In this case, the number of stream acres for this facility consists of only the streams within five miles of the facility that are flooded year-round.

Facility #62

For this facility, EPA had standing stock data for two small streams located within five miles of the facility. In this case EPA decided to include these streams in the estimate of the number of streams miles within five miles of the facility. Thus, the total number of stream miles includes (i) the miles of major stream within five miles plus its tributaries within five miles of the facility, and (ii) the two smaller streams for which EPA has data. Other smaller streams were not included on the assumption that they are too small to support fish populations that would attract recreational fishers.

Facility #81

For this facility, the number of stream miles within five miles of the facility consists of the major river and its tributaries within five miles of the facility. Smaller streams were excluded from the analysis, as were lakes and reservoirs.

2.4 RESULTS

2.4.1 Results of the Tier 1 Analysis

The results of the **Tier 1** screening analysis are discussed below. For a more detailed description of these results, refer to Appendix C of this document. Note that results from Tier 1 screening of the beef and milk ingestion pathway, for the "homegrown" population, indicate that no facilities are of concern for further analysis for this pathway. As shown in Appendix C for the beef and milk ingestion pathway, for the "homegrown" population, all facilities had no population noncancer effects, and population cancer risks were estimated to be so low that they do not add up to a single excess cancer case across all the facilities.

Population Risks of Significance

In this document EPA uses the terms "significance" or "significant" in association with population cancer risks or population noncancer effects to describe the following:

- Facility-specific estimates of *population cancer risk* that are relatively large enough that, when combined with estimates from other facilities analyzed, cumulatively contribute to more than 99 percent of a total population risk calculated across facilities (and, in Tier 1, a total population risk equal to at least one excess lifetime cancer case due to exposure).
- Facility-specific estimates of *population noncancer effects* that correspond to at least one person exposed to levels exceeding the noncancer effects thresholds.

"Homegrown" and Subsistence Farmer Populations

The results of the **Tier 1** screening analysis are shown in Exhibits 2.2 and 2.3 for population noncancer effects and cancer risks, respectively. In Exhibit 2.2, facilities not shown had no population noncancer effects, predicted based on the estimated individual noncancer effects. Exhibit 2.3 shows

Exhibit 2-2

Population Non-cancer Effects, Across Facilities

"Homegrown"		"Subsistence Farmer"	
Plant ID	No. of People Above Hazard Index = 1	Plant ID	No. of People Above Hazard Index = 1
60	2.91E+04	55	7.25E+04
		66	4.39E+04
		60	2.91E+04
		30	2.02E+04
		29	1.25E+04
		62	9.43E+03
		72	5.84E+02
	2.91E+04		1.88E+05

Exhibit 2-3

Population Cancer Risks, Across Facilities

"Homegrown"		"Subsistence Farmer"	
Plant ID	No. of Cancer Cases	Plant ID	No. of Cancer Cases
55	7.18E-01	55	7.18E+00
66	4.34E-01	66	4.34E+00
63	3.71E-01	62	9.34E-01
60	2.88E-01	44	6.48E-01
25	2.06E-01	54	6.21E-01
7	1.90E-01	72	5.78E-01
49	1.54E-01	63	3.71E-01
29	1.24E-01	60	2.88E-01
33	9.55E-02	30	1.82E-01
62	9.34E-02	67	1.72E-01
57	8.49E-02	4	1.39E-01
44	6.55E-02	61	1.05E-01
54	6.21E-02	33	9.55E-02
22	5.94E-02		
72	5.78E-02		
80	5.59E-02		
42	3.21E-02		
53	2.46E-02		
30	2.02E-02		
46	1.96E-02		
18	1.92E-02		
4	1.82E-02		
67	1.74E-02		
15	1.58E-02		
83	1.01E-02		
	3.24E+00		1.56E+01

the contribution of each facility (denoted by Plant ID) to the total population cancer risks. Facilities not shown had facility-specific population cancer risks estimated to be so low that they did not contribute significantly to the total population cancer risk across facilities (only facilities that cumulatively contributed to more than 99 percent of the total population risk are shown). The screening results indicate that 26 of the 82 facilities included in the analysis potentially have population cancer risks of significance, and 7 among these 26 also potentially have population noncancer effects of significance. That is, across these 26 facilities there is at least one excess lifetime cancer case due to exposure (i.e., population cancer risk ≥ 1 excess lifetime cancer case) and/or at least one person exposed to levels exceeding the noncancer effects thresholds (i.e., population noncancer effects ≥ 1 person).

Recreational Fisher Population

The screening results indicate that only four facilities have population noncancer effects of significance, and no facilities have significant population cancer risks. The results of this screening analysis are shown in Exhibit 2.4 (facilities are denoted by Plant ID). Facilities not shown had no population noncancer effects (predicted based on the estimated individual noncancer effects), or had population cancer risks so low that, across all facilities, they did not contribute significantly to the total.

2.4.2 Results of the Tier 2 Analysis

The Tier 2 analysis was conducted for facilities having potentially significant population risks in the Tier 1 screening analysis, i.e., 26 facilities for the "homegrown" and subsistence farmer populations, and four facilities for the recreational fisher population.

"Homegrown" and Subsistence Farmer Populations

The results of this analysis (as well as the supporting data) are presented in Exhibits 2.5 and 2.6. For a more detailed description of the raw data used in this analysis, refer to Appendix D of this document. In summary, the population cancer risk characterization shows that, across all the people living within five miles of the 82 cement plants examined for the NODA, less than one excess cancer case can be expected in the exposed population over a 70-year period. That is, exposures via vegetable and beef and milk ingestion or vegetable ingestion would potentially lead to about 0.08 excess cancer cases in the subsistence farmer population, or about 0.95 excess cancer cases in the "homegrown" population, respectively. In terms of population noncancer effects, across all the people living within five miles of the 82 facilities, about 7,883 individuals from the "homegrown" population are exposed via vegetable ingestion to contamination exceeding noncancer effects thresholds (i.e., hazard index greater than 1). Likewise, 625 individuals from the subsistence farmer population are estimated to be exposed via vegetable ingestion to contamination exceeding noncancer effects thresholds. It is unknown how many of these individuals would actually have adverse effects as a result of these exposures (*i.e., the noncancer estimates are not cases, but simply the number of exposures above the RfD.*)

As an additional refinement of the estimate of the "homegrown" and subsistence farmer populations potentially exposed, the Agency assessed in more site-specific terms how far away from a given facility contamination is likely to travel. For this assessment EPA first determined, by examining previous MMSOILs modeling results, that contamination at agricultural fields and backyard gardens is due mostly to surface runoff and only in small part to atmospheric deposition.[5] Then EPA examined the hydrologic/drainage patterns surrounding the facilities to determine how far contamination is likely to travel via surface runoff before being "captured" by any kind of a channel (e.g., stream). The Agency examined topographic maps first for the seven facilities identified in Tier 2 as having significant population noncancer effects and determined that contamination from CKD waste piles can travel between a few hundred feet to a few thousand feet via surface runoff before being captured. EPA measured the approximate distance that the contamination can travel via overland runoff for each of the seven facilities and then recalculated the populations potentially exposed using the smaller radii (determined from the maps) to define the areas of influence. EPA initially focused the additional refinement on only facilities with population noncancer effects because the total population cancer risk estimate for these populations was low, i.e., less than one cancer case across all facilities. For the remaining facilities, EPA assumed that contamination is likely to travel up to a distance of 1.0142 miles, and accordingly recalculated the populations potentially exposed using this smaller radius. (The distance of 1.0142 miles was determined to be the furthest that contamination is likely to travel, among the seven facilities examined in detail.) The results of this analysis are shown in Exhibit 2.7. Across all 26 facilities, approximately 25 subsistence farmers and approximately 4 people from the "homegrown" population are expected to be exposed to concentrations exceeding the noncancer effects thresholds when (i.e., hazard index greater than 1) when topographic factors are considered. Likewise, exposures via vegetable and beef and milk ingestion or vegetable ingestion would potentially lead to about 0.006 excess cancer cases in the subsistence farmer population, or about 0.02 excess cancer cases in the "homegrown" population, respectively.

Exhibit 2-4
Population Noncancer Effects, by Facility
(from Tier I analysis)

Plant ID	No. of People Above Hazard Index = 1
62	9.43E+03
35	9.40E+03
81	5.44E+03
37	4.65E+03

(Note that a slightly modified methodology was used for estimating the number of subsistence farmers within the smaller area of influence. In cases where a single subsistence farmer was "calculated" to be present, the Agency assumed that a subsistence farm family was more likely to be present. The number of people in such a family was estimated to be equal to the average number of people per household within that county. The census data indicated that approximately three people were present per household for counties representing all the seven facilities of interest; thus, for each

[5] Note that other fate and transport models may or may not support this finding, depending on the complexity of their atmospheric transport and deposition algorithms.

Exhibit 2-5
Data Used For Estimating the Population Risks

Plant I.D.	Total county farm population	No. of farmers within five miles of the facility	Total no. of farms in the county	No. of subsistence farms in the county	No. of subsistence farmers within five miles of the facility	Total population within five miles of the facility	Total county population	Total county urban population	Urban population within five miles of the facility	Non-urban population within five miles of the facility	No. of "backyard gardeners" within five miles of the facility	"Homegrown vegetable" population within five miles of the facility
4	1,296	178	707	333	84	10,705	17,035	9,488	5,962	4,743	4,565	3,460
7	691	102	354	206	59	1,922	13,966	5,150	709	1,213	1,111	699
15	540	81	391	226	47	15,781	292,594	250,159	13,492	2,289	2,208	3,996
18	2,172	137	1,872	831	61	191,915	1,185,394	1,118,354	181,061	10,854	10,717	44,732
22	1,610	351	625	328	184	59,376	96,246	44,157	27,241	32,135	31,784	20,463
25	1,310	274	641	382	163	20,812	87,777	65,102	15,436	5,376	5,102	5,803
29	1,387	169	922	523	96	12,518	38,816	22,929	7,395	5,123	4,955	3,929
30	1,143	125	1,037	698	84	20,233	34,119	15,820	9,381	10,852	10,727	6,932
33	214	28	258	157	17	965	5,528	0	0	965	937	433
42	208	14	504	442	12	3,240	480,577	459,439	3,097	143	129	741
44	1,617	277	809	384	132	65,458	121,393	68,172	36,760	28,698	28,421	21,022
46	189	16	195	72	6	1,975	118,934	112,667	1,871	104	88	461
49	836	114	379	245	74	15,559	30,605	11,354	5,772	9,787	9,672	5,663
53	487	68	617	495	55	24,553	51,832	37,223	17,633	6,920	6,852	6,976
54	1,761	332	621	210	112	6,275	20,488	2,589	793	5,482	5,150	2,712
55	1,277	166	757	489	107	72,527	633,232	611,229	70,007	2,520	2,354	16,520
57	457	55	222	134	33	8,572	44,739	7,479	1,433	7,139	7,084	3,525
60	2,114	292	821	123	44	29,085	46,733	37,181	23,140	5,945	5,653	7,883
61	1,328	232	849	552	151	10,583	42,836	18,486	4,567	6,016	5,784	3,689
62	2,950	350	1,346	695	180	9,433	150,208	86,689	5,444	3,989	3,639	3,004
63	2,299	312	1,203	659	171	37,469	61,633	43,694	26,563	10,906	10,594	10,752
66	1,104	232	391	176	104	43,851	247,105	173,033	30,706	13,145	12,913	12,694
67	4,806	333	1,669	260	52	17,407	106,913	65,957	10,739	6,668	6,336	5,494
72	3,307	32	1,995	615	10	584	543,477	455,300	489	95	63	158
80	1,233	190	1,157	927	26	55,918	335,749	261,024	43,473	12,445	12,413	15,315
83	2,026	169	1,521	1,126	125	10,136	85,167	40,007	4,761	5,375	5,205	3,434

Exhibit 2-6
Population Risks via the Vegetable Ingestion Pathway

Plant I.D.	Individual cancer risk; "subsistence"	Individual cancer risk; "homegrown"	Individual non-cancer Hazard Index; "subsistence"	Individual non-cancer Hazard Index; "homegrown"	No. of cancer cases; "subsistence"	No. of cancer cases; "homegrown"	No. of people exposed to Hazard Index greater than or equal to 1; "subsistence"	No. of people exposed to Hazard Index greater than or equal to 1; "homegrown"
4	1.30E-05	1.70E-06	<1	<1	1.09E-03	5.88E-03	0	0
7	0.00E+00	9.90E-05	<1	<1	0.00E+00	6.92E-02	0	0
15	0.00E+00	1.00E-06	<1	<1	0.00E+00	4.00E-03	0	0
18	0.00E+00	1.00E-07	<1	<1	0.00E+00	4.47E-03	0	0
22	0.00E+00	1.00E-06	<1	<1	0.00E+00	2.05E-02	0	0
25	0.00E+00	9.90E-06	<1	<1	0.00E+00	5.74E-02	0	0
29	9.90E-05	9.90E-06	9.90E+00	<1	9.48E-03	3.89E-02	96	0
30	9.90E-06	1.00E-06	9.90E+00	<1	8.31E-04	6.93E-03	84	0
33	9.90E-05	9.90E-05	<1	<1	1.66E-03	4.28E-02	0	0
42	0.00E+00	9.90E-06	<1	<1	0.00E+00	7.34E-03	0	0
44	9.90E-06	1.00E-06	<1.	<1	1.30E-03	2.10E-02	0	0
46	0.00E+00	9.90E-06	<1	<1	0.00E+00	4.57E-03	0	0
49	0.00E+00	9.90E-06	<1	<1	0.00E+00	5.61E-02	0	0
53	0.00E+00	1.00E-06	<1	<1	0.00E+00	6.98E-03	0	0
54	9.90E-05	9.90E-06	<1	<1	1.11E-02	2.68E-02	0	0
55	9.90E-05	9.90E-06	9.90E+00	<1	1.06E-02	1.64E-01	107	0
57	0.00E+00	9.90E-06	<1	<1	0.00E+00	3.49E-02	0	0
60	9.90E-06	9.90E-06	9.90E+00	9.90E+00	4.33E-04	7.80E-02	44	7,883
61	9.90E-06	1.00E-07	<1	<1	1.50E-03	3.69E-04	0	0
62	9.90E-05	9.90E-06	9.90E+00	<1	1.79E-02	2.97E-02	180	0
63	9.90E-06	9.90E-06	<1	<1	1.69E-03	1.06E-01	0	0
66	9.90E-05	9.90E-06	9.90E+00	<1	1.03E-02	1.26E-01	104	0
67	9.90E-06	1.00E-06	<1	<1	5.13E-04	5.49E-03	0	0
72	9.90E-04	9.90E-05	9.90E+00	<1	9.74E-03	1.56E-02	10	0
80	0.00E+00	1.00E-06	<1	<1	0.00E+00	1.53E-02	0	0
83	0.00E+00	1.00E-06	<1	<1	0.00E+00	3.43E-03	0	0
				Total:	7.82E-02	9.51E-01	625	7,883

Exhibit 2-7
Refined Population Risks via the Vegetable Ingestion Pathway

	Without Refinement Based on Topographic Information**							With Refinement Based on Topographic Information						
Plant I.D.	Distance of Interest (miles)	No. of Subsistence Farmers	"Homegrown" Population	No. of cancer cases; "Subsistence"	No. of cancer cases; "Homegrown"	No. of people exposed to Hazard Index greater than or equal to 1; "subsistence"	No. of people exposed to Hazard Index greater than or equal to 1; "homegrown"	Distance of Interest (miles)	No. of Subsistence Farmers	"Homegrown" Population	No. of cancer cases; "Subsistence"	No. of cancer cases; "Homegrown"	No. of people exposed to Hazard Index greater than or equal to 1; "Subsistence"	No. of people exposed to Hazard Index greater than or equal to 1; "Homegrown"
4	5	84	3,460	1.09E-3	5.88E-3	0	0	1.0142	3	142	4.48E-05	2.42E-04	0	0
7	5	59	699	0.00E+0	6.92E-2	0	0	1.0142	3	28	0.00E+00	2.79E-03	0	0
15	5	47	3,996	0.00E+0	4.00E-3	0	0	1.0142	3	163	0.00E+00	1.63E-04	0	0
18	5	61	44,732	0.00E+0	4.47E-3	0	0	1.0142	3	1,840	0.00E+00	1.84E-04	0	0
22	5	184	20,463	0.00E+0	2.05E-2	0	0	1.0142	8	842	0.00E+00	8.42E-04	0	0
25	5	163	5,803	0.00E+0	5.74E-2	0	0	1.0142	7	239	0.00E+00	2.36E-03	0	0
29	5	96	3,929	9.48E-3	3.89E-2	96	0	0.0282	3	3	2.97E-04	2.97E-05	3	0
30	5	84	6,932	8.31E-4	6.93E-3	84	0	0.4508	3	55	2.97E-05	5.51E-05	3	0
33	5	17	433	1.66E-3	4.28E-2	0	0	1.0142	3	16	2.97E-04	1.57E-03	0	0
42	5	12	741	0.00E+0	7.34E-3	0	0	1.0142	3	29	0.00E+00	2.91E-04	0	0
44	5	132	21,022	1.30E-3	2.10E-2	0	0	1.0142	5	865	5.36E-05	8.65E-04	0	0
46	5	6	461	0.00E+0	4.57E-3	0	0	1.0142	3	18	0.00E+00	1.81E-04	0	0
49	5	74	5,663	0.00E+0	5.61E-2	0	0	1.0142	3	233	0.00E+00	2.31E-03	0	0
53	5	55	6,976	0.00E+0	6.98E-3	0	0	1.0142	3	286	0.00E+00	2.86E-04	0	0
54	5	112	2,712	1.11E-2	2.68E-2	0	0	1.0142	5	112	4.58E-04	1.10E-03	0	0
55	5	107	16,520	1.06E-2	1.64E-1	107	0	0.0282	3	3	2.97E-04	2.97E-05	3	0
57	5	33	3,525	0.00E+0	3.49E-2	0	0	1.0142	3	144	0.00E+00	1.42E-03	0	0
60	5	44	7,883	4.33E-4	7.80E-2	44	7,883	0.1127	3	4	2.97E-05	3.90E-05	3	4
61	5	151	3,689	1.50E-3	3.69E-4	0	0	1.0142	6	152	6.15E-05	1.52E-05	0	0
62	5	180	3,004	1.79E-2	2.97E-2	180	0	1.0142	7	124	7.35E-04	1.22E-03	7	0
63	5	171	10,752	1.69E-3	1.06E-1	0	0	1.0142	7	442	6.96E-05	4.38E-03	0	0
66	5	104	12,694	1.03E-2	1.26E-1	104	0	0.1127	3	5	2.97E-04	5.04E-05	3	0
67	5	52	5,494	5.13E-4	5.49E-3	0	0	1.0142	3	225	2.97E-05	2.25E-04	0	0
72	5	10	158	9.74E-3	1.56E-2	10	0	0.4508	3	3	2.97E-03	2.97E-04	3	0
80	5	26	15,315	0.00E+0	1.53E-2	0	0	1.0142	6	622	0.00E+00	6.22E-04	0	0
83	5	125	3,434	0.00E+0	3.43E-3	0	0	1.0142	5	141	0.00E+00	1.41E-04	0	0
			Total	7.82E-2	9.51E-1	625	7,883			Total:	5.67E-3	2.17E-2	25	4

**This information is summarized from Exhibit 2-6

Exhibit 2-8
Population Risks via the Fish Ingestion Pathway
(including underlying data used for estimating the population risks)

Facility number	Stream length within the five-mile radius (miles)	Average stream width (miles)	Stream acres within five miles of the facility (acres)	Standing stock (lbs/acre/year)	Exploitation rate	Pounds of fish caught per year within the area of influence (lbs/yr)	Percent of fish tissue that is edible	Pounds of fish ingested per year per recreational fisher	Number of recreational fishers that can be supported by the harvest	No. of recreational fishers exposed to Hazard Index greater than or equal to 1
35	(a) small streams: 2 (b) large streams: 7.5	(a) small streams: 1/350 (b) large streams: 1/35	140.8	82.2	0.2	2,314.75	0.35	5.86	138	138
37	15	1/350	27	593.2	0.2	3,250.74	0.35	5.86	194	194
62	(a) small streams: 24.5 (b) large streams: 9	(a) small streams: 1/350 (b) large streams: 1/70	127.1	89.5	0.2	2,275.09	0.35	5.86	136	136
81	(a) small streams: 7 (b) large streams: 7	(a) small streams: 1/350 (b) large streams: 1/70	76.8	219	0.2	3,363.84	0.35	5.86	201	201
									Total	**669**

facility, a total of three people per household was assumed to be exposed at subsistence levels of vegetable and beef and milk ingestion.)

Recreational Fisher Population

The results of this analysis (as well as the supporting data) are presented in Exhibit 2.8. For a more detailed description of the raw data used in this analysis, refer to Appendix D of this document. In summary, for potential population noncancer effects, across all the people who fish and consume recreationally caught fish within five miles of the 82 facilities, about 670 individuals are exposed via fish ingestion to contamination exceeding noncancer effects thresholds (i.e., hazard index greater than 1). The predicted population cancer risk for this pathway is extremely small, ar less than one excess cancer case.

2.4.3 Results Extrapolated to Full Universe

As noted before, the focus of the Tiers 1 and 2 analyses was on assessing risks at 82 of the total 108 cement facilities. (These 82 facilities can be denoted as the "known universe.") The remaining 26 facilities were excluded because a lack of relevant data (e.g., data on constituents in CKD wastes or on types of waste management practices) prevented them from being assessed directly in the original individual risk analyses done for RTC and NODA. (These 26 facilities can be denoted as the "unknown universe.") This does not mean, however, that there are no potential risks due to the CKD being generated and managed at these 26 facilities. To derive a composite picture of potential population risks across the full universe of cement facilities, therefore, EPA estimated the potential population risks within the unknown universe by extrapolation from results within the known universe.

Given the lack of knowledge regarding the unknown universe, EPA used a two-step process to extrapolate the results from the known to the unknown universe, thereby estimating the potential population risks for the full universe.

Step 1: To begin, EPA defined the "bounds" of the results for the full universe of cement facilities. To define a conservative upper bound measure of the population risks, EPA assumed that every single facility in the unknown universe is as "risky" as the highest-risk facility in the known universe. The corollary is that to define a lower bound measure of the population risks, it is reasonable to assume that every single facility in the unknown universe is as "risky" as the lowest-risk facility in the known universe. The Agency believes that, working from the results of the known universe, the true results for the full universe are unlikely to be beyond the range defined by upper and lower bounds as defined above (the results cannot be lower than the lower bound). The relevant calculations are shown below, using as an example the potential noncancer population effects due to fish ingestion. The same approach was used for cancer risk.

Upper bound measure of population risks[6] across the full universe	=	Total population risks[7] for the known universe	+	Risk from highest-risk facility	x	No. of facilities in the unknown universe
	=	669	+	201	x	26

Thus, the upper bound measure of population risks (i.e., the potential noncancer population effects due to fish ingestion) across the full universe is 5,895.

Lower bound measure of population risks[7] across the full universe	=	Total population risks[7] for the known universe	+	Risk from lowest-risk facility	x	No. of facilities in the unknown universe
	=	669	+	0	x	26

Likewise, the lower bound measure of population risks (i.e., the potential noncancer population effects due to fish ingestion) across the full universe is 669.

Step 2: Having defined the bounds, the next step would be to determine where the true results for the full universe of cement facilities are likely to fall within the range defined by the upper and lower bounds. Given the lack of critical data, EPA believes that a reasonable assumption is that the distribution of risks among facilities within the (smaller) unknown universe is similar to the distribution of risks among facilities within the (larger) known universe. In such a case, the results from the known universe can be directly extrapolated to the unknown universe, preferably using one or more "weighting factors" that are common to both universes and are expected to be related to the potential risks. The only such common factor for which data are available is the "quantity of CKD waste generated." Thus, EPA extrapolated the results from the known universe, weighted by the

[6] As explained on page 2-9, EPA uses in this document the term "population risk" as a loose, collective term to refer to both population cancer risk and population noncancer effects. Population cancer risk is used to denote "excess cancer incidence," i.e., the number of excess cancer cases in the exposed population, and population noncancer effects is used to denote the number of persons exposed to levels above the thresholds for noncancer effects.

amount of CKD wasted,[7] as follows (example shown for potential noncancer population effects due to fish ingestion):

$$\text{Total population risks across the full universe} = \text{Total population risks for the known universe} \times \frac{\text{Quantity of CKD wasted in the known universe} + \text{Quantity of CKD wasted in the unknown universe}}{\text{Quantity of CKD wasted in the known universe}}$$

$$998.8 = 669 \times \frac{2{,}497{,}911\ \text{tons} + 1{,}231{,}422\ \text{tons}}{2{,}497{,}911\ \text{tons}}$$

The upper bound, lower bound, and most reasonable estimates of the total population risks, for all relevant pathways, across all 108 facilities in the CKD universe are summarized in Exhibit 2-9.[8]

Note that although EPA chose to use the refined results for the "homegrown" and subsistence farmer populations (as discussed in section 2.4.2, EPA derived more refined results for the known universe for these populations based on site-specific topographic data) for extrapolating results to the full universe, there is significant uncertainty in this extrapolation. This is because topography data are site-specific and assumptions about topography can not easily be made from some facilities in the known universe to others in the unknown universe.

In the individual risk estimates derived previously, the driving constituents for cancer risks and noncancer effects were identified for each exposure pathway. These constituents were identified as "producing" the highest estimated risk. For this population risk analysis, arsenic, which can cause both systemic and carcinogenic effects, was the driving constituent for cancer risks via the food chain pathway across all cement plants analyzed. Likewise, for noncancer effects, the driving constituent in the food chain pathway was one of the following across all cement plants analyzed: thallium, chromium, cadmium, beryllium, or barium.

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[7] Extrapolation using waste quantity as a weighting factor is less straightforward for potential noncancer population effects than for population cancer risks. This is because an increase in waste quantity could lead to either an increase in the magnitude of HI exceedances at only those facilities that already have potential noncancer population effects, or, in addition, an increase in the magnitude of HI exceedances at facilities that previously did not have potential noncancer population effects. (In effect, this means that one cannot do a linear extrapolation on a nonlinear dose-response model.) Total potential population noncancer effects (i.e., number of people exposed above an HI of 1.0) would remain the same in the former case, and increase in the latter.

[8] Note that a similar extrapolation based on the ratio of the number of facilities in the full universe to that in the known universe (i.e., not weighted by waste quantity) would yield relatively similar results (scale-up of 1.3 (i.e., 108/82) versus 1.5).

Exhibit 2-9
Potential Population Noncancer Effects and Population Cancer Risks, Extrapolated to the Full Universe of Cement Plants

	Lower Bound	Most Reasonable	Upper Bound
Potential Population Noncancer Effects (i.e., the number of persons exposed to levels above the thresholds for noncancer effects)			
"Homegrown"	4	6	108
Subsistence Farmer	25	37	207
Recreational Fisher	669	999	5,895
Population Cancer Risks (i.e., the number of excess cancer cases in the exposed population)			
"Homegrown"	0.02	0.03	0.13
Subsistence Farmer	0.006	0.009	0.08

2.5 MAJOR LIMITATIONS AND UNCERTAINTIES

This study has significantly enhanced EPA's understanding of the extent to which populations living near cement plants are potentially at risk due to indirect pathways. The Agency recognizes, however, several limitations and uncertainties inherent in the analysis. Limitations and uncertainties associated with the indirect exposures analysis include those that apply across the entire analysis, and those that apply specifically to either the vegetable ingestion or fish pathways; these are discussed in Section 2.5.1. In Section 2.5.2, EPA discusses the feasibility of using an alternative approach to calculate population risks and its associated limitations.

2.5.1 Limitations and Uncertainties for the Indirect Exposures Analysis

- Estimates of the individual cancer risk and noncancer hazard indices used for both the vegetable and fish ingestion pathways to develop population risk estimates were derived originally based on methodologies explained in the RTC and NODA technical background documents. There are two major limitations associated with using the original individual risk estimates as a starting point for the current analysis.

  - First, the original individual risk estimates were not designed specifically to feed into a population risk analysis. That is, they were not designed to reflect the distribution of risks in specific exposed populations. For example, the individual risk estimates for the fish ingestion pathway do not reflect the spatial variability in the exposure concentrations, taking into account that streams farther from the site will likely have lower concentrations than the single closest stream for which the individual risks were derived. Because it was not possible to account for such spatial variability in the current analysis, the population risks will tend to be overestimated.

- Second, all the limitations and uncertainties associated with the original estimates of the individual risks carry over into the current analysis as well. For example, for some facilities, the original methodology used a scaling approach to derive estimates of individual risks that were presented as being within "order of magnitude" ranges. For the current analysis EPA used the upper end of such ranges to represent individual risks. This would most likely lead to an overestimate of the population risks. Furthermore, the individual risk estimates do not include effects of exposure to dioxins/furans that may potentially be present in the CKD waste. This would lead to an underestimate of the population risks. Also, it should be noted that there is a degree of uncertainty associated with using individual hazard index estimates denoted as "best estimates" to calculate population noncancer effects. The best estimate hazard index for a given constituent is based on the best estimate exposure concentration of that constituent, which takes the average of all measured exposure concentrations for that constituent. If the average concentration is less than the RfD, then the hazard index will be less than one. This hazard index is then applied to all the measured concentrations that were used in calculating the average concentration, even though some of the measured concentrations may actually be greater than the RfD (i.e., resulting in HI > 1). Therefore, in using the best estimate individual hazard indices, the population with a hazard index greater than one can be underestimated.

Vegetable Ingestion Pathway

- The farm population, the number of subsistence farmers, and the urban population within five miles of the facility were calculated using the total county farm population, the number of subsistence farms in the county, and the county urban population, respectively, and the ratio of the area within five miles of the facility to the total area of the county. These calculations implicitly assume that the three populations are distributed uniformly throughout the county. This would not be the case in reality because these populations would most likely be concentrated in different areas of the county. The populations calculated for the five-mile radius surrounding the facilities may be overestimated or underestimated depending on whether the facility is located in an urban or in a rural area. For example, if the facility is located in an urban area, the calculated urban population within five miles of the facility will be underestimated and the calculated farm population and number of subsistence farmers within five miles of the city will be overestimated. If the facility is located in a rural area, then the calculated urban population within five miles of the facility will be overestimated and the calculated farm population and number of subsistence farmers within five miles of the facility will be underestimated.

- The number of subsistence farmers living within the county was estimated using a proxy for subsistence farms, which in turn were estimated based on data on the sale of agricultural products. This method assumes that farms with sales of less than $10,000 per year are subsistence farms. Since $10,000 per year is below the poverty level, these people most likely sell agricultural products in order to supplement their income or grow agricultural products in order to supplement their diet, thus consuming a greater portion of homegrown vegetables and beef and milk than the general population. This methodology would tend to overestimate the number of subsistence farms in the county because people who farm part-time or who sell livestock could be counted as subsistence farmers given the assumptions used in this analysis. The extent of such "false positives" may be minor, however, because the data used were collected by the Census of Agriculture in such a manner that they target primarily farmers (i.e., the Census solicits information from farmers identified based on information from previous censuses, USDA surveys, and IRS information) and exclude to the extent possible those people who do not identify farming as their principal occupation.

- The "homegrown vegetable" population was calculated by determining the percentage of non-urban, non-farm population and also the percentage of non-rural or urban population that could be expected to participate in backyard gardening. 1995 data from the National Gardening Association indicate that 45% of rural and 22% of non-rural U.S. households participate in backyard gardening. Thus, 45% of the calculated non-urban, non-farm population and 22% of the calculated urban population within five miles of the facility were considered to be the population of backyard gardeners that actually participates in home gardening. This assumes that 45% of households participate in backyard vegetable gardening in all rural areas throughout the country, while in reality this percentage most likely varies from region to region. Likewise, the 22% of urban households that participate in backyard vegetable gardening may not be applicable to all urban areas.

- To derive a composite picture of the potential population risks across the full universe of cement facilities, EPA estimated the potential population risks within the unknown universe by extrapolation from results within the known universe. As discussed in section 2.4.2, EPA derived more refined results for the known universe for the vegetable ingestion pathway based on site-specific topographic data for seven facilities. EPA chose not to use these refined results for extrapolating results for the full universe, however, because topography data are site-specific and assumptions about topography can not reasonably be made from some facilities in the known universe to others in the unknown universe and, therefore, it would not be reasonable to believe that the refined population risk results can be extrapolated to the unknown universe. Because EPA used the more conservative (i.e., not refined) population risk estimates for the extrapolation to the unknown universe, the overall results for the full universe of cement facilities for the vegetable consumption pathway are likely to be overestimated.

Fish Ingestion Pathway

- The approach used for calculating the populations potentially exposed via fish ingestion assumes that atmospheric deposition and surface runoff from the CKD waste piles can contribute contaminants to all the streams within a five-mile radius of the facility (i.e., in addition to the single stream closest to the facility). This is likely to overestimate the population risks because site-specific hydrologic factors may dictate that fewer streams, i.e., only those close to the facility, may receive significant levels of the contamination, at least through surface runoff.

- The approach used in this analysis for calculating the populations potentially exposed via fish ingestion involved determining the number of fishers that can be "supported" by the available fish biomass (i.e., standing stock) within the area of interest. In most cases, standing stock data were not available for the streams located closest to the facilities. Standing stock data were, therefore, extrapolated to the nearby streams from other streams located within the counties of interest. In some cases, standing stock data were available for a large stream and were extrapolated to small streams. In other cases, data from a small stream were applied to larger streams located within five miles of the facilities. Because many chemical and biological factors can affect the fish population of a stream, it is likely that extrapolating standing stock data from one stream to another either overestimates or underestimates the actual standing stock of the streams located within five miles of the facilities.

- Standing stock data were often available for only one sampling site along a stream. In calculating the standing stock, it was necessary therefore to assume that data from one sampling site are representative of other locations along the stream. In cases where data were provided for more than one sampling site, an average value of the standing stock was used in calculating the standing stock within five miles of the facility.

- For one facility, the surrounding land is primarily swamp that is known to support fish populations. Including in this analysis the entire swamp area within five miles of the facility would have lead to an extreme overestimate of the number of fishers that can be supported by the available standing stock. It was necessary to refine the estimate by including only those areas of swamp that are known to support fish populations year-round. Thus, the calculation for this facility includes only the stream miles that are flooded at all times of the year. This refinement will tend to underestimate the overall available standing stock, and, consequently, the number of fishers that can be supported because it does not include areas of the swamp that support fish populations at only certain times of the year.

- The standing stock data provided by the state and local agencies were sometimes given as a single value, representing all species present at the sampling site. In other cases, the data were provided separately for each species present at the sampling site. Thus, for some facilities it was not possible to eliminate data for species that would not commonly be consumed by a recreational fisher. To be consistent across all facilities, all species were included in the calculation of the standing stock, including those that are not typically consumed by recreational fishers. Since all species are included in the estimate of the available standing stock, the number of recreational fishers that can be supported by this standing stock is likely to be overestimated. However, the degree of the overestimate may be negligible since the species of fish that are not commonly consumed tend to weigh very little and, thus, would not contribute significantly to the total standing stock value.

- Some facilities have large lakes or reservoirs located within a five-mile radius of the facility; these waterbodies were not included in the analysis even though they may support fish populations. They were not included because it is expected that since these lakes are very large, contaminants would likely be diluted significantly in the water column. (This analysis does not account for any accumulation of metals in the sediments within the lakes/reservoirs and potential subsequent transfer into the foodchain). In addition, it is less appropriate to extrapolate lake standing stock data from one area to another since lake fish populations would tend to be concentrated in certain areas of the lake and at certain depths.

2.5.2 Alternative Approach to Calculate Population Risks and Associated Limitations

In Section 2.3.2 of this Technical Background Document, EPA provides details on the specific calculations used to estimate population risks associated with the ingestion of contaminated vegetables. In brief, the approach used in this analysis for calculating population risks assumes that a certain proportion of the people living within five miles of a cement facility is likely to be exposed via ingestion of contaminated vegetables. This proportion is estimated, for each cement facility analyzed, based on county-level data on the number of farmers and backyard gardeners, prorated to account for the relationship between the area around the facility to the total area in the county. Thus, this approach is based on the assumption that the potentially exposed population is located entirely within the five-mile radius surrounding the facility, and does not account for persons who live outside of this boundary and may be exposed to vegetables "exported" from the vicinity of the facility.

As part of the current analysis, EPA also reviewed potentially applicable alternative approaches to calculating population risks. In the **Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions** (EPA/600/AP-93/003, November 1993 Review Draft) EPA has outlined an approach to calculating population risks due to ingestion of contaminated food in general that is based on an estimate of total food production within the area affected by contamination. The suggested equation for calculating population risk in this approach is as follows:

$$\text{population risk} = \frac{q^* \times ED \times C_X \times FP_X}{BW \times LT}$$

where:

q^*	=	cancer slope factor (kg-day/mg)
ED	=	exposure duration (yr)
C_X	=	concentration of contaminant in the food from area X (mg/g)
FP_X	=	production of the food in area X (g/d)
BW	=	body weight (kg)
LT	=	lifetime (yr)

As can be noticed, the key difference between the calculation used in this November 1993 Addendum approach and that used in the approach for the current analysis is the use of the "food production" term. The use of this term leads to the assumption that the number of people potentially exposed to contaminated food (vegetables, in the case of the current analysis) depends on the amount of food that is produced within the area of interest (i.e., all food that is produced within the area of interest is consumed by someone, either within this same area, or elsewhere). In contrast to the calculation used in the current approach, the potentially exposed population calculated according to the November 1993 Addendum approach could include people living outside the five-mile radius of the facility.

EPA considered the pros and cons of the two approaches, and decided against using the November 1993 Addendum approach, primarily because it is relatively less flexible in terms of its data needs, would not be applicable to all receptors of interest, and would not yield results that are any more accurate and/or certain. Key points against the use of the November 1993 Addendum approach include the following:

- This approach is relevant for only linear, non-threshold effects; thus, it can be used to estimate population cancer risks, but not population noncancer effects.

- This approach will not allow one to differentiate between risks to farmers/home gardeners and risks to subsistence farmers.

- This approach would require the development and use of several "adjustment factors," many of which will introduce greater uncertainty in the final results:

  - the approach may lead to an overestimate of risks because it assumes that all food produced is eaten; one would need to derive and apply factors to account for the portion of food that is not eaten due to "wastage" or loss during preparation and processing/handling.

  - the approach would require facility-specific food production data, calculated possibly using county-level data. The most readily-available source for these data is the Census of Agriculture. Production data available from the Census are given as "the value of agricultural products sold per year" or the "number of acres harvested per year" for specific agricultural products. If the value of agricultural products sold per year were used for the calculation, it would be necessary to use a factor to convert the value per year to grams per day with the unit price of each individual vegetable. If the number of acres harvested per year were used in the calculation, it would be necessary to use a conversion factor for the amount of a certain vegetable that can be grown on an acre of land. Such conversion factors are likely to be highly variable and not easily derived.

- This approach requires use of individual risk estimates that are slightly different from those available for use from the previous CKD-related analyses, because it requires that concentrations used are an average for that area of interest. So far, data are available from previous analyses that provide concentrations of contaminants in vegetables from one particular farm or region; these concentrations may often represent a maximum for that region, but it is unlikely that they represent an average concentration across the entire area of interest.