver. 2000R 3.71.26	Pre-World War II Steel with Pb and Cu lining

The four detectors are identical cylindrical NaI (TI) detectors connected to pre-amplifiers, which feed the detector signals to an ANS Quantum 2000R multi-channel analyzer (MCA). The MCAs for all four systems are connected to a single desktop computer for analyzing the spectral data. The computer used the ANS Quantum MCA Gold/Pu, version 3.71.26 analysis software. The centrifuge tube containing the sample was inserted into the central detector well. The sample is almost totally surrounded by the NaI (TI) detector, which yields a high counting efficiency.

Standards and Procedures - The laboratory had a specially designed and calibrated, National Institute of Standards and Technology traceable ^{241}Am source for calibrating each of the systems. Each source was contained in a centrifuge tube. Each unit was calibrated and used per a standard operating procedure, see DTRA report 2001b.

Instrument Sensitivities and Efficiency – The laboratory counting system efficiencies are listed in the DTRA report 2001b.

Data Recording - The computer software automatically performed data recording. Data obtained from background and sample counting was retained as a hard copy in a specially designed spreadsheet. Appendix D of the DTRA report 2001b has a complete list of the data.

H-7.2 QA/QC Procedures

Forty-eight of the 197 samples (24%) were randomly selected for recount to provide quality control and assurance. Additionally, there were five samples above the soil cleanup level of 13.5 pCi/g. They were included in the 48 recounts to ensure accuracy.

The QA/QC data results shown in Appendix E of the DTRA Report 2001b, confirm that the counting system performed to standard and the counting results are valid.

H-8 Sampling Results and Conclusions

A complete list of the raw laboratory results is in Appendix D of the DTRA Report 2001b.

H-8.1 Offshore RCA Results

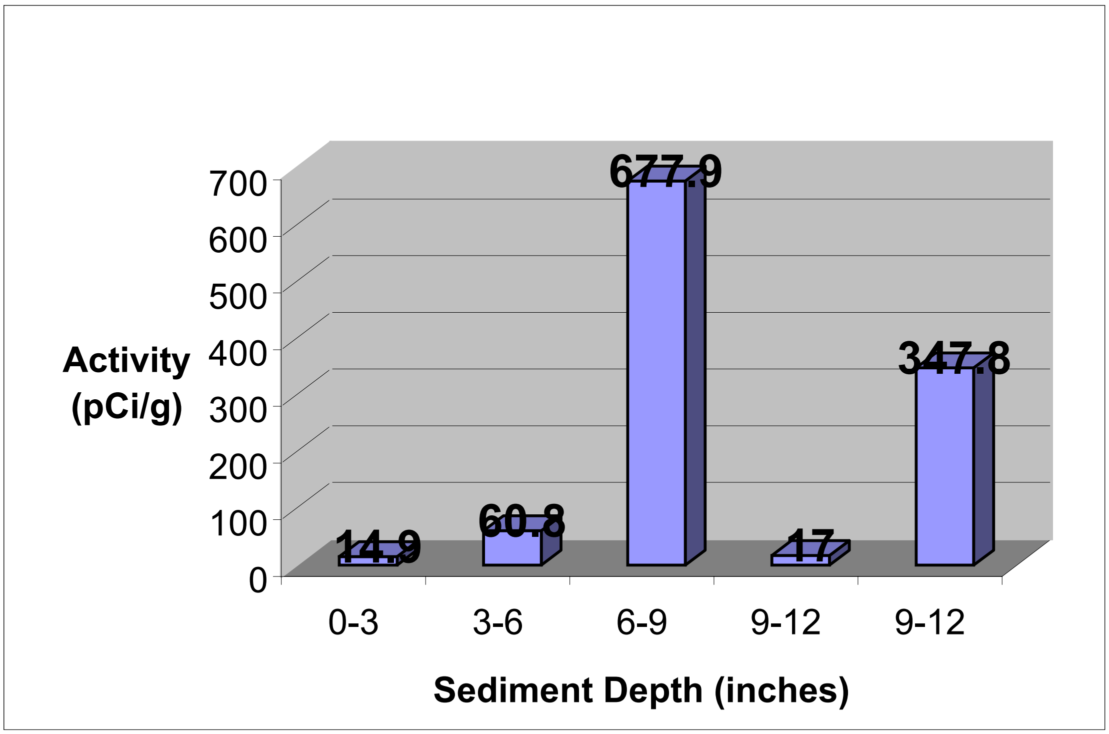
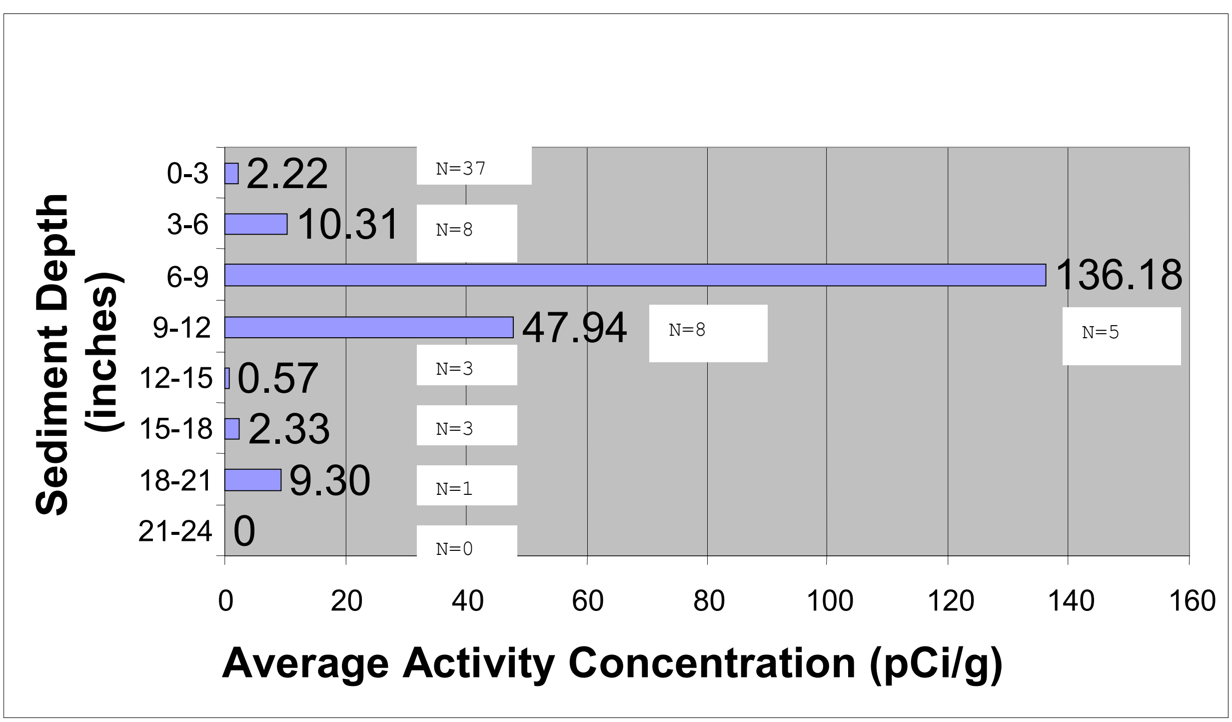


Figure 11 Offshore RCA Elevated Activities Lagoon Survey Results



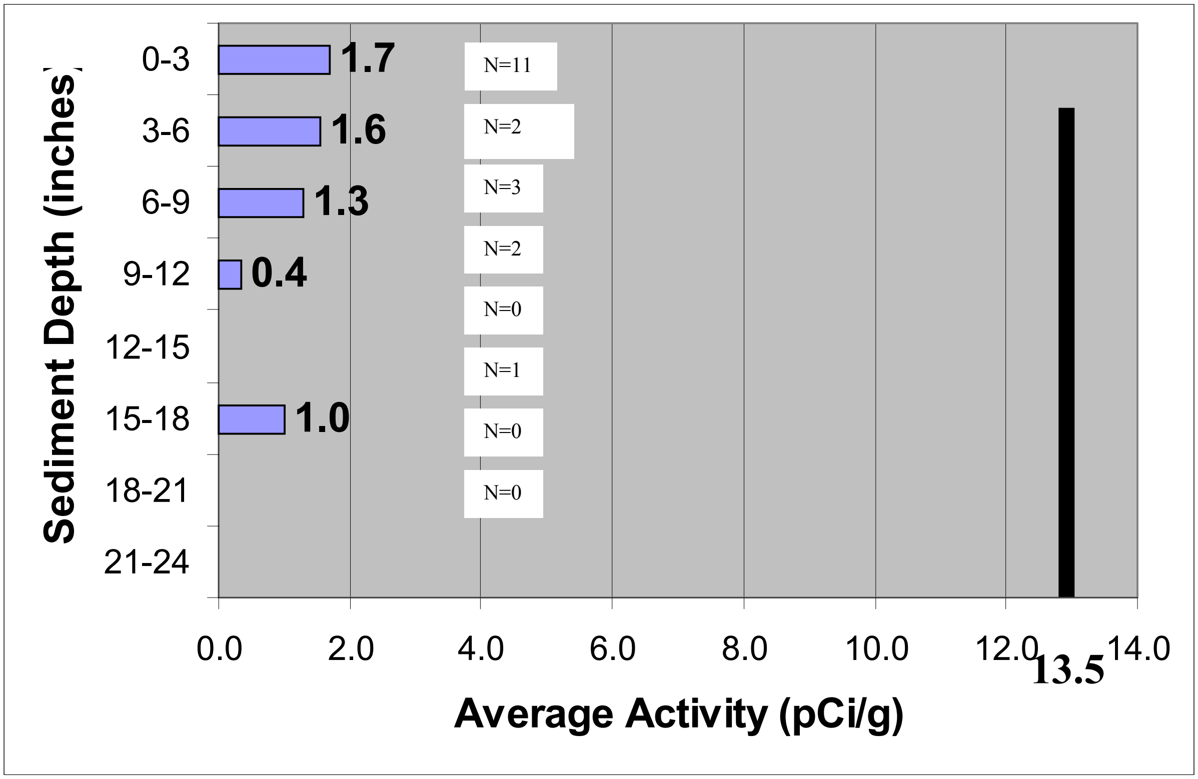


Figure 13 Sand Island Stratification Lagoon Survey Results

H-8.2 Sand Island Offshore Results

A second area of concern was the area offshore of Sand Island. According to the HSA, debris from the aborted STARFISH event was found on and around Sand Island. A total of 19 laboratory samples from around the outer perimeter of the island were prepared and analyzed from 11 cores. The average activities are listed above in Figure 31. The average activities are well below the soil cleanup level, with the single highest sample activity being 3.4 pCi/g found in the 0-3 inch depth range.

H-8.3 Johnston Atoll excluding RCA & Sand Island Offshore Results

Excluding the Offshore RCA & Sand Island data, the average activity for the remaining 113 laboratory samples prepared from 61 cores was calculated for the rest of the atoll. This TRU distribution with depth is shown below in Figure 32.

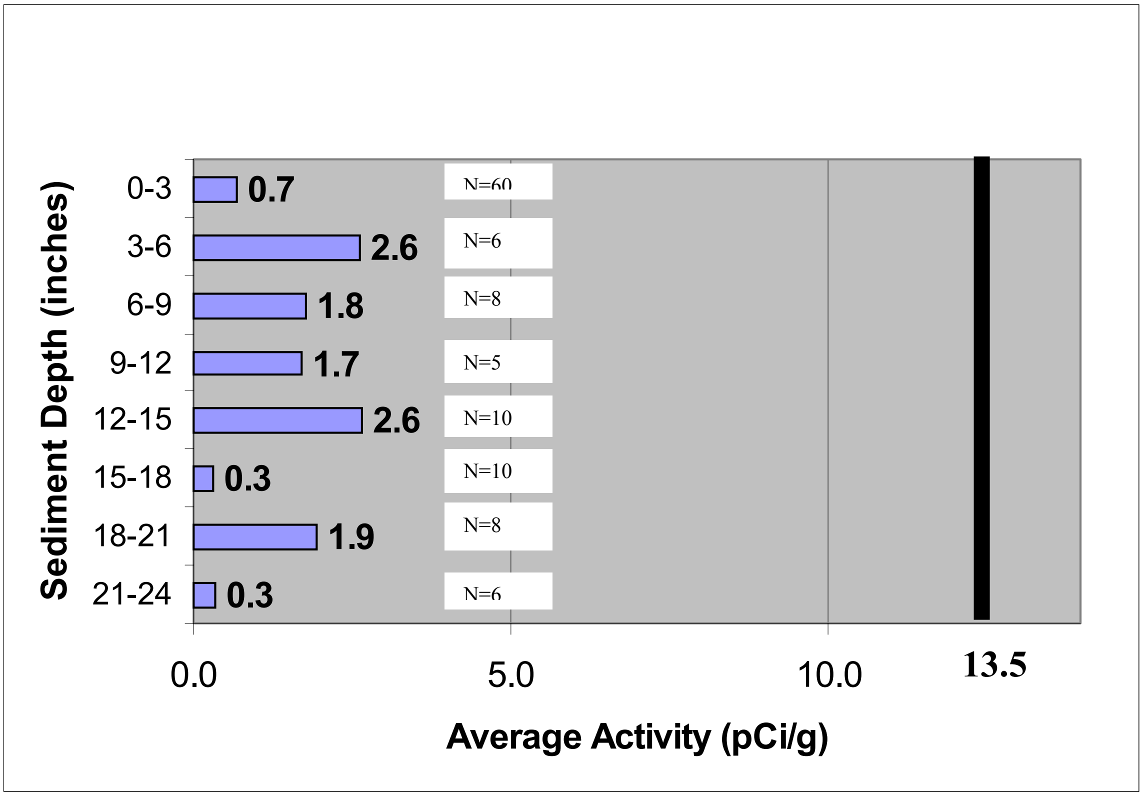


Figure 14 JA Stratification Less Offshore RCA & Sand Island Lagoon Survey Results

This analysis also shows that the average activity for the entire atoll, less offshore the RCA and Sand Island areas, is below the soil cleanup level. The highest sample activity found was 4.8 pCi/g in the 15-18 inch depth range.

H-8.4 Offshore Sand and North Island Results

An analysis was conducted of 12 laboratory samples prepared from 6 cores collected offshore Sand and North Island. This provided an estimate of sediment concentrations available to bottom feeding fish. The results are shown below in Figure 33.

The results show that the average activities are below the soil cleanup level of 13.5 pCi/g. The highest sample activity found was 3.4 pCi/g in the 0-3 inch depth range.

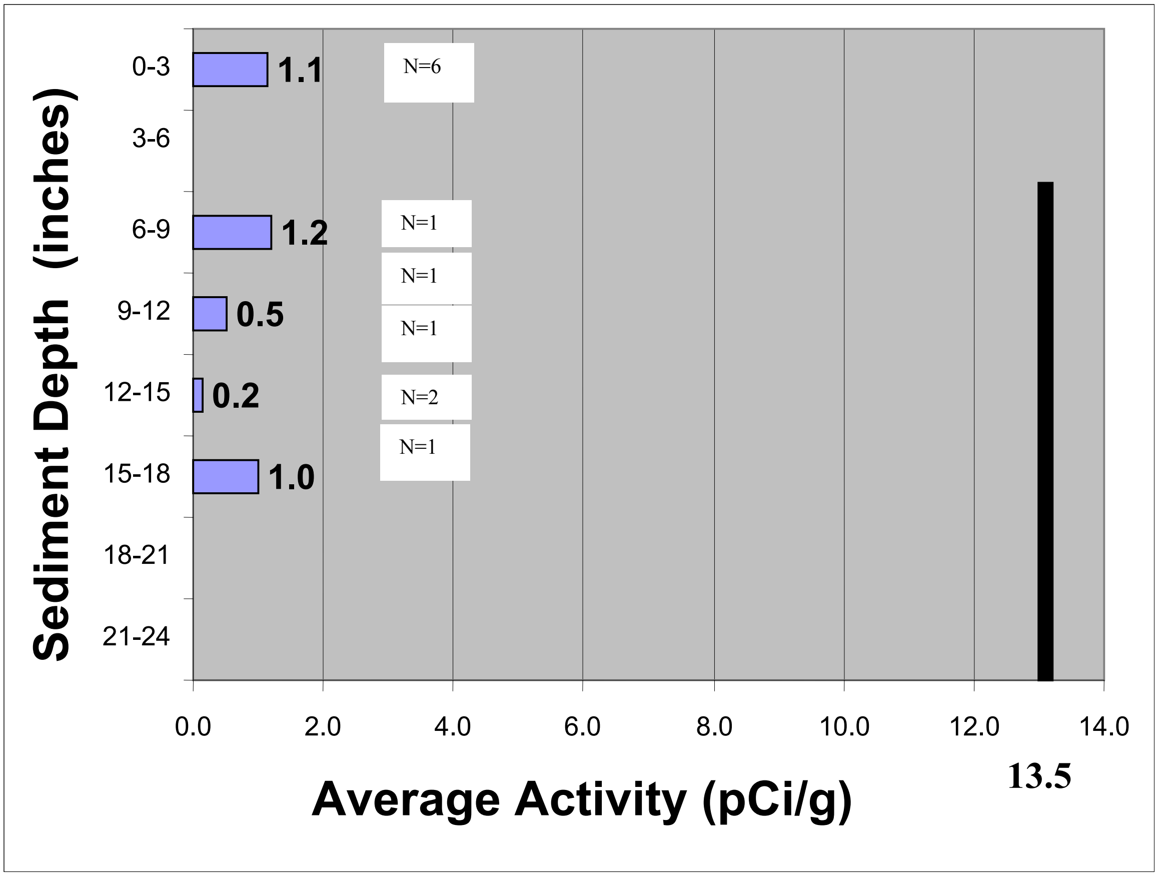


Figure 15 Offshore Sand and North Island Stratification Lagoon Survey Results

H-8.5 Previous Study Comparison

The DTRA made a comparison between the results of DTRA's core samples and previously collected cores by Noshkin in March 1980 from similar sites. The activities in the Noshkin Study were only given in $^{239/240}$Pu pCi/g. Since DTRA's activities were total TRU, a conversion was made using the $^{239/240}$Pu TRU ratio of 7.89E-01 to match units. The results are listed in Table H-2 below.

Table H-2 Comparison of Sediment Concentration For Similar Locations		
Sediment - Nov 2000 (DTRA) Activity $^{239/240}Pu$ (pCi/g)		**Sediment – Mar 1980 (Noshkin)** Activity $^{239/240}Pu$ (pCi/g)
0.394		0.039
1.026		1.070
3.392		1.650
1.657		0.004
3.392		0.015
AVERAGE	**1.972**	**0.556**
STANDARD DEVIATION	**1.371**	**0.763**

The next step was to conduct a statistical analysis to see if there are differences between the two sediment-sampling results. The statistical software package MINITAB© was used to conduct all the statistical analysis. The Mann-Whitney test was used due to the small sample size available.

MINITAB© tested the data for equal variance. Since the P-values (0.282 and 0.292) are greater than 0.05 (95% confidence interval (CI)), there is not sufficient reason to reject the null hypothesis (the variance in not equal), therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test (DTRA Report 2001b).

The Mann-Whitney test determines if there is a difference between the medians. Since the p-value (0.094) is not less than the chosen a level of 0.05, the conclusion is that there is insufficient evidence to reject the null hypothesis (the sample medians are different). Therefore, there is no difference between the medians. This analysis reveals that both sediment surveys found the same median activity at JA (DTRA Report 2001b).

The results show that both average activities are below the soil cleanup level of 13.5 pCi/g. MINITAB© verifies the DTRA's sample results are greater than Noshkin's, but within the appropriate standard deviations.

H-8.6 Conclusions

The objectives of the survey were met. Plutonium oxide concentrations both at the surface and sub-surface sediments were characterized, and comparison data was established for biological sampling. Only 5 out of 197 samples showed elevated activities above the soil cleanup level of 13.5 pCi/g. Only one was on the surface (0-3 inch depth) with its activity just above the soil cleanup level. The possible hazard to lagoon biota is therefore minimal. The results show that the highest concentrations are at sediment depths between 6-12 inches.

Annex I BIOTA SURVEY

I-1 Introduction and Overview

The objective of the biota survey was to quantify plutonium oxide and other radionuclides in selected reef fishes and macroalgae at selected sites within the JA lagoon. This biota survey follows the completion of the sediment survey conducted by Environet, Inc. and ADL during November 2000. This sediment survey provided a map of sediment radioactivity measurements against which the biota survey was planned. The data collected from this biota survey was used to determine the estimated radiation dose to fish, to humans consuming the fishes, to the green sea turtle consuming the algae, and to the Hawaiian monk seal consuming the fish. A complete discussion to include all data and calculations can be found in DTRA Report 2001a.

Dr. Philip S. Lobel (Boston University) and Lisa Kerr Lobel (University of Massachusetts, Boston) collected and prepared the biota in January 2001. Fish were collected northwest of the RCA to determine the maximum-possible-exposed fish dose. Fish were collected from Donovan's Reef and Hawaii to provide a baseline measurement assessment. Macroalgae samples were collected for food pathway analysis for the green sea turtle off the southern side of JI, which is a known feeding location.

Subsequent laboratory analysis was conducted by ORNL, Grand Junction, Colorado. Fish, viscera, and algae samples were analyzed by alpha spectrometry for ^{241}Am, ^{244}Cm, ^{238}Pu, $^{239/240}$Pu, and ^{242}Pu. This biological sampling was done to complete the analysis of radionuclide uptake and effects on the species around JA. Original sampling from 1995 was not appropriate for complete analysis of the effects of radionuclides on the animals around JA.

I-2 Summary of Selected Survey Sites

Six survey sites were selected for the collection of biota (fish and algae); maps are included in Appendix A of the DTRA Report 2001a. Summary discussions of the rationale used for each survey site chosen are included below. Table I-1 provides a brief description of each site and its GPS location.

I-2.1 North of the RCA on JI

After the BLUEGILL PRIME event, remedial action included constructing a ramp on the northwest corner of the launch area using contaminated soils. The primary focus of this sampling effort was the area northwest of the RCA where the ramp was constructed after the BLUEGILL PRIME event. Results from previous sediment samples informally taken from undocumented locations north of the RCA in 1999 were less than the established cleanup level of 13.5 pCi/g. Results from the sediment survey show that five samples from three cores taken from the lagoon north of the RCA exceed 13.5 pCi/g (DTRA 2001b). Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.2 South Shore of Johnston Island (Turtle Site)

This area is the main location where green sea turtles have been observed feeding. The sediment survey did not identify any significant radioactivity near this site. This site was very shallow with a rubble bottom and without significant reef structure. Consequently, macroalgae flourish due, in part, to a general decreased standing population of fishes. Thus, macroalgae was sampled here. Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.3 Sand Island

The results listed in the Outer Island Survey Report (USACOE 1999) found only 3 out of 383 samples above 13.5 pCi/g TRU of coral on Sand Island. The FIDLER walkover data found only one small-localized area (<4 m^2) of elevated activity on the southwest side of the island by the old U.S. Coast Guard barracks. These results supported a less aggressive sediment sampling effort in the lagoon surrounding the island. However, because a small-localized area of contamination was found, and the fact that the HSA documented debris falling onto Sand Island, lagoon sediment samples were taken 360 degrees around the island. No underwater hot spots were discovered (DTRA, 2001b). Fish samples were collected; Table I-2 lists the number collected.

I-2.4 Blue Hole (North Island)

North and East Islands were created after the nuclear testing era. The HSA found no previous history of radioactive contamination on either of these two islands. The Outer Island Survey Report (USACOE, 1999) documented the lack of contamination on East and North islands. Based on this information, the lagoon sediment sampling requirement in these areas was significantly reduced. If no contamination is on the surface of an island made from the sediments surrounding it, the chance of contamination being in the lagoon bottom around these areas is very small. This was confirmed by the sediment survey which did not identify radioactivity above the level of concern. North Island's reef east of the "Blue Hole" was one of two locations where fish (surgeonfish, *Ctenochaetus strigosus*) were sampled previously (DTRA 2001a). Fish samples were collected; Table I-2 lists the number collected.

I-2.5 Donovan's Reef

The area referred to as "Donovan's Reef" is the shallowest reef located at the extreme northeast corner of the atoll. It is the farthest (approximately 5 miles) reef site from the JA islands and, therefore, far from the center of plutonium fallout. Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.6 Hawaii

Hawaii was chosen as the reference site with collected specimens providing a measure of background comparison. The collection location was Kaneohe Bay, Oahu. Fish and algae were collected from this site, see Table I-2.

I-3 Sampling Strategy

Species were collected at five sites throughout the atoll and two in Hawaii. The locations, a species summary and the sample size used are provided below in Table I-1 and I-2.

I-3.1 Surgeonfish (*Acanthuridae*)

All surgeonfishes are herbivores but differ in whether they ingest sand. Grazers are species with thick-wall stomachs and ingest fine grain sand with algae. Browsers are species with thin-wall acidic stomachs and avoid sand ingestion.

Table I-1 Biota Sampling Sites

Short Name	Brief Description	GPS Location
N. of RCA	Northwest of the RCA; sediment survey identified four hotspots.	16° 43.892 N, 169° 32.534 W
Turtle Site	South shore of JI. Green Sea Turtle feeding area.	16° 43.820 N, 169° 31.705 W
Sand Island	Sand Island – Area of the wharf just west of the island. One of two previous fish collection sites.	16° 44.812 N, 169° 31.031 W
Blue Hole	North Island – East edge of reef commonly called “Blue Hole.” One of two previous fish collection sites.	16° 45.810 N, 169° 30.818 W
Donovan’s	Donovan’s Reef – East reef margin of the Atoll. Approximately 5 miles from JI.	16° 47.018 N, 169° 27.823 W
Hawaii	Hawaii – Kaneohe Bay, Oahu	6° 20.74 N, 157° 40.8 W

Goldring Surgeonfish, *Ctenochaetus strigosus* (C. Strig), **Kole** or **Golden-eyed**

A herbivore grazer feeding mainly on micro-algae mixed thickly with fine grain sand particles. It digests algal food mainly by mechanical trituration in a thick-wall stomach (Lobel and Kerr 2000). Sand is processed through the gut along with food.

The kole has a population difference between different JA sites, suggesting that there is a high degree of local isolation. It is the most abundant species overall in the lagoon with an estimated population size of 1,650,300 individuals (Irons et al. 1989). It is also one of the top two fishes taken by fishermen on the atoll with a typical annual harvest of about 1,200 fish.

The kole was collected at all sites except Hawaii and served as the main fish bioindicator since it is the most numerous species in JA. Fish species with this specific tropic specialization are ones known to be the best accumulators of radionuclides in the reef environment (Noshkin et al. 1997a). Noshkin et al. (1997a) also determined that “(radionuclide) concentrations associated with surgeonfishes were always greater than levels in flesh of goatfish and generally exceeded or were equivalent to the levels in mullet.” The emphasis on *C. Strig* is based upon the existing data set and the fact that this is the most common and easily collected species at JA.

C. Strig was first sampled in May 1995 because individual fishes were found having various deformities. These specimens were analyzed for radioactivity by ORNL in July 2000. A total of 20 specimens, collected off Sand and North Island in 1995, were analyzed revealing that 35% of the analyzed samples had detectable levels of ^{241}Am and ^{238}Pu in their tissues and 70% had detectable levels of $^{239/240}Pu$. There was no statistical difference in the radioactivity of deformed vs. normal fish, see Appendix B of DTRA report 2001a.

Convict Surgeonfish, *Acanthurus triosegus sandvicensis* (*A. Trig*), **Manini**

A herbivore browser feeding mainly on fine filamentous algae while avoiding ingestion of carbonate sand particles. It digests alga food mainly by acid-lysis in a thin-wall and distensible stomach (Lobel and Kerr 2000).

A. Trig is one of the top ten fishery species and has an estimated population size of 599,600 individuals in the lagoon, making it the tenth most abundant fish (Irons et al. 1989). Radiological data for this same species in the Marshall Islands was collected by Noshkin et al. 1997 and allowed for a direct comparison of results.

I-3.2 Goatfish (*Mullidae*)

These fish are predatory benthic carnivores feeding on all types of small invertebrate, crustaceans, fish prey, and other animals that are usually buried in sand. They use their specialized chin-barbels, which are covered with taste buds to detect prey hidden in sand. These fishes often swallow large amounts of sand with their food. There are 7 species (2 genera) of goatfish at JA. These fish are one of the popular fishery species and among the 10 most frequently caught at JA.

Goatfish were more difficult to find and collect than surgeonfish at every site and especially in Hawaii. This is because they are less numerous than herbivorous surgeonfishes and are also more intensely fished. Collection focused on *Mulloidichthys flavolineatus*, which is the same species collected in the Marshall Islands by Noshkin et al. (1997a, reported by the synonym *Mulloides samoensis*). Noshkin et al. (1997a) also collected other goatfish species in fewer quantities.

Yellowstripe Goatfish, *Mulloidichthys flavolineatus* (*M. Flavo*), **Weke ‘a**

This species population has been estimated to be about 188,900 individuals in the lagoon and is one of the 10 main fishery species at JA (Irons et al. 1989). This species usually displays a black spot on its side, below the first dorsal fin.

Yellowfin Goatfish, *Mulloidichthys vanicolensis* (*M. Vani*), **Weke ‘ula**

This species is very similar to *M. flavolineatus* but without the black spot on the side. Both species aggregate in resting groups and mostly feed at night.

Manybar Goatfish, *Parupeneus multifasciatus* (*P. Multi*), **Moana**

This species is one of the 10 most common species at JA. An estimated population of 61,850 fish live in the lagoon.

Doublebar Goatfish, *Parupeneus bifasciatu* (*P. Bifas*), **Mumu**

This species is one of the main fishery species at JA. An estimated population of 48,000 fish live in the lagoon.

I-3.3 Macroalgae (*Chlorophyta* - green algae)

Algae are known to be responsive to the soluble phase of constituents in the ambient medium but they do not respond to elements associated with particulate matter (Pentreath 1985, Sam et al. 1998). Even so, algae were found to be effective bio-indicators for monitoring marine radioactivity levels. Around JA, macroalgae are most abundant in the area along the south shore, near the JACADS facility. This is due partly to the lack of reef structure in this area. Thus, there are fewer herbivorous fishes, which allow algae to become macro. Algae at other sites around the atoll had less mass and abundance. *Caulerpa serrulata* was the only species collected and used for analysis.

I-3.4 Green Corkscrew Alga, (*Caulerpa serrulta,* (*Caul serra)),* **Limu**

This species is the dominant macroalga in the JA lagoon, especially in the winter season. In the area along the south shore where green sea-turtles are most frequently observed, it was the only macroalga found and it was present in abundant large mats. The green sea turtle, *Chelonia mydas*, is one of only two herbivorous sea turtle species, and it is known to eat *Caulerpa serrulata* algae (Marquez 1990).

I-4 Selection of Sample Size

To determine the sample size necessary to statistically test for concentration differences in biota between sites, radiological data from the May 1995 sampling of *Ctenochaetus stigosus* were used. A power analysis was used to determine the minimum sample size required to detect differences of 1 pCi/sample in radionuclide concentration between survey collection sites using an analysis of variance (ANOVA) test. Based on the isotope with the largest degree of variability ($^{239/240}$Pu), a minimum sample size of ten fish would be able to detect a significant difference at an alpha = 0.05 with a power (1 - β) of around 0.94. Generally a power greater than 0.80 is considered desirable (Zar 1984).

A Dunnet's multiple comparison test was used to determine if any of the JA samples differed significantly from the reference sites at Donovan's reef and in Hawaii. It is also important to note that a different result is obtained using the variance for ^{241}Am and $^{239/240}$Pu to calculate minimum sample sizes. It shows that with sample sizes as small as five fish, the probability of detecting significant differences at the 0.05 level is greater than 99% (power = 0.99). Thus, we used the more conservative minimal sample size of 10 specimens based on the $^{239/240}$Pu data.

I-5 Sampling Methods

The Lobels conducted the field collection effort. Specific sampling site coordinates were determined using a GPS navigation instrument. Underwater scuba diving equipment was utilized to collect fish and algae specimens. Individual fish specimens were speared and sealed in a bag. Collection focused on the largest and therefore presumably the oldest fishes at a site. Macroalgae were uprooted by hand (roots and all) and placed into individual labeled bags and sealed underwater. Each specimen was taxonomically identified to species and labeled appropriately. During field collection, a visual survey was conducted of the site and an effort made to assess any abnormal animals or otherwise unusual situations present. None were noted.

Once collection was complete, specimens were stored on ice until transferred to the laboratory for preparation and dissection. Table I-2 below lists the number of sample species collected from each of the six survey sites.

Table I-2 Biota Sample Numbers by Location

SITE	***C. Strig* (KOLE)**	***A. Trios* (MANINI)**	**GOATFISH (All species)**	**(*Caul Serra*) ALGAE**
1. North of RCA	10	10	5	5
2. Turtle Site	10	--	--	5
3. Sand Island	10	--	5	--
4. Blue Hole	10	--	--	--
5. Donovan's	9	10	5	5
6. Hawaii	--	7	1	5
Total Specimens	**49**	**27**	**16**	**20**

I-6 Sample Processing

Fish samples were blot-dried and weighed whole, then eviscerated with the viscera being weighed separately. The standard length and mass (g) of each fish were measured. Each specimen was carefully visually assessed macroscopically for the identification of deformities or lesions. None were noted. The fish were also dissected to remove their otolith bones. The otoliths can be used to determine the age of a fish. These otoliths were archived for possible future analysis. Algae samples were also blot-dried, weighed whole, sealed in plastic and frozen until shipped to ORNL for radiological analysis.

I-7 Laboratory Analysis

Laboratory analysis of the fish and algae was performed by ORNL. Both the eviscerated fish and its viscera were analyzed separately for radioactivity. The separation was done to allow different human and biota risk assessments to be completed.

The entire sample was first dry ashed to prepare it for analysis; therefore, no duplicate analysis was performed. Samples were placed in tared platinum crucibles and controls and internal standards were added to the batch.

The samples were fused and the flux from the fusion dissolved in 1000 mL of 1 M HCl. The sample was split into two equal aliquots after the dissolution. One 500-mL aliquot was set aside and analysis was continued and completed using the other aliquot. Additional americium purification from rare earth elements was also completed before analysis. Samples were analyzed by alpha spectrometry for presence of ^{241}Am, ^{244}Cm, ^{238}Pu, $^{239/240}$Pu, and ^{242}Pu using ORNL procedure RC-19 R06.

Analysis conducted on the data focused on answering six questions:

1) How do the sites (North of the RCA, Turtle Site, Blue Hole, Sand Island, and Donovan's Reef) on JA compare to each other (as plutonium oxide muscle concentration)?
2) How does JA compare to other sites in the U.S. (as plutonium oxide muscle concentration)?
3) What is the radiological dose to the fish?
4) What is the radiological dose to humans from consuming fish from JA?
5) What is the radiological dose to the green sea turtle from consuming macroalgae at JA?
6) What is the radiological dose to the Hawaiian monk seal from consuming fish at JA?

I-8 Results and Data Analysis

I-8.1 Introduction

The following discussion will explain the analysis rationale and method, any assumptions, the testing of those assumptions, the calculations, and the conclusions. This discussion focuses on answering the first question (section I-7), how do the sites (North of the RCA, Turtle Site, Blue Hole, Sand Island, and Donovan's Reef) on JA compare to each other (as plutonium oxide muscle concentration)? The data used for the analysis can be found in the DTRA report 2001a.

I-8.2 Data Analysis

Intercomparison between JA sampling locations - Graphical Review of Viscera Activity to Total Activity Ratio

Rationale: The ratio of viscera activity to total activity is used because it illustrates where the plutonium oxide resides in the fish. This analysis determines (visually) if there are equalities between species or locations. The average and median ratios across the entire atoll are shown in Figure 34. The ratio is used for plutonium oxide tissue partitioning, tissue concentration calculations and comparisons, later dose calculations, and the ratio is independent of total activity (small activities can be compared to large activities). The equation is shown below and raw data is in DTRA Report 2001a.

$$\text{Viscera Ratio} = \frac{\text{Viscera Activity}}{(\text{Viscera Activity} + \text{Eviscerated Activity})}$$

Method: The method was to plot the average and median viscera activity to total activity ratios by sampling location and species (Figure 34) for JA and Hawaii. The error bars for the average are at the 95% CI.

Conclusion: Visual inspection of Figure 34 shows that there are differences and similarities between column sets (areas, locations and species). Specifically, the data from Donovan's Reef and Hawaii are similar to each other as well as surgeonfish species from north of the RCA. A statistical comparison follows.

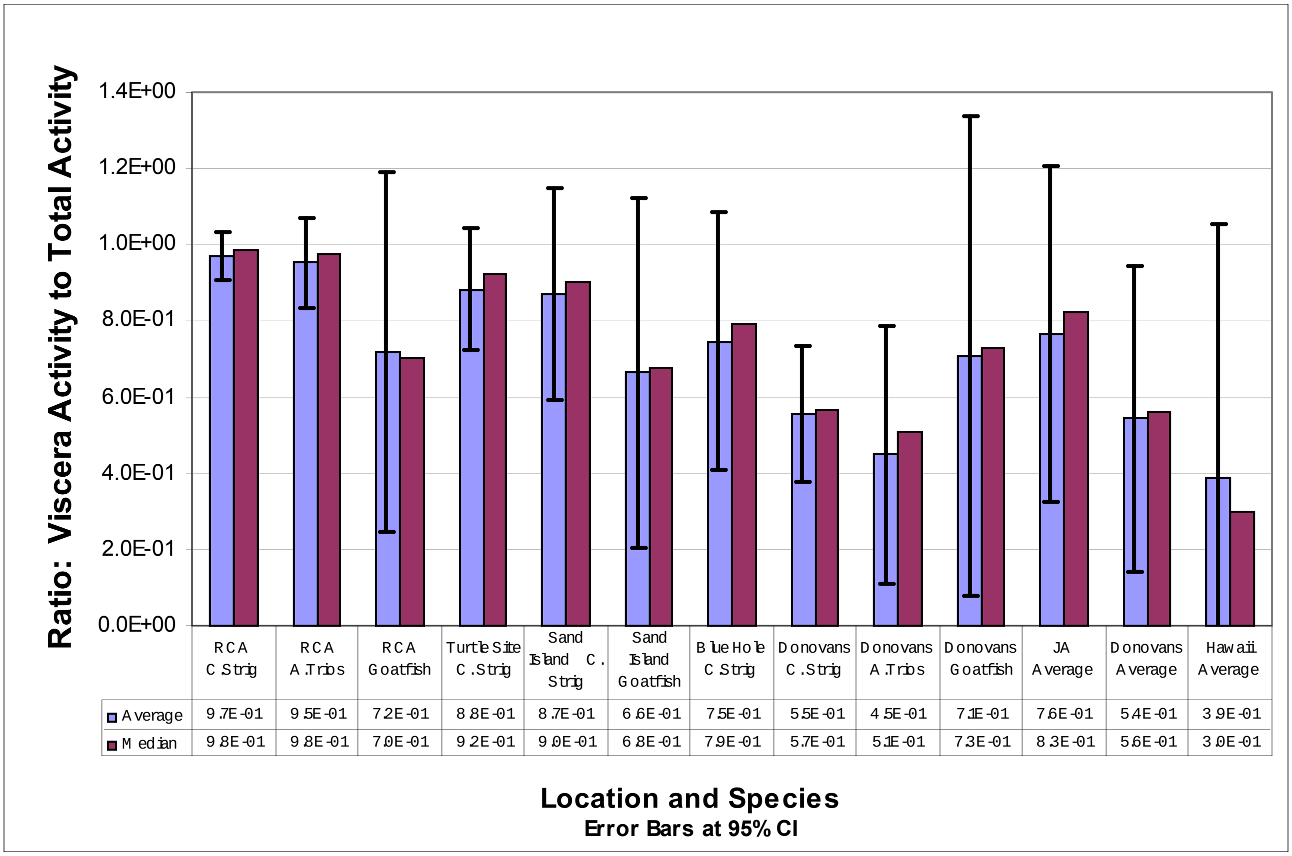


Figure 16 Intercomparison Between JA Biota Sample Locations and Species

I-8.3 Statistical Analysis for Inter-comparison between Surgeonfish Species

Rationale: The first analysis determines if there are differences between the two control sites, Donovan's Reef and Hawaii. The next analysis determines if there are differences between two different species of surgeon fish (C. Strig and A. Trios) collected at both Donovan's Reef and north of the RCA. Each site will be analyzed for species equality.

Method: To test this, a statistical analysis was conducted to see if there is a difference between samples. The raw data used for this analysis is shown in the tables within each of the following subsections. The statistical software package MINITAB© was used to conduct all the statistical analysis. The Mann-Whitney test (also known as the two-sample Wilcox rank sum test) was used due to the small sample size available. The Mann-Whitney test tests the equality of two population medians, and calculates the corresponding point estimate and confidence intervals. The hypotheses are:

H0: h1 equals h2 versus H1: h1 is not equal h2, where h is the population median and H0 is the null hypothesis

Assumptions: An assumption for the Mann-Whitney test is that the data are independent random samples from two populations that have the same shape (hence the same variance) and a scale that is continuous or ordinal (possesses natural ordering) if discrete. Therefore, a variance test must first be conducted to perform hypothesis tests for equality or homogeneity of variance among the two populations using an F-test and Levene's test. The test for equal variances generates a plot that displays Bonferroni 95% confidence intervals for the response standard deviation at each level. The data must pass at least one of the Equal Variance tests before the Mann-Whitney test will be started.

I-8.4 Donovan's Reef and Hawaii

Raw Data: The viscera ratio ($^{239/240}$Pu in the viscera to total $^{239/240}$Pu) in the same species is calculated and is shown in Table I-3 for Donovan's Reef and Hawaii.

Equal Variance Test Interpretation: Since the P-Values (0.077 and 0.251) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

Mann-Whitney Test: The Mann-Whitney test determines if there is a difference between the medians. The data for Donovan's Reef fish and Hawaii fish is shown below in Table I-3.

Table I-3 Donovan's Reef & Hawaii A. Trios Viscera Pu Ratio Data		
Donovan's Reef A. Trios	viscera ratios	Hawaii A. Trios
0.50		0.41
0.56		0.00
0.27		0.63
0.63		0.28
0.61		1.00
0.39		0.15
0.52		0.30
0.42		
0.07		
0.53		

The Mann-Whitney Test Interpretation: There is no difference between locations. Since the test's significance score (0.46) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that A. Trios is equal in their uptake of plutonium oxide at Donovan's Reef and Hawaii.

I-8.5 Donovan's Reef

Raw Data: The viscera ratio for surgeonfish is calculated and is shown in Table I-4 for Donovan's Reef.

Table I-4 Donovan's Reef Surgeonfish Viscera Pu Ratio Data		
C. Strig		A. Trios
fish (viscera ratio)		fish (viscera ratio)
0.43		0.50
0.64		0.56
0.57		0.27
0.64		0.63
0.45		0.61
0.63		0.39
0.56		0.52
0.43		0.42
0.63		0.07
		0.53

Equal Variance Test Interpretation: Since the P-values (0.084 and 0.313) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

The Mann-Whitney Test Interpretation: There is no difference between fish species. Since the test's significance score (0.09) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that C. Strig and A. Trios are equal in their uptake of plutonium oxide at Donovan's Reef.

I-8.6 North of the RCA

The area north of the RCA had the same two fish species collected.

Raw Data: The viscera ratio for surgeonfish is calculated and is shown in Table I-5 for the area north of the RCA.

Table I-5 North of the RCA Surgeonfish Viscera Pu Ratio Data

A. Trios		C. Strig
Viscera ratio		Viscera ratio
0.91		1.00
0.99		0.99
0.95		0.98
1.00		1.00
0.99		0.99
0.80		0.96
0.97		0.98
0.98		0.99
0.99		0.91
0.95		0.92

Equal Variance Test Interpretation: Since the P-values (0.080 and 0.406) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

Mann-Whitney Test Interpretation: there is no difference between fish species. Since the test's significance score (0.43) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal between C. Strig and A. Trios from north of the RCA. The conclusion from both this site and Donovan's Reef is that C. Strig and A. Trios are equal in their uptake in plutonium oxide.

I-8.7 Fish Size Comparison

Rationale: The next level of comparison is to determine if the size of the fish impacts the viscera activity ratio. Since the Donovan's Reef data set has been shown to have equality between the species and has a large number of samples available (since the surgeonfish species are equal, both can be used for this analysis) only the Donovan's Reef data will be used.

Method: The same statistical method for comparison will be used as before. The line separating the "small" fish and "large" fish will be 100 g in mass.

Assumptions: A small fish is one less than 100 g and a large fish is greater than 100 g.

Raw Data: The raw data for fish size comparison is presented in Table I-6 below.

Table I-6 Donovan's Reef Fish Size and Plutonium Oxide Ratios Data

Small Fish Data Set <100 g		Large Fish Data Set >100 g	
Small Fish Mass (g)	Small Fish Ratio	Large Fish Mass (g)	Large Fish Ratio
50	0.63	153	0.53
50	0.64	155	0.39
50	0.56	172	0.42
54	0.57	184	0.52
55	0.45	193	0.50
59	0.43	196	0.07
66	0.63	199	0.61
67	0.43	203	0.56
71	0.64	209	0.63
		227	0.27

Equal Variances Test Interpretation: Since both P-values (0.095 and 0.346) are greater than 0.05 (95% CI), then the assumption of equal variance is valid and meets the requirements of the Mann-Whitney Test.

Mann-Whitney Test Interpretation: There is no difference between small and large fish. Since the test's significance score (0.09) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that small and large size fish are equal in their uptake of plutonium oxide at Donovan's Reef.

Conclusions: There is no difference between species (C. Strig and A. Trios) at two different sites. There is no difference between the smaller and larger fish with respect to their viscera to eviscerated fish activity ratios. These results allow comparison to other sites regardless of fish size and species type.

I-8.8 Muscle Tissue Concentration Calculations

Rationale: To allow for comparison to other locations cited in the literature, the muscle tissue concentration of $^{239/240}Pu$ is required. A literature review discovered partitioning values for plutonium in fish (Noshkin 1980). The next step is to apply Noshkin's partitioning value for fish to the collected JA fish. Noshkin's data table is reproduced in part below as Table I-7. This data table was selected because it matched for plutonium, was also in a South Pacific atoll environment, and used the same fish species. The equations for this calculation can be found in DTRA report 2001a.

Table I-7 Data Table from Noshkin 1980 p. 400			
Reconstructed Concentrations of Radionuclides in Bikini Atoll Fish	A (Muscle)	B (Muscle & Skin)	C (Muscle, Skin, & Bone)
$^{239/240}$Pu (pCi/kg) in Convict Surgeon Fish	0.11	1.20	2.81
^{241}Am (pCi/kg) in Convict Surgeon Fish	0.026	0.32	0.48
$^{239/240}$Pu (pCi/kg) in Goatfish	0.073	0.57	0.89
^{241}Am (pCi/kg) in Goatfish	0.030	0.20	0.41

I-8.9 Application of the Partitioning Value

The viscera and the eviscerated fish were analyzed separately. With this division of the fish, the Noshkin ratio with the eviscerated fish activity can accurately predict the muscle concentration. The partitioning value for surgeon fish is 4.5% and 7.5% for goatfish. Complete analysis can be found in the DTRA Report 2001a.

The summary of muscle concentrations by area and species are shown below in Figure 35.

Conclusion: Therefore, to answer the first question about how the sites compare, Figure 35 shows how plutonium oxide muscle concentrations compare between sites.

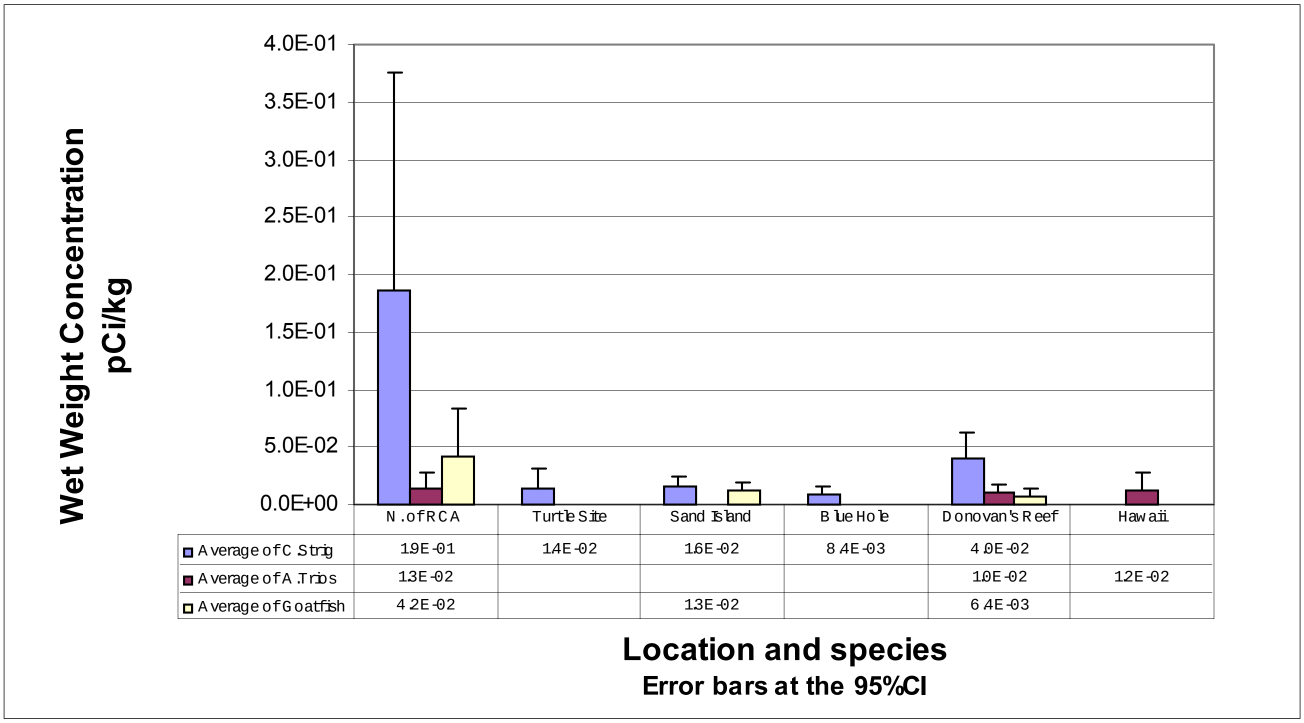


Figure 17 Plot of $^{239/240}$Pu Muscle Concentration in Biota Samples for Comparison Between Locations Around JA

I-9 Site Comparison

The plutonium oxide muscle concentration can be compared to other sites in the other parts of the U.S. (Figure 36) (Robison et al. 1981). Figure 36 answers the second question (section I-7), how does JA compare with other sites.

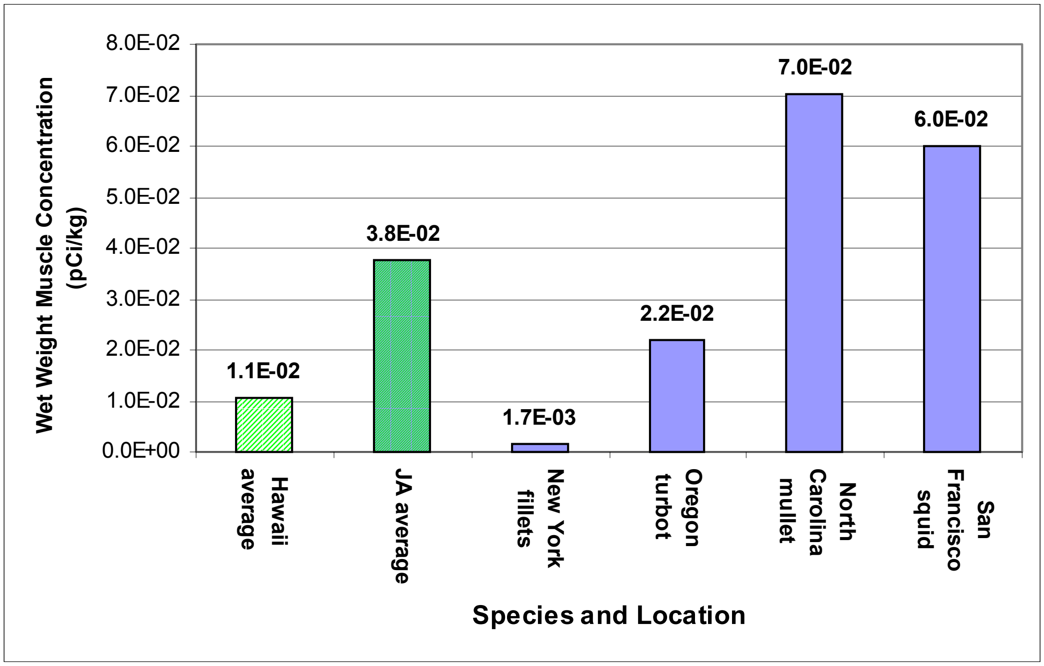


Figure 18 U.S. Comparison of $^{239/240}$Pu Muscle Concentration in Fish Muscle Tissue

I-10 Fish Dose Calculations

Rationale: To answer question 3(section I-7), calculating the radiological dose from the plutonium oxide to fish at JA is the goal. This calculation will allow comparison of the calculated values to International Atomic Energy Agency (IAEA) dose limits for animals.

Method: Calculation of the radiological dose to fish is done by determining the total energy absorbed per kilogram of tissue. The energy absorbed is the sum of all the particle's energies from each contributing isotope. Only the alpha energy is considered in this dose calculation. The gamma radiation emitted (60 keV) from these isotopes is approximately 2 orders of magnitude less than the alpha (5 MeV) therefore the gamma is negligible and was not considered. The complete set of calculations can be found in the DTRA report 2001a.

I-10.1 Gastrointestinal Tract Crossing

The first assumption to test is whether all the isotopes cross the gastrointestinal tract the same way. The method to test this is to see if the transuranic ratio (total alpha activity divided by ^{241}Am activity) changes between the viscera and the eviscerated fish. All the viscera's transuranic ratios were calculated and compared to the eviscerated fish's ratio for all the fish at JA in DTRA Report 2001.

Graphical Review: Figure 37 shows the viscera's transuranic ratios compared to the eviscerated fish's ratio along with the 95% CI error bars on the distribution of the ratios.

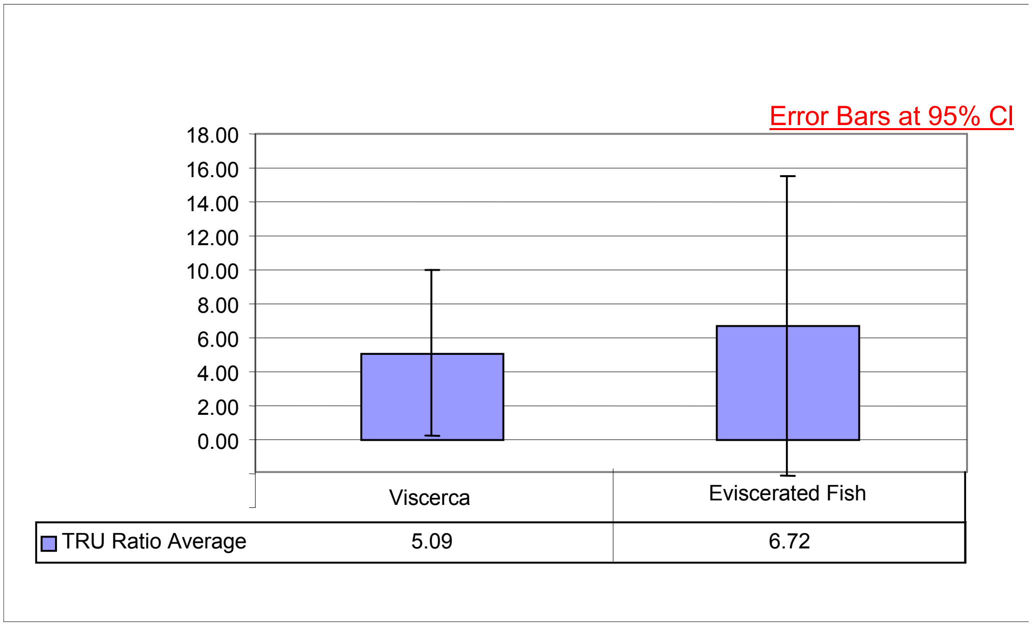


Figure 19 TRU Ratio Average for Viscera and Eviscerated Fish

Statistical Analysis: The same method used before will be applied to this analysis.

Equal Variance Test Interpretation: Since both P-values are less than 0.05 (95% CI), the assumption of equal variance is not valid and fails to meet the Equal Variance requirement.

Alternative Statistical Test: The 2-Sample T-test is used without assuming equal variances. The 2-Sample T-Test prefers to have a normal distribution on the data. Neither of these two data sets are normal in their distribution. However, data sets with sample sizes greater than 30 are considered large. This analysis uses 167 total samples, because the viscera results from sample number 88 were lost in shipment. Large sample sizes decrease the dependence upon normalcy.

Two-sample T Test Interpretation: The 95% CI (-3.10, 0.94) includes zero; therefore, it suggests there is no difference. The hypothesis test includes a P-value of 0.291, and 135 degrees of freedom. Since the P-value is greater than 0.05, there is no evidence for a difference in transuranic ratios between the viscera and the eviscerated tissue. This supports the assumption that the isotopes move across the gastrointestinal tract equally.

I-10.2 Dose Calculation

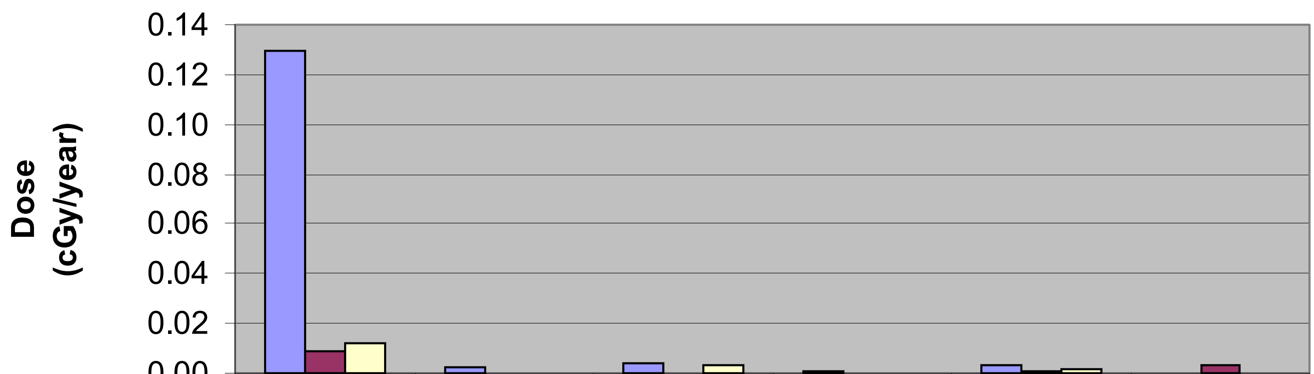
Using the individual isotope's activity in each eviscerated fish and the partitioning fraction into the tissue types (muscle, bone, and scales/skin), the total energy deposited in that tissue type can be calculated. The equation can be found in DTRA Report 2001a.

The ratio of tissue type to whole body weight for surgeonfish and goatfish is shown below in Table I-8 (Noshkin 1987). The values will be used to determine the radiological dose (energy absorbed per kg of tissue).

Table I-8 Fish Tissue Fractions by Mass

Name	Muscle	Bone	Scales/Skin
Surgeonfish	0.663	0.08	0.116
Goatfish	0.663	0.08	0.116

The summary average dose results are shown in Figure 38. The IAEA has an animal dose limit of 40 μGy/hr (Linsley 1997) (about 0.1 cGy/day or 36.5 cGy/yr). All the calculated doses are less than 1% of the established limit.



	N. or RCA	Turtle Site	Sand Island	Blue Hole	Donovans	Hawaii
C.Strig	1.3E-01	2.7E-03	4.1E-03	1.2E-03	2.9E-03	
A.Trios	9.1E-03				7.7E-04	3.0E-03
Goatfish	1.2E-02		3.1E-03		1.6E-03	

Figure 20 Average Dose to Fish Species at JA Locations

`I-11` Human Doses

Rationale: The next step is to calculate the potential doses to humans from consuming the fish from JA and answer question 4 (section I-7). The fish from Donovan's Reef are omitted from this analysis. Fishing in Donovan's reef for bottom fish, like goatfish and surgeonfish, is normally not done since other (larger) fish species are available. Two scenarios are considered, consuming the entire fish and consuming only the muscle tissue. Both scenarios use equal amounts of fish intake of 200 g per day for the entire year (Noshkin 1987) and uses the ICRP Publication 30 dose conversion values.

Methods:

I-11.1 Muscle Tissue Scenario

The average concentration (TRU) of the muscle tissue, and of the entire fish was used at the 95% CI of the average (0.26 pCi/kg). The complete set of calculations can be found in DTRA report 2001a.

Table I-9 Human Dose Calculation from Fish Muscle Ingestion at JA

Ingested Mass	73,000 g/yr				
TRU intake (TRU)	18 pCi/yr				
Isotope	^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)	3.4E+00	7.4E+00	1.3E+00	1.3E+00	4.7E+00
Intake Amount (Bq)	1.27E-01	2.75E-01	4.96E-02	4.97E-02	1.75E-01
Dose[1] (Sv)	2.79E-04	1.81E-06	9.42E-08	3.58E-07	2.58E-09
Dose[1] (rem)	2.79E-02	1.81E-04	9.42E-06	3.58E-05	2.58E-07
		Total Dose Annual (Sv)			***2.3E-06***
Mortality[2] Risk/Bq	2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks					
	3.25E-10	9.99E-10	1.00E-10	1.71E-10	6.11E-10
			Total Risk		**2.2E-09**

[1] based on ICRP 30
[2] based on EPA 1999a

I-11.2 Entire Fish Scenario

The average concentration (TRU) of the entire fish around JI was used at the 95% CI of the average (196 pCi/kg). The calculations can be found in DTRA Report 2001a. The average values are used since the entire fish was consumed. The same calculation is done for consuming the entire fish. The results are shown below in Table I-10.

Table I-10 Human Dose Calculation from Entire Fish Ingestion at JA					
Ingested Mass	73,000 g/yr				
TRU intake (TRU)	14,300 pCi/yr				
Isotope	^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)	3.2E+03	6.9E+03	6.8E+02	8.4E+02	2.8E+03
Intake Amount (Bq)	1.2E+02	2.6E+02	2.5E+01	3.1E+01	1.1E+02
Dose[1] (Sv)	1.7E-03	8.8E-05	1.8E-04	4.6E-07	1.5E-06
Dose[1] (rem)	1.7E-01	8.8E-03	1.8E-02	4.6E-05	1.5E-04
		Total Dose Annual (Sv)			**0.002**
Mortality[2] Risk/Bq	2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks					
	3.0E-07	9.3E-07	5.0E-08	1.1E-07	3.6E-07
				Total Risk	**1.8E-06**

[1] based on ICRP 30
[2] based on EPA 1999a

Conservative Assumption Discussion: These scenarios assume that only benthic fish are consumed at JA and none of the common larger fishes inhabiting JA (tuna, mahi-mahi, ono) are eaten. Since the exact fraction of benthic fish in the human diet is unknown, this is considered the upper boundaries for each scenario. Plutonium does not bioaccumlate and plutonium concentrations actually decrease with trophic level (Noshkin 1979 and 1987). The large difference between the muscle tissue scenario and the entire fish scenario reflect the fact that plutonium oxide does not significantly cross the gastrointestinal tract (plutonium oxide is insoluble).

I-12 Green Sea Turtle Dose Estimate

Rationale: The Green Sea Turtle is a threatened species, inhabits JA and consumes macroalgae. A dose assessment is warranted to answer question 5 (section I-7). The calculated dose can then be compared to IAEA dose limits for animals.

Method: The turtle is not a human and therefore using human dose conversion factors from intake is inaccurate. The method used to calculate the equilibrium concentration of the transuranics inside the turtle and then the resulting dose from that concentration is summarized below. The equilibrium value is used since it is the maximum concentration possible in the animal resulting in the most conservative dose. Since "inside the turtle" means the activity that crosses the gastrointestinal tract, an f1 value must be applied. The f1 value is the fraction that crosses the gastrointestinal tract into the bloodstream. The equations and full discussion can be found in DTRA Report 2001a.

The 95% CI food intake for a turtle with a body mass of 99,760 g is 1,540 g (dry) or 30,800 g (wet). The DTRA used the 95% CI wet value of 30,800 g with a standard deviation of 12,600 g.

The average algae concentration is 0.05 pCi (TRU)/g with a standard deviation of 0.12 pCi/g which translates to about 2,200 pCi per day at the 95% CI and the Q value is 854 pCi in a 99,760-gram turtle. This equates to 3.2×10^{-4} Bq/g of tissue (1 Bq = 27 pCi). Using the maximum possible alpha emitter energy of 5.8 MeV/Bq the dose is calculated to be 0.001 cGy per year.

Conclusion: The dose is 0.001 cGy/year. This is insignificant (less than 0.003%) compared to the IAEA limit of 36.5 cGy/year (Linsley 1997) for reproductive effects in animals. If the quality factor (20 for alpha particles) is applied (this turns gray into sievert or calculates dose equivalent from dose), the corresponding dose to a human would be 0.2 mSv/year. Even treating the turtle as a human, the dose is well below (20% below) the general population limit of 1 mSv/year (10CFR20).

I-13 Monk Seal Dose Estimate

Rationale: Since the Hawaiian monk seal eats the JA fish, a dose assessment is warranted to answer question 6 (section I-7). The calculated dose can then be compared to IAEA dose limits for animals.

Method: The monk seal is close enough to humans that the ICRP human dose conversion factors using the whole fish ingestion scenario can be used. The 95% CI for consumption is calculated using the below equations.

Fish Consumption = 3,000 g/day (Greiner 2001)
Estimated Standard Deviation = 1,000 g/day (EPA 1993b)
Average TRU concentration of JA fish = 0.03 pCi/g
Standard Deviation of the TRU concentration = 0.09 pCi/g

Using these values yields 90 pCi/day ingested, an error of 272 pCi/day, and a 95% CI ingestion rate of 623 pCi/day intake rate or 227,000 pCi/year. The dose calculations are shown below in Table I-11.

Table I-11 Dose Calculation for the Monk Seal from JA Fish Consumption					
Ingested Mass		1.1E+06 g/y			
Annual TRU intake (TRU)		2. 3E +05 pCi/y			
Isotope	^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)	5.0E+04	1.1E+05	1.1E+04	1.3E+04	4.5E+04
Intake Amount (Bq)	1.9E+03	4.0E+03	4.0E+02	5.0E+02	1.7E+03
Dose[1] (Sv)	2.7E-02	1.4E-03	2.9E-03	7.3E-06	2.5E-05
Dose[1] (rem)	2.7E+00	1.4E-01	2.9E-01	7.3E-04	2.5E-03
				Total Dose Annual (Sv)	**0.03**
Mortality[2] Risk/Bq	2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks					
	4.8E-06	1.5E-05	8.1E-07	1.7E-06	5.8E-06
				Total Risk:	**2.8E-05**

[1] based on ICRP 30
[2] based on EPA 1999a

Discussion: Assuming the Hawaiian monk seal resides at JA year-round, eats only bottom-feeding fish, and feeds exclusively in the area of the lagoon immediately offshore of the RCA, calculations indicate that the dose to the monk seal would be about 10% of the annual limit set by the IAEA. These assumptions are very conservative; that is, they represent an improbable worst-case scenario.

The Hawaiian monk seal is a rarity at JA. The National Marine Fisheries Service recently evaluated data on the range of the Hawaiian monk seal and concluded that JA is "probably at or near the range boundary," and that "development of a seal subpopulation is hindered by the long distance from a source of immigrants and by a limited amount of undisturbed beach area on which the seals could rest" (NOAA 2001). Monk seals have been sighted at JA but their preferred habitat is in the northwestern Hawaiian Islands (the only known breeding area) approximately 500 miles from JA area (Marine Mammal Commission 2000, NOAA 1999). Monk seals introduced to JA from French Frigate Shoals did not remain at JA (Marine Mammal Commission, 2000). Hawaiian monk seals tend to stay near their breeding area year round with occasional excursions to deep water. Usually the seal will return within a few days to up to a month later (NOAA 1999, Earthtrust 2001, animalinfo 2001).

The second conservative factor is the ingestion total. The ingestion amount (0.2 pCi/g of fish) is set to protect an individual at the 95% CI, but examination of the JA fish concentration data set reveals that the large standard deviation (over three times the average) is driven by a few large samples which skew the results. The seal would have to feed only on the maximally contaminated fish in the lagoon near the RCA to achieve the calculated activity intake. Realistically, the seal would feed across the entire atoll and on a variety of other species. The normal diet of adult seals includes a variety of reef fish, eels, octopi and lobsters (NOAA 1999, Marine Mammal Commission 2000, Earthtrust 2001, Gilmartin 1983). "Although these food items are available nearshore, the dive data collected at Lisianski Island indicate that the animals regularly range away from the island to feed in the deeper waters of the outer reef and reef slope" (Gilmartin 1983, p. 7). The area of the lagoon outside the RCA is 1% of the total available feeding area of the lagoon. Thus, the dose estimate is probably high by a factor of 100. Furthermore, bottom-feeding fish in the area weigh on the order of 100 g each, so consuming 30 fish per day would quickly lead the seal to expand its feeding area or to consume other (non-bottom-feeding) fish less likely to contain plutonium.

Thirdly, the Hawaiian monk seal's average body weight is 400-600 lbs, two to three times greater than the weight and/or mass of the human model used for the seal's dose calculation. Since the dose is dependent upon the mass of the organism, this is a dose overestimation by a factor of two or three.

Lastly, the dose is actually distributed over a 50-year life span but by convention is assigned during the year of the intake. Since a Hawaiian monk seal's typical life span is 20 to 30 years (Earthtrust 2001, animalinfo 2001, Monachus 2001), the dose is probably overestimated by another factor of two. Using all these conservative assumptions, the annual dose equivalent is calculated to be 0.03 Sv/year (30 mSv/year). By comparison, the IAEA recommended limit for reproductive effects in animals is 0.365 Gy/year (36.5 cGy/year) (Linsley 1997). The annual dose equivalent calculation used human quality factors to convert the dose rate to a dose equivalent rate. The IAEA recommended limit is for gamma exposure; by applying the human quality factor (1 for gamma rays) to the recommended dose limit (to convert gray to sievert), the IAEA dose equivalent limit would be 0.365 Sv/year (365 mSv/year), ten times higher than the value calculated for the Hawaiian monk seal.

The dose calculation assumed the Hawaiian monk seal lived in the JA area all year and ate only the highest average Pu-concentrated fish throughout the year for its entire life, which contradicts the seals' actual habits and life cycle. Considering the seals' actual diet, movement and feeding habits, and their current occupancy rates around JA, achieving even 10% of the IAEA annual limit is impossible. Chronic exposure to radiation usually does not manifest into a health risk until after 20 years and the chronic mortality limit recommended by the IAEA is ten times higher than the reproductive limit, this adds additional conservative aspects to the seal's dose calculation. The actual risk associated with the dose could be hundreds, even a thousand times less depending on how much fish is actually consumed and how often the eaten fish were surgeonfish from offshore of the RCA in addition to the other conservative estimates discussed above.

Annex J RESPONSES TO PUBLIC COMMENTS FROM MAY 2001 MEETINGS

The Defense Threat Reduction Agency (DTRA) has prepared a corrective measures study/feasibility study (CMS/FS) to evaluate several alternatives for the disposition of radioactive coral, metal and concrete debris located on Johnston Island (JI), Johnston Atoll (JA). From May 21-24, 2001, DTRA conducted a series of public availability sessions and a public meeting at several locations in the state of Hawaii. The combined purpose of these events was to present a status report on DTRA's plutonium cleanup project at JA, to solicit public comment on those draft alternatives, and to seek input on other possible approaches. As a result of this public scoping process, seven separate submissions, each containing a number of comments, were received by June 15, 2001, the end of the public comment period. Two attendees at the public availability sessions made videotaped statements for the record.

Comment: One commenter suggested the formation of a National Plutonium Cleanup Task Force to address the cleanup of JA.

Response: DTRA, which is responsible for the cleanup of the radioactive contamination, has involved regulatory and other government agencies in this project including the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Air Force. Scientists from Boston University, Oregon State University, and Oak Ridge National Laboratory (ORNL), in particular, have also been involved. DTRA has also sought public input throughout the project's decision-making process. This project is being conducted in accordance with applicable established regulations and procedures (see comment below and the CMS/FS introduction for the applicable regulations), and all appropriate agencies and the public will have ample opportunity to review the documents. Additional review by such a task force would only result in an additional delay.

Comment: Several commenters questioned why this effort was not being conducted under the National Environmental Policy Act (NEPA).

Response: This effort was conducted under the Defense Environmental Restoration Program (DERP), a program formally established by statute that provides for the cleanup of hazardous substances associated with past Department of Defense (DoD) activities consistent with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which covers Atomic Energy Act materials. The overall NEPA mandate for a fully-informed and well-considered decision will be achieved through adherence to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which implements CERCLA, and through adherence to the DERP statute. The NCP requires, among other things, public involvement, consideration of environmental effects, and selection of a remedial action that meets legally applicable standards under Federal or state law (including the Endangered Species Act), which are also NEPA's substantive requirements. The document DTRA has prepared, the CMS/FS, is equivalent in detail and comprehensiveness to an environmental impact statement prepared under NEPA, and the process is analogous to the NEPA process. The Department of Justice and the courts have upheld CERCLA's functional equivalency to NEPA.

Comment: Several commenters stated that the public sessions were not advertised widely enough or far enough in advance.

Response: Paid advertisements appeared in both statewide newspapers as well in as the three neighbor island newspapers, exceeding the statutory requirements of CERCLA. Notices also appeared in the statewide environmental publications, the *Midweek* and *The Environmental Notice*. Interviews of DTRA personnel appeared in two of the newspapers before the meetings; both articles contained the meeting schedule. All major television and radio stations were notified and were reminded the week before the public sessions began. In all, 19 print news media outlets, 27 radio stations, and eight television stations were provided news releases via facsimile; receipt was confirmed by telephone. Public libraries throughout the state were sent copies of the notice for their public display areas in accordance with advice provided by the Hawaii State Public Library System. DTRA also posted this information on its website. More than 80 individual notices were sent to interested parties and environmental organizations, including those who attended the previous public meeting on July 12, 2000. A media availability day was held in Honolulu on May 18, 2001. However, DTRA appreciates the efforts by some attendees to pass along the meeting information to other interested parties who may not have seen the public notices.

Comment: Two commenters suggested holding public meetings at other locations around the United States.

Response: It is DoD policy to involve the local community throughout the environmental restoration process. Unlike most military installations, which have local communities adjacent to the installation, the nearest community to JA is 800 miles away, in Hawaii. Therefore, DTRA selected Hawaii as the location in which to hold public meetings. Holding additional meetings at other U.S. locations would increase project costs and would not involve U.S. populations that are closer to the atoll.

Comment: One commenter stated that the public comment period was very short.

Response: The comment period for the draft alternatives and other possible approaches began on May 7, 2001, and ended on June 15, 2001. In advance of this, information was distributed to various public libraries in Hawaii and to involved organizations and citizens who had previously expressed interest in the project. Our intent was to provide a status report on the project and solicit public input on the various alternatives for the disposition of the coral, metal and concrete debris. DTRA believes that 40 days was sufficient because there was no significant document to review during this scoping stage. The total amount of time for public comment for this project to date has been 120 days (80 days in 2000 for the highly technical risk assessment and proposed cleanup level, and 40 days for the scoping effort in 2001). For the draft final CMS/FS, DTRA has planned a public comment period from March 1 through April 19, 2002, with public meetings scheduled on March 13, 15, 18, and 20.

Comment: One commenter suggested that the structure of the public meeting was flawed.

Response: The purpose of the scoping meeting was to provide a status report on the plutonium cleanup project at JA, introduce the various alternatives under consideration and solicit public input for the disposition of the coral, metal and concrete debris.

Comment: Commenters submitted two additional alternatives. One, to cover JA with a 24-inch-thick concrete cap and an additional impervious membrane, would destroy all bird nesting habitat.

The second alternative, phytoremediation, has a number of drawbacks. Research has shown that, while some plutonium is incorporated into plant tissues, the concentrations are typically orders of magnitude less than found in soils and sediments. Plutonium oxide (PuO_2) is not soluble in water and not bioavailable. Phytoremediation has been shown to work for uniformly distributed contaminants, but the PuO_2 at JA is localized and very particularized, further reducing the possible effectiveness of phytoremediation efforts.

There are other concerns with phytoremediation. The first is whether non-native plants (such as corn, wheat, and soybeans) can survive and grow in the calcium carbonate (coralline) matrix at JA. If they cannot, then soil amendments and fertilizer would have to be imported and mixed with the on-site soil, adding to the volume of PuO_2-containing material. The USFWS would likely object to the introduction of non-native species for this purpose. The proposal also appears to be labor intensive. JA is being closed as a military installation; the USFWS, which now manages and will continue to manage the JA National Wildlife Refuge (JANWR), plans to have a only a small research team on the atoll for relatively short periods of time. After each growing season, replanting would be necessary, since the plants would have to be harvested to remove the PuO_2. This effort would require annual labor and logistical support. Annual plowing, harrowing, and planting would destroy nesting habitat. There also remains the question of what to do with the plants if such an effort were successful—the PuO_2 would still exist in the harvested plants.

The climate at JA is subhumid, with an average annual precipitation of 26 inches. Annual precipitation is extremely variable because major rainfalls are associated with sporadic storms, and the evaporation rate is high. There are no natural, permanent bodies of fresh water on JA. Due to the high permeability of the soil, the unavailability of fresh water would limit the effectiveness of any phytoremediation effort. There would be no way to produce sufficient fresh water with the projected infrastructure once the DoD leaves JA. DTRA will revegetate the cap for the landfill alternatives with native plants likely to survive on JA for erosion control and bird habitat improvement in cooperation with the USFWS, but it does not plan to conduct phytoremediation research.

Comment: One commenter wanted to know if "hot spots" of radiological contamination in the “above” pile could be identified.

Response: The coral was separated by the Segmented Gate System (SGS) according to its radiological contamination. Coral above 13.5 pCi/g was placed in the “above” pile. Further separation of the "above" pile by the SGS is impractical since the cleanup level was established at 13.5 pCi/g, the original target level for separation. DTRA approached private industry in 1997 to seek alternative methods to separate PuO_2 from coral. Although some methods showed some early promise, none were effective or practical for the volume of the “above” pile.

Comment: One commenter raised a concern about the possibility of plutonium leaching into the groundwater over the years.

Response: The solubility and column leachate tests conducted by ORNL showed that plutonium oxides do not significantly move into solution at JA. PuO_2 is essentially insoluble in water, and especially so in the carbonate environment at JA. A sampling program showed that the level of radioactivity in the brackish water lens that serves as the source for drinking water on JI is 1% of the EPA's drinking water standard for radionuclides. This is less than one would see from natural radioactivity as water percolates through uranium-bearing rocks and soil. Furthermore, the groundwater is not potable without treatment, and no future use of the groundwater as a water supply is anticipated.

Comment: One commenter stated that DTRA was limiting discussion to only the alternatives presented.

Response: One of the stated purposes of this public scoping effort was to solicit public input to determine whether DTRA had overlooked one or more alternatives or some recently developed and applicable technology. Two additional alternatives were proposed in writing during the public comment period (see discussion above).

Comment: One commenter favored the alternative of a landfill with a concrete cap, but suggested not revegetating the final cap at all, as that would likely attract wildlife.

Response: Revegetation will inhibit erosion and may provide additional habitat for nesting and roosting birds. DTRA has demonstrated that it is extremely unlikely that either resident or migratory shorebirds or seabirds would receive doses in excess of recommended limits (DNA 1991). Since the atoll is a National Wildlife Refuge, the creation or improvement of habitat is a goal of the remediation process.

Comment: A commenter suggested covering the atoll with a layer of salt to "help mitigate the radiation" and prevent wind-blown redistribution of the residual surface contamination.

Response: Presumably, the thought is that the salt would form a protective crust, preventing transport by wind. A layer of salt, which is water-soluble, would have adverse impacts on wildlife and vegetation and would not reduce the already low risk from radioactivity (see CMS/FS section 3.3).

Comment: Another commenter suggested that any alternative selected should leave open the possibility of removing the radioactively contaminated material at a later date if technology is developed to further reduce the volume or level of radioactivity.

Response: The alternative selected does not preclude such an outcome, although removal of the 2-foot-thick coral cap would require the importation and use of heavy equipment. The vitrification and concrete slurry alternatives would complicate any future removal.

Comment: One commenter inquired as to the rationale behind a 2-foot thick cap of coral from the “below” pile.

Response: The reason for that particular thickness is that DTRA has been advised by a JANWR manager that the birds on JA that burrow in the surface generally do not burrow below a depth of 61 cm (2 feet).

Comment: One commenter inquired as to when the results of the various field investigations would be made available to the public for review.

Response: They are available as appendices to the CMS/FS.

Comment: Two commenters stated that plutonium is the most toxic (or hazardous) substance known to man.

Response: This claim is without basis in science and has been discredited thoroughly in the technical literature. While plutonium is toxic, it is by no means the most toxic substance known.

Comment: A commenter stated that "inhalation of even one tiny speck of plutonium dust is enough to cause death."

Response: This is known as the "hot particle" theory, and it has been studied at length and rejected by the U.S. Atomic Energy Commission (now the U.S. Department of Energy (DOE)), the U.S. Nuclear Regulatory Commission (NRC), a committee of the U.S. National Academy of Sciences, the U.S. National Council of Radiation Protection and Measurement, and the British Medical Research Council, among other groups (see CMS/FS section 4.3).

Comment: Two commenters asked DTRA to consider the effects of global warming and rising sea levels on JA.

Response: Increased erosion would be a likely consequence of relative sea-level rise (whatever the cause) at JA, particularly along the south shore, which is already the most vulnerable to erosion by wave action, as discussed in the CMS/FS (section 9). The maximum elevation on JA is about 5 m (16 feet) above sea level, with the average elevation approximately 2 m (7 feet). The CMS/FS (section 9) addresses the scenario of complete submergence because of erosion and seawall failure.

Comment: Several commenters were concerned about the level and distribution of radioactivity below the surface layer and whether DTRA planned to survey the subsurface.

Response: Statistically, DTRA expects the distribution of radioactivity at depth in these portions of the island to be the same as at the surface, considering how the islands were expanded and the characteristics of the contaminants. Over the years, the islands have been reworked significantly for construction of facilities. Radiological surveys were conducted for every excavation, no matter how minor, and after hurricanes, and all "hot spots" were removed and placed in the Radiological Control Area (RCA) for further action. Almost all of the buildings and facilities date from the mid-1960s, and some of those excavations were substantial, such as those for the foundations for large buildings. The physics of radiation (alpha particles and low-energy gamma rays) and the shielding effects of the coralline soil prevent subsurface viewing. The estimated concentration of the subsurface is 2.57 pCi/g. A complete survey of the subsurface would require progressive removal of soil layers, with each new surface scanned sequentially, until the original 1962 ground level was reached, much like peeling an onion. This approach would result in the destruction of dozens of acres of existing and potential bird habitat. A surface cleanup level of 13.5 pCi/g is very protective of human health and wildlife. The RCA itself has been excavated to well below grade and was resurveyed in 1999. Land-use controls (LUCs) and limitations for use when this project is completed can be found in the CMS/FS (section 5.3).

Comment: Several commenters asked about the radiological surveys completed at JA.

Response: The radiological surveys conducted on the RCA, the Outer Islands, and JI were conducted according to the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). The manual is a multi-agency consensus document developed by the DoD, the DOE, the EPA, and the NRC. The manual lays out specific planning steps, equipment requirements, and quality assurance procedures. DTRA followed the guidance from the manual when conducting the surveys. The areas covered by buildings, concrete, the runway and taxiway, or heavy brush are not accessible. It is a physical impossibility to "see" any plutonium underneath these surfaces. It is reasonable to say that the areas covered are not significantly different than the exposed areas. All accessible areas have been surveyed, and the survey results are part of the CMS/FS (section 2.3). The entire accessible (undeveloped) land surface surveyed outside of the RCA is approximately 14 million square feet or 320 acres. The developed areas were surveyed at the time of facility construction, and "hot spots," if any, were removed at that time. For the recent radiological survey, detected "hot spots" were removed to the radiological material storage bunker. Less than 0.5% of the samples exceeded the recommended soil cleanup level. DTRA does not expect the distribution in the developed areas or the distribution below the surface to be different from what was observed in the surveyed areas. DTRA does not plan to perform additional surveys.

Comment: Several commenters suggested DTRA remove contamination from the lagoon in an "environmentally friendly" way.

Response: Several years ago, DTRA developed a prototype underwater radiation detector to conduct surveys in the lagoon at JA. It was labor intensive, cumbersome, and unreliable. Since the material is covered by sediments in the lagoon or encased in the nonliving coral skeletons, it is better left where it lies. Investigations conducted since the 1960s have detected no adverse effect on the marine life. Under water is an acceptable place for materials that emit alpha particles, whose range is greatly reduced from that in air. Sediments have built up, covering the material and reducing its exposure to plants and marine life. Even if DTRA were able to easily detect locations of radioactive material and attempt to remove it from the lagoon, it would do more harm than good to dredge it up, thereby creating other problems in the lagoon (as a result of the effects of increased turbidity) and damaging coral heads. There is no way to remove the material with surgical precision. Even if DTRA removed as much as 95% of the material, much of what would remain would settle on the surface. Dredging would reverse nature's healing process, damage the reef, and be prohibitively expensive. Dredging would also expose the submerged PuO_2 to the air, making it a possible inhalation hazard to humans. A recent lagoon sediment sampling program revealed that of 113 cores, only 5 had values greater than the cleanup level of 13.5 pCi/g, and all were in the area immediately offshore of the RCA . Only 1 of those 5 samples was at the surface, and the others were at depths greater than 3 inches. The preponderance of the radioactive material was found at depths from 6-12 inches below the sediment surface.

Comment: Three commenters were concerned about plutonium in the Pacific Ocean outside the atoll.

Response: Any material outside the atoll platform is considered unreachable because the ocean floor drops precipitously beyond the coral reef. During the initial cleanup efforts in 1962, material was packed in containerized express boxes and disposed of approximately 8 miles outside the reef at a depth of about 6,000 feet. Review of the available records found only brief descriptions of the disposed material. Measurements at the site have shown that the concentrations of radioactive material are not distinguishable from global fallout levels common at the depths sampled in this region of the Pacific Ocean.

Comment: Two commenters raised the issue of radioactive fallout.

Response: This project is limited to the cleanup of PuO_2 from the oxidation of weapons-grade plutonium that was distributed across JA as a result of two aborted missile launches in 1962. This is unrelated to the widespread radioactive fallout from other atmospheric nuclear tests.

Comment: Two commenters preferred the vitrification alternative or some variation with additional engineered features, such as placing the vitrified material in a concrete vault with an impervious liner.

Response: The vitrification alternative was not selected for reasons explained in the CMS/FS (section 8). Additional engineered features would not provide measurably greater protection from radioactivity or erosion, and the added expense would not be commensurate with the insignificant reduction in the already negligible risk. The RCA, where a landfill would be constructed, is located in the area of JA that is already the least vulnerable to erosion by wave action; placing the vitrified material elsewhere would eliminate that advantage.

Comment: Several commenters proposed that DTRA conduct more research on the effects of radioactivity on birds, seals, fish, coral, crustaceans, eels, mollusks, shellfish, and insects before proceeding with its restoration efforts. In support of this suggestion, one commenter cited "reported fin deformities" in reef fish.

Response: There is no evidence of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA. After consultation with the EPA, the USFWS, and Boston University marine scientists, it was agreed that the best species to be sampled for plutonium uptake were the bottom-feeding surgeonfish and the goatfish.

DTRA and Boston University marine scientists collected fish both with and without fin deformities and had them analyzed by ORNL. There was no statistical difference in plutonium concentration between the normal fish and those with fin deformities. This is addressed in detail in the CMS/FS (annex I section 3-1). Abnormalities occur with some frequency in nature, and observed abnormalities at JA have always been within the range of natural variation and have not been attributed to any particular contaminant or combination of contaminants. Because these species have a short natural life, there is less chance of a chronic effect from the radioactivity.

Comment: One commenter specifically asked why DTRA did not sample the parrotfish, which grazes on coral polyps.

Response: The parrotfish would not be a species likely to have plutonium uptake. Because there is no evidence of radioactivity in the water column, and PuO_2 is not soluble in the environment at JA, it is unlikely that the coral polyps, on which the parrotfish feed, would contain plutonium. The only place PuO_2 is likely to be found in the nonliving calcium carbonate skeletal structure is in the growth dating from 1962, not in more recent growth or in the actively growing coral. The fish selection criteria are discussed further in the CMS/FS (annex I, section 3).

DTRA's risk assessment demonstrated that it was extremely unlikely that either resident or migratory birds would receive doses in excess of recommended limits because of limited exposure pathways, low bioaccumulation factors, and low radiation dose factors from the soils. The cleanup level of 13.5 pCi/g is well below international standards for the protection of human health and wildlife, and far below levels at which effects would be observed. The EPA has established that a standard at a level designed to protect human health also protects many ecological receptors. However, the prediction of ecological effects at contaminated sites is problematic because the radiation dose-response relationships are not well understood. The responses of aquatic populations to chronic radiation exposure are difficult to document and quantify and will vary with life stage. As for acute exposures, very low doses (i.e., 1% of the lethal dose) are not likely to produce measurable perturbations in populations or communities. From a review of extant literature, the EPA concluded that:

Invertebrates (including insects), non-vascular plants, and reptiles and amphibians are highly resistant to radiation effects compared to mammals such as humans;

Several species of large mammals appear to be equally sensitive as humans to acute radiation exposure;

Certain pines and some wild birds are as radiosensitive as many mammals following chronic radiation exposures;

Birds are generally less radiosensitive than most mammals; and
Aquatic vertebrates are more radiosensitive than invertebrates and exhibit sensitivities similar to that of terrestrial mammals.

Although reproductive and early developmental stages in aquatic organisms are most sensitive to chronic radiation, studies at JA over the years have shown no adverse impacts from radioactivity to the marine life since the aborted launches. One of the country's leading ornithologists, who has studied the birds at JA since 1983, has stated that there are no documented effects on tropicbirds and other species on JA from contaminants, including radioactivity. There is no area on JA that has reduced hatching success of eggs or fledging success of chicks. None of the seabirds picks up food on land to eat, so they would not pick up contaminated soil. No data indicate that seabirds are ingesting any contaminants that affect their reproductive success and survival. None of the nesting species at JA generally feed in the lagoon, but rather in the open ocean. Therefore, no lagoon contaminants are likely to be reflected in the birds, because their diet is primarily flying fish and squid, which are pelagic species, not bottom-feeders. Based on DTRA's investigations of the fish in the lagoon, the risks to human health (from consumption of lagoon fish) and to wildlife at JA are so low they do not warrant further investigation.

DTRA's recent investigations of the ecological effects of radioactivity at JA demonstrate that the birds, fish, and green sea turtles would receive well under 1% of the International Atomic Energy Agency (IAEA) dose limits established for those organisms. Furthermore, the natural resources have been studied extensively since the early 1980s when planning began for the Johnston Atoll Chemical Agent Disposal System (JACADS). Ecological surveys date back to 1923. Scientists from the University of Hawaii, Woods Hole Oceanographic Institution, Boston University Marine Program, Oregon State University, the Smithsonian Institution, and the DOE National Laboratories, among others, have conducted numerous surveys and research activities at JA, including radiological research sponsored by DTRA. From all indications, the marine and bird populations at JA are thriving. There is no evidence of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA. DTRA has demonstrated that this is due to limited exposure pathways, low bioaccumulation factors, insolubility of PuO_2 in the environment, and low radiation dose factors from the soils and sediments.

Even assuming that the Hawaiian monk seal resides at JA year-round, eats 3,000 grams of only bottom-feeding fish per day, and feeds exclusively in the area of the lagoon immediately offshore of the RCA, calculations indicate that the dose to the 400- to 600-pound monk seal would be about 10% of the annual limit set by the IAEA. These assumptions are very conservative; that is, they represent a worst-case scenario that is highly improbable. Bottom-feeding fish in the area weigh on the order of 100 grams each, so an intake of 30 fish per day per seal would quickly lead the seals to expand their feeding area. Furthermore, the Hawaiian monk seal is a rarity at JA. The National Marine Fisheries Service recently evaluated data on the range of the Hawaiian monk seal and concluded that JA is "probably at or near the range boundary," and that "development of a seal subpopulation is hindered by the long distance from a source of immigrants and by a limited amount of undisturbed beach area on which the seals could rest" (NOAA 2001).

Comment: Two commenters expressed concern that use of the “below” pile of coral as the final cap for the landfill alternatives would result in wind-blown redistribution of the radioactivity.

Response: DTRA thinks that is a highly improbable scenario. Years of air measurements immediately downwind of the RCA indicate that the maximum air concentrations of plutonium reached only 1% of the NRC’s workplace standard and remained below the limit for the general public (10CFR20, Appendix B) for plutonium. Those maximum concentrations were achieved during heavy equipment operations (bulldozing, excavating, and rock crushing) that would generate dust. DTRA has no reason to think that landfill construction would result in higher concentrations. Each layer or lift would be wetted down during placement to further reduce the possibility of airborne contaminants. The “below” pile of coral meets the same cleanup standard as the soil covering the remainder of the atoll, which is deemed suitable for unrestricted use, including airfield and refueling operations. Considering those results and the crushed and compacted coral's cementitious nature, it is unlikely that measurable wind-blown redistribution would result from the coral from the “below” pile after placement as a cap over one of the landfill alternatives. DTRA would expect similar results when the “above” pile is moved and placed in the excavation.

Comment: Two commenters asked about the metal and concrete debris.

Response: The metal debris and concrete debris have only surface contamination. Since 1962, the concrete has been broken into more manageable pieces, exposing surfaces that were protected from the original contamination. Today, there is a larger exposed surface area than in 1962. Additionally, the debris has been exposed to the weather since 1962, possibly reducing the surface contamination. If the concrete were to be used for rip-rap or artificial reef building, the concrete would have to be reduced further in size for manageability and then radiologically surveyed for release at 16.8 pCi/cm^2. The concrete that passed the survey (below that level) could be taken out of the RCA for use. Concrete that failed the survey or was not reducible to manageable sizes would remain in the RCA for other action. Shipping the concrete off-island would require it to be reduced to manageable sizes, and a complete radiological characterization would have been required. The level of the characterization would be determined by the final destination; it would include, at a minimum, surface scans and swipe tests.

The metal debris is coated with rust and would be impossible to survey; as a result, this limits the alternative for the metal debris to landfilling. The unrestricted release standard, as stated in American National Standards Institute N13.12 (1987), is 20 disintegrations per minute/100cm^2 (dpm/100cm^2)(removable) and 200 dpm/100cm^2 (total). Any scrap metal dealer willing to accept the metal would determine the actual standards. An additional concern is the uncertainty of the final use of the recycled metal. The landfill alternative for the concrete and metal does not require a survey because the debris would not leave the RCA.

Comment: Several commenters raised, either directly or indirectly, the issue of land-use restrictions or prohibitions, particularly if JA becomes a refueling point for aircraft and there is a need to excavate trenches for pipes. DTRA has developed draft LUCs as part of the CMS/FS (section 5.3).

Response: With proper LUCs, it will not be necessary, as one commenter suggested, to prohibit all human activities except for research activity and monitoring. Nor will it be necessary to prohibit any future activity that could disturb the subsurface area for a distance of 100 yards around the site of the landfill. Excavation will be prohibited in the RCA. Enforcement of the LUCs will be the responsibility of the USFWS. Some of these LUCs will not be finalized or refined until DoD transfers JA completely to the USFWS, particularly if the USFWS modifies its plans for the JANWR. The draft LUCs are more than adequate to limit additional risks to human health and birds given the current land-use plans for the JANWR.

Comment: Several commenters expressed concern that natural processes, such as hurricanes, or human activity could expose PuO_2 at levels higher than the cleanup standard of 13.5 pCi/g.

Response: If such exposures are detected, DTRA will have the "hot spots" shipped off-island to a permitted radioactive waste facility. However, there is no evidence—observed, detected, or anecdotal—of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA at any time since the aborted launches. A LUC will be developed to cover the possibility that "hot spots" may be exposed in the future.

DTRA plans to monitor the landfill site for construction and cap integrity annually for a period of 5 years or until routine, scheduled airline service to JA is terminated, whichever comes first, to determine whether any problems have arisen in the event of improper construction. If any radioactive contamination above 13.5 pCi/g is found after landfill monitoring is completed, the contamination will be evaluated by DTRA health physics staff. The DoD does not plan to monitor or maintain any portion of the seawall. Without periodic maintenance and repair, the seawall will fail; a rough estimate of seawall duration in its current state is between 30-50 years. There is no way to predict what section of the seawall will fail first or what the ultimate sequence of events will be. However, the portion of the seawall that is closest to the RCA is subject to less wave action than anywhere else on JI and is perhaps the least likely to fail within that period.

1 INTRODUCTION

This document is the Corrective Measures Study/Feasibility Study (CMS/FS) for the disposition of metal and concrete debris, and the coral pile with a transuranic (TRU) radioactive concentration above 13.5 pCi/g of coral[1]. It provides the history of JA, the events that led to the plutonium oxide contamination, health effects of plutonium exposure or plutonium oxide exposure, historical remediation efforts, future remediation options, option analysis for the metal and concrete debris and the “above” coral pile, and the impacts to the environment and marine biota within the Atoll. The options analysis follows the guidance provided by the EPA (1997 and 1999). In accordance with that guidance, the DTRA is confident that “remedies selected generally will satisfy Resource Conservation and Recovery Act (RCRA) Corrective Action; …” The DTRA has applied these “principles, as appropriate, to promote cost-effective remedial decision making and consistency with Superfund” (the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)) (EPA 1997, p. 1).

This effort has been conducted under the Defense Environmental Restoration Program (DERP). The DERP is a program formally established by statute (Title 10, United States Code, Sections 2701-2708 and 2810) that provides for the cleanup of hazardous substances associated with past DoD activities consistent with the provisions of the CERCLA, as amended, which covers Atomic Energy Act materials. The CERCLA is implemented through the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Title 40, Code of Federal Regulations, Part 300) and Executive Order 12850. This CMS/FS is intended to comply with the National Environmental Policy Act (NEPA) of 1969. The overall NEPA mandate for a fully-informed and well-considered decision has been accomplished by adherence to the NCP and to the DERP statute. The NCP requires, among other things, public involvement, consideration of environmental effects, and that a remedial action meets legally applicable standards under Federal or state law.

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," February 16, 1994, requires each Federal agency to promote nondiscrimination in its programs that substantially affect human health and the environment. In accordance with Executive Order 12898 and DoD policy, it is also the DTRA's goal to ensure that no segment of the population, regardless of race, color, national origin, or income, bears disproportionately high and adverse human health and environmental effects as a result of its policies, programs, and activities.

[1] Correspondence and official documentation to date has used units of pCi/g for TRU coral concentration. The CMS/FS will continue to use these units instead of the SI units of Bq/g and Ci instead of Bq. 13.5 pCi/g is equal to 0.5 Bq/g.

Because of its original small size, remote location in the central Pacific Ocean, and lack of fresh water, JA, an unincorporated territory of the United States (U.S.), was uninhabited and never supported an indigenous or permanent human population. Since 1934, JA has been used exclusively as a military installation, and the nearest civilian population is located more than 700 miles away in Oahu, Hawaii. Consequently, no action will result from this project that will have disproportionately high and adverse human health and environmental effects on any segment of the population.

2 JA HISTORY AND BACKGROUND

2.1 General

At 16°44' North latitude and, 169°31' West longitude, JA is the near-surface portion of a submarine mountain, or guyot. It is located in the central Pacific Ocean on the northern extension of the Christmas Ridge (an underwater mountain range) approximately 1,328 km (825 mi) west-southwest of Oahu, Hawaii. This makes it one of the most remote atolls in the world. The main outer reef and a poorly defined southern reef cut across the platform of the atoll to enclose a shallow lagoon. Of the four islands in the atoll, East and North are completely manmade; while Sand and JI have been expanded by dredge and fill activity.

2.2 Missile Event History

During 1962, the U.S. conducted high-altitude nuclear weapon tests at JA as part of OPERATION DOMINIC I. The activities associated with those high altitude tests resulted in aborted events that contaminated JI, the lagoon, and to a lesser extent, Sand Island with radioactive debris (Berkhouse et al. 1963 and AEC 1974).

2.2.1 BLUEGILL

The first high altitude test, BLUEGILL, was launched successfully from JI shortly before midnight on June 3, 1962. Although the Thor missile apparently flew a normal trajectory, the tracking system lost track of the missile as it neared the point of planned detonation. With ships and aircraft in the vicinity and no way of predicting where the nuclear test device would detonate if the test continued, the Range Safety Officer (RSO) gave the signal to destroy the missile. Destruction occurred approximately 15 minutes into the flight by a non-nuclear explosion (Berkhouse et al. 1963). The aborted event occurred about 36 km downrange, and at a high altitude. Due to the distance of the abort from JA, it is unlikely that contamination from the destruction of the missile and test device reached JA. Therefore, this event can be excluded as a contributor to contamination on the islands.

2.2.2 STARFISH

STARFISH, the second high-altitude launch of a Thor missile with a nuclear test device, launched on June 20, 1962. The missile flew a normal course for the first minute. Then the rocket motor stopped and the RSO ordered the missile destroyed (Berkhouse et al. 1963). Although specific trajectory information regarding this launch is limited, it has been determined through personal communications with two eyewitnesses that the non-nuclear detonation from the STARFISH event occurred directly over or nearly directly over, the Launch Emplacement 1 (LE-1) launch pad. Two references place the detonation altitude at 28,000 feet (SNL 1963, SNL 1965), and a third places the altitude at approximately 30,000 to 35,000 feet (JTF-8 1962a). One experimental reentry vehicle, the instrument pod, and various missile parts fell on JI. A substantial amount of debris fell on JI, Sand Island, and in the surrounding water. U.S. Navy Explosive Ordnance Disposal and Underwater Demolition Team swimmers spent two weeks recovering debris from the lagoon waters around JA. They recovered and disposed of approximately 250 pieces of debris; some were radiologically contaminated (Berkhouse et al. 1963).

2.2.3 BLUEGILL PRIME

By far the most significant source of contamination on JI was caused by the third high altitude test in the series, BLUEGILL PRIME. On July 25, 1962, the launch team made their second attempt to launch the BLUEGILL test device. For this event, one pod and two reentry vehicles, each heavily instrumented, and the test device itself were mated to the Thor missile. The missile malfunctioned after ignition. Before liftoff, the RSO destroyed the missile and test device by radio command. The resulting explosion and fire of the missile and test device caused extensive damage to the LE-1 pad and associated equipment. Although destruction of the warhead prevented any possible nuclear explosion, it caused extensive radioactive contamination on the launch pad. Contaminated debris was scattered throughout the area of the pad, mostly limited to an area enclosed by concertina wire. The explosion and the wind carried most of the particulate contamination out into the lagoon northwest of the RCA (Berkhouse et al. 1963). See Annex A for a detailed description of the activity levels in the ocean and along the shore.

2.3 Cleanup Summary

The greatest amount of island contamination from the aborted tests was found on the aircraft runway and in the area of LE-1. The runway was excavated and the island was scraped. Contaminated runway debris and the top layers of coral/soil were relocated to the RCA.

Remedial action after the BLUEGILL PRIME event included constructing a ramp on the northwest corner of the launch area using contaminated coral. The ramp was used to load utility landing craft with miscellaneous contaminated debris for deep-sea disposal. The disposition of the contaminated fill forming the ramp is unclear, and any contamination not re-deposited onto the island through dredge and fill operations still resides in the lagoon.

The DTRA operated the specially designed SGS in the RCA to separate the excavated coral into two piles depending on the plutonium oxide concentration in the coral: the pile below 13.5 pCi/g called the “below” pile and the pile above 13.5 pCi/g called the “above” pile. Two separate types of contaminated materials exist in the coral: (1) dispersed activity (volume), and (2) hot particles (point sources). The dispersed activity consists of particles approximately 10 microns (0.0004 in) in diameter with approximately 10 becquerel (Bq) (270 pCi) of TRU activity. The discrete, hot particles measure more than 45 microns (0.0018 in) in diameter, with an approximate activity of 5,000 Bq (135,000 pCi), and are relatively immobile unless affected by erosion, excavation or other physical means of disturbance (ORNL 1998).

A radiological survey of the outer islands of JA was completed by the DTRA contractor, Geo-Centers, Inc., and approved for unrestricted use by the EPA. The report also included a risk assessment of JI (DTRA 2000a). The EPA "concluded that the JA risk assessment conforms with the standard and uniform methods for evaluation of site-specific risk. We acknowledge that DTRA's proposed cleanup standard of 40 pCi/g is appropriate for the conditions at JA and within EPA's acceptable risk range. However, for years DTRA has voluntarily pursued a more stringent cleanup standard of 13.5 pCi/g. We are recommending that DTRA continue to use 13.5 pCi/g because it is as low as reasonably achievable…" (EPA 2000, p. 3). A radiological survey following the MARSSIM (EPA 2000b) was also conducted on JI to verify that contamination outside the RCA met applicable standards. The survey report prepared by Roy F. Weston, Inc. (2001) stated that all accessible areas outside the RCA are below 13.5 pCi/g.

2.4 Major Facilities

Major facilities on JI include the airfield, harbor, munitions storage area, Johnston Atoll Chemical Agent Disposal System (JACADS) facility, and various utility plants. JI is the largest island in the atoll and is the only populated island. It was maintained as a military storage and destruction site for chemical munitions. The population on JI currently consists of transient military and civilian personnel. No native or indigenous population has permanently resided on JA.

3 GENERAL SETTING AT JA

3.1 Climate and Weather Patterns

The climate is tropical, and dominated by the northwest trade winds. The wind direction is predominant from the east and northeast, with a mean annual velocity of 25 km (16 mi) per hour. Temperatures are uniform, with a mean annual high of 83^{o} Fahrenheit (F) and a mean annual low of 75^{o} F. The highest temperature recorded was 94^{o} F and the lowest was 62^{o} F. The mean annual relative humidity is 77%; the mean annual precipitation is 67 cm (26 in) per year. Annual precipitation can be variable because rainfall is often associated with sporadic, monsoon-like storms.

3.2 Biological Resources

The President of the U. S. designated JA a National Wildlife Refuge. Biological resources at JA include birds (both seabirds and shore birds), vegetation, insects, reptiles and mammals, marine biota (300 species of fish) and the occasional and transient presence of some endangered or threatened species of marine animals.

3.2.1 Birds

Since JA is the only landmass within approximately 800,000 square miles of ocean, it supports an abundance of bird life. The sooty tern is the most numerous species with an estimated population of nearly one-half million. Other common seabirds that migrate to and from JA include the Bulwer’s petrel, christmas shearwater, brown booby, red-footed booby, great frigatebird, gray-backed tern, masked booby, and brown noddy. Shorebirds found include the Pacific golden plover, bristle-thighed curlew, wandering tattler, ruddy turnstone, and the sanderling. Fifteen species of seabirds breed on the islands including the wedge-tailed shearwater, the red-tailed tropicbird, the black noddy, and the white tern (USFWS 1999).

3.2.2 Vegetation

No listed, proposed, endangered, or threatened species of plants have been identified at JA. Humans largely introduced the flora found on JI. A scientific expedition in 1923 found only three plant species. In 1976, 127 species were identified. Major tree species on the island include coconut palm, ironwood, and seagrape. Shrub species providing important nesting areas for island sea birds include *Pluchea cardinesis*, *Scaevola sevicea*, and *Hibiscus tiliaceous*. Introduced ornamental plants are adjacent to many of the major buildings on JI.

3.2.3 Insects

No listed, proposed, endangered, or threatened insect species have been recorded at JA. Relatively few insect species have been identified on JA. Prior to 1926, 24 species were identified; 68 were identified in 1952. Of the species that are known to exist, most are common Pacific species or closely related to

Hawaiian species. In the 1960s, 34 species of avian parasites were identified and studied. These parasites include two tick species, five chiggers, two nasal mites, twenty-three biting lice, and two louse flies.

3.2.4 Reptiles and Mammals

There are no terrestrial reptiles or mammals native to JI. No listed, proposed, or endangered or threatened species of terrestrial reptiles or mammals are known to use the JA area as a major breeding or feeding area. The only known introduced mammal on the atoll is the house mouse. The introduced reptiles are the house gecko, fox gecko, mourning gecko, and snake-eyed skink.

3.2.5 Marine Biota

Prior to 1965, only one species of algae had been identified for JA; 93 species have now been identified. Twenty-nine species of Scleractinian and three species of hydrozoan corals have been identified on JA. The dominant coral are *Acropora spp*., *Montipora sp. Millepora sp*., and *Porites spp*. They are locally common in the shallow northwest reefs. The species' richness is relatively low compared to other regions; however, all major atoll biotypes are represented and coral coverage ranges between 80-100% of the available lagoon substrate. The low species richness is attributable to the atoll's small size and isolation rather than any unfavorable habitat conditions.

3.2.6 Fish

Over 300 species of fish have been reported at JA. With the exception of the *Centropyge nahackyi*, none of these species are believed to be endemic (CMA 2001). Pelagic food and game fish species in open water near JA include the blue marlin, mahi mahi, little tunny, skipjack tuna, wahoo, and the yellow fin tuna. Other pelagic fish likely to transit the area include pelagic sharks (e.g., mako, thresher, oceanic, white tip, gray reef, and silky) and assorted bony fish including flying fish, sunfish, mackerel, albacore, swordfish, and various bait fish (USFWS 1999).

3.2.7 Threatened or Endangered Species

The threatened green sea turtle is commonly sighted at JA, and there was a possible sighting of the endangered hawksbill turtle. The resident green sea turtles (*Chelonia mydas*) are often seen feeding along the south shore of JI. Approximately 200 green sea turtles use the area around the atoll as a feeding ground. They are healthier and more robust than turtles studied in the northwest Hawaiian Islands (Raytheon 1994). In 1996, two nests were found on the south side of JI; however, no eggs were observed to hatch and both nests were believed to have been made by the same turtle.

Whales and porpoises have been sighted outside and within the lagoon, including the endangered humpback whale that visits JA regularly and is sighted nearly every winter. Four individual humpbacks (*Megaptera novaeangliae*) were observed in April 1992, and since calves have been observed alongside adult