COMMERCIAL PRODUCTION AND DISTRIBUTION OF
FRESH FRUITS AND VEGETABLES: A SCOPING STUDY
ON THE IMPORTANCE OF PRODUCE PATHWAYS TO DOSE

Hanford Environmental
Dose Reconstruction Project

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MASTER

PREFACE

The primary purpose of the Hanford Environmental Dose Reconstruction (HEDR) Project is to develop estimates of the radiation doses that populations could have received from Hanford Site operations since 1944, and to describe the uncertainties inherent in such estimates. The project, directed by an independent Technical Steering Panel, is conducted by Battelle, Pacific Northwest Laboratories staff under contract to the Centers for Disease Control.

The research presented in this report summarizes the results of a scoping study to determine the importance of fresh fruit and vegetable pathways to dose. The information developed for this study was used to calculate radiation dose estimates from the Hanford Site operations for specific populations living in selected locations within the HEDR study area.

This scoping study is not a definitive description of the fresh fruit and vegetable pathways; it is intended only to provide a basis for a decision by the Technical Steering Panel on how much work will be required to meet project objectives.

This letter report completes HEDR Milestone 0603C: Potential Importance to Dose of Exposed Fresh Fruit and Vegetable Pathways (Shipler 1992, p. 7.8). The methods used in this report were approved by HEDR staff after discussions with members of the Technical Steering Panel. The work described in this report was conducted according to the appropriate requirements of Battelle's Quality Assurance (QA) program.

SUMMARY

This letter report summarizes a scoping study that examined the potential importance of fresh fruit and vegetable pathways to dose. A simple production index was constructed with data collected from the Washington State Department of Agriculture (WSDA), the United States Bureau of the Census, and the United States Department of Agriculture (USDA). Hanford Environmental Dose Reconstruction (HEDR) Project staff from Battelle, Pacific Northwest Laboratories, in cooperation with members of the Technical Steering Panel (TSP), selected lettuce and spinach as the produce pathways most likely to impact dose.

County agricultural reports published in 1956 provided historical descriptions of the predominant distribution patterns of fresh lettuce and spinach from production regions to local population centers. The distribution patterns of lettuce and spinach were derived from this information and the production data. An individual expert reviewed the fresh lettuce and spinach distribution patterns in an informal interview. Pathway rankings and screening dose estimates were calculated for specific populations living in selected locations within the HEDR study area.

The findings of this study related to dose are

- Lettuce and spinach account for 65-76% of the total fresh fruit and vegetable dose for an average individual who consumed regionally grown and distributed fruits and vegetables.
- The magnitude of the fresh leafy vegetable dose is controlled by the produce distribution system.
- Based on current modeling assumptions, the commercial fresh fruit and vegetable dose constitutes as much as 23% of the commercial milk dose.
- The consumption of commercially available leafy vegetables yields a dose that is as much as 40% of the TSP dose decision level for a child, and 8% of the dose decision level of an adult (Shleien 1992, p. 9).

The findings of this study related to the production and distribution processes are

- Spokane, Walla Walla, and Klickitat counties produced more than 80% of the fresh market lettuce and spinach that was distributed in the HEDR study area in 1945 and nearly 100% in 1951.
- The Spokane distribution area included population centers in the counties of the northern portion of the HEDR study area: Spokane, Whitman, Lincoln, Adams, Douglas (1951 only), and Grant.
- The Walla Walla distribution area included the majority of the cities in the southeast and central counties: Walla Walla, Columbia, Garfield, Asotin, Umatilla, Morrow, Franklin, Benton, and Yakima.
- The Klickitat distribution area included population centers in the southwest counties of the HEDR study area: Klickitat, Sherman, and Gilliam.
- Fresh markets in Kittitas county likely received lettuce and spinach from outside the HEDR study area.

Estimated doses for the commercial leafy vegetable pathway in 1945 are small; ranging from about 17 mrad/yr to 390 mrad/yr to a child's thyroid and from about 8 mrad/yr to 170 mrad/yr to an adult's thyroid. These estimated doses are below the TSP annual dose decision level of 1000 mrad/yr to the thyroid of an infant, and 2000 mrad/yr to the thyroid of an adult (Shleien 1992, p. 9). Based on the TSP annual dose decision levels, the recommendation is that no further work in the commercial fresh fruit and vegetable pathways be performed, and that the production and distribution information collected for this scoping study be used to represent the fruit and vegetable pathways to dose.

ACKNOWLEDGMENTS

Secondary data were the principal sources of information for the production and distribution processes described in this scoping study. Primary data were used to confirm secondary data and to provide additional unpublished information. Dr. Albert H. Harrington, an agricultural economist and professor emeritus of the Agricultural Economics Department for Washington State University, reviewed the distribution patterns derived from secondary sources and provided information to refine the distribution patterns of fresh lettuce and spinach. Dr. Harrington was active in the marketing research of fresh fruits and vegetables within the Hanford Environmental Dose Reconstruction study area during the study period. Derrick J. Bates, senior research scientist at Battelle, Pacific Northwest Laboratories, contributed statistical analysis of the fruit and vegetable ingestion estimates used in this study. Richard A. Fowler, technical specialist at Battelle, Pacific Northwest Laboratories, provided data collection and data entry support.

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1.0 INTRODUCTION

In the 1940s and 1950s, during facility operations at Hanford, iodine-131 was released to the atmosphere. Fruits and vegetables produced on farms in the surrounding open-air agricultural environment were potentially exposed to these releases. Individuals who consumed the fresh produce likely ingested radionuclides.

Phase I of the Hanford Environmental Dose Reconstruction (HEDR) Project, which ended in July 1990, provided dose estimates from specific radionuclides for individuals and populations in a limited geographical area (10 counties surrounding the Hanford Site) and period (for atmospheric releases, 1944-1947). Dose estimates were calculated under the assumption that all fruits and vegetables ingested by individuals in the HEDR study area were locally grown (Pacific Northwest Laboratory 1991, p. 4.22). The results suggested that commercially produced fresh fruits and vegetables were potentially important exposure pathways for some populations, geographical areas, and periods (Shipler 1992, p. 7.7).

The purpose of this report is to study the importance of fresh fruit and vegetable pathways to dose for 1944-1957. Production and distribution processes that existed in the HEDR study area during 1945 and 1951 were reconstructed for selected produce, and this information was used to calculate screening dose estimates for specific populations in selected regions. The relative importance ranking of different types of fruits and vegetables and the dose estimates presented in this report are based on the single radionuclide iodine-131. Iodine-131 was identified as providing over 95% of the effective dose equivalent, and over 99.9% of the thyroid dose, from historical Hanford atmospheric releases for all combinations of exposure pathways (Napier 1991, p. 4.5).

The two study years, 1945 and 1951, were chosen because recorded air releases of radionuclides in those years were high relative to other periods (Pacific Northwest Laboratory 1991, p. 4.4). Information collected for 1945 and 1951 provided data for comparing the changes that occurred in agricultural production and distribution from World War II to the post-war period.

The HEDR study area, a direct expansion of the 10-county Phase I region, is composed of 15 counties in central Washington and 4 counties in northern Oregon (Figure 1.1). The counties added to those already included in Phase I are (in Washington) Douglas, Lincoln, Spokane, Whitman, Columbia, Garfield, and Asotin, and (in Oregon) Sherman and Gilliam. The HEDR study area referred to in the remainder of this report will be the 19-county study area.

The pathways to consumption for fresh fruits and vegetables that existed in 1945 and 1951 are described in Section 2.0 of this report. Section 3.0 details the development of the methodology used in this study, and includes a summary of the data sources. Section 4.0 discusses the data quality assurance measures and objectives. Section 5.0 summarizes the production data and discusses distribution patterns. Section 6.0 discusses the importance of produce pathways to dose and provides screening dose estimates. The conclusions and recommendations derived from this study are presented in Section 7.0.

FIGURE 1.1. The HEDR Study Area

2.0 COMMERCIAL PRODUCE PATHWAYS

During the study period of 1944-1957, fruits and vegetables that were potentially exposed to radioactive releases from Hanford Site facilities were distributed for human consumption. The fresh fruits and vegetables commercially produced and distributed in the HEDR study area during 1945 and 1951 are listed in Table 2.1. This list was compiled from available agricultural statistics reports and is as complete as possible, given the amount of data available.

Farmers produced the crops on the limited irrigated land in counties around the Hanford Site. The agricultural production process began in the early spring and extended until late fall. Throughout this period, operations at Hanford Site facilities released iodine-131 to the air, which was then carried by the wind and deposited on fruits and vegetables growing in the fields. The growing seasons in 1945 coincided with high levels of iodine-131 releases from separation plants.

The pathways to consumption of the fruit and vegetables were fresh markets, local processing plants, and storage facilities (Figure 2.1). The fresh produce was distributed to local city markets for immediate consumption and home canning. The processed produce was shipped to local, regional, and national markets. Storage crops were distributed within several months after harvest. The shipments of leafy vegetables to fresh markets are recognized as potentially important produce pathways for the ingestion of radionuclides (Napier 1991).

Key parameters that influenced the dose from radioactive iodine are the growing seasons and delay times. The growing season is the period between the two production dates of planting and harvest. These dates define the primary intervals during which produce were exposed to releases of radionuclides. The delay time, the period between harvest and consumption, defines the interval during which decay of radioactive iodine could occur prior to consumption (iodine-131 has a short half-life of 8 days.)

Favorable climatic conditions in the HEDR study area enabled farmers to produce fruits and vegetables in one or more growing seasons. For example,

TABLE 2.1. Fresh Fruits and Vegetables Produced and Distributed in the HEDR Study Area

<u>Fruits</u>	<u>Vegetables</u>
Apples	Asparagus
Apricots	Beans, Lima
Cherries	Beans, Snap
Grapes	Beets
Melons	Broccoli
Peaches	Cabbage (Early)
Pears	Cabbage (Late)
Plums	Carrots
Strawberries	Cauliflower
Other Berries	Celery
	Corn
	Cucumbers
	Lettuce (Early)
	Lettuce (Late)
	Onions, Green
	Onions (Early)
	Onions (Late)
	Peas, Green
	Peppers, Green
	Potatoes
	Spinach (Early)
	Spinach (Late)
	Squash/Pumpkins
	Tomatoes
	Turnips/Rutabagas

FIGURE 2.1. Commercial Produce Pathways for Fruits and Vegetables

lettuce and spinach varieties were grown in early (spring) and late (fall) seasons, while asparagus had a single spring season (Gray et al. 1948, pp. 60-61). Farmers adjusted the planting dates of some crops so harvest would coincide with delivery dates to local processing plants. They staggered planting dates of the fresh market crops to lengthen the growing season. This increased the value of the farmers' product and provided fresh produce to consumers over an extended marketing period.

Delay times depended on the specific fruit or vegetable and its pathway to consumption. Processing techniques preserved produce for an extended time, thereby diminishing the amount of radionuclides consumers ingested. Crops

such as beets, cabbage, carrots, celery, and onions could be stored for several months past the harvest period (Parker and Royston 1945, p. 1). This extended marketing season for storage crops allowed the radioactive iodine to decay before the produce was ingested. Some fresh market crops such as lettuce, spinach, and asparagus were consumed within days after harvest, so little decay of radioactive iodine occurred before consumption.

3.0 TECHNICAL APPROACH

Subsection 3.1 presents an overview of the technical procedures used to complete this scoping study, and subsection 3.2 provides a review of the data sources.

The research process to determine the importance of produce pathways to dose began with this initial scoping study and will be followed by a more detailed definitive study, if required. The objective of this scoping study is to collect fruit and vegetable production and distribution information from secondary sources. Primary source information provides additional details that are not in the published literature.

If it is determined that a more definitive study is needed as a result of this preliminary assessment, this study, combined with additional detailed assessment of production and distribution information and interviews with additional experts, can be used to construct an explicit description of the fruit and vegetable pathways in the HEDR study areas for 1945 and 1951.

3.1 METHODOLOGY

The methodology to estimate the importance of fresh fruit and vegetable pathways to dose was developed in four stages. In the first stage, secondary information on commercial production and distribution processes was collected and analyzed. In the second stage, HEDR staff from Battelle, in cooperation with members of the Technical Steering Panel (TSP), selected fresh lettuce and spinach as the produce pathways for study. The third stage consisted of reconstructing distribution patterns using information from secondary sources and expert judgment. For the fourth stage, information from the previous three stages was used to calculate screening dose estimates for specific populations in selected regions, and a pathway importance ranking of fruits and vegetables was developed.

3.1.1 Production

Production information from secondary sources provided data for each county in the HEDR study area. The geographic location of production, crop

acreage, volume harvested (or shipped), and production dates represent the supply component of each fruit or vegetable market.

Produce balance, a crude measure of the difference between production and consumption of fresh lettuce and spinach, is calculated for each HEDR county for 1945 and 1951 (Appendix A). Counties are classified as surplus, deficit, or self-sufficient. A county is classified as a surplus county when production of a crop exceeded demand by local consumers; a deficit county when consumer demand exceeded production; and a self-sufficient county when production equaled demand. The annual demand was estimated by multiplying the county population by the annual per capita consumption (farm level) of a fruit or vegetable. The farm level per capita measure is the weight of the raw produce shipped from the farm, unadjusted for weight loss due to marketing and processing.

3.1.2 Pathways Selected for Reconstruction

Because each fresh fruit and vegetable has a unique pathway to the consumer, it was not feasible in a scoping study to reconstruct distribution estimates for each kind of produce. The selected alternative was to reconstruct the produce pathways most likely to have resulted in exposure of individuals to radioactive iodine.

After discussion with members of the TSP, HEDR staff from Battelle identified fresh lettuce and spinach as the produce pathways for reconstruction. This decision took into consideration the production and national per capita consumption estimates for 1945 and 1951, the expected delay times between harvest and consumption, produce utilization (fresh, processed, or stored), and the physical characteristics and processes of the fruits and vegetables. The iodine-131 concentration of leafy vegetables at consumption, relative to other vegetables, grain, and tree fruit, is shown in Figure 3.1. The determination of radionuclide concentration in fruits and vegetables is discussed in Appendix B.

3.1.3 Distribution Patterns

The distribution systems of lettuce and spinach were reconstructed to determine the geographic origin of the fresh produce consumed in the

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FIGURE 3.1. Relative Iodine-131 Concentration for Produce Categories

population centers of each county within the HEDR study area. Distribution patterns were derived from secondary sources and corroborated by an expert who was active in agricultural marketing in the 1940s and 1950s. This individual provided distribution information for lettuce and spinach during two informal meetings with HEDR staff from Battelle. In the first meeting, production and distribution processes of lettuce and spinach were discussed. In the second meeting, the individual used production and per capita consumption (farm level) data for 1945 and 1951, a 1948 road map, and irrigated land maps to review and refine distribution patterns for early and late season lettuce and spinach.

3.1.4 Produce Ranking and Screening Dose Calculations

The methods for estimating the relative importance to dose of 30 different fresh fruits and vegetables involves estimating radionuclide concentrations in the plants, human consumption rates, and the availability of regionally grown produce. These combined factors are used to indicate which of the 30 fresh fruits and vegetables contribute significantly to dose.

The intent of the ranking is to determine the effects on dose of fruit and vegetable production and distribution within the HEDR study area. To obtain this ranking, average individual consumption rates are used. These consumption rates are intended to reflect the relative importance of fruits and vegetables that would have been obtained from local markets.

The ranking of the fresh fruits and vegetables indicates the relative importance of each to the intake of radionuclides. The results of the ranking calculations are presented in Section 6.0. The ranking does not put the fruit and vegetable doses in context with the total dose from other pathways, such as milk consumption. This study compared the HEDR Phase I dose estimates for milk with doses for selected leafy vegetables, and estimated the impact of the distribution system on the dose to individuals who obtained their produce from a local or regional commercial source. The impact of the distribution system was determined using derived plant concentrations, consumption rates, and market share information. The importance ranking and dose estimates were calculated for representative areas: Prosser (Benton County), Riverview (Franklin County), Walla Walla (Walla Walla County), Pendleton (Umatilla County), and Heppner (Morrow County). These locations were chosen because agriculture took place on irrigated land there and fruits and vegetables could have been produced locally.

3.2 DATA SOURCES

Primary and secondary data sources are presented in this subsection. Secondary data were the principal source of information for the production and distribution processes. Information not published, but required to complete this study, was solicited from an individual expert.

3.2.1 Washington State Agricultural Statistics

Horticultural data assembled by the Washington State Department of Agriculture (WSDA) in cooperation with the United States Department of Agriculture (USDA) Bureau of Agricultural Economics was the primary source of agricultural production information (volume of production) for the Washington counties (WSDA and U.S. Bureau of Agricultural Economics 1945, pp. 1-38; 1951,

pp. 4-55; and 1953, pp. 1-45). The data were preferred to U.S. Census of Agriculture data because they were recorded for 1945 and 1951 and compiled from hundreds of reliable sources including growers, railroads, county extension agents, county committees, processors, manufacturers, and other organizations such as the WSDA and U.S. Bureau of Agricultural Economics.

The WSDA, USDA, and the Washington Crop and Livestock Reporting Service published county agricultural data reports for 1956 (WSDA et al. 1958a, pp. 39, 55; 1958b, pp. 19, 46; 1958c, pp. 44-46; 1958d, pp. 36, 47; 1958e, pp. 22, 47; 1958f, pp. 46-49; and 1958g, pp. 37, 47, 48). The primary objective of these documents was to describe the history and nature of agriculture in each county. These reports provided the locations of vegetable production regions within particular counties and described the historical produce distribution patterns that existed in the HEDR study area prior to 1956.

3.2.2 U.S. Census of Agriculture Data

Production data for the Oregon counties in the HEDR study area were collected from the U.S. Census of Agriculture (U.S. Bureau of the Census 1946, pp. 46-53 and 1956, pp. 298-305). The 1945 and 1950 U.S. Census estimated production data for the crop years 1944 and 1949. Therefore, crop production for 1944 and 1949 approximated the 1945 and 1951 figures. Crop acreage was the only production estimate recorded for vegetables.

3.2.3 Maps

Land use maps identified irrigated land within the 19-county HEDR study area. The USDA land use map of the United States (USDA 1950), based on the 1945 U.S. Census of Agriculture, was the primary resource used to identify irrigated regions. This was supplemented by a land use map of the Columbia Basin Project (U.S. Bureau of Reclamation 1978).

A 1948 transportation map of Washington and Oregon identified existing highways and showed possible routes used by distributors of fresh produce (Mobilgas 1948).

3.2.4 Population Estimates

Population estimates for 1945 and 1951 for the Washington counties and for Umatilla and Morrow counties in Oregon are from Beck et al. (1992, pp. 29-58). The Oregon State Population Center in Portland, Oregon, provided population estimates for Sherman and Gilliam counties.

3.2.5 Consumption Estimates

Two measures of fruit and vegetable consumption are used in this scoping study: annual per capita consumption estimates at the farm level, and average human ingestion rates. Farm level consumption rates are used to classify the study counties as surplus, deficit, or self-sufficient in fruit and vegetable production. Annual farm level consumption of a particular produce for an individual in the HEDR study area was approximated, using national per capita consumption for 1945 and 1951. Per capita raw produce consumption estimates (farm level) were collected from the USDA (USDA 1965, pp. 30-45). Information on average fruit and vegetable ingestion rates that were used to develop the produce rankings and to calculate the screening dose estimates (Section 6.0) are based on 1965 survey data (USDA 1972) back-cast to 1945. The development of these ingestion rates is discussed in Appendix D.

3.2.6 Individual Expert

Dr. Albert H. Harrington, professor emeritus of the Agricultural Economics Department at Washington State University, has been actively involved in fruit and vegetable marketing in the HEDR study area since 1946. Dr. Harrington's involvement has included regional research of fresh produce marketing and working closely with the Asparagus Growers Association. Dr. Harrington has invaluable knowledge of the impact that transportation systems, policies during World War II, and historical distribution patterns had on the marketing of fresh produce within the HEDR study area. Dr. Harrington attended two working meetings with HEDR staff from Battelle. The first meeting involved a preliminary discussion of fruit and vegetable distribution processes; in the second meeting, Dr. Harrington reviewed fresh market distribution patterns of early and late season lettuce and spinach.

4.0 QUALITY ASSURANCE

This report is produced in accordance with the Battelle, Pacific Northwest Laboratories Quality Assurance (QA) program requirements. All work and computer calculations are appropriately documented to provide a traceable path, from raw data to reported data.

Data collected for this report are used as input to calculate screening dose estimates. The data are constructed to satisfy four quality objectives established by Shipler (1992, p. 7.8): accuracy, precision, representativeness, and comparability.

Accuracy - The accuracy objective requires the use of secondary data, when available, and the use of primary data when information is not available from secondary sources. The secondary sources used in this study are recognized as authoritative in the fields of agricultural production and distribution, and food consumption. Data checks were conducted to ensure that the data used in the analysis for this report are accurate. In addition, the data were corroborated by an individual expert who acquired firsthand knowledge of fresh fruit and vegetable marketing in the HEDR study area, having worked with farmers, processors/distributors, and grocers since 1946. These data were used as input to calculate screening dose estimates.

Precision - The objective is to attain precision in the assignment for market share and distribution patterns. To meet this objective, distributions of market share and distribution patterns were derived from historical data and corroborated by expert judgment. The distribution estimates derived from secondary sources were refined by the individual expert to reduce uncertainty of the assigned distributions of market share for fresh lettuce and spinach.

Representativeness - The objective is to reconstruct the fruit and vegetable production and distribution processes and consumption rates that existed in the HEDR study area during the study period 1944-1957. This was accomplished by collecting key secondary and primary information available for the study years 1945 and 1951. Using these two years to represent the study period

provided a method of examining the changes in agricultural production and distribution processes from World War II to the post-war era. Because Phase I results suggested that leafy vegetables may be important to the ingestion pathway to dose, fresh lettuce and spinach were selected to characterize the 1945 and 1951 produce pathway for dose calculations.

Comparability - The objective is that the results of this scoping study be comparable in detail and resolution to those prepared for the Phase I milk model. The HEDR study area used in this scoping study included all 10 counties included in Phase I and 9 additional counties. This study addresses all three aspects of production, distribution, and consumption, as did Phase I. In addition, this scoping study provides information that relates the thyroid dose obtained from the ingestion of fresh lettuce and spinach to the dose obtained from drinking milk. Because milk cows were located in many parts of the study area, the Phase I milk study used county census districts as the smallest geographic area of analysis. Fresh lettuce and spinach for the commercial market were grown in only a few locations, therefore the smallest geographic unit of analysis was irrigated land within a county. A county census-level analysis of the fresh fruit and vegetable production and distribution processes would not improve the findings of this study.

5.0 PRODUCTION AND DISTRIBUTION RESULTS

This section provides production and distribution information for the top-ranked produce, fresh lettuce and spinach.

5.1 PRODUCTION

County production data are used to identify the commercially grown fruits and vegetables distributed and consumed in the HEDR study area. These data, recorded in acres (acreage) and tons (volume) of production, constitute a production index for 1945 and 1951 (production data are enumerated in Appendix A). Single varieties of crops were produced in multiple regions in the HEDR study area during World War II. A trend toward regionalized production of crops appeared by 1951. This trend was most apparent in Benton and Franklin counties.

5.2 DISTRIBUTION

This subsection presents the fresh lettuce and spinach distribution patterns that link the geographic location of production with the location of the consumer. The first step is to locate the areas of production within each county. The second step is to define the production dates. The final step is to use an expert to review secondary information and provide a "best estimate" of the percent of market share consumed in each county in the HEDR study area.

5.2.1 Production Location

Commercial fruit and vegetable farms in the HEDR study area were located on irrigated land. Figure 5.1 shows the distribution of irrigated land for 1951 (identical to the irrigated land map for 1945, with the exception of Blocks 1 and 2). Information was obtained from a land use map of the United States that was based on the 1945 U.S. Census of Agriculture (USDA 1950), and a Bureau of Reclamation map for the Columbia Basin Project (U.S. Bureau of Reclamation 1978). The Columbia Basin Project was in the initial stages of

FIGURE 5.1. Irrigated Land (grey areas) 1951. (Identical to irrigated land map of 1945, with the exception of Blocks 1 and 2 added in 1948 and 1950, respectively.)

providing water for irrigation use in 1948. Block 1 (in Franklin County), consisting of 5790 acres northeast of Richland, and Block 2 (in Walla Walla County), consisting of 1319 acres southeast of Pasco, began irrigation activities in 1948 and 1950, respectively.

Secondary sources described tracts of irrigated land that were used to produce fresh vegetables. This secondary source information supplements and refines the geographic location of vegetable-producing regions provided by the land use maps (see Table 5.1).

5.2.2 Lettuce and Spinach Production

Klickitat, Walla Walla, and Spokane counties produced a surplus of fresh lettuce in 1945 and 1951. Benton, Franklin, and Yakima counties produced lettuce in 1945 but were classified as deficit counties in 1951 (Figures 5.2 and 5.3).

Benton, Franklin, Klickitat, Spokane, Walla Walla, and Yakima were classified as surplus counties in spinach production for 1945. By 1951, Walla Walla, Spokane, and Klickitat counties were the only recorded commercial producers of spinach in the HEDR study area (Figures 5.4 and 5.5). Production and farm level consumption data are located in Appendix A.

TABLE 5.1. Vegetable Production Regions in the HEDR Study Area

<u>County</u>	<u>Geographic Location</u>
Benton	Lower Yakima river valley
Franklin	Southernmost tip of Franklin county, 2000 acres started in 1945
Klickitat	Lower valley lands of southwestern Klickitat county
Spokane	Spokane and Latah river valleys
Yakima	Lower Yakima river valley; Wapato and Toppenish vicinities and between Grandview and Sunnyside

FIGURE 5.2. 1945 Total Lettuce Production

FIGURE 5.3. 1951 Total Lettuce Production

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FIGURE 5.4. 1945 Total Spinach Production

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FIGURE 5.5. 1951 Total Spinach Production

5.2.3 Production Periods

Production dates for fresh market lettuce and spinach are presented in Table 5.2 (Parker and Royston 1945, pp. 36, 52). These dates indicate periods

TABLE 5.2. Production Dates in the HEDR Study Area

<u>Produce</u>	<u>Planting Period</u>	<u>Harvest Period</u>
Lettuce		
(Early)	February 1 to June 15	May 1 to July 31
(Late)	July 15 to August 15	September 1 to November 30
Spinach		
(Early)	March 1 to April 30	May 1 to June 30
(Late)	May 1 to June 30	July 1 to August 31

when the main part of the crop, up to 80%, is planted and harvested in most years. The harvest period is defined as the time when crops are harvested and does not extend into the period in which crops are stored in the field or at a warehouse. These periods do not cover unusual extremes of individual seasons.

5.2.4 Lettuce and Spinach Distribution

County agricultural reports published in 1956 (see subsection 3.2.1) provided historical descriptions on the predominant flows of perishable vegetables from production regions to local fresh markets. Benton and Franklin counties shipped to local city markets in Kennewick, Pasco, and Richland. Klickitat County supplied cities in the lower Columbia Valley. Spokane County shipped vegetables to the Spokane urban area and they were redistributed throughout a vast area. Walla Walla County shipped to local city markets in Walla Walla, Richland, Pasco, and Kennewick, as well as to Columbia and Umatilla counties.

HEDR project staff at Battelle estimated general distribution patterns of fresh lettuce and spinach using only secondary sources and a set of basic assumptions. The distribution patterns based on these estimates were to represent the HEDR study area for 1945 and 1951, and they were presented to Dr. Albert H. Harrington for review (see Appendix C).

Dr. Harrington reviewed the distribution patterns and refined several estimates. From this process a "best estimate" of the distributions of market share for early and late season fresh lettuce and spinach in each

county of the HEDR study area for 1945 and 1951 was derived (Appendix C). Dr. Harrington based the review on all the available information summarized in this report, and on his professional expertise.

Dr. Harrington provided invaluable insight into the distribution systems of fresh vegetables and determined that distribution was governed by available transportation and historic distribution patterns. For the distribution of fresh vegetables:

- Consumption of fresh fruits and vegetables was limited to the harvest season.
- One truck on a route delivered both the fresh lettuce and spinach.
- Distribution areas were limited to approximately a 100-mile radius around the surplus production areas.
- Lettuce and spinach produced in the early season were used for fresh market consumption.
- Fresh markets were located at the population centers in each county.
- Maximum delay time for fresh lettuce and spinach, trucked from the field to the consumer, was 5 days. Average delay time was 3 to 4 days.

6.0 PRODUCE RANKING AND SCREENING DOSE ESTIMATES

The relative importance of 30 different fresh fruits and vegetables to dose was investigated (see Section 3.1.4). Assuming a unit iodine-131 deposition rate, the relative concentrations of iodine-131 were determined for each fruit and vegetable. The basic equations used to estimate the relative concentrations are as documented from the GENII computer code (Napier et al. 1988). The equations used are very similar but not identical to those used in the HEDR Phase I dose calculations. The GENII models used here are best suited for the estimation of the dose from chronic releases. The assumption of a chronic release is appropriate for the screening dose calculation contained in this report.

The estimate of fresh fruit and vegetable concentrations requires a series of plant-specific parameters related to radionuclide distribution within the plant, plant biomass, growing period, holdup time, dry-to-wet weight ratios, and washing removal fractions. All of these parameters are listed in Tables D.1 and D.2 in Appendix D. These plant-specific factors are consistent with those documented in Snyder (1992). Special consideration was given to the effects of produce preparation in cooking by using a washing removal fraction. This factor is neither part of the GENII model nor included in the HEDR Phase I dose model, but it is included in the revised dose model (Snyder 1992).

In addition to plant-specific data, information on average fresh fruit and vegetable consumption rates was developed and used in the ranking. The consumption rates are based on 1965 survey data (USDA 1972) back-cast to 1945. The method of developing the back-casting ratios is included in Appendix D. The consumption rates derived for adult males, and children ages 1 to 4 years, are included in Appendix D in Tables D.1 and D.2, respectively.

A factor that accounts for the fraction of fresh fruits and vegetables that is grown and consumed in the HEDR study area is also used in the ranking calculations. The estimates of regionally produced fractions for each produce type developed for this study are detailed in Appendix D.

6.1 FRESH FRUIT AND VEGETABLE IMPORTANCE RANKINGS

Tables 6.1 and 6.2 show the results of the fresh fruit and vegetable ranking for adults and children, respectively. The predicted intake of iodine-131 based on a unit deposition of iodine-131 is shown. These estimated intake rates are not doses but are indicative of the relative doses that would result from the consumption of fresh fruits and vegetables. The percent of total indicates the percent of total intake that results from the consumption of each produce type. The cumulative percent values indicate the percent of the total iodine-131 intake that results from the combination of each produce type and all higher ranked produce types.

The results indicate that for an average adult male (20-34 years of age), the consumption of lettuce alone accounts for 39% of the total fresh fruit and vegetable dose (Table 6.1). Furthermore, the combined consumption of lettuce and spinach accounts for 76% of the total fresh produce dose. For an average child (1-4 years of age), the consumption of spinach accounts for 50% of the total fresh fruit and vegetable dose (Table 6.2). The combined consumption of lettuce and spinach accounts for 65% of the fresh produce dose.

6.2 IMPACT OF PRODUCE DISTRIBUTION ON DOSE

Since not all types of produce were grown commercially in all parts of the study area, the distribution of produce within the area could impact the dose an individual received. The impact of the fresh lettuce and spinach commercial production and distribution system can be estimated by combining the information in Tables 6.1 and 6.2 with the data discussed in Section 5.0. Doses that may have resulted from the consumption of commercial produce in each of five representative locations were derived using HEDR Phase I deposition data for all lettuce and spinach production areas, and the market share data presented in Appendix C.

Two types of commercially available produce were considered for this study. The first type is locally available commercial produce, that is, produce grown and consumed within the same county. The concentration of radioactivity in this commercial produce is expected to be similar to that of backyard-grown fruits and vegetables. The second type is commercial produce

TABLE 6.1. Importance Ranking of Commercially Produced Fresh Fruits and Vegetables (Average Adult Male) - Summary

Rank	Plant Type	Human Consumption (kg/yr)	Regionally Produced Fraction	Intake Ci/yr per Ci/m ² -s	Percent of Total	Cumulative Percent
1	Lettuce	3.462	1	8.60E+04	38.80%	39%
2	Spinach	1.86	1	8.30E+04	37.50%	76%
3	Corn, Sweet	1.853	1	1.30E+04	5.60%	82%
4	Peas, Green	0.926	1	7.10E+03	3.20%	85%
5	Apples	2.79	1	5.90E+03	2.60%	88%
6	Cabbage	3.221	1	4.90E+03	2.20%	90%
7	Carrots	1.242	1	4.20E+03	1.90%	92%
8	Melons	2.53	0.5	3.70E+03	1.70%	94%
9	Tomatoes	1.723	1	2.80E+03	1.20%	95%
10	Beans, Snap	0.465	0.1	1.80E+03	0.80%	96%
11	Peaches	0.613	1	1.60E+03	0.70%	96%
12	Onions	0.469	1	1.20E+03	0.50%	97%
13	Broccoli	0.251	0.16	1.20E+03	0.50%	97%
14	Asparagus	0.125	1	1.00E+03	0.50%	98%
15	Pears	0.556	1	1.00E+03	0.50%	98%
16	Apricots	0.239	1	7.20E+02	0.30%	99%
17	Sweet Cherries	0.189	1	6.90E+02	0.30%	99%
18	Cauliflower	0.038	0.51	4.70E+02	0.20%	99%
19	Other Berries	0.096	1	4.20E+02	0.20%	99%
20	Celery	0.056	0.42	3.40E+02	0.20%	100%
21	Onions, Green	0.062	0.1	2.80E+02	0.10%	100%
22	Beans, Lima	0.141	0.1	2.20E+02	0.10%	100%
23	Turnips/Rutabagas	0.081	1	1.90E+02	0.10%	100%
24	Strawberries	0.06	1	1.60E+02	0.10%	100%
25	Beets	0.533	0.1	1.50E+02	0.10%	100%
26	Squash/Pumpkins	0.081	0.1	2.40E+01	0.00%	100%
27	Grapes	0.012	1	2.30E+01	0.00%	100%
28	Cucumbers	0.078	0.36	1.60E+01	0.00%	100%
29	Plums	0.003	1	8.00E+00	0.00%	100%
30	Peppers, Green	0.006	0.1	3.90E+00	0.00%	100%

TABLE 6.2. Importance Ranking of Commercially Produced Fresh Fruits and Vegetables (Average Child 1-4 years) - Summary

Rank	Plant Type	Human Consumption (kg/yr)	Regionally Produced Fraction	Intake Ci/yr per Ci/m ² -s	Percent of Total	Cumulative Percent
1	Spinach	0.814	1	3.60E+04	50.30%	50%
2	Lettuce	0.424	1	1.10E+04	14.60%	65%
3	Apples	2.717	1	5.70E+03	7.90%	73%
4	Corn, Sweet	0.763	1	5.20E+03	7.10%	80%
5	Carrots	0.871	1	2.90E+03	4.00%	84%
6	Peas, Green	0.303	1	2.30E+03	3.20%	87%
7	Melons	1.326	0.5	1.90E+03	2.70%	90%
8	Cabbage	0.775	1	1.20E+03	1.60%	91%
9	Peaches	0.377	1	9.70E+02	1.30%	93%
10	Pears	0.487	1	9.10E+02	1.30%	94%
11	Beans, Snap	0.18	0.1	6.90E+02	1.00%	95%
12	Celery	0.106	0.42	6.50E+02	0.90%	96%
13	Tomatoes	0.314	1	5.00E+02	0.70%	97%
14	Broccoli	0.094	0.16	4.40E+02	0.60%	97%
15	Asparagus	0.053	1	4.40E+02	0.60%	98%
16	Apricots	0.137	1	4.10E+02	0.60%	98%
17	Sweet Cherries	0.048	1	1.80E+02	0.20%	99%
18	Beans, Lima	0.11	0.1	1.70E+02	0.20%	99%
19	Other Berries	0.039	1	1.70E+02	0.20%	99%
20	Turnips/Rutabagas	0.057	1	1.30E+02	0.20%	99%
21	Onions	0.044	1	1.10E+02	0.20%	99%
22	Cauliflower	0.008	0.51	9.80E+01	0.10%	100%
23	Onions, Green	0.017	0.1	7.50E+01	0.10%	100%
24	Strawberries	0.028	1	7.50E+01	0.10%	100%
25	Plums	0.022	1	7.10E+01	0.10%	100%
26	Beets	0.248	0.1	6.80E+01	0.10%	100%
27	Squash/Pumpkins	0.045	0.1	1.30E+01	0.00%	100%
28	Grapes	0.004	1	7.10E+00	0.00%	100%
29	Cucumbers	0.031	0.36	6.50E+00	0.00%	100%
30	Peppers, Green	0	0.1	2.60E-01	0.00%	100%

that is grown in one county and enters the region produce pool to be consumed in that same county or another county of the study area. For example, regionally available lettuce consumed in Franklin County during 1945 was composed of 45% from Benton County, 45% from Franklin County, and 10% from Walla Walla County. The representative iodine-131 lettuce concentration for a Franklin County grocery store was calculated as the market share weighted concentration of these three counties. Representative concentrations for grocery stores in Benton, Franklin, Walla Walla, Umatilla, and Morrow counties were combined with 1945 consumption data to estimate doses. All commercially available produce concentrations include a 4-day holdup from the time of harvest to consumption.

Lettuce and spinach doses are calculated using July, August, and September 1945 (averaged) iodine-131 deposition rates from HEDR Phase I data for each of the subject counties (Ramsdell and Burk 1991; Heeb and Morgan 1991). The ratios of the dose from regionally available versus locally produced lettuce and spinach are shown in Table 6.3. The consumption rates were assumed to be identical for both commercial sources. The results are shown for the years 1945 and 1951 because the produce distribution system changed over this period. By 1951 all commercially available lettuce and spinach consumed in the study area counties was grown in Walla Walla County.

The results show that if local produce was grown at a location with high deposition, the local produce would have provided a higher dose than the dose received from commercially available regional produce that may have come from a location with less deposition. This is the case for Franklin County, where the consumption of regional lettuce in 1945 yields a dose that is less than the dose from the consumption of local produce. The same is true for Franklin County in 1951. For counties such as Benton, Umatilla, and Morrow, the regional produce came primarily from Walla Walla and gives a dose that is higher than the dose from produce grown locally. The local produce dose in Walla Walla is the same as the regional produce dose because all produce (local and regional) consumed in Walla Walla County was grown there.

TABLE 6.3. Ratio of Regional Produce Dose to Local Produce Dose

	County				
	<u>Benton</u>	<u>Franklin</u>	<u>Walla Walla</u>	<u>Umatilla</u>	<u>Morrow</u>
<u>1945</u>					
Spinach	5.3	0.6	1.0	3.1	5.4
Lettuce	4.1	0.5	1.0	3.1	5.4
<u>1951</u>					
Spinach	2.3	0.2	1.0	3.1	5.4
Lettuce	2.3	0.2	1.0	3.1	5.4

6.3 IMPORTANCE OF FRUITS AND VEGETABLES TO DOSE

Although the impact of the distribution system of commercial produce may be important for estimating doses from fresh produce, the impact on total dose is largely unaffected. Table 6.4 shows the estimated lettuce, spinach, and milk doses for a child residing in each of five counties. The commercial milk doses were taken from the HEDR Phase I results for each of the five counties. No distinction was made between local and regional commercial milk doses in Phase I. For this study, local and regional milk doses are assumed to be the same. These results indicate that the combined lettuce and spinach doses for all locations, and both local or regional potential fresh produce sources, are less than 4% of the commercial milk dose. Table 6.5 shows the same information for an adult residing in each of the five counties. The results indicate that for adults, the combined lettuce and spinach doses for all locations and both local or regional potential fresh produce sources are as much as 23% of the commercial milk dose.

Phase I results indicated that backyard-grown fruits and vegetables accounted for approximately 10% of the milk dose for a child, and up to 50% for an adult. While the results presented in this report are for commercially available lettuce and spinach, the ratios differ from Phase I. For example, in this study the local lettuce and spinach dose in Franklin County for a child is estimated to be 0.39 rad. The Phase I result for the same area was

TABLE 6.4. Impact of Produce Distribution on a Child's Thyroid Dose - 1945 (rad/yr)

	Benton Co.		Franklin Co.		Walla Walla Co.		Umatilla Co.		Morrow Co.	
	Local	Regional	Local	Regional	Local	Regional	Local	Regional	Local	Regional
Spinach	0.031	0.166	0.301	0.166	0.073	0.073	0.023	0.073	0.013	0.073
Lettuce	0.009	0.037	0.087	0.045	0.021	0.021	0.007	0.021	0.0039	0.021
Commercial Milk	35	35	212	212	55	55	24	24	2.7	2.7
<u>Spinach and Lettuce Dose as a Percentage of Commercial Milk Dose</u>										
	0.1%	0.6%	0.2%	0.1%	0.2%	0.2%	0.1%	0.4%	0.6%	3.5%
<u>Spinach and Lettuce Dose as a Percentage of the ISP Dose Decision Level of 1 rad/yr (Thyroid)</u>										
	4%	20%	39%	21%	9%	9%	3%	9%	2%	9%

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TABLE 6.5. Impact of Produce Distribution on an Adult's Thyroid Dose - 1945 (rad/yr)

	Benton Co.		Franklin Co.		Walla Walla Co.		Umatilla Co.		Morrow Co.	
	Local	Regional	Local	Regional	Local	Regional	Local	Regional	Local	Regional
Spinach	0.009	0.045	0.082	0.045	0.020	0.020	0.006	0.020	0.004	0.020
Lettuce	0.009	0.036	0.085	0.044	0.021	0.021	0.007	0.021	0.0038	0.021
Commercial Milk	1.8	1.8	10	10	4.8	4.8	1.3	1.3	0.18	0.18
<u>Spinach and Lettuce Dose as a Percentage of Commercial Milk Dose</u>										
	0.1%	4.6%	1.7%	0.9%	0.4%	0.8%	0.1%	3.1%	0.1%	22.5%
<u>Spinach and Lettuce Dose as a Percentage of the ISP Dose Decision Level of 2 rad/yr (Thyroid)</u>										
	1%	4%	8%	4%	2%	2%	1%	2%	4%	2%

46.8 rad. The incorporation of a produce washing removal fraction, slightly longer holdup times for commercial produce, and different consumption rates account for some of this difference. The remainder of the difference arises from the computational methods used in Phase I. The Phase I vegetation doses were "greatly affected by the loss of correlations" between source term, atmospheric transport components, and ingestion rate estimates (Simpson 1991, p. 7). The result of losing the correlation structure was that for a number of different pathways, the estimated iodine-131 doses were too large. The doses calculated in this report are believed to be more representative of the relative impacts of the different food pathways than are the data given in the Phase I reports.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The purpose of this scoping study is to determine the impact of fresh fruit and vegetable production and distribution on dose. The following is a summary of the production and distribution results, and the results of the pathway ranking index and dose calculations.

Spokane, Walla Walla, and Klickitat counties were the principal suppliers of lettuce and spinach for the HEDR study area in 1945 and 1951. These counties produced over 80% of the fresh market lettuce and spinach in 1945, and 100% in 1951. The predominant distribution pathways for lettuce and spinach originated from these three production regions.

The Spokane distribution area included population centers in the counties of the northern portion of the HEDR study area: Spokane, Whitman, Lincoln, Adams, Douglas, and Grant. The Walla Walla distribution area included the majority of the cities in the southeast and central counties: Walla Walla, Columbia, Garfield, Asotin, Umatilla, Morrow, Franklin, Benton, and Yakima. The Klickitat distribution area included population centers in the southwest counties of the HEDR study area: Klickitat, Sherman, and Gilliam. Fresh markets in Kittitas County likely received lettuce and spinach from outside the 19-county study area.

Secondary sources contained information that described the general distribution regions for counties with surplus production of fruits and vegetables. Dr. Harrington defined distribution patterns consistent with this published information.

The importance of 30 different fresh fruits and vegetables as contributors to dose were investigated. The results indicated that between 65% and 76% of the total fresh fruit and vegetable dose is controlled by lettuce and spinach. The distribution system for commercially produced lettuce and spinach lead to elevated intakes of iodine-131 in areas that otherwise would have had lower doses from local sources. In some locations, the produce obtained from local sources dominated the dose from regional commercial sources. Even

though the distribution system has an effect on the dose to an individual, the local and commercial fresh fruit and vegetable dose is estimated to be less than 4% of the milk dose for a child and up to 23% for an adult. The dose to the thyroid of a child from commercially available lettuce and spinach can be as much as 40% of the TSP dose decision level (1 rad/yr).

Estimated doses for the commercial leafy vegetable pathway in 1945 are small; ranging from about 17 mrad/yr to 390 mrad/yr to a child's thyroid and from about 8 mrad/yr to 170 mrad/yr to an adult's thyroid. These estimated doses are below the TSP annual dose decision level of 1000 mrad/yr to the thyroid of an infant, and 2000 mrad/yr to the thyroid of an adult (Shleien 1992, p. 9). Based on the TSP annual dose decision levels, the recommendation is that no further work in the commercial fresh fruit and vegetable pathways be performed, and that the production and distribution information collected for this scoping study be used to represent the fruit and vegetable pathways to dose.

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APPENDIX A

PRODUCTION DATA

APPENDIX A

PRODUCTION DATA

This appendix includes county-level production data and produce balance tables. Tables A.1-A.4 show fruit and vegetable production volume (tons) for the Washington counties in the HEDR study area. The data in Table A.1 are from WSDA (1945); the 1945 volume data of sweet corn are estimated at 3.2 tons/acre, which was the Washington State average for 1945 (U.S. Bureau of the Census 1946). Table A.2 shows production volume of vegetables for 1951 (WSDA 1951; spinach data from WSDA 1953). Tables A.3 and A.4 show shipments of fresh fruits by truck for 1945 (WSDA 1948) and 1951 (WSDA 1951), respectively. Several counties were pooled together by the WSDA and the production data was recorded for the group; in that case, equal proportions of production volume were assigned to each county in the group. Table A.5 shows acreage of vegetables produced in the Oregon counties (U.S. Bureau of the Census 1946). Blank spaces in the tables indicate there was no commercial production recorded for that fruit or vegetable. Table A.6 contains the produce balance estimates for early and late season lettuce and spinach (equal proportions of consumption were assigned for early and late seasons).

TABLE A.1. 1945 Vegetable Production (Tons)

Plant Type	Counties							
	Adams	Asotin	Benton	Columbia	Douglas	Franklin	Garfield	Grant
Asparagus		12	5970	1584	7	60		36
Beans, Lima								
Beans, Snap								
Beets								
Broccoli								
Cabbage (Early)					28			
Cabbage (Late)								
Carrots			464					120
Cauliflower								
Celery								
Corn		13	141	406	70	13	10	35
Cucumbers								
Green Peas			90		10			330
Lettuce (Early)			75			38		
Lettuce (Late)			210			109		
Onions, Green								
Onions (Early)			396			264		
Onions (Late)			350			350		1920
Peppers, Green								
Spinach (Early)			160			70		
Spinach (Late)			240			96		
Squash/Pumpkins								
Tomatoes		120	770			150	8	
Turnips/Rutabagas			300			150		

TABLE A.1. (Contd)

Plant Type	Counties						
	<u>Kittitas</u>	<u>Klickitat</u>	<u>Lincoln</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Whitman</u>	<u>Yakima</u>
Asparagus				36	2356		7744
Beans, Lima							
Beans, Snap							
Beets							
Broccoli					40		
Cabbage (Early)		26		300	886		100
Cabbage (Late)		124		6694			
Carrots		524		504	990		6171
Cauliflower		320		132	32		
Celery		89		770	60		
Corn	15,955	16	51	1530	170	16	1238
Cucumbers		130		60			40
Green Peas				120	17		150
Lettuce (Early)		108		1140	1089		43
Lettuce (Late)		385		985	1527		100
Onions, Green							
Onions (Early)					6315		
Onions (Late)					60		11,161
Peppers, Green							
Spinach (Early)		55		170	195		130
Spinach (Late)		200		204	1716		50
Squash/Pumpkins							
Tomatoes		434		1700	150	24	6900
Turnips/Rutabagas							3500

TABLE A.2. 1951 Vegetable Production (Tons)

Plant Type	Counties						
	Adams	Asotin	Benton	Columbia	Douglas	Franklin	Grant
Asparagus			3400	1800	7	150	260
Beans, Lima							
Beans, Snap							
Beets							
Broccoli							
Cabbage (Early)							
Cabbage (Late)							
Carrots		400					
Cauliflower							
Celery							
Corn, Sweet					20		
Cucumbers							580
Green Peas			70				
Lettuce (Early)							
Lettuce (Late)							
Onions, Green							
Onions, Dry			250				9300
Peppers, Green							
Spinach (Early)							
Spinach (Late)							
Squash/Pumpkins							
Tomatoes		100	145		50		
Turnips/Rutabagas			525				

TABLE A.2. (Contd)

Plant Type	Counties						
	Kittitas	Klickitat	Lincoln	Spokane	Walla Walla	Whitman	Yakima
Asparagus		25			1950		9675
Beans, Lima							
Beans, Snap		130					
Beets							
Broccoli							
Cabbage (Early)		500		300	550		
Cabbage (Late)		50		5000			
Carrots		100		370	4800		2900
Cauliflower				250			
Celery				900			
Corn, Sweet	15,000			300	430		28,000
Cucumbers				1150			650
Green Peas		10		20	20		350
Lettuce (Early)		75		1420	1000		
Lettuce (Late)				1600	1125		
Onions, Green							
Onions, Dry					6000		7400
Peppers, Green							
Spinach (Early)		30		150	170		
Spinach (Late)		45		150	4200		
Squash/Pumpkins							
Tomatoes		180		2300	150	120	16,300
Turnips/Rutabagas							5000

TABLE A.3. 1945 Fresh Fruit Shipments by Truck

	<u>Adams</u>	<u>Asotin</u>	<u>Benton</u>	<u>Columbia</u>	<u>Douglas</u>	<u>Franklin</u>	<u>Garfield</u>	<u>Grant</u>
Apples (boxes)	0	45,486	27,930	1596	194,446	0	0	194,446
Apricots (tons)	0	0	12	0	90	0	0	0
Sweet Cherries (tons)	0	125	88	0	0	0	25	0
Grapes (tons)	0	0	60	0	0	12	0	0
Peaches (tons)	0	25	504	0	0	0	25	0
Bartlett Pears (boxes)	0	1512	2268	0	0	0	1512	0
Other Pears (boxes)	0	0	3024	0	12,348	0	0	12,348
Plums/Prunes (tons)	0	38	188	0	0	0	0	0
Other Berries (tons)	0	118	300	0	0	150	0	0
Strawberries (tons)	0	25	770	0	0	150	8	0

	<u>Kittitas</u>	<u>Klickitat</u>	<u>Lincoln</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Whitman</u>	<u>Yakima</u>	
Apples (boxes)	271,320		1596	0	19,950	37,506	0	271,320
Apricots (tons)	0	24	0	0	0	0	0	240
Sweet Cherries (tons)	0	0	0	17	0	150	0	313
Grapes (tons)	0	0	0	24	0	0	0	12
Peaches (tons)	0	466	0	38	202	1386	0	1260
Bartlett Pears (boxes)	0	0	0	6048	0	756	0	59,724
Other Pears (boxes)	0	1512	0	0	0	0	0	16,632
Plums/Prunes (tons)	0	13	0	75	13	0	0	188
Other Berries (tons)	0	0	0	910	34	0	0	3500
Strawberries (tons)	0	434	0	1700	150	24	0	6900

TABLE A.4. 1950-1951 Fresh Fruit Shipments by Truck

	<u>Adams</u>	<u>Asotin</u>	<u>Benton</u>	<u>Columbia</u>	<u>Douglas</u>	<u>Franklin</u>	<u>Garfield</u>	<u>Grant</u>
								0
Apples (boxes)	0	26,334	11,970	15,960	524,818	0	0	0
Apricots (tons)	0	0	0	0	4	0	24	8
Sweet Cherries (tons)	0	0	19	0	8	19	0	0
Grapes (tons)	0	96	96	0	0	96	0	4
Peaches (tons)	0	63	0	0	4	0	63	7056
Bartlett Pears (boxes)	0	1512	1512	0	7056	0	1512	7812
Other Pears (boxes)	0	756	1512	0	7812	0	0	8
Plums/Prunes (tons)	0	25	50	0	8	0	0	0
Other Berries (tons)	0	57	0	0	4	0	0	6
Strawberries (tons)	0	14	25	25	4	0	0	

	<u>Kittitas</u>	<u>Klickitat</u>	<u>Lincoln</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Whitman</u>	<u>Yakima</u>	
Apples (boxes)	1,594,803		0	0	47,880	31,920	0	1,594,803
Apricots (tons)		0	0	0	0	0	48	600
Sweet Cherries (tons)		0	0	0	25	0	0	138
Grapes (tons)		0	0	0	0	0	0	132
Peaches (tons)		0	0	0	0	0	76	353
Bartlett Pears (boxes)		0	0	0	3024	0	1512	128,520
Other Pears (boxes)		0	0	0	0	0	0	41,580
Plums/Prunes (tons)		0	0	0	38	0	0	425
Other Berries (tons)		0	80	0	260	38	0	0
Strawberries (tons)		0	20	0	175	380	0	120

TABLE A.5. Vegetable Acreage for Oregon Counties from the U.S. Census of Agriculture

	1945				1951			
	<u>Gilliam</u>	<u>Morrow</u>	<u>Sherman</u>	<u>Umatilla</u>	<u>Gilliam</u>	<u>Morrow</u>	<u>Sherman</u>	<u>Umatilla</u>
Asparagus						9		52
Beans, Lima								
Beans, Snap	1			42		1		21
Beets								2
Broccoli								
Cabbage (Early)								
Cabbage (Late)	1	1		20	3			11
Carrots								7
Cauliflower								
Celery								
Corn	1			63		1	1	39
Cucumbers								
Green Peas				47,542				47,916
Lettuce (Early)								
Lettuce (Late)								
Onions, Green								
Onions (Early)					1	2		11
Onions (Late)								
Peppers, Green								
Potatoes								
Spinach (Early)								
Spinach (Late)								
Squash/Pumpkins								
Tomatoes	1	1		297		1	2	260
Turnips/Rutabagas								

TABLE A.6. Produce Balance

	1945									
	<u>Adams</u>	<u>Asotin</u>	<u>Benton</u>	<u>Columbia</u>	<u>Douglas</u>	<u>Franklin</u>	<u>Garfield</u>	<u>Grant</u>	<u>Kittitas</u>	
Population	6400	9100	30,300	4900	8400	9800	3200	12,000	20,300	
<u>Production (tons)</u>										
Lettuce (Early)	0.0	0.0	75.0	0.0	0.0	38.0	0.0	0.0	0.0	
Lettuce (Late)	0.0	0.0	210.0	0.0	0.0	109.0	0.0	0.0	0.0	
Spinach (Early)	0.0	0.0	160.0	0.0	0.0	70.0	0.0	0.0	0.0	
Spinach (Late)	0.0	0.0	240.0	0.0	0.0	96.0	0.0	0.0	0.0	
<u>Annual Consumption (tons)</u>										
Lettuce	54.1	76.9	256.0	41.4	71.0	82.8	27.0	101.4	171.5	
Spinach	7.4	10.5	34.8	5.6	9.7	11.3	3.7	13.8	23.3	
<u>Produce Balance (tons)</u>										
Early Season										
Lettuce	-27.0	-38.4	-53.0	-20.7	-35.5	-3.4	-13.5	-50.7	-85.8	
Spinach	-3.7	-5.2	142.6	-2.8	-4.8	64.4	-1.8	-6.9	-11.7	
Late Season										
Lettuce	-27.0	-38.4	82.0	-20.7	-35.5	67.6	-13.5	-50.7	-85.8	
Spinach	-3.7	-5.2	222.6	-2.8	-4.8	90.4	-1.8	-6.9	-11.7	
	<u>Klickitat</u>	<u>Lincoln</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Whitman</u>	<u>Yakima</u>	<u>Gilliam</u>	<u>Morrow</u>	<u>Sherman</u>	<u>Umatilla</u>
Population	11,200	10,300	201,500	35,500	26,500	112,100	2200	4000	1700	29,700
<u>Production (tons)</u>										
Lettuce (Early)	108.0	0.0	1140.0	1089.0	0.0	43.0	0.0	0.0	0.0	0.0
Lettuce (Late)	385.0	0.0	985.0	1527.0	0.0	100.0	0.0	0.0	0.0	0.0
Spinach (Early)	55.0	0.0	170.0	195.0	0.0	130.0	0.0	0.0	0.0	0.0
Spinach (Late)	200.0	0.0	204.0	1716.0	0.0	50.0	0.0	0.0	0.0	0.0
<u>Annual Consumption (tons)</u>										
Lettuce	94.6	87.0	1702.7	300.0	223.9	947.2	18.6	33.8	14.4	251.0
Spinach	12.9	11.8	231.7	40.8	30.5	128.9	2.5	4.6	2.0	34.2
<u>Produce Balance (tons)</u>										
Early Season										
Lettuce	60.7	-43.5	288.7	939.0	-112.0	-430.6	-9.3	-16.9	-7.2	-125.5
Spinach	48.6	-5.9	54.1	174.6	-15.2	65.5	-1.3	-2.3	-1.0	-17.1
Late Season										
Lettuce	337.7	-43.5	133.7	1377.0	-112.0	-373.6	-9.3	-16.9	-7.2	-125.5
Spinach	193.6	-5.9	88.1	1695.6	-15.2	-14.5	-1.3	-2.3	-1.0	-17.1

TABLE A.6. (Contd)

	1951									
	Adams	Asotin	Benton	Columbia	Douglas	Franklin	Garfield	Grant	Kittitas	
Population	6500	11,200	58,300	4400	11,500	14,800	3000	26,700	20,700	
<u>Production (tons)</u>										
Lettuce (Early)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lettuce (Late)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Early)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Late)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<u>Annual Consumption (tons)</u>										
Lettuce	58.5	100.8	524.7	39.6	103.5	133.2	27.0	240.3	186.3	
Spinach	5.2	9.0	46.6	3.5	9.2	11.8	2.4	21.4	16.6	
<u>Produce Balance (tons)</u>										
Early Season										
Lettuce	-29.3	-50.4	-262.4	-19.8	-51.8	-66.6	-13.5	-120.2	-93.2	
Spinach	-2.6	-4.5	-23.3	-1.8	-4.6	-5.9	-1.2	-10.7	-8.3	
Late Season										
Lettuce	-29.3	-50.4	-262.4	-19.8	-51.8	-66.6	-13.5	-120.2	-93.2	
Spinach	-2.6	-4.5	-23.3	-1.8	-4.6	-5.9	-1.2	-10.7	-8.3	
Klickitat										
Population	12,000	10,400	229,000	40,000	31,500	134,400	3100	4800	2200	43,300
<u>Production (tons)</u>										
Lettuce (Early)	75.0	0.0	1420.0	1000.0	0.0	0.0	0.0	0.0	0.0	0.0
Lettuce (Late)	0.0	0.0	1600.0	1125.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Early)	30.0	0.0	150.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Late)	45.0	0.0	150.0	4200.0	0.0	0.0	0.0	0.0	0.0	0.0
<u>Annual Consumption (tons)</u>										
Lettuce	108.0	93.6	2061.0	360.0	283.5	1209.6	27.9	43.2	19.8	389.7
Spinach	9.6	8.3	183.2	32.0	25.2	107.5	2.5	3.8	1.8	34.6
<u>Produce Balance (tons)</u>										
Early Season										
Lettuce	21.0	-46.8	389.5	820.0	-141.8	-604.8	-14.0	-21.6	-9.9	-194.9
Spinach	25.2	-4.2	58.4	154.0	-12.6	-53.8	-1.2	-1.9	-0.9	-17.3
Late Season										
Lettuce	-54.0	-46.8	569.5	945.0	-141.8	-604.8	-14.0	-21.6	-9.9	-194.9
Spinach	40.2	-4.2	58.4	4184.0	-12.6	-53.8	-1.2	-1.9	-0.9	-17.3
Umatilla										
Population	12,000	10,400	229,000	40,000	31,500	134,400	3100	4800	2200	43,300
<u>Production (tons)</u>										
Lettuce (Early)	75.0	0.0	1420.0	1000.0	0.0	0.0	0.0	0.0	0.0	0.0
Lettuce (Late)	0.0	0.0	1600.0	1125.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Early)	30.0	0.0	150.0	170.0	0.0	0.0	0.0	0.0	0.0	0.0
Spinach (Late)	45.0	0.0	150.0	4200.0	0.0	0.0	0.0	0.0	0.0	0.0
<u>Annual Consumption (tons)</u>										
Lettuce	108.0	93.6	2061.0	360.0	283.5	1209.6	27.9	43.2	19.8	389.7
Spinach	9.6	8.3	183.2	32.0	25.2	107.5	2.5	3.8	1.8	34.6
<u>Produce Balance (tons)</u>										
Early Season										
Lettuce	21.0	-46.8	389.5	820.0	-141.8	-604.8	-14.0	-21.6	-9.9	-194.9
Spinach	25.2	-4.2	58.4	154.0	-12.6	-53.8	-1.2	-1.9	-0.9	-17.3
Late Season										
Lettuce	-54.0	-46.8	569.5	945.0	-141.8	-604.8	-14.0	-21.6	-9.9	-194.9
Spinach	40.2	-4.2	58.4	4184.0	-12.6	-53.8	-1.2	-1.9	-0.9	-17.3

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APPENDIX B

DETERMINATION OF RADIONUCLIDE CONCENTRATION IN PRODUCE AND
THE RELATIVE IMPORTANCE OF DIFFERENT PRODUCE CATEGORIES

APPENDIX B

DETERMINATION OF RADIONUCLIDE CONCENTRATION IN PRODUCE AND THE RELATIVE IMPORTANCE OF DIFFERENT PRODUCE CATEGORIES

One of the potential exposure pathways to humans is the ingestion of produce that has been contaminated by deposition of airborne radionuclides. Different types of produce may be contaminated to different extents because of morphological differences in the plants and variations in produce storage times and food preparation.

The HEDR modeling effort includes four broad categories of produce: leafy vegetables, all other vegetables and berries, tree fruit, and grain. The purpose of this appendix is to show the major parameters (factors) used in calculating dose from eating produce and to discuss the reasons why some produce categories are more important contributors to ingestion dose than others.

DOSE FROM PRODUCE CONSUMPTION

Several factors determine the dose received from ingestion of produce. These factors are the concentration of radionuclide in the produce, how much produce is consumed, and the radionuclide-specific ingestion dose factor. A simple equation shows how dose is determined:

$$D = \text{Consumption} \cdot \text{Concentration} \cdot \text{Dose Factor} \quad (1)$$

All of these factors are directly proportional to the dose received, that is, the dose varies directly as each of these parameters varies. For example, if consumption increases by a factor of two, so will the dose received, as long as the other factors remain constant. Similarly, a decrease in consumption results in a decrease in the dose received.

Produce Consumption

Produce consumption, which may also be called the ingestion rate, is specific to different individuals, or categories of individuals, and may vary greatly between individuals of different ages, lifestyles, and locations. Because of these differences, the determination of representative consumption rates is an important consideration in the HEDR Project. Section 6.0 of this report examines the probable ingestion doses from the consumption of different types of produce by representative individuals.

Dose Factor

The dose factor is determined using basic biological research and metabolic and physiological modeling, typically sponsored by scientific organizations such as the International Commission on Radiological Protection (ICRP). Dose factors are specific to a particular radionuclide and are assumed to apply across a range of metabolically similar individuals. For example, one dose factor for iodine-131 is assumed to apply to male and female adults, while a different dose factor is applied to infants. Established dose factors are used in the HEDR Project and applied uniformly to the ingestion of all plant types.

Produce Concentration

Produce concentration is another parameter that can vary widely depending on the type of plant, location, storage, and consumption, and is important to the HEDR Project. How concentration is determined for different produce categories is discussed in greater detail below, using simplified models that highlight the major processes and parameters of importance.

DETERMINING RADIONUCLIDE CONCENTRATION IN PRODUCE

Concentration is initially dependent on the amount of material deposited over a given area, such as a square meter (m^2). Because all types of plants in the same general area are likely to be exposed to the same deposition, this is not a factor in the different concentrations that may be found in different plant types.

The total concentration in a plant is the sum of the concentration from deposition on the above-ground parts (typically leaves and/or fruit) and the uptake through the roots:

$$C_{\text{total}} = C_{\text{leaves}} + C_{\text{roots}} \quad (2)$$

Concentration from root uptake is a function of the radionuclide deposition rate (dr), the soil density (ρ), the plant-to-soil concentration ratio (CR), and the build-up of radioactive material in the soil:

$$C_{\text{roots}} = \frac{dr}{\rho} \cdot CR \cdot \left(\frac{1 - e^{-\lambda_r t}}{\lambda} \right) \quad (3)$$

For a relatively short-lived radionuclide like iodine-131, which has a radioactive half-life of 8.05 days, the nuclide decays to the stable element before it reaches the soil root zone; therefore, the radionuclide uptake by roots from the soil is negligible, and the radionuclide concentration from root uptake is essentially zero and not considered further in this discussion.

Radionuclide concentration in the leaves and edible portions of the plant is determined differently, as a function of the same radionuclide deposition rate (dr), but using the fraction of deposited material that the plant intercepts (r), the above-ground biomass of the plant (B), the translocation from plant surface to inner tissue (T), and the build-up of radioactivity considering losses from radioactive decay (λ_r) and weathering (λ_w):

$$C_{\text{leaves}} = \frac{dr \cdot r \cdot T}{B} \cdot \left(\frac{1 - e^{-(\lambda_r + \lambda_w)t}}{\lambda_r + \lambda_w} \right) \quad (4)$$

The concentration in produce at the time it is consumed is a function of how long the produce has been stored (t_{hp}) and whether food preparation (W) may remove radionuclides:

$$C_{\text{consumption}} = C_{\text{total}} \cdot (1 - W) \cdot e^{-\lambda_r t_{hp}} \quad (5)$$

DETERMINING THE RELATIVE IMPORTANCE OF DIFFERENT PRODUCE CATEGORIES

The four categories of produce included in the HEDR environmental pathway and dose modeling effort (leafy vegetables, other vegetables and berries, tree fruit, and grain) can be defined by five major crop-dependent parameters: biomass, interception fraction, translocation factor, food processing loss, and holdup time. These five parameters can be used to compare the relative importance of the four produce categories.

Parameter Descriptions

Biomass. Biomass (B) is the mass of plant matter produced in a given area of land, in units of kg/m^2 (dry). Dry biomass (water removed) values are given to allow different types of plants, which may have significantly different water content, to be compared on the same basis. Biomass typically includes the leaves and edible, non-woody portions of the plant, but does not include inedible woody parts such as the tree trunk and branches. Biomass is used 1) in calculating the interception fraction, which is proportional to the biomass, and 2) for determining plant radionuclide concentration; the radionuclide content of the plant is divided by the biomass. Thus, as biomass increases it increases the interception fraction and the total quantity of radionuclide on the plant, but decreases the overall concentration of radionuclide in the plant, resulting in lower doses for higher biomass values.

Interception Fraction. The interception fraction (r) is that fraction of the total radionuclide deposition that is intercepted by the plant, with the remaining fraction ($1-r$) falling on the soil surface. The interception fraction is calculated using the plant dry biomass (B) and an empirically determined/observed interception parameter (α) using the following equation:

$$r = 1 - e^{\alpha B} \quad (6)$$

This equation and its origination are discussed in greater detail by Napier et al. (1992, p. 3.13-3.15).

Translocation Factor. The translocation factor (T) represents the portion of the radionuclide deposited on the plant surface that is moved into the inner tissues of the plant or is made unremovable and indistinguishable from radionuclides in the inner tissue. Translocation may take place via root uptake to the edible portions of the plant, but as previously mentioned, root uptake is considered negligible for iodine-131.

Food Processing Loss Factor. The food processing loss factor (W) is the removal of radionuclides from some types of produce when prepared for consumption. Typically, this is loss of material from the plant surface. Food preparation loss is considered important for leafy vegetables, somewhat important for tree fruit, and unimportant for other vegetables and grains.

Holdup Time. The holdup time, t_{hp} , is the length of time a particular type of produce is stored prior to its consumption. The holdup time is not explicitly considered in this evaluation because it can vary greatly; however, for qualitative analysis it is considered, on average, to be short (< 1 week) for leafy vegetables; medium (1 - 4 weeks) for other vegetables, long (4 - 12 weeks) for tree fruit, and very long (> 12 weeks) for grains.

Evaluation of Relative Importance

The relationship of the various factors to one another in determining the concentration of radionuclides in produce is shown in Equation 7. This equation shows the relative importance of each produce category, based on plant concentration, from a unit deposition of radionuclide. Without considering holdup time, this evaluation can be applied to other radionuclides for which holdup time is less important than it is for iodine-131.

$$C \propto \frac{r \cdot T \cdot (1 - W)}{B} \quad (7)$$

The values of the various parameters for each produce category are shown in Table B.1. These values are calculated from values in the Phase I parameters report (Shindle et al. 1992) for dry biomass (pp. 2.4-2.5), and interception fraction (pp. 2.4-2.7), and taken directly from the report for translocation (pp. 2.9-2.10). Food processing loss was not considered in the Phase I conceptual model (Napier 1991, p. A.1-A.8), but is included in the revised conceptual model (Ikenberry et al. 1992, p. 2.31).

The results of this evaluation are shown in Table B.2. Leafy vegetables are the most important produce category, accounting for 83% of the normalized radionuclide concentration of all produce consumed. The contributions from grain, all other vegetables, and tree fruit are 9%, 6%, and 1%, respectively.

TABLE B.1. Parameter Values for Each Produce Category

<u>Calculation Parameters</u>		<u>Produce Categories</u>			
		<u>Leafy Vegetables</u>	<u>Other Vegetables</u>	<u>Grain</u>	<u>Tree Fruit</u>
Biomass (dry)	B	0.2	0.5	0.14	0.54
Interception	r	0.4	0.8	0.3	0.9
Translocation	T	1	0.05	0.05	0.05
Food Preparation	W	0.5	0	0	0.2
Holdup Time	t_{hp}	Short	Medium	Very Long	Long

TABLE B.2. Results of Calculated Relative Importance Evaluation Without Considering Holdup Time

		<u>Produce Categories</u>			
		<u>Leafy Vegetables</u>	<u>Other Vegetables</u>	<u>Grain</u>	<u>Tree Fruit</u>
Relative Concentration		1.1	0.08	0.12	0.015
Percent of Total Contribution		83%	6%	9%	1%

Importance of Holdup Time and Consumption of Fresh and Stored Produce

While leafy vegetables are shown to be the most important produce category, this evaluation in fact underestimates the importance of leafy vegetables and overestimates the importance of other produce (particularly grain) because holdup time and consumption of stored produce are not considered during those periods when fresh produce is unavailable. The evaluation was expanded to include a specific radionuclide, iodine-131, and quantitative assumptions of average holdup times based on the qualitative holdup time described above. This expanded evaluation presents a more realistic picture of the relative importance of produce categories for iodine-131.

The assumption was that leafy vegetables were consumed almost entirely fresh, with an average holdup time of 4 days. Although other vegetables are often consumed fresh, many are also canned, or dried, and stored for extended periods of time. An average holdup time of 21 days was assumed for other vegetables. Similarly, tree fruit are often consumed fresh, but many are suitable for extended storage. An average holdup time of 60 days was assumed for tree fruit. Grain is rarely consumed fresh and is stored for long periods of time, principally as wheat flour. An average holdup time of 120 days was assumed for grain.

Table B.3 shows the importance of holdup or storage times for a short-lived radionuclide such as iodine-131, which has a half-life of 8 days. Produce stored for 8 days before consumption will have one-half the iodine-131

TABLE B.3. Relative Importance of Holdup Times of Produce Categories for Iodine-131

	<u>Produce Categories</u>			
	<u>Leafy Vegetables</u>	<u>Other Vegetables</u>	<u>Grain</u>	<u>Tree Fruit</u>
Holdup time, days	4	21	120	60
Relative Concentration	0.78	0.013	0.00003	0.006
Percent of Total Contribution	98.4%	1.6%	0.0005%	0.05%

concentration of produce consumed immediately after harvest. Storage has relatively little effect on the concentration in leafy vegetables, which are essentially harvested continuously during the season and are mainly consumed fresh. However, storage has a major effect on grains, which are harvested only once per year and mainly consumed after an extended storage period.

Therefore, for iodine-131, a radionuclide with a short half-life, leafy vegetables are far more important contributors to dose from produce ingestion than are all other produce categories combined. If no leafy vegetables are consumed, the contribution from the other produce categories is so low that dose from the entire produce ingestion pathway becomes unimportant.

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APPENDIX C

DISTRIBUTION DATA

APPENDIX C

DISTRIBUTION DATA

The distribution patterns and market share distributions developed for this scoping study are not definitive estimates, but represent the likely flow of commercial lettuce and spinach from the locations of production to local fresh markets. This distribution information is input to screening dose calculations to determine the potential importance of fresh lettuce and spinach distribution systems to dose. The tables presented in this appendix contain distributions of market share for early and late season lettuce and spinach. The following is a discussion of how these distribution patterns were developed.

Initial distribution estimates were derived by Battelle HEDR staff from secondary data sources using a set of basic assumptions:

1. The fresh fruit and vegetable markets were located at county population centers (county seats).
2. Distribution patterns were derived from secondary information when available, when unavailable, county populations were allocated fresh market lettuce and spinach from the closest surplus county.
3. Deficit counties did not ship lettuce and spinach outside the county.
4. Annual farm level consumption estimates were divided proportionally between early and late seasons; for example, early season lettuce (8.45 lbs per capita) and late season lettuce (8.45 lbs per capita).

The 1945 early season fresh lettuce distribution pattern derived from secondary sources is presented as an example in Table C.1. The counties that produced commercial lettuce are listed across and the consumption counties are in the left-hand column. For example, estimated consumption in Benton County was 128 tons (right-hand column); 75 tons came from within Benton County and 53 tons from Walla Walla County.

Dr. Albert H. Harrington reviewed the distribution patterns and confirmed the allocation of market shares, derived from secondary information, for 14 of the 19 counties. Dr. Harrington then provided information for

TABLE C.1. Example of Derived Distribution Pattern

1945 Early Season Lettuce Distribution Pattern

Consumer	Production by County (Tons)						Total Consumption	Population
	Benton	Franklin	Klickitat	Spokane	Walla Walla	Yakima		
	75	38	108	1140	1089	43		
	Consumption (Tons)							
Adams	0	0	0	27	0	0	27	6400
Asotin	0	0	0	0	38.4	0	38.4	9100
Benton	75	0	0	0	53	0	128	30,300
Columbia	0	0	0	0	20.7	0	20.7	4900
Douglas	0	0	0	35.5	0	0	35.5	8400
Franklin	0	38	0	0	3.4	0	41.4	9800
Garfield	0	0	0	0	13.5	0	13.5	3200
Grant	0	0	0	50.7	0	0	50.7	12,000
Kittitas	0	0	0	0	85.8	0	85.8	20,300
Klickitat	0	0	47.3	0	0	0	47.3	11,200
Lincoln	0	0	0	43.5	0	0	43.5	10,300
Spokane	0	0	0	851.3	0	0	851.3	201,500
Walla Walla	0	0	0	0	150	0	150	35,500
Whitman	0	0	0	112	0	0	112	26,500
Yakima	0	0	0	0	430.6	43	473.6	1,112,100
Gilliam	0	0	9.3	0	0	0	9.3	2200
Morrow	0	0	0	0	16.9	0	16.9	4000
Sherman	0	0	7.2	0	0	0	7.2	1700
Umatilla	0	0	0	0	125.5	0	125.5	29,700
Consumption	75	38	63.89	1120	937.80	43		
Production	75	38	108	1140	1089	43		
Difference	0	0	44.11	20	151.2	0		

refining the distribution of market shares for Benton, Douglas, Franklin, Kittitas, and Yakima counties. He confirmed that Walla Walla County would ship to Benton and Franklin counties, and that Richland, Kennewick, and Pasco consumers would likely have received market shares consisting of equal portions of lettuce, because those cities are only short distances apart (see Table C.2). Dr. Harrington also noted that Douglas and Kittitas counties were located far from any of the surplus counties within the HEDR study area.

**TABLE C.2. 1945 Early/Late Season Lettuce
(Fraction of Market Share)**

Consumer	Producer							Total
	Benton	Franklin	Klickitat	Spokane	Walla Walla	Yakima	Other ^(a)	
Adams	0	0	0	1.00	0	0	0	1.00
Asotin	0	0	0	0	1.00	0	0	1.00
Benton	0.30	0.30	0	0	0.40	0	0	1.00
Columbia	0	0	0	0	1.00	0	0	1.00
Douglas	0	0	0	0	0	0	1.00	1.00
Franklin	0.45	0.45	0	0	0.10	0	0	1.00
Garfield	0	0	0	0	1.00	0	0	1.00
Grant	0	0	0	1.00	0	0	0	1.00
Kittitas	0	0	0	0	0	0	1.00	1.00
Klickitat	0	0	1.00	0	0	0	0	1.00
Lincoln	0	0	0	1.00	0	0	0	1.00
Spokane	0	0	0	1.00	0	0	0	1.00
Walla Walla	0	0	0	0	1.00	0	0	1.00
Whitman	0	0	0	1.00	0	0	0	1.00
Yakima	0	0	0	0	0	0.10	0.90	1.00
Gilliam	0	0	1.00	0	0	0	0	1.00
Morrow	0	0	0	0	1.00	0	0	1.00
Sherman	0	0	1.00	0	0	0	0	1.00
Umatilla	0	0	0	0	1.00	0	0	1.00

(a) Counties outside the HEDR study area.

Because of distance and restrictions on available gasoline and tires during World War II, consumers in Douglas County probably did not receive vegetable shipments from Spokane until 1951. It is likely that Yakima and Kittitas counties also did not receive fresh produce from other counties in the HEDR study area during 1945 and 1951.

This process for developing distribution patterns was completed for early and late season lettuce and spinach for 1945 and 1951. The distribution estimates in the remainder of this appendix (Tables C.3 - C.6), converted to fractions of market share, are "best estimates" incorporating both secondary information and the expert judgment provided by Dr. Harrington.

**TABLE C.3. 1951 Early Season Lettuce
(Fraction of Market Share)**

<u>Consumer</u>	<u>Producer</u>				<u>Total</u>
	<u>Klickitat</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Other^(a)</u>	
Adams	0	1	0	0	1
Asotin	0	0	1	0	1
Benton	0	0	1	0	1
Columbia	0	0	1	0	1
Douglas	0	1	0	0	1
Franklin	0	0	1	0	1
Garfield	0	0	1	0	1
Grant	0	1	0	0	1
Kittitas	0	0	0	1	1
Klickitat	1	0	0	0	1
Lincoln	0	1	0	0	1
Spokane	0	1	0	0	1
Walla Walla	0	0	1	0	1
Whitman	0	1	0	0	1
Yakima	0	0	1	0	1
Gilliam	1	0	0	0	1
Morrow	0	0	1	0	1
Sherman	1	0	0	0	1
Umatilla	0	0	1	0	1

(a) Counties outside the HEDR study area.

TABLE C.4. 1951 Late Season Lettuce
(Fraction of Market Share)

<u>Consumer</u>	<u>Producer</u>			<u>Total</u>
	<u>Spokane</u>	<u>Walla Walla</u>	<u>Other^(a)</u>	
Adams	1	0	0	1
Asotin	0	1	0	1
Benton	0	1	0	1
Columbia	0	1	0	1
Douglas	1	0	0	1
Franklin	0	1	0	1
Garfield	0	1	0	1
Grant	1	0	0	1
Kittitas	0	0	1	1
Klickitat	0	0	1	1
Lincoln	1	0	0	1
Spokane	1	0	0	1
Walla Walla	0	1	0	1
Whitman	1	0	0	1
Yakima	0	1	0	1
Gilliam	0	0	1	1
Morrow	0	1	0	1
Sherman	0	0	1	1
Umatilla	0	1	0	1

(a) Counties outside the HEDR study area.

**TABLE C.5. 1945 Early/Late Season Spinach
(Fraction of Market Share)**

Consumer	Producer							Total
	Benton	Franklin	Klickitat	Spokane	Walla Walla	Yakima	Other ^(a)	
Adams	0	0	0	1.0	0	0	0	1.00
Asotin	0	0	0	0	1.00	0	0	1.00
Benton	0.50	0.50	0	0	0	0	0	1.00
Columbia	0	0	0	0	1.00	0	0	1.00
Douglas	0	0	0	0	0	0	1.00	1.00
Franklin	0.50	0.50	0	0	0	0	0	1.00
Garfield	0	0	0	0	1.00	0	0	1.00
Grant	0	0	0	1.00	0	0	0	1.00
Kittitas	0	0	0	0	0	0	1.00	1.00
Klickitat	0	0	1.00	0	0	0	0	1.00
Lincoln	0	0	0	1.00	0	0	0	1.00
Spokane	0	0	0	1.00	0	0	0	1.00
Walla Walla	0	0	0	0	1.00	0	0	1.00
Whitman	0	0	0	1.00	0	0	0	1.00
Yakima	0.50	0	0	0	0	0.50	0	1.00
Gilliam	0	0	1.00	0	0	0	0	1.00
Morrow	0	0	0	0	1.00	0	0	1.00
Sherman	0	0	1.00	0	0	0	0	1.00
Umatilla	0	0	0	0	1.00	0	0	1.00

(a) Counties outside the HEDR study area.

TABLE C.6. 1951 Early/Late Season Spinach
(Fraction of Market Share)

<u>Consumer</u>	<u>Producer</u>				<u>Total</u>
	<u>Klickitat</u>	<u>Spokane</u>	<u>Walla Walla</u>	<u>Other^(a)</u>	
Adams	0	1	0	0	1
Asotin	0	0	1	0	1
Benton	0	0	1	0	1
Columbia	0	0	1	0	1
Douglas	0	1	0	0	1
Franklin	0	0	1	0	1
Garfield	0	0	1	0	1
Grant	0	1	0	0	1
Kittitas	0	0	0	1	1
Klickitat	1	0	0	0	1
Lincoln	0	1	0	0	1
Spokane	0	1	0	0	1
Walla Walla	0	0	1	0	1
Whitman	0	1	0	0	1
Yakima	0	0	1	0	1
Gilliam	1	0	0	0	1
Morrow	0	0	1	0	1
Sherman	1	0	0	0	1
Umatilla	0	0	1	0	1

(a) Counties outside the HEDR study area.

APPENDIX D

IMPORTANCE RANKING OF COMMERCIALY PRODUCED FRESH FRUITS AND VEGETABLES

APPENDIX D

IMPORTANCE RANKING OF COMMERCIALY PRODUCED FRESH FRUITS AND VEGETABLES

The pathway importance ranking of commercially produced fresh fruits and vegetables for adult males (20-34 years) and infants (1-4 years) is shown in Tables D.1 and D.2. The input data used in the pathway ranking and in dose calculations (growing seasons, harvest periods, food consumption rates, and fraction regionally produced) are presented in Tables D.3 - D.7.

The intake of iodine-131 resulting from the consumption of each fresh fruit and vegetable is calculated using equation 1. The intakes (Ci/yr) are based on a unit iodine-131 deposition rate of 1 Ci/m²-s.

$$\text{Intake} = \frac{\text{dr} \cdot 86400 \cdot T \cdot C \cdot f_{\text{pr}} \cdot f_d (1 - e^{-\alpha B}) (1 - e^{-(\lambda_r + \lambda_w)t_g}) (e^{-\lambda_r t_{\text{hp}}}) (1 - W)}{B (\lambda_r + \lambda_w)}$$

where dr = iodine-131 deposition rate (1 Ci/m²-s)

86400 = conversion factor (s/d)

T = tranlocation of radioiodine from the plant surface to inner tissue (unitless)

C = consumption rate for each fruit or vegetable (kg[wet]/yr)

f_{pr} = fraction of produce that is produced in the region (unitless)

f_d = plant dry-weight to wet-weight ratio (unitless)

α = foliar interception constant (m²/kg(dry))

B = above-ground biomass of the plant (kg[dry])

λ_r = radiological decay constant (1/d)

λ_w = plant weathering decay (1/d)

t_g = plant growing period (d)

t_{hp} = plant holdup time from harvest to consumption (d)

W = washing removal fraction (unitless)

**TABLE D.1.1. Importance Ranking of Commercially Produced Fresh Fruits and Vegetables
(Adult Male 20 - 34 years)**

Rank	Plant Type	Trans- location (fraction)	Dry Biomass (kg/m ²)	Dry to Wet Ratio (fraction)	Growing Period (day)	Holdup Time (day)	Washing Removal (fraction)	Human Con- sumption (kg/yr)	Fraction Regionally Produced	Intake (Ci/yr per m ² -s)	Percent of Total	Cumu- lative Percent
1	Lettuce	1	0.2	0.05	60	4	0.5	3.462	1	8.60E+04	38.80%	39%
2	Spinach	1	0.2	0.09	60	4	0.5	1.86	1	8.30E+04	37.50%	76%
3	Corn, Sweet	0.05	0.3	0.2	90	7	0	1.853	1	1.30E+04	5.60%	82%
4	Peas, Green	0.05	0.2	0.25	90	7	0.2	0.926	1	7.10E+03	3.20%	85%
5	Apples	0.05	0.5	0.18	90	14	0.2	2.79	1	5.90E+03	2.60%	88%
6	Cabbage	0.05	0.2	0.09	90	14	0.2	3.221	1	4.90E+03	2.20%	90%
7	Carrots	0.05	0.2	0.16	90	14	0	1.242	1	4.20E+03	1.90%	92%
8	Melons	0.05	0.5	0.2	90	14	0	2.53	0.5	3.70E+03	1.70%	94%
9	Tomatoes	0.05	0.5	0.06	90	7	0	1.723	1	2.80E+03	1.20%	95%
10	Beans, Snap	0.2	0.2	0.25	80	7	0	0.465	0.1	1.80E+03	0.80%	96%
11	Peaches	0.05	0.5	0.12	90	7	0.2	0.613	1	1.60E+03	0.70%	96%
12	Onions	0.05	0.2	0.12	120	14	0	0.469	1	1.20E+03	0.50%	97%
13	Broccoli	1	0.5	0.11	120	7	0.5	0.251	0.16	1.20E+03	0.50%	97%
14	Asparagus	1	0.1	0.08	2	7	0.5	0.125	1	1.00E+03	0.50%	98%
15	Pears	0.05	0.5	0.16	90	14	0.2	0.556	1	1.00E+03	0.50%	98%
16	Apricots	0.05	0.5	0.14	90	7	0.2	0.239	1	7.20E+02	0.30%	99%
17	Sweet Cherries	0.05	0.5	0.17	90	7	0.2	0.189	1	6.90E+02	0.30%	99%
18	Cauliflower	1	0.5	0.09	120	7	0.5	0.038	0.51	4.70E+02	0.20%	99%
19	Other Berries	0.05	0.3	0.13	30	7	0	0.096	1	4.20E+02	0.20%	99%
20	Celery	1	0.5	0.1	150	14	0.5	0.056	0.42	3.40E+02	0.20%	100%
21	Onions, Green	1	0.2	0.12	30	7	0.5	0.062	0.1	2.80E+02	0.10%	100%
22	Beans, Lima	0.05	0.3	0.85	90	14	0	0.141	0.1	2.20E+02	0.10%	100%
23	Turnips/Rutabagas	0.05	0.2	0.11	60	14	0	0.081	1	1.90E+02	0.10%	100%
24	Strawberries	0.05	0.3	0.08	30	7	0	0.06	1	1.60E+02	0.10%	100%
25	Beets	0.05	0.2	0.13	90	14	0	0.533	0.1	1.50E+02	0.10%	100%
26	Squash/Pumpkins	0.05	0.5	0.2	120	14	0	0.081	0.1	2.40E+01	0.00%	100%
27	Grapes	0.05	0.5	0.07	90	7	0	0.012	1	2.30E+01	0.00%	100%
28	Cucumbers	0.05	0.5	0.04	60	14	0	0.078	0.36	1.60E+01	0.00%	100%
29	Plums	0.05	0.5	0.15	90	7	0.2	0.003	1	8.00E+00	0.00%	100%
30	Peppers, Green	0.05	0.3	0.2	150	7	0	0.006	0.1	3.90E+00	0.00%	100%

**TABLE D.2. Importance Ranking of Commercially Produced Fresh Fruits and Vegetables
(Average Child 1 - 4 years)**

Rank	Plant Type	Trans- location (fraction)	Dry Biomass (kg/m ²)	Dry to Wet Ratio (fraction)	Growing Period (day)	Holdup Time (day)	Washing Removal (fraction)	Human Con- sumption (kg/yr)	Fraction Regionally Produced	Intake Ci/yr per Ci/m ² -s	Percent of Total	Cumu- lative Percent
1	Spinach	11	0.2	0.09	60	4	0.5	0.814	1	3.60E+04	50.30%	50%
2	Lettuce	11	0.2	0.05	60	4	0.5	0.424	1	1.10E+04	14.60%	65%
3	Apples	10.05	0.5	0.18	90	14	0.2	2.717	1	5.70E+03	7.90%	73%
4	Corn, Sweet	10.05	0.3	0.2	90	7	0	0.763	1	5.20E+03	7.10%	80%
5	Carrots	10.05	0.2	0.16	90	14	0	0.871	1	2.90E+03	4.00%	84%
6	Peas, Green	10.05	0.2	0.25	90	7	0.2	0.303	1	2.30E+03	3.20%	87%
7	Melons	10.05	0.5	0.2	90	14	0	1.326	0.5	1.90E+03	2.70%	90%
8	Cabbage	10.05	0.2	0.09	90	14	0.2	0.775	1	1.20E+03	1.60%	91%
9	Peaches	10.05	0.5	0.12	90	7	0.2	0.377	1	9.70E+02	1.30%	93%
10	Pears	10.05	0.5	0.16	90	14	0.2	0.487	1	9.10E+02	1.30%	94%
11	Beans, Snap	10.2	0.2	0.25	80	7	0	0.18	0.1	6.90E+02	1.00%	95%
12	Celery	11	0.5	0.1	150	14	0.5	0.106	0.42	6.50E+02	0.90%	96%
13	Tomatoes	10.05	0.5	0.06	90	7	0	0.314	1	5.00E+02	0.70%	97%
14	Broccoli	11	0.5	0.11	120	7	0.5	0.094	0.16	4.40E+02	0.60%	97%
15	Asparagus	10.05	0.1	0.08	2	7	0.5	0.053	1	4.40E+02	0.60%	98%
16	Apricots	10.05	0.5	0.14	90	7	0.2	0.137	1	4.10E+02	0.60%	98%
17	Sweet Cherries	10.05	0.3	0.17	90	7	0.2	0.048	1	1.80E+02	0.20%	99%
18	Beans, Lima	10.05	0.3	0.85	90	14	0	0.11	0.1	1.70E+02	0.20%	99%
19	Other Berries	10.05	0.3	0.13	30	7	0	0.039	1	1.70E+02	0.20%	99%
20	Turnips/Rutabagas	10.05	0.2	0.11	60	14	0	0.057	1	1.30E+02	0.20%	99%
21	Onions	10.05	0.2	0.12	120	14	0	0.044	1	1.10E+02	0.20%	99%
22	Cauliflower	11	0.5	0.09	120	7	0.5	0.008	0.51	9.80E+01	0.10%	100%
23	Onions, Green	11	0.2	0.12	30	7	0.5	0.017	0.1	7.50E+01	0.10%	100%
24	Strawberries	10.05	0.3	0.08	30	7	0	0.028	1	7.50E+01	0.10%	100%
25	Plums	10.05	0.5	0.15	90	7	0.2	0.022	1	7.10E+01	0.10%	100%
26	Beets	10.05	0.2	0.13	90	14	0	0.248	0.1	6.80E+01	0.10%	100%
27	Squash/Pumpkins	10.05	0.5	0.2	120	14	0	0.045	0.1	1.30E+01	0.00%	100%
28	Grapes	10.05	0.5	0.07	90	7	0	0.004	1	7.10E+00	0.00%	100%
29	Cucumbers	10.05	0.5	0.04	60	14	0	0.031	0.36	6.50E+00	0.00%	100%
30	Peppers, Green	10.05	0.3	0.2	150	7	0	0	0.1	2.60E-01	0.00%	100%

TABLE D.3. Estimates of Growing Seasons and Harvest Periods

	Average Growing Season (days)	Reference	Average Harvest Period (HP) (days)	Reference
Asparagus	2	Dr. Albert H. Harrington	60	USDA 1977, p. 3
Beans, Lima	90	Snyder et al. 1943, pp. 6-17	30	USDA 1977, p. 4
Beans, Snap	80	Snyder et al. 1943, pp. 6-17	60	USDA 1977, p. 11
Beets	90	Snyder et al. 1943, pp. 6-17	60	USDA 1977, p. 12
Broccoli	120	Snyder et al. 1943, pp. 6-17	60	USDA 1977, p. 13, Oregon
Cabbage	90	Snyder et al. 1943, pp. 6-17	165	Gray et al. 1948, p. 60
Carrots	90	Snyder et al. 1943, pp. 6-17	180	Gray et al. 1948, p. 60
Cauliflower	120	Snyder et al. 1943, pp. 6-17	30	Gray et al. 1948, p. 60
Celery	150	Snyder et al. 1943, pp. 6-17	150	Gray et al. 1948, p. 60
Corn, Sweet	90	Snyder et al. 1943, pp. 6-17	90	USDA 1977, p. 27
Cucumbers	60	Snyder et al. 1943, pp. 6-17	60	USDA 1977, p. 34
Lettuce	60	Snyder et al. 1943, pp. 6-17	180	Gray et al. 1948, p. 60
Onions	120	Snyder et al. 1943, pp. 6-17	150	Gray et al. 1948, p. 61
Onions, Green	30	Snyder et al. 1943, pp. 6-17	120	Snyder et al. 1943, pp. 6-17
Peas, Green	90	Snyder et al. 1943, pp. 6-17	45	Gray et al. 1948, p. 61
Peppers	150	Snyder et al. 1943, pp. 6-17	30	USDA 1977, p. 42, California
Spinach	60	Snyder et al. 1943, pp. 6-17	180	Gray et al. 1948, p. 61
Squash/Pumpkins	120	Snyder et al. 1943, pp. 6-17	30	Judge 1946, p. 184, Oregon
Tomatoes	90	Snyder et al. 1943, pp. 6-17	60	Gray et al. 1948, p. 61
Turnips/Rutabagas	60	Snyder et al. 1943, pp. 6-17	30	Snyder et al. 1943, pp. 6-17
Apples	90	WSDA 1989, p. 34	120	Judge 1946, p. 180
Apricots	90	WSDA 1989, p. 34	30	Judge 1946, p. 180
Grapes	90	WSDA 1989, p. 34	30	WSDA 1989, p. 34
Melons	90	Snyder et al. 1943, pp. 6-17	60	Gray et al. 1948, p. 61, Watermelon
Other Berries	30	WSDA 1989, p. 34	30	Judge 1946, p. 180, Blackberries, and p. 182, Raspberries
Peaches	90	WSDA 1989, p. 34	30	Judge 1946, p. 180
Pears	90	WSDA 1989, p. 34	60	Judge 1946, p. 180
Plums/Prunes	90	WSDA 1989, p. 34	30	Judge 1946, p. 180, Plums
Strawberries	30	WSDA 1989, p. 34	30	Gray et al. 1948, p. 61
Sweet Cheeries	90	WSDA 1989, p. 34	30	Judge 1946, p. 180

GROWING SEASONS AND HARVEST PERIODS

Secondary data sources contain a usual period over which growing seasons and harvest periods extend, rather than an exact harvest date for each crop. The exact harvest dates and growing seasons can differ for the various fruits and vegetables, depending on the particular climatic conditions in a year and the exact geographic location of production. The growing seasons and harvest periods (Table D.3) are therefore point estimates that represent each period.

FRUIT AND VEGETABLE CONSUMPTION RATES

Fruit and vegetable consumption rates provided in this scoping study were calculated using raw responses to the 1965-1966 Household Food Consumption Survey (USDA 1972). These data were acquired on magnetic tape from the USDA Health and Nutrition Information Service. Because the raw survey responses exist only for the spring sample, all calculations are based on data for consumption during only the spring season (April through June). The 1965 data were used in lieu of the more complete 1977-1978 National Food Consumption Survey (NFCS) data because the latter were not available at the time the analysis was required.

The 1965 intake data were aggregated from more than 1800 represented food types to the 74 food types outlined in Anderson (1992, Appendix B). This aggregation was based on similar work performed in Phase I, and originally on the work of Nelson and Yang (1984) and Yang and Nelson (1986). For fruits and vegetables, this exercise is relatively straightforward. All categories in the 1965 NFCS that could not be excluded from fresh fruits and vegetables were included in the analysis. For example, in the survey coding documentation (USDA 1966), apple pie is listed under the heading of "grain products," and the subheading of "other baked goods." No indication is given of whether or not the apples used were fresh. In this and many similar cases, it was assumed that such groups must be included as fresh consumption, because it was not possible to exclude them using the coding documentation.

To convert the 1965 estimates of food consumption for use in developing a produce pathway importance ranking for 1945, the 1965 estimates were multiplied by the ratio of per capita consumption in 1945 to per capita consumption

in 1965, following techniques presented in Callaway (1992, pp. 12-13) and Anderson (1992, pp. 3-4, and Appendix A). Agricultural Statistics (USDA 1952, 1970) were used to develop the per capita consumption multipliers (ratios) shown in Table D.4. Consumption estimates were provided for the age/sex groups outlined in Anderson (1992, Appendix C) and Napier et al. (1992, p. 2.11). Because this is a scoping study, no attempt was made to adjust the data by other variables such as geographic region, season, or race of respondent.

This crude approach provided the most accurate measure of consumption rates available, compared to other methods that were considered to reconstruct the food consumption behavior of nearly 50 years ago. Alternative methods might rely on consumption data gathered at the household level from national surveys (USDA 1941, 1944, 1954, 1957, 1961). Although individual food intake data were gathered for these surveys, all information is reported at the household level and no raw data, such as the original surveys, were maintained. Where slight amounts of individual data are reported, there is no consistency between reports and hence, no reliable time series of data reported. The estimated per capita multipliers (ratios) developed for this analysis, although based on gross disappearance data, are also based on relatively consistent annual time series maintained by the USDA for most of this century. The consumption estimates used in this report are based on actual individual intake data, although 20 years removed from the years of interest. Under ideal circumstances, individual food intake survey data would have been collected in the years of interest.

Prior to the 1977-1978 NFCS, reported results were separated into North and South regions. The North consisted of the aggregation of Northeast, Northcentral, and West population census regions; the South was the South census region. This previous alignment made testing across regions for 1945 impractical. In reviewing the published results of the 1977-1978 NFCS, it was found that there may be greater variation across urbanizations than across regions. Yang and Nelson (1986) compared F-values for sources of variation in consumption across region, subregion, urbanization, season, sex, and age, that were found from analysis of the 1977-1978 NFCS. For leafy vegetables, they reported significant differences ($0.01 < p < 0.05$) in consumption by

TABLE D.4. Derived 1945:1965 Food Consumption Multipliers

<u>Plant Type</u>	<u>Multiplier 1945/1965</u>	<u>1945 Per Capita Consumption: 1952 Agricultural Statistics</u>	<u>1965 Per Capita Consumption: 1970 Agricultural Statistics</u>
Green Peas	1.8293	Page (P) 325, Table (T) 368, canned	Page (P) 202, Table (T) 292, canned
Corn	1.1273	P325, T368, canned	P202, T292, canned
Asparagus	1.5729	P263, T298, fresh, calculated	P157, T227, fresh, calculated
Tomatoes	1.2423	P312, T356, fresh, calculated	P195, T284, fresh, calculated
Snap Beans	0.7500	P325, T368, canned	P202, T292, canned
Cabbage	2.4605	P272, T306, fresh, calculated	P166, T240, fresh, calculated
Lettuce	0.7434	P287, T329, calculated	P177, T261, calculated
Spinach	3.8441	P306, T350, fresh, calculated	P191, T278, fresh, calculated
Cauliflower	2.5601	P278, T312, calculated	P169, T245, calculated
Celery	1.3297	P280, T315, calculated	P170, T247, calculated
Broccoli	2.5601	Ratio same as cauliflower	Ratio same as cauliflower
Carrots	1.3039	P276, T310, calculated	P168, T243, calculated
Green Onions	1.5193	P813, T815, All fresh vegetables	P576, T799, All fresh vegetables
Other Onions	0.9638	P289, T331, calculated	P180, T264, calculated
Beets	4.9594	P270, T304, fresh, calculated	P162, T233, fresh, calculated
Turnips/Rutabagas	1.5193	P813, T815, All fresh vegetables	P576, T799, All fresh vegetables
Squash/Pumpkins	1.5193	P813, T815, All fresh vegetables	P576, T799, All fresh vegetables
Cucumbers	0.7941	P282, T318, fresh, calculated	P173, T251, fresh, calculated
Green Peppers	0.6061	P293, T335, calculated	P181, T266, calculated
Lima Beans	2.1533	P265, T300, fresh, calculated	P159, T230, fresh, calculated
Fresh White Potatoes	1.1574	P321, T362	P200, T290
Fresh Sweet Potatoes	2.9355	P321, T362	P200, T290
Apples	1.0069	P193, T225, fresh, calculated	P211, T304, fresh, calculated
Pears	3.3898	P237, T270, fresh, calculated	P244, T352, fresh, calculated
Strawberries	0.5092	P246, T282, calculated	P248, T362, fresh, calculated
Other Berries	1.6592	P813, T815, All fresh fruit	P576, T799, All fresh fruit
Sweet Cherries	1.6247	P206, T240, fresh, calculated	P220, T319, fresh, calculated
Melons	1.5763	P321, T362	P200, T290
Grapes	1.2850	P226, T257, fresh, calculated	P235, T336, fresh, calculated
Apricots	4.5606	P198, T232, fresh, calculated	P215, T312, fresh, calculated
Peaches	2.3511	P233, T265, fresh, calculated	P240, T344, fresh, calculated
Plums/Prunes	1.3895	P241, T276, 81, fresh, calculated	P245, T354, 356, fresh, calculated
Other Noncitrus	1.5169	P257, T292, fresh	P258, T376

subregion ($F = 3.07$) and urbanization ($F = 2.64$). Age was shown to be the greatest contributor to differences in consumption ($F = 43.49$ at $p < 0.01$). All previous National Food Consumption Surveys report generally lower individual intake of specific fresh leafy vegetables, such as lettuce and spinach, by nonmetropolitan or rural households, as compared to central city, urban, and suburban households (see Table D.5).

As noted in Table D.4, in some cases the multipliers were estimated based on calculated values derived from the respective issues of Agricultural Statistics. For example, in many cases the values found in published tables represented the grand total of production termed in units such as bushels, hundred-weight, or tons. These values were converted to pounds and divided by the population that consumed from domestic food supplies to yield per capita consumption in the particular year.

Table D.4 shows how the multipliers and per capita values were estimated. Consider lettuce, it has a multiplier of 0.7434 constructed by the ratio of the 1945 per capita consumption in Table 329 (T329) on page 287 (P287) of the 1952 Agricultural Statistics to the 1965 per capita consumption in Table 261 (T261) on page 177 (P177) of the 1970 Agricultural Statistics. In some cases (noted as calculated in columns 3 and 4 of Table D.4), the multipliers were estimated based on per capita consumption values derived from the respective issues of Agricultural Statistics. Columns 3 and 4 of Table D.4 indicate whether per capita consumption was of fresh produce (fresh) or of canned produce (canned). For certain produce, such as turnips and rutabagas, there was insufficient information to estimate per capita

TABLE D.5. Household Consumption of Selected Fruits and Vegetables, 1977-1978 NFCS (Pounds per household, per week)

	<u>Central City</u>	<u>Suburban</u>	<u>Nonmetropolitan</u>
Spinach	0.06	0.06	0.03
Lettuce	1.16	1.35	1.03
Corn	0.41	0.61	0.72
Apples	1.37	1.71	1.63
Melons	1.14	1.06	0.95

Source: USDA (1983).

consumption values. In that case, the total per capita consumption of all fresh vegetables was used to approximate consumption.

The 1945 estimates of a particular fruit or vegetable consumption rate (CFV) is calculated with the equation $CFV = BR \cdot HP \cdot AC \cdot PC / 1000$, where BR is the back-casting ratio, HP is the period over which consumption could occur (harvest period), AC is the average ingestion rate (in grams) of an individual who consumed that particular produce, and PC is the probability of consuming a particular food type on a given day. The estimates for HP are listed in Table D.3, the estimates for BR are in Table D.4, and the estimates for CFV, AC, and PC are listed in Table D.6. The representative groups are males 20-34 years and infants 1-4 years.

FRACTION REGIONALLY PRODUCED

The fraction of regionally produced (FRP) fruit or vegetable (Table D.7) is a measure of the relationship between the total recorded fresh market production (TFP) of the Washington counties in the HEDR study area and the total estimated consumption (TEC) of the study counties. Total consumption is calculated by multiplying the 1945 annual per capita consumption (farm level) by the 1945 population estimate in the HEDR study area. The percentage of the state total of fresh market produce (SF) and the percentage of state total of processed produce (SP) for Washington is calculated and used to estimate the percent of fresh market production in the HEDR study area, when needed (this was necessary only for corn and asparagus). Let TPH be the total production for a fruit or vegetable in the HEDR study area, then

$$TFP = TPH \cdot SF$$

is the estimated amount of fresh production in the HEDR study area. The relationship among total production, fresh market use, and processing use in Washington State (ST) is approximated by the equation $ST = SF + SP$. The mathematical equation to calculate FRP is:

$$\begin{aligned} FRP &= 1, & \text{if } TFP \geq TEC \\ FRP &= TFP / TEC, & \text{if } TFP < TEC \end{aligned}$$

TABLE D.6. 1945 Food Consumption Calculations

Fresh Consumption	Back-Casting Ratio (BR) 1945/1965	Average Ingestion Rate (AC) Males 20-34 1965 Grams	Probability Consumed (PC)	Consumption Rate (CFV) 1945 kilograms	Average Ingestion Rate (AC) Infants 1-4 1965 Grams	Probability Consumed (PC)	Consumption Rate (CFV) 1945 kilograms
Asparagus	1.573	102.000	0.013	0.125	40.000	0.014	0.053
Beans, Lima	2.153	84.000	0.026	0.141	55.000	0.031	0.110
Beans, Snap	0.750	76.000	0.136	0.465	33.000	0.121	0.180
Beets	4.959	112.000	0.016	0.533	52.000	0.016	0.248
Broccoli	2.560	96.000	0.017	0.251	47.000	0.013	0.094
Cabbage	2.461	103.000	0.077	3.221	53.000	0.036	0.775
Carrots	1.304	84.000	0.063	1.242	53.000	0.070	0.871
Cauliflower	2.560	55.000	0.009	0.038	26.000	0.004	0.008
Celery	1.330	40.000	0.007	0.056	38.000	0.014	0.106
Corn, Sweet	1.127	126.000	0.145	1.853	66.000	0.114	0.763
Cucumbers	0.794	68.000	0.024	0.078	54.000	0.012	0.031
Green Peas	1.829	97.000	0.116	0.926	40.000	0.092	0.303
Lettuce	0.743	75	0.345	3.462	32.000	0.099	0.424
Onions, Green	1.519	20.000	0.017	0.062	13.000	0.007	0.017
Onions	0.964	54.000	0.060	0.469	34.000	0.009	0.044
Peppers, Green	0.606	32.000	0.010	0.006	7.000	0.003	0.000
Spinach	3.844	112.000	0.024	1.860	49.000	0.024	0.814
Tomatoes	1.242	136.000	0.170	1.723	81.000	0.052	0.314
Squash/Pumpkins	1.519	111.000	0.016	0.081	82.000	0.012	0.045
Turnips/Rutabagas	1.519	59.000	0.030	0.081	60.000	0.021	0.057
Apples	1.007	179.000	0.129	2.790	146.000	0.154	2.717
Pears	3.390	171.000	0.016	0.556	114.000	0.021	0.487
Strawberries	0.509	130.000	0.030	0.060	88.000	0.021	0.028
Other Berries	1.659	121.000	0.016	0.096	158.000	0.005	0.039
Sweet Cherries	1.625	121.000	0.032	0.189	90.000	0.011	0.048
Melons	1.576	743.000	0.036	2.530	584.000	0.024	1.326
Grapes	1.285	108.000	0.003	0.012	49.000	0.002	0.004
Apricots	4.561	175.000	0.010	0.239	111.000	0.009	0.137
Peaches	2.351	167.000	0.052	0.613	109.000	0.049	0.377
Plums/Prunes	1.390	60.000	0.001	0.003	106.000	0.005	0.022

TABLE D.7. Fraction Regionally Produced

	HEDR Study Area Recorded Production (tons)	Annual Farm Level Per Capita Consumption (pounds)	Total Consumption HEDR Population 539,100	Ratio	Fraction Regionally Produced
	<u>1945</u>	<u>1945</u>	<u>1945</u>	<u>1945</u>	<u>1945</u>
Asparagus	10,505	1.1	296.51	35.43	1
Beans, Lima	0	0.6	161.73	0	0.1
Beans, Snap	0	4.8	1293.84	0	0.1
Beets	0	1.2	323.46	0	0.1
Broccoli	40	0.9	242.6	0.16	0.16
Cabbage (Early)	1340	20.5	5525.78	1.48	1
Cabbage (Late)	6818				
Carrots	8773	11.7	3153.74	2.78	1
Cauliflower	484	3.5	943.43	0.51	0.51
Celery	919	8.2	2210.31	0.42	0.42
Corn, Sweet	3339	7.9	2129.45	1.57	1
Cucumbers	230	2.4	646.92	0.36	0.36
Green Peas, Fresh	717	1.6	431.28	1.66	1
Lettuce (Early)	2493	16.9	4555.4	1.28	1
Lettuce (Late)	3316				
Onions (Early)	6975	13.9	3746.75	5.56	1
Onions (Late)	13,841				
Green Peppers	0	2.1	566.06	0	0.1
Spinach (Early)	780	2.3	619.97	5.3	1
Spinach (Late)	2506				
Squash/Pumpkins	0		0		0.1
Tomatoes	10,256	16.1	4339.76	2.36	1
Turnips/Rutabagas	3950	0.4	107.82	36.64	1
Apples (tons, 48 lbs/box)	373,336.32	22.9	6172.7	60.48	1
Apricots (tons)	10,416	6	1617.3	6.44	1
Sweet Cherries (tons)	14,545.83	1.1	296.51	49.06	1
Grapes (tons)	348	5.6	1509.48	0.23	1
Peaches (tons)	10,936.8	18.2	4905.81	2.23	1
Pears (tons, 48 lbs/box)	62,109.94	7.3	1967.72	31.56	1
Plums/Prunes (tons)	13,766.67	2.3	619.97	22.21	1
Other Berries (tons)	5012	1.3	350.42	14.3	1
Strawberries (tons)	10,161	1.3	350.42	29	1

The fraction of each fresh fruit and vegetable produced in the HEDR study area ranges from 0.1 to 1. Commercial county production records did not contain data for fresh market beets, green onions, green peppers, lima beans, pumpkins, snap beans, and squash. These vegetables were assigned a value FRP = 10%, to account for possible unrecorded production. Grapes were also assigned a value FRP = 1, as they were considered a luxury produce. Consumption of turnips/rutabagas are canned estimates.

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