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SecPop Version 4: Sector Population, Land Fraction, and Economic Estimation Program

Users' Guide, Model Manual, and Verification Report

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ABSTRACT

In 1973 the U.S. Environmental Protection Agency (EPA) developed SecPop to calculate population estimates to support a study on air quality. The Nuclear Regulatory Commission (NRC) adopted this program to support siting reviews for nuclear power plant construction and license applications. Currently SecPop is used to prepare site data input files for offsite consequence calculations with the MELCOR Accident Consequence Code System (MACCS). SecPop enables the use of site-specific population, land use, and economic data for a polar grid defined by the user.

Updated versions of SecPop have been released to use U.S. decennial census population data. SECPOP90 was released in 1997 to use 1990 population and economic data. SECPOP2000 was released in 2003 to use 2000 population data and 1997 economic data. This report describes the current code version, SecPop version 4.3, which uses 2010 population data and both 2007 and 2012 economic data. It is also compatible with 2000 census and 2002 economic data. At the time of this writing, the current version of SecPop is 4.3.0, and that version is described herein.

This report contains guidance for the installation and use of the code as well as a description of the theory, models, and algorithms involved. This report contains appendices which describe the development of the 2010 census file, 2007 county file, and 2012 county file. Finally, an appendix is included that describes the validation assessments performed.

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ABBREVIATIONS AND ACRONYMS

AHS	American Housing Survey
BEA	U.S. Bureau of Economic Analysis
BLS	U.S. Bureau of Labor Statistics
CPI	Consumer Price Index
EPA	U.S. Environmental Protection Agency
EPZ	Emergency Planning Zone
FIPS	Federal Information Processing Standard
GDP	Gross Domestic Product
IC	Independent City
MACCS	MELCOR Accident Consequence Code System
NRC	U.S. Nuclear Regulatory Commission
NRCS	National Resources Conservation Service
NRI	National Resources Inventory
PCI	Per Capita Income
REAcct	Regional Economic Accounting Tool
SecPop	Sector Population and Economic Estimator
USDA	U.S. Department of Agriculture

1.0 INTRODUCTION

1.1 Background

In 1973 the U.S. Environmental Protection Agency (EPA) developed Sector Population and Economic Estimator (SecPop) to calculate population estimates. The code used 1970 population census data and was created to support a study on air quality. The NRC adopted this program to perform siting reviews for nuclear power plant construction and license applications.

With updates to census and economic data, a number of newer versions of SecPop were released. The previous two major SecPop releases were SECPOP90[1] [1] and SECPOP2000 [2]. SECPOP90 supported both site and regional analyses. The site analysis provides population and economic data estimates for any location within the continental United States. Regional analysis assesses compliance of available sites against siting parameters (i.e., specific population density criteria); however, this feature was removed for SECPOP2000 because some of the software packages originally used for regional analysis were no longer available. Similarly, more recent versions of SecPop only support site analyses.

1.2 Current Version

An update to SecPop was necessary for the following reasons:

1. To process updated population data from the 2010 U.S. Census.
2. To process updated economic and land use data from 2007 and 2012 databases.
3. To improve the code interface for greater ease of use.
4. To include an improved algorithm for assigning economic regions.
5. To add the capability to produce site files compatible with the newly developed MACCS alternative economic consequence model that integrates REAcct (Regional Economic Accounting Tool) to calculate business disruption costs in terms of GDP (gross domestic product) losses.

SecPop can perform calculations with 2010 and 2000 population data and 2012, 2007, and 2002 economic data. The set of counties (and the corresponding Federal Information Processing Standard [FIPS] codes) contained in the 2012 and 2007 files differ from those in the 2002 file. As a result, the 2002 county file should be used with the 2000 census file. Either the 2007 or 2012 county file should be used with the 2010 census file. Other combinations are not compatible.

The most recently available economic data are from 2012. Data are also available from 2007, which was near the peak of a housing bubble. This may cause the corresponding economic values presented in the code to be high, and users should verify that the values are appropriate for the purpose of the analysis. Using the 2012 database alleviates this problem.

The values calculated by SecPop were compared with the raw data in the most recent census and county files and all tests passed. Additionally, the current version was regression tested against previous versions and these tests all passed as well. Regression testing compares newer versions with older ones to ensure consistency where consistency is expected and to

[1] Previously the code naming convention was to include the year of the U.S. Census database rather than the code version number but that has been changed in the last decade to be more consistent with naming of other NRC computer codes. Also, the code name now uses some lower-case letters (SecPop) instead of all capital letters (SECPOP).

verify that recent changes have not fixed one problem but introduced another. Details of the comparisons are provided in Appendix E.

The current version of SecPop at the time of this writing is 4.3.0 and this document is based on that version. However, this document is generally relevant to earlier versions (starting with 4.2.0) and is expected to be relevant for subsequent versions of SecPop.

1.3 Objective

The objective of this document is to provide guidance to users on the application and use of the SecPop code and to describe the models, algorithms, and sources of data for the calculations. The document provides step by step instructions on the installation, setup, and execution of site analyses in SecPop. The document also describes the validation tests and results.

1.4 Hardware and Software Requirements

SecPop is a Java-based program that was developed to run on a personal computer. The SecPop software requires approximately 500 megabytes of hard-disk storage, which is primarily used to store census and county databases. Currently, the executable file that is distributed to install SecPop is compatible with Windows only and has been tested on Windows XP™ and Windows 7™ operating systems. Because it has not been tested on other operating systems, the user should perform basic testing for functionality and reliability if SecPop is installed on another operating system.

2.0 USERS' GUIDE

SecPop allows the user to estimate population, land use, and economic values related to a specific site. It creates a site file that is needed by MACCS to perform a site-specific offsite consequence analysis of the health, economic, and environmental impacts of a hypothetical, atmospheric release of radioactive material from a nuclear facility.

The census files included with SecPop contain population and area information at the census block level. The county file contains economic and land-use information at the county level. SecPop provides estimates based on the site location, radial distances, and compass sectors centered on the site. The user enters the radii and selects the number of compass sectors for the grid. SecPop supports 16, 32, 48, and 64 compass sectors.

2.1 Installation

SecPop is installed by clicking on the setup.exe file and selecting the menu entry "Run as Administrator" if you are logged in as a standard user. If you are logged in as an administrator, double clicking on the setup.exe file starts the installation of SecPop. The installation process requires that the license agreement is accepted. Administrative privileges are required to install SecPop. The default installation folder is C:\Program Files (x86)\SecPop. This folder contains a folder named Census containing the 2010 census data (Census2010.bin and Census2010.aux), the 2000 census data (Census00.bin), the 2012 county data (County2012.dat), the 2007 county data (County2007.dat), and the 2002 county data (County2002.dat).

The installation folder also contains a folder named Sites containing the latitude and longitude coordinates of nuclear facilities in the United States. These data can be imported by SecPop and used to define a site location.

After SecPop is installed, the following are added to the SecPop group found in the Windows Start menu:

- The entry readme is a link to the file readme.rtf. This file contains more information about the SecPop installation and details and a list of modifications.
- The entry SecPop is a link to SecPop.bat. Selecting this link starts SecPop.
- SecPop Users' Guide is a link to the pdf version of the SecPop Users' Guide.
- The entry Uninstall SecPop removes the SecPop software from your computer.

2.2 Menus

SecPop opens with the main menu, which consists of the following items listed along the top of the main application window.

- File menu is used to import a previously created site file or define program preferences such as the default file locations.
- Problem menu is used to create a new project, open an existing project, save, or close a project.
- Calculate menu is used to perform site-specific population and economic calculations.
- View Results menu is used to view results associated with the last calculation.
- Help menu is used to identify the current version number.

2.2.1 File Menu

2.2.1.1 Import Site File

The Import MACCS Site File command under the File menu is active when a project is open. Selecting the command opens a dialog box pointing to the default program directory and allows the user to select a MACCS site file (.inp extension). An .inp file is a SecPop output file and does not need to have been created with the current SecPop version. Importing one of these site files populates several fields in the project tabs using values from the imported site file. Not every site file contains every needed SecPop input field, such as latitude and longitude. Comment fields in the imported site file are not copied to the project; however, the Problem Remarks field shows the name of the imported site file and the version of SecPop used to create it. This function allows the user to quickly create a new project from an existing site file.

2.2.1.2 Preferences

Clicking Preferences under the File menu opens a form that allows the user to choose the data files for SecPop to use and identifies the default locations for files, as shown in Figure 2-1. The Census File option opens a dialog box to the location of the current census file. The 2010 census (Census2010.bin) and the 2000 census (Census00.bin) files are included with SecPop. The 2010 file is selected by default on installation.

The Economic File button is used to change the county file. Data are available from 2012 (County2012.dat), 2007 (County2007.dat), and 2002 (County2002.dat), with 2012 the default selection. It is generally recommended to use the most current versions of the data files; however, it is sometimes useful to be able to reproduce results based on the older data files. The 2002 county file can only be used with the 2000 census file; similarly, the 2007 and 2012 county files can only be used with the 2010 census file. SecPop generates an error message when incompatible file combinations are selected.

The Problem Directory button is used to select the default directory where projects and output are saved. The user needs to select the location where he or she wants to save SecPop projects. This only needs to be done once unless the user subsequently wants to change the location.

The Site Directory button is used to change the default location of predefined site-location (coordinate) files. These coordinate files, installed with SecPop, include the latitude and longitude for all U.S. reactors and some fuel facilities (see Appendix A for complete list). The user does not need to change this directory unless he or she manually moves the files.

Clicking Save closes the window and maintains directory locations selected by the user.

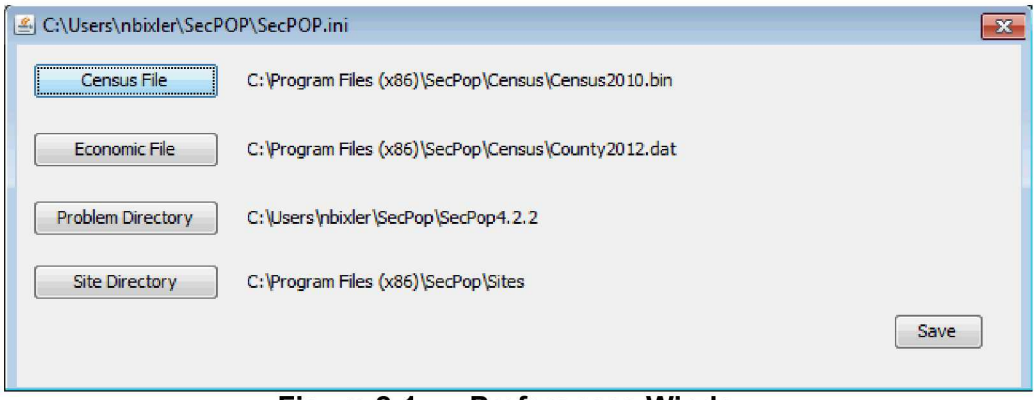


Figure 2-1 Preferences Window

2.2.1.3 Exit

Clicking Exit from the File menu closes the SecPop program. A message box opens, prompting the user to save the project settings of the current project (see Figure 2-2). Clicking Yes saves the project settings and closes the application. Clicking No does not save the project settings and closes the application. Clicking the X in the upper right corner does not save the project settings and closes the application.

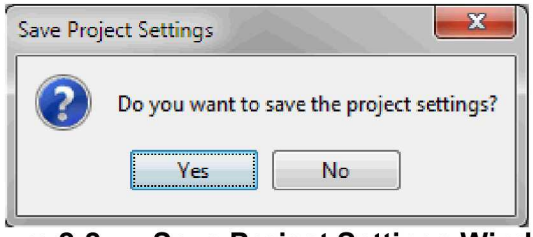


Figure 2-2 Save Project Settings Window

2.2.2 Problem Menu

The Problem menu contains functions that allow basic management of a SecPop project.

2.2.2.1 New

Under the Problem menu, clicking New opens a window (see Figure 2-3) displaying the default problem directory and a text box to enter a project name. The Problem Directory is initially the same as the directory defined in the Preference form but can be modified by clicking the Problem Directory button. A project name must be entered in the Project Name field before creating the new project.

The example used in this section is a 16-sector site file centered on Arkansas Nuclear One, a two-unit nuclear reactor site in Russellville, AR, based on a target year of 2014. It is recommended that the project name include the site, target year, and number of sectors. In this example, the project name is “Example – Arkansas – 2014 – 16 Sectors.” A folder is created with this name in the problem directory. This is where the project file and any resulting output files are saved.

Clicking Save opens a project window that is described in Section 2.3 and illustrated in Figure 2-11.

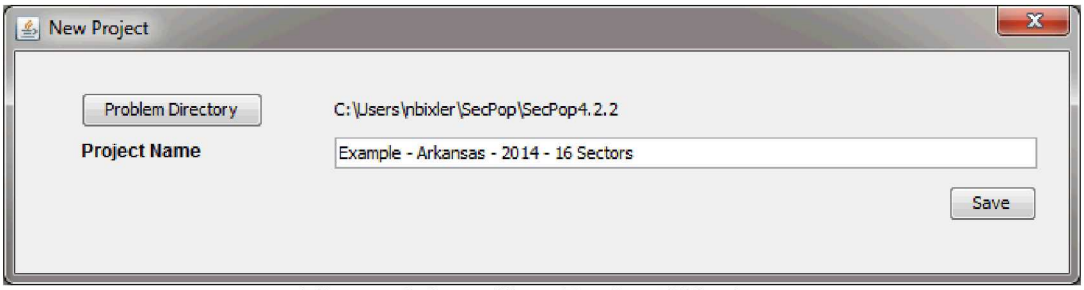


Figure 2-3 New Project Window

2.2.2.2 Open

Clicking Open in the Problem menu opens a dialog window as shown in Figure 2-4. The window is initialized to the default Problem Directory and filters for existing SecPop project files (.spproj extension). The user can navigate to any other folder where SecPop project files have been saved. Choosing a file and clicking Open opens a project window that is described in Section 2.3.

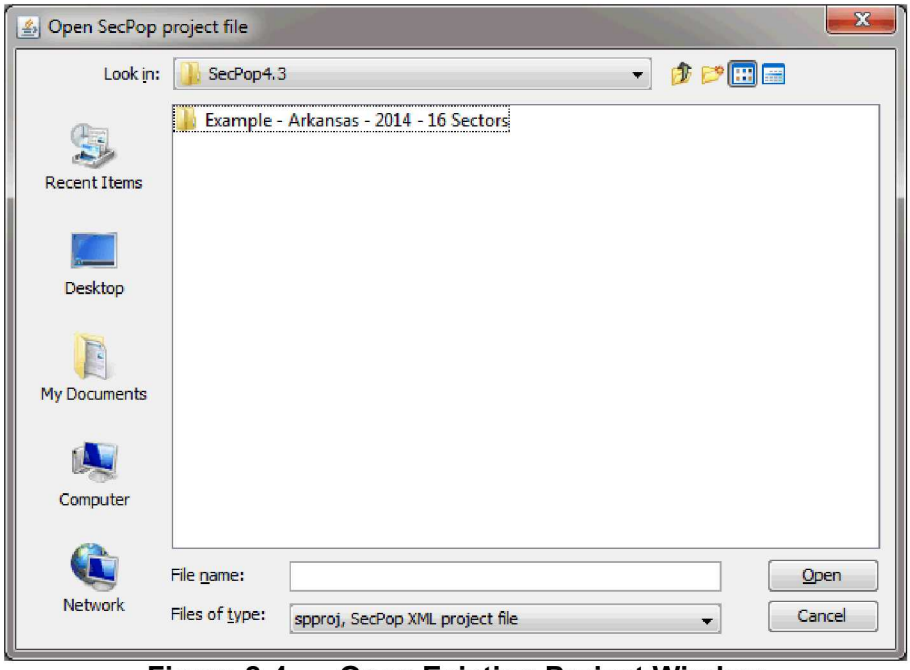


Figure 2-4 Open Existing Project Window

2.2.2.3 Save

Clicking Save in the Problem menu saves the current project settings to the project file.

2.2.2.4 Save As

Clicking SaveAs in the Problem menu opens a window similar to the one in Figure 2-3 that displays the default problem directory and a text box to enter a project name. The Problem Directory is initially the same as the directory defined in the Preference form but can be modified by clicking the Problem Directory button. A project name must be entered in the Project Name field. After the new project directory is created, SecPop saves the project file with the values consistent with the previous project opened in the new project folder. None of the previous result files are copied to the new project directory.

2.2.2.5 Close

Selecting the Close option closes the current project but does not close the application. A dialog box is displayed as shown in Figure 2-2. Clicking Yes saves the project settings and closes the project. Clicking No does not save the project settings and closes the project. Clicking the X in the upper right corner does not save the project settings and closes the project.

2.2.3 Calculate Menu

Once all the input fields for the three tabs in the project window have been entered (discussed further in Section 2.3), a site-specific calculation may be performed by clicking on Population from the Calculate menu. At this point, the calculation window shown in Figure 2-5 opens.

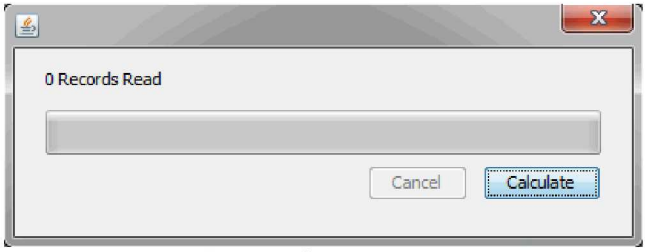


Figure 2-5 Calculate Window

When Calculate is clicked, SecPop checks to see if output files already exist in the project folder. If so, the message in Figure 2-6 appears, asking if output files should be overwritten. SecPop only checks for files with the default names, so renaming the output files or moving them into a different folder allows for multiple output sets to be saved in the project or other folder.

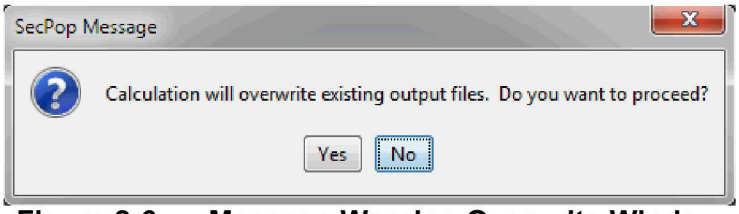


Figure 2-6 Message Warning Overwrite Window

Once SecPop has checked for output files, it checks whether all required fields have been assigned correctly. If the information is incomplete, an error message is displayed. The missing information must be provided before the calculation can proceed. The project settings are saved before the calculation starts. The status of the calculation is shown by updating the census block record counter and the status bar as shown in Figure 2-7. Cancel can be clicked to terminate the calculation. No intermediate results are available.

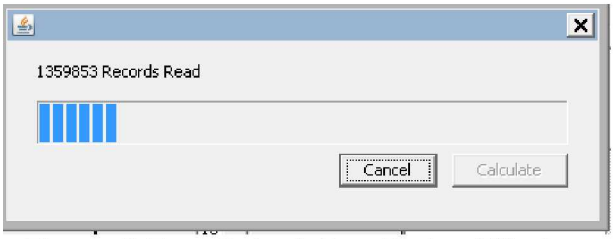


Figure 2-7 Calculation Status Window

Once the calculation is complete, the text “Calculation Completed” is displayed in the Calculate window, as shown in Figure 2-8, as well as the number of census blocks read. The results are available in the project folder. Clicking the X in the upper right corner closes this window.

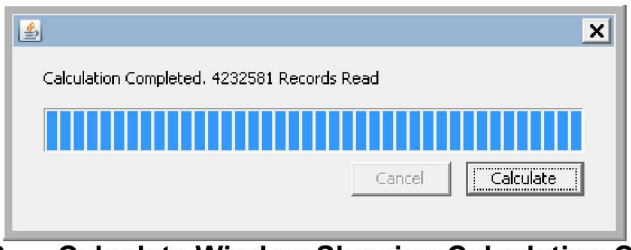


Figure 2-8 Calculate Window Showing Calculation Completed

2.2.4 View Results Menu

Once the calculation has completed, the commands to view result files are available in the View Results menu. These files are created automatically during a calculation. They are available to open in Notepad from the View Results menu. They can also be opened using other applications such as Excel or Word from the project folder. There are four types of results files, as described in Table 2-1. The name of each file begins with the project name followed by an extension. The sample file names are based on the project name MyProject.

Table 2-1 SecPop Results File Types

Menu Item	Sample File name	Description
MACCS Site File	MyProject.inp	MACCS formatted input file for use with MACCS and WinMACCS containing population, land use, and economic data
Extended Site File	MyProject_site_extended.tsv	Extended, tab-separated data file corresponding to the “MyProject.inp” file. Land use and economic data are reported by grid element rather than by economic region.
REAcct Input File	MyProject_REAcct.econ	MACCS formatted input file for use with the alternative, REAcct, GDP-based economic model. Contains county land-area fraction and county population fraction for each grid element in XML format.
REAcct Tab Separated File	MyProject _REAcct_Extended.tsv	Extended, tab-separated data file corresponding to the “MyProject_REAcct.econ” file. Contains county land-area fraction and county population fraction for each grid element in tab-separated format. Economic data from the county file are included for the counties referenced in this file.

The MACCS site file can be used for a MACCS calculation. The tab separated files are provided to facilitate post-processing of results in a spreadsheet program such as Excel. The REAcct input file and the REAcct tab-separated files described in Table 2-1 are not compatible with MACCS 3.10 and earlier versions but will be compatible with a future version.

All four of these files are saved automatically in the project folder as text files when the calculation is completed. Any text editor, such as Notepad, can be used to view these files. In addition to these files, the two tab separated files are formatted to be viewed in Excel. Displaying populations using a graphic rosette is not supported in SecPop 4.3.

2.2.4.1 MACCS Site File

The MACCS site file contains input to the MACCS offsite consequence analysis code. The file begins with two comment lines that contain quality assurance information and parameter settings. The first portion of a site file is shown in Figure 2-9. The data fields in the MACCS site file are described in Table 2-2.

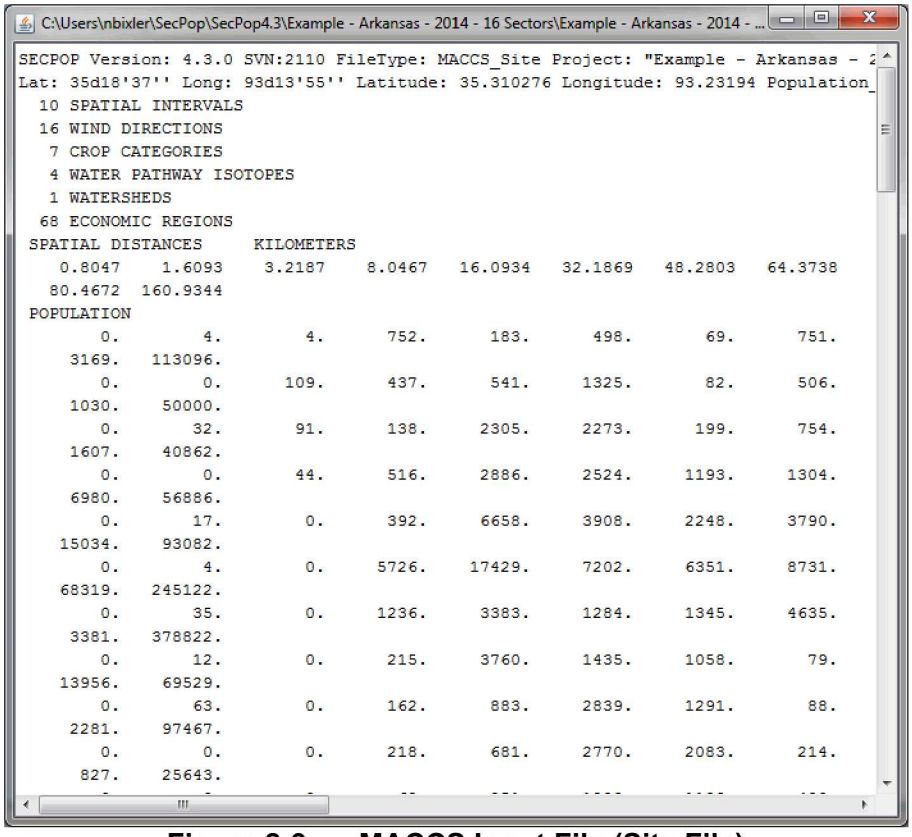


Figure 2-9 MACCS Input File (Site File)

Table 2-2 MACCS Input File Data Fields

Keyword	Description	Units
SPATIAL INTERVALS	Number of radial spatial intervals	None
WIND DIRECTIONS	Number of sectors in the spatial grid	None
WIND DIRECTIONS	Number of crop categories that are used by the food pathway model	None
WATER PATHWAY ISOTOPES	Number of radionuclides in drinking water pathway	None
WATERSHEDS	Number of water pathways	None
ECONOMIC REGIONS	Number of economic regions	None
SPATIAL DISTANCES[2]	Distance to the outer radii of each ring	km
POPULATION	Number of people for each grid element	None
LAND FRACTION	Fraction of area that is land for each grid element	None
REGION INDEX	Economic region number for each grid element	None
WATERSHED INDEX	Defines watershed to use for each grid element	None
CROP SEASON AND SHARE	Name of Crop	None
	Start of the growing season	Julian Day
	End of the growing season	Julian Day
	Fraction of farmland used for the crop	None
WATERSHED DEFINITION	Radionuclide	None
	Ingestion Factor for watershed class 1	None
	Ingestion Factor for watershed class 2	None
	Ingestion Factor for watershed class 3	None
	Ingestion Factor for watershed class 4	None
REGIONAL ECONOMIC DATA	Economic region number	None
	Name of region	None
	Fraction of land used for farming	None
	Fraction of farm sales resulting from dairy	None
	Total annual farm sales	$/hectare
	Farmland property value	$/hectare
	Non-farmland property value	$/person

SecPop does not perform any calculations for estimating crop season and crop share or for estimating watershed data. The values in the site file for those categories (watershed index, crop season, crop share, watershed radionuclides, wash off rates, and ingestion factors) are default values. The default values are mostly the same as the ones used in NUREG-1150 [3], with the exception that two watersheds were defined in NUREG-1150 to distinguish between freshwater and saltwater bodies in terms of water ingestion. Only a single watershed is defined in the current version of SecPop because watershed definitions are highly site dependent and SecPop does not allow a user to enter this information through the interface.

If the user desires to modify any of these parameters, the site file must be edited manually after it is created. The MACCS site file is sensitive to the column numbers for the data, i.e., it is a fixed-format file. Additional information on the format and data fields for the MACCS site file can be found in the MACCS users' guide [4].

[2] Note that the output files always show radial boundaries in kilometers, even if miles were used as the units for SecPop inputs.

2.2.4.2 Extended Site File

The extended site file begins with two comment lines that contain quality assurance information and parameter settings used. The data fields in the extended site file are described in Table 2-3.

The differences between the extended site file and the MACCS site file are as follows:

- The watershed data are not included in the extended site file.
- The crop data are not present in the extended site file.
- The economic region data are not present in the extended site file.
- The extended site file format is tab separated rather than fixed.
- Grid data in the extended site file are listed so all values corresponding to a compass sector are on a single line. The MACCS site file breaks up the data associated with a compass sector into multiple lines.
- Economic data are listed for each grid element.

The extended site file is for the convenience of the user, is intended to be used with a spreadsheet program such as Excel, and is not currently used as a MACCS input. Note that the extended file provides economic values for every grid element, independent of the economic regions defined in SecPop.

Table 2-3 Extended Site File Data Fields

Keyword	Description	Units
SPATIAL_INTERVALS	Number of radial spatial intervals	None
WIND_DIRECTIONS	Number of compass sectors in the spatial grid	None
SPATIAL_DISTANCES	Distance to the outer radius of each ring	km
POPULATION	Number of people who reside within each grid element	None
LAND_FRACTION	Fraction of area that is land for each grid element	None
FARM_FRACTION	Fraction of land used for farming	None
DAIRY_SALES_FRACTION	Fraction of farm sales resulting from dairy	None
AGRICULTURAL_SALES_PER_HECTARE	Total annual farm sales	$/hectare
FARM_VALUE_PER_HECTARE	Farmland property value	$/hectare
NON_FARM_WEALTH_PER_CAPITA	Non-farmland property value	$/person

The extended site file is for the convenience of the user, is intended to be used with a spreadsheet program such as Excel, and is not currently used as a MACCS input. Note that the extended file provides economic values for every grid element, independent of the economic regions defined in SecPop.

2.2.4.3 REAcct Input File

The REAcct input file is in extensible markup language (XML) format, making it both machine and human readable. An XML formatted file is based on keywords and attributes associated with a keyword. An excerpt from a REAcct input file is shown in Figure 2-10.

A REAcct input file lists each grid element starting with the keyword *Grid*. To identify a grid element, attributes of *radius*, *direction*, and *distance* are used.

For grid elements that contain one or more census blocks, each county that is at least partially contained in the grid element is included in the section named *County*. Each county is described by its name using the attribute *name* and its Federal Information Processing Standard (FIPS) code using the attribute *fips*. Population fraction and land area fraction within the county are described using the keywords *pop_frac* and *area_frac*. If a county is completely contained within the spatial grid, the sum of all population and area fractions in the REAcct input file are 1.0 for that county.

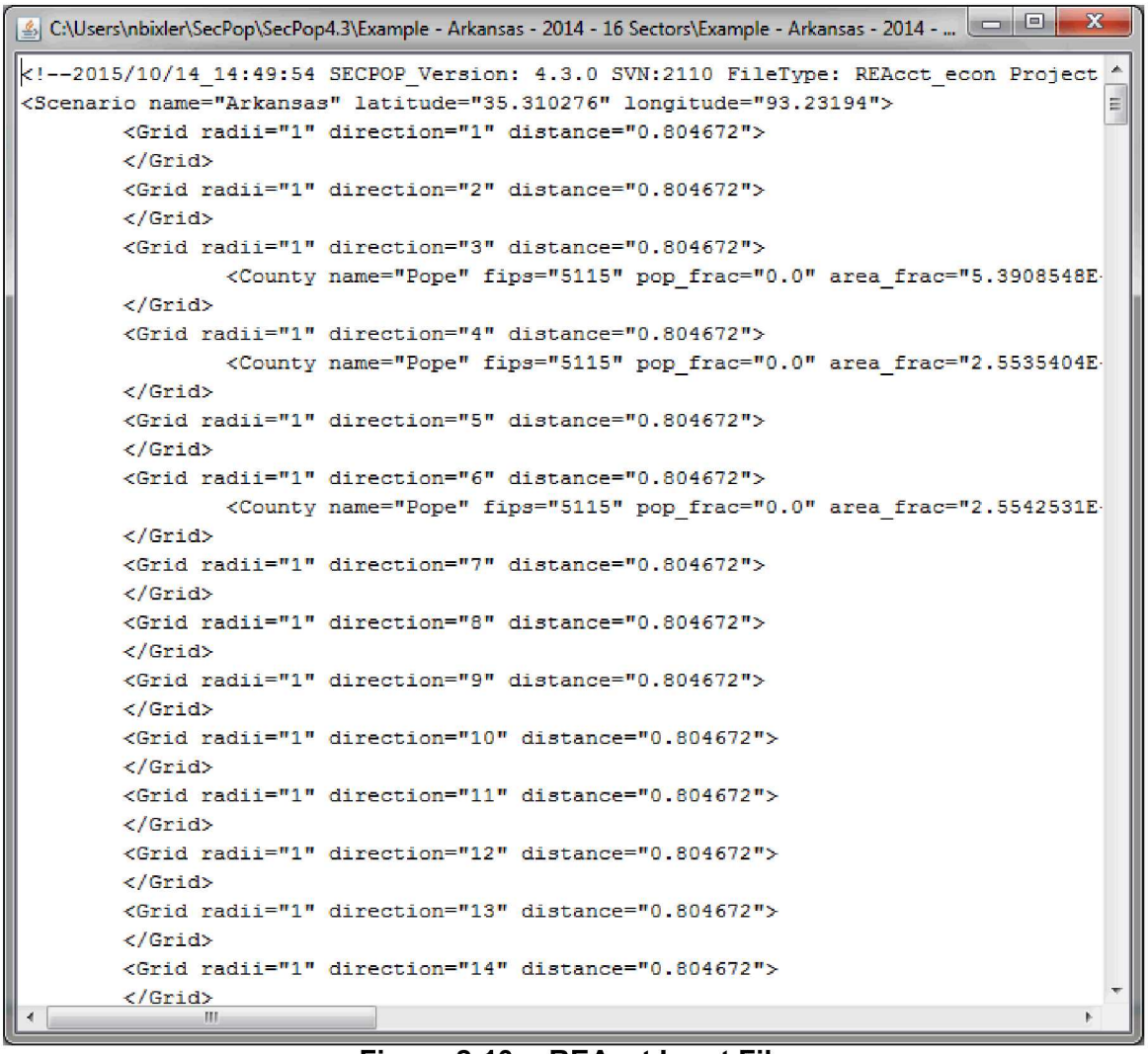


Figure 2-10 REAcct Input File

2.2.4.4 REAcct Tab Separated File

The REAcct tab-separated file contains the same information as the REAcct input file plus economic values for each county from the county file. The specific data fields are described in Table 2-4. This additional information is available for the benefit of the user for post-processing with a spreadsheet program such as Excel.

The features of the REAcct tab separated file that differ from the REAcct input file are as follows:

- The first two lines of the REAcct tab separated file contain quality control information. The next three lines contain headings.
- Only the grid elements that have census blocks assigned to them are listed.
- There is no hierarchical structure in the REAcct tab separated file. There is a single line for each county portion assigned to a grid element with repeated information as applicable.
- Each line is associated with a county. Additional information taken from the county data and census files is listed on the same line.

Table 2-4 REAcct_Extended.tsv File Data Fields

Data Group	Column	Description	Units
Data by Grid Element	1	Radius index	None
	2	Sector number (1 means north)	None
	3	Distance (outer radial boundary)	km
	4	Fraction of the county population residing within grid element	None
	5	Land area fraction of county area within grid element	None
County Description	6	County name	None
	7	State name	None
	8	County FIPS code	None
Data by County	9	Land area	m^2
	10	Population	None
	11	Land fraction	None
	12	Dairy fraction of agricultural sales	None
	13	Value of farm land	$/hectare
	14	Value of nonfarm wealth	$/person
	15	Agricultural sales	$/hectare
	16	County FIPS code (same as column 8)	None

2.2.5 Help Menu

The Help menu provides the full title of SecPop with the version number.

2.3 Project Tabs

When a project is opened, a window specifies the site-specific parameters. This window contains three tabs organizing the project parameters into three categories.

2.3.1 Basic Parameters Tab

The Basic Parameters tab is shown in Figure 2-11. The values on this tab are described in the following subsections.

2.3.1.1 Problem Remarks

Problem Remarks is a text field where project notes can be entered, such as a justification for a population and economic multiplier. These notes are saved to the project file but are not echoed in any output file. This field is optional.

If a MACCS site file is imported into SecPop using the menu item File/Import MACCS Site File command, the name and path of the site file and the SecPop version used to create the MACCS site file is written to the *Problem Remarks* field.

2.3.1.2 Population Multiplier

A decimal number to be used as a population multiplier is entered in this field. This multiplier is uniformly applied throughout the grid. The default value is 1.0. This field is required and currently must be a positive number less than or equal to 10.

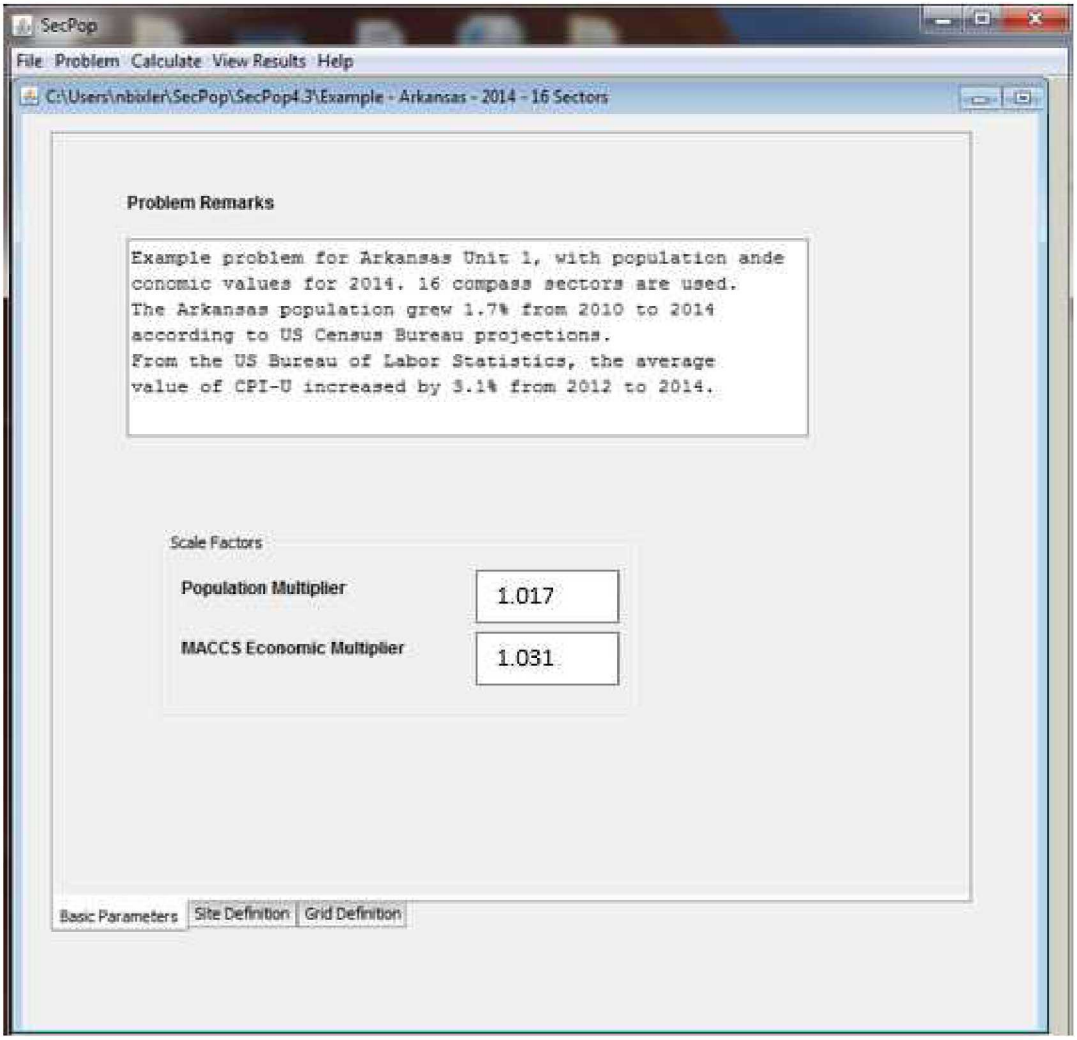


Figure 2-11 Basic Parameters Window

This multiplier is intended to facilitate calculations for years other than those represented by the census files. The U.S. census website has national and state level population forecasts that can be used to estimate an appropriate value for this multiplier. Since the multiplier is a real number, fractional population values can be generated.

For the Arkansas example, the population multiplier could be the target year (2014) population estimate for the state of Arkansas, 2,966,369[3], divided by the 2010-census Arkansas

[3] See Population Estimates available at http://www.census.gov/popest/data/state/totals/2014/index.html

population, 2,915,918, yielding a population multiplier of 1.017. Note that this approach assumes the population in the calculational grid has the same growth rate as the whole state. If the calculational grid includes multiple states, the user could consider the population growth of each state and use a weighted average or simply consider the growth for the entire US.

2.3.1.3 MACCS Economic Multiplier

A decimal number multiplier for economic values is entered in this field. The default value is 1.0. This field is required and must be a positive number less than or equal to 10.

The multiplier is applied uniformly to all economic values contained in the county file, namely agricultural sales, farmland property values, and non-farm property values. This multiplier is intended to facilitate calculations for years other than those represented by the county files. Typically, an inflation factor based on the consumer price index (CPI) is used as the multiplier. CPI-U is a statistical metric published by the U.S. Bureau of Labor Statistics (BLS) to monitor the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services, excluding the most volatile components of the market basket. According to the BLS, the all urban consumer group represents about 94% of the total U.S. population.

For the Arkansas example, the economic multiplier could be estimated to be the target year (2014) average CPI-U-RS for all items less food and energy of 342.4[4] divided by the base year (2012) average CPI-U of 330.7, yielding an economic multiplier of 1.035. This multiplier is applied to all values in the site file with units of dollars.

2.3.2 Site Definition Tab

The second tab in the project window is Site Definition, as shown in Figure 2-12. The components on the Site Definition tab are defined in the following paragraphs.

The required inputs on this tab are the latitude and longitude representing the location of the reactor or other facility. A set of these is provided for various nuclear power plant and nuclear fuel cycle facilities in the U.S. Coordinates represent the reactor center for a single unit site or the center point between reactors at a multi-unit site. Single unit analyses at a multi-unit site could also use coordinates centered on the reactor of interest. The coordinates should be reviewed to ensure they represent the specific release location of interest.

[4] See Table 24 in the CPI Detailed Report available at https://www.bls.gov/cpi/tables/supplemental-files/home.htm

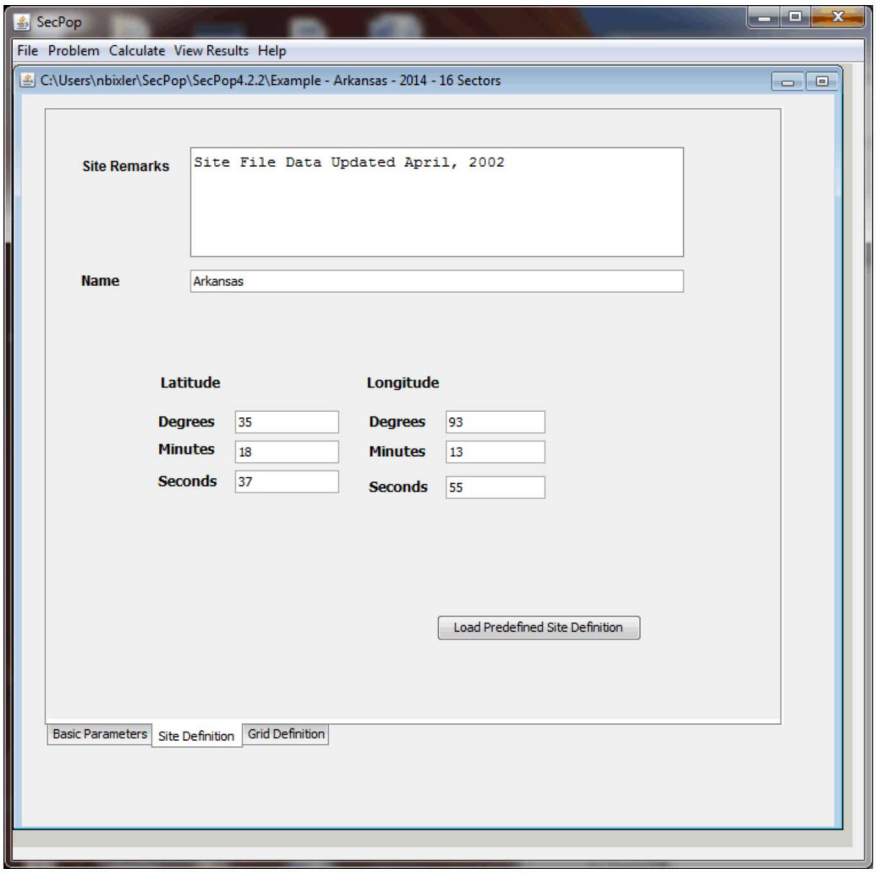


Figure 2-12 Site Definition Window

2.3.2.1 Site Remarks

Site Remarks is a text field where any notes about the site, for example plant specific information like containment type, may be entered. These notes are saved to the project file but do not appear in any output files. This field is optional. If a predefined site file is imported by clicking *Load Predefined Site Definition*, the *Site Remarks* field in the predefined site file is copied to this text field.

2.3.2.2 Name

The name field is a descriptive name of the reactor or facility. This field is printed in the REAcct input files but not the MACCS site files and has no impact on the SecPop calculations. This field is optional. If a predefined site file is imported by clicking *Load Predefined Site Definition*, the *Site Name* field in the predefined site file is copied to this text field.

2.3.2.3 Latitude and Longitude

The latitude and longitude of the site is entered in integer values of degrees, minutes, and seconds. Latitude is considered north and must be between 0 and 90. Longitude is considered west and must be between 0 and 180. Negative values are not allowed. All three fields for latitude and longitude are required. A zero (0) must be entered when the minutes or seconds are equal to zero.

Often, latitude and longitude are given in decimal format instead of degrees. The following example converts 72.5375 degrees to degrees, minutes, and seconds.

- The *Degrees* field is the integer portion of the decimal. In this example, it is 72.

- The *Minutes* field is the integer portion of (*Decimal – Degrees)**60. In this example, (72.5375 – 72)*60 = 32.25. The integer portion is 32 minutes.
- The *Seconds* field is ((*Decimal – Degrees*)*60 – *Minutes)**60. In this example, this is (32.25 – 32) * 60, or 15 seconds. This number should be rounded to the nearest integer.

To convert from degrees, minutes, and seconds to a decimal value, use the following formula:
Decimal = *Degrees* + *Minutes*/60 + *Seconds*/3600.

SecPop checks to see if the coordinates of the site lie outside of the contiguous U.S. by comparing the coordinates to the minimum and maximum coordinates of the contiguous U.S. SecPop considers the contiguous U.S. to be from latitude 24° to 47° north and longitude 67° to 125° west. If the coordinates are determined to be outside of the contiguous U.S., SecPop displays a warning message. This message does not stop the calculation from proceeding.

2.3.2.4 Load Predefined Site Definition

Instead of inputting the latitude and longitude manually, the more common option is to use one of the predefined coordinate (.sit extension) files that are distributed with SecPop by clicking *Load Predefined Site Definition*. A dialog window opens, initialized to the default directory for coordinate files as specified in the SecPop *Preferences* window. This default directory contains a coordinate file for every operating reactor in the U.S. as well as some decommissioned reactors and fuel facilities (See Appendix A for a complete list). Selecting any of these files automatically populates the latitude and longitude fields, as well as the *Site Remarks* and *Name* text field. Figure 2-12 shows the results of selecting the coordinate file Arkansas.sit.

2.3.3 Grid Definition Tab

The third tab is the Grid Definition tab, as shown in Figure 2-13. The number of compass sectors, the radial boundaries, and the economic regions are chosen on this tab.

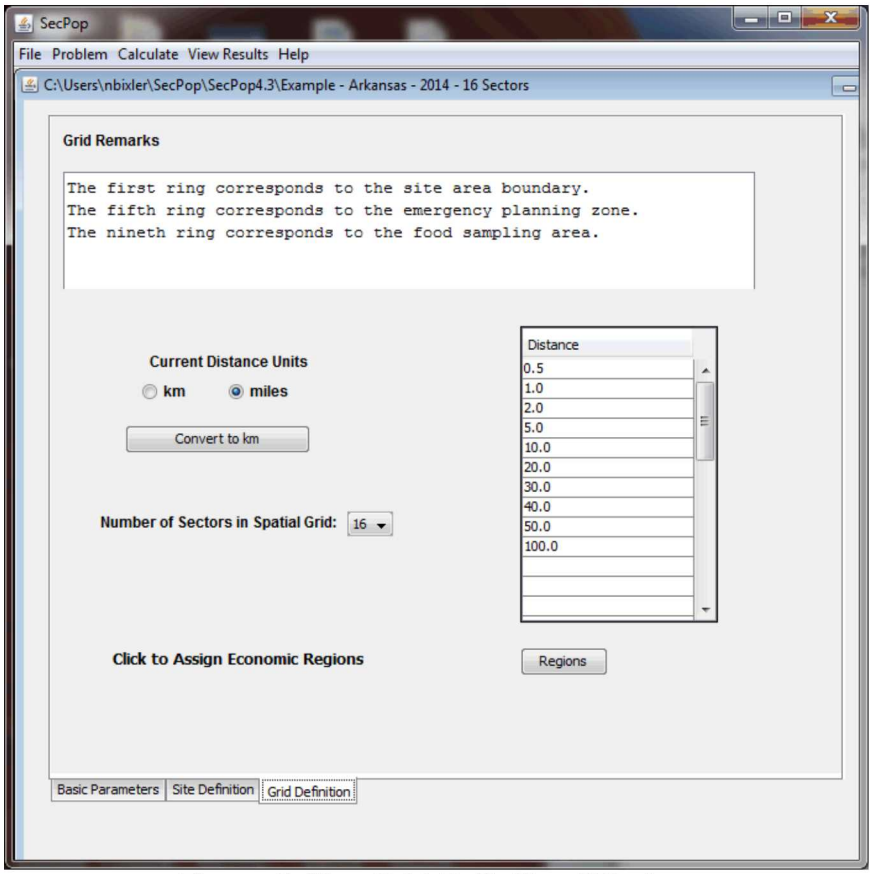


Figure 2-13 Grid Definition Window

The inputs of the grid definition tab are defined as follows.

2.3.3.1 Grid Remarks

Grid Remarks is a text field where any notes about the grid, for example justification for the radial distances, may be entered. These notes are saved to the project file but do not appear in any of the output files. This field is optional.

2.3.3.2 Current Distance Units

Radial distances can be entered in miles or kilometers. Clicking either *km* or *miles* defines the units used in the *Distance* grid.

2.3.3.3 Convert to km or Convert to miles

When the *Current Distance Units* is set to km, the button is labeled *Convert to miles.* Clicking this button converts all values in the *Distance* grid to miles. When the *Current Distance Units* is set to miles, the button is labeled *Convert to km.* Clicking this button converts all values in the *Distance* grid to km.

2.3.3.4 Radial Distances

The Grid Definition tab contains a table input field where the radii of interest for the problem are entered. Input is limited to 35 radii to maintain compatibility with MACCS. At least two radii must be defined. The radii should be consistent with the number of radii (NUMRAD) and distances (SPAEND) to be used in MACCS. The radii and number of sectors are used to define a rosette around the facility for which each grid element has an assigned economic region

number. Users should consider the magnitude of radionuclide release along with the purpose of the MACCS offsite consequence analysis to determine a calculational grid appropriate to capture offsite consequences. Radii are commonly entered at distances corresponding to the power plant site boundary, the 10-mile plume exposure pathway emergency planning zone (EPZ), and the 50-mile ingestion pathway EPZ. The 10-mile radius also corresponds to the NRC Quantitative Health Objective for cancer fatality risk and the 50-mile radius is commonly used as the outer boundary for regulatory cost-benefit analysis.

2.3.3.5 Number of Sectors

A drop-down menu allows the user to choose the number of compass sectors in the spatial grid. The options are 16, 32, 48, and 64 sectors, with a default of 16 sectors. The number of sectors in SecPop must be the same as NUMCOR in MACCS. It must also be the same as the number of wind directions in the meteorological data file to be used by MACCS. Sector one is always centered on due north and the site is always at the center of the grid.

Figure 2-14 shows an example of a polar grid that has 16 compass sectors and nine radial rings. A sector is the same as a compass direction (16 total), while a grid element is a single cell in a compass direction. There are 16 × 9 = 144 grid elements shown in Figure 2-14.

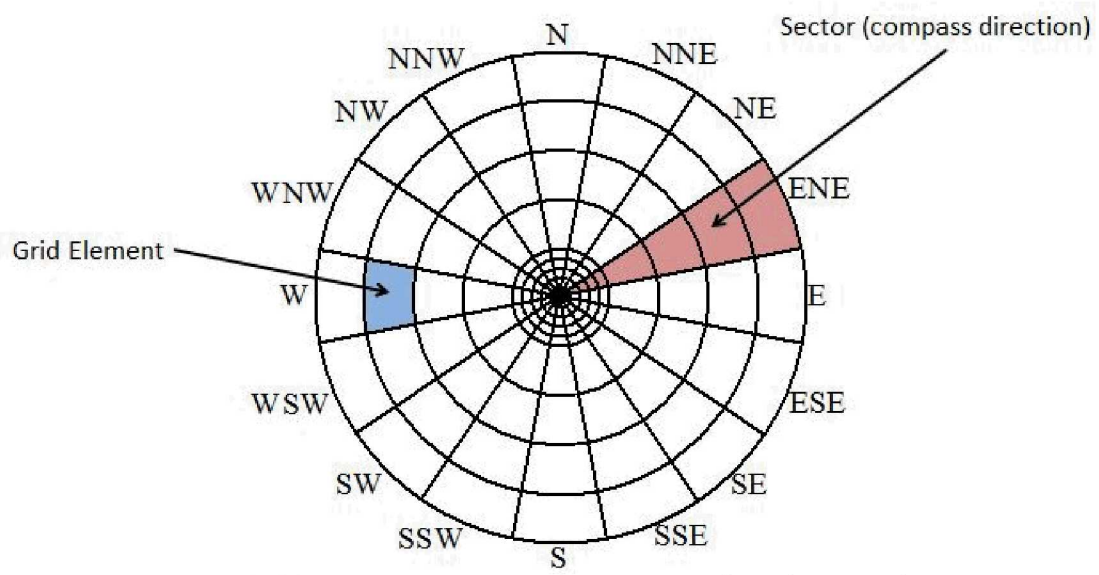


Figure 2-14 Example Polar Calculation Grid (Rosette)

2.3.3.6 Regions

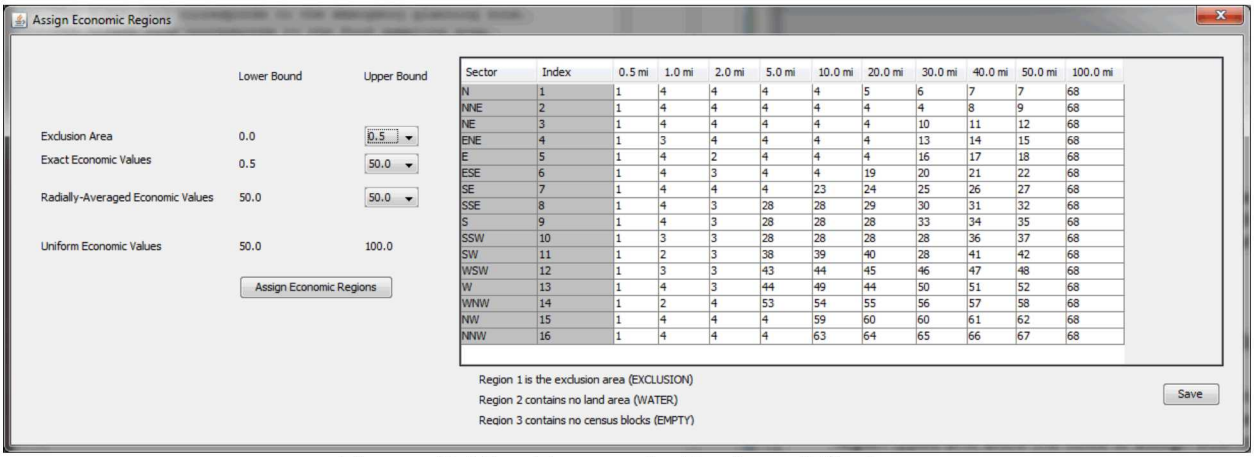
Selecting “Regions” opens a window where economic regions are defined. This window is described further in the following section. At least two radii must be entered in the Grid Definition screen before the Regions window can open.

When economic regions are not defined by the user, SecPop automatically defines the regions when a calculation is requested. SecPop uses a simple algorithm that assigns the exclusion area to all grid elements within the first radius, a unique economic region to all grid elements between the first and second radii, and the same economic region to all other grid elements. This has the effect of defining a minimal exclusion area and applies the average land use and economic values over all grid elements beyond the second radius. This default definition of economic regions is useful only when economic results are not important, so it is recommended in most cases to use the Assign Economic Regions function.

2.4 Assign Economic Regions Window

The final step before calculations are performed is to assign economic regions. Economic regions are defined by either importing an existing site file with economic regions already defined or by using the *Assign Economic Regions* form as described in this section.

Clicking *Regions* on the *Grid Definition* tab opens a window used to assign the economic regions, as shown in Figure 2-15.



Sector	Index	0.5 mi	1.0 mi	2.0 mi	5.0 mi	10.0 mi	20.0 mi	30.0 mi	40.0 mi	50.0 mi	100.0 mi
N	1	1	4	4	4	4	5	6	7	7	68
NNE	2	1	4	4	4	4	4	4	8	9	68
NE	3	1	4	4	4	4	4	10	11	12	68
ENE	4	1	3	4	4	4	4	13	14	15	68
E	5	1	4	2	4	4	4	16	17	18	68
ESE	6	1	4	3	4	4	19	20	21	22	68
SE	7	1	4	4	4	23	24	25	26	27	68
SSE	8	1	4	3	28	28	29	30	31	32	68
S	9	1	4	3	28	28	28	33	34	35	68
SSW	10	1	3	3	28	28	28	28	36	37	68
SW	11	1	2	3	38	39	40	28	41	42	68
WSW	12	1	3	3	43	44	45	46	47	48	68
W	13	1	4	3	44	49	44	50	51	52	68
WNW	14	1	2	4	53	54	55	56	57	58	68
NW	15	1	4	4	4	59	60	60	61	62	68
NNW	16	1	4	4	4	63	64	65	66	67	68

Figure 2-15 Economic Regions Window

There are three main options for assigning economic regions.

1. SecPop can assign region numbers to the grid based on the user-defined areas corresponding to the four region assignment types: exclusion area, exact economic values, radially-averaged economic values, and uniform economic values. The user enters the upper (outer) bound for each region assignment type using the drop-down menus and then clicks *Assign Economic Regions*.
2. Region numbers can be manually entered or modified in the grid.
3. Regions can be imported from an existing MACCS site file by using the *File/Import MACCS Site File* option in the main menu.

A detailed description of each region assignment type is provided below. The *Exclusion Area* is required to contain at least one ring. The *Lower Bound* and the *Upper Bound* may be equal for *Exact Economic Values and Radially-Averaged Economic Values.* In general, the use of different region types allows flexibility to specify the greatest resolution computational grid. Though region numbers may exceed the upper bound of 99 in this window, SecPop does not allow saving the economic region assignment when the upper bound of 99 economic regions is exceeded. The limit of 99 is the result of a current MACCS limitation that only allows the region index to be two-digit integers. This limit may be relaxed in the future and the need to average economic values over multiple grid elements may be eliminated. The current options for averaging economic values are described in this section.

2.4.1 Exclusion Area

The NRC defines the exclusion area as the area surrounding a reactor where the licensee has the authority to determine all activities, including exclusion or removal of personnel and property. It is expected that no population reside within it. The exclusion area boundary for a given reactor site is defined by the licensee. Each grid element within the exclusion area is assigned an economic region number of 1, as illustrated in Figure 2-15. This region is assigned zero population and zero economic values. This region type must contain at least the first ring.

If any people are found to be in the exclusion area, this population is not included in the SecPop calculation and the user is alerted via a message window like the one in Figure 2-16. In this example, the exclusion area is assigned to the two inner rings corresponding to the area within 1.0 mile. SecPop calculates about 213 people in this area that would be excluded from the population array in the MACCS site file corresponding to the following compass directions in the ring from 0.5 to 1.0 mile: 1, 3, 5, 6, 7, 8, 9, 13, 15, and 16 (corresponding to directions of N, NE, E, ESE, SE, SSE, S, W, NW, and NNW). (The actual population calculated by SecPop is not an integer because the population from the census data is multiplied by a real value to account for population growth.) The radius of the exclusion area should therefore be decreased so this population is not excluded from the calculation. In this Arkansas example, adjusting the exclusion area to be within 0.5 miles corrects this because no population is located within this radius.

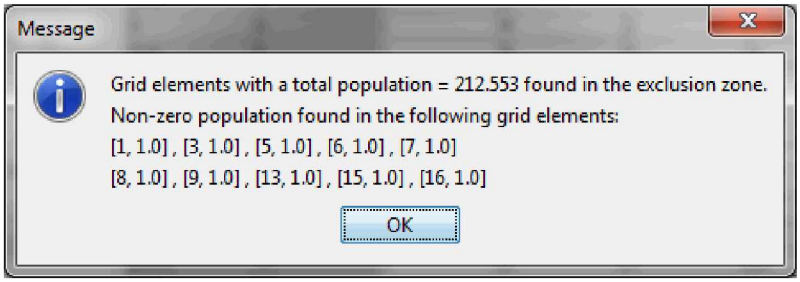


Figure 2-16 Non-Zero Exclusion Area Population Message

2.4.2 Exact Economic Values

When the user selects an area for the *Exact Economic Values* region assignment type, each grid element in that area usually has a unique economic region number assigned. However, there are a few exceptions to this rule. The first exception is when a grid element is comprised exclusively of one county. If one or more other grid elements are also exclusively comprised of the same county, these grid elements share the same region number. In this case, the MACCS site file uses the county name as part of the economic region description field. Another exception is when a grid element contains no land area, perhaps corresponding to a large river, lake or ocean. These grid elements are assigned to region number 2, which has zero population and zero economic values. The third exception is when a grid element contains no census blocks; these grid elements are assigned to region number 3. Region 3 has zero population but has economic data related to farmland. The user is reminded of the definitions for regions 1, 2, and 3 at the bottom of the Economic Regions window, as shown in Figure 2-15. The capitalized words shown in this legend (i.e., EXCLUSION, WATER, and EMPTY) are used as part of the region description in the MACCS site file.

Any grid element in this area that contains two or more counties is assigned a unique region number and the economic values of the counties in that grid element are weighted averages. Averaging is done by population weighting for nonfarm values and by land-area weighting for farm values.

In the example shown in Figure 2-15, region numbers 4, 7, 17, 28, 35, 44, and 60 are individual counties and the others are mixtures of counties. The *Exact Economic Values* region assignment type provides the greatest resolution and therefore should be used for as much of the grid as possible. In this example, using exact economic values from 0.5 to 50 miles and uniform economic values from 50 to 100 miles creates 68 economic regions, which is below the upper bound of 99. When the computational grid uses more radii or more compass sectors, the user might need to take an iterative approach to adjust the upper bound radius for *Exact Economic Values* to keep the total number of regions below 100. As a rule, *Exact Economic Values* and *Radially Averaged Economic Values* should be used within the area for which economic results are to be reported. *Uniform Economic Values* should be reserved for the area beyond which economic results are to be reported.

2.4.3 Radially-Averaged Economic Values

When the user selects an area for the *Radially Averaged Economic Values* region assignment type, every grid element in this area that is in the same angular compass sector is assigned the same region number. The exception is when a grid element is composed of a single county that has previously been assigned a region number. In the example shown in Figure 2-15, this region assignment type is not used. However, in a more finely meshed computational grid, the maximum region number may exceed 99. In this case, it would be appropriate to use this region assignment type.

2.4.4 Uniform Economic Values

When the user selects an area for the *Uniform Economic Values* region assignment type, every grid element in this area is assigned the same economic region number regardless of angular compass sector or radius. The only exception is when a grid element is composed of a single county that has already been assigned a region number. In the example shown in Figure 2-15, this region assignment type is applied to the ring between 50 and 100 miles and all 16 grid elements in this area are assigned to region number 68. The grid elements with the same region number have economic values averaged over all represented counties, weighted by land area or population, depending on the economic value calculated. This region uses the coarsest approximation and in general should be used sparingly and outside the region for which offsite consequence analysis results are to be reported.

2.4.5 Assign Economic Regions

Once the areas are defined for each region assignment type, the user clicks *Assign Economic Regions*. The census file is read and region numbers are assigned using the defined criteria. When the number of unique economic regions exceeds 99, the user should take an iterative approach to adjust the areas corresponding to the region assignment types of *Exact Economic Values* and *Radially Averaged Economic Values.* It is recommended that the user seek the greatest resolution possible while maintaining the total number of regions below 100. Each time these limits are adjusted, click *Assign Economic Regions* to redefine the assignment of economic regions. The census file only needs to be read the first time this button is clicked so subsequent revisions of the areas are relatively fast.

A large census block may span two or more grid elements, but is only assigned to the one grid element that contains the centroid of the census block, potentially leaving surrounding grid elements defined as having no population. The user should also be aware of the possibility with

concave-shaped census blocks for the centroid of population to lie outside the actual census block.

Grid elements with the same assigned region number have the same economic values assigned in the MACCS site file. Once the economic regions are defined, *Save* closes the window and saves the assigned regions. The window can also be closed at any time without saving by clicking the X in the upper right corner.

3.0 COMPUTATIONAL METHODOLOGY

The SecPop code uses block-level census data and county-level land use and economic data to estimate the population, land fraction, and other economic information for each of the user-defined grid elements. The methodology involved can be broken down into (1) the algorithms used within the code to accomplish this purpose and (2) the database structures used for the block and county level databases. This section discusses the algorithms for population estimation and determining distances based on latitude and longitude. Appendices B, C, and D discuss the structure of the census and county files, respectively and the sources of data used to generate them.

3.1 Population Estimation and Density Algorithms

For a user-defined site location and radial grid, SecPop establishes latitude and longitude boundaries that encompass the grid for computational optimization. When a point (corresponding to a census block) is found to lie within the boundaries of the grid, the distance of that point from the site is calculated using the equations provided in the following subsection to determine if in fact the point lies within the outer limit of the grid. If the point meets the distance criteria, it is then processed to determine the exact grid element in which it lies based on its radial distance and direction from the site. The population associated with that data point is then added to the population of the appropriate grid element.

The algorithm used to determine the latitude and longitude boundaries of the grid is discussed in Subsection 3.1.1. The iterative algorithm used to determine the westernmost point in the census data file lying on or to the west of the western longitude boundary of the grid is discussed in Subsection 3.1.2. Finally, the algorithms used to determine if a data point lies within the grid and to determine the specific grid element within which any point lies are discussed in Subsection 3.1.3.

3.1.1 Boundaries Algorithm

The heart of the boundaries algorithm is the calculation of distance (in km) per degree latitude and per degree longitude for a specific geodetic latitude. The geodetic latitude is first converted to radians. The corresponding latitude in the master coordinate system, which is geocentric, is then calculated using Equation 3-1:

$$\theta_{GC} = \tan^{-1}\left[\left(\frac{R_{ep}}{R_{eq}}\right)^2 \tan\theta_{GD}\right] \qquad \text{Equation 3-1}$$

Where

θ_{GC} = the geocentric latitude (radians)
R_{ep} = the polar radius of the earth, 6356.752 km
R_{eq} = the equatorial radius of the earth, 6378.137 km
θ_{GD} = the geodetic latitude (radians)

The distinction between geodetic and geocentric latitudes is in the way angle is calculated in an ellipsoidal coordinate system. Geodetic latitude is based on the angle between the normal to the surface and the equatorial plane. Geocentric latitude is based on the angle between the equatorial plane and a line segment connecting a point on the surface with the center of the ellipsoidal coordinate system. For an oblate ellipsoid, like the earth, the geodetic latitude is

always greater in magnitude or equal to the corresponding geocentric latitude. They are equal at three loci, any point on the equator (both latitudes are zero) and at both of the poles (both latitudes are 90°).

The geocentric radius, R_{GC}, is then calculated using Equation 3-2:

$$R_{GC} = \frac{R_{eq} R_{ep}}{\sqrt{R_{eq}^2 \sin^2\theta_{GC} + R_{ep}^2 \cos^2\theta_{GC}}} \qquad \text{Equation 3-2}$$

The geocentric radius is the radius from the center to a point on the surface of an ellipsoid that approximates the actual shape of the earth and this radius is a function only of latitude, as shown in Equation 3-2. The distance (km) per degree latitude, DPDLAT, and the distance (km) per degree longitude, DPDLON, are specified by Equations 3-3 and 3-4:

$$DPDLAT = R_{GC} \frac{\sin\theta_{GC}}{\sin\theta_{GD}} \cdot \left(\frac{\pi}{180}\right) \qquad \text{Equation 3-3}$$

$$DPDLON = R_{GC} \cos\theta_{GC} \cdot \left(\frac{\pi}{180}\right) \qquad \text{Equation 3-4}$$

It can be shown that if the west-east longitudinal boundaries are established at the longitudes corresponding to the boundary of the outer radius of the grid on the latitude of the site, the entire grid lies between those same two longitudinal boundaries. The values of those longitudinal boundaries can be found by dividing the outer radius of the grid by DPDLON, the distance per degree longitude at the geodetic latitude of the site. Finding the north and south latitudinal boundaries is more complex. The distance per degree latitude decreases with increasing latitude. To ensure that the boundaries encompass the entire grid, distance per degree latitude determined at the Tropic of Cancer is used for the half of the grid lying below the latitude of the site, and the distance per degree latitude determined at the site is used for the half of the grid north of the site. As a result, the north and south boundaries are always outside the grid, but this is acceptable since the boundaries are used only to eliminate the census data points that do not need to undergo further processing.

3.1.2 First Element Location Algorithm

A binary search algorithm is used to determine the first point in the census data file that lies on or to the west of the western longitudinal boundary of the grid. The set of records in the census data file is divided into two halves and it is determined in which half the western boundary lies. The procedure is then repeated concentrating on that half of the set. This is continued until one of two situations occurs. If two adjacent points are found which straddle the boundary, the easternmost record is marked. If a point is found that lies on the western boundary, the records are searched backward sequentially until the first of the data elements is found that lies to the west of the boundary and that point is marked.

3.1.3 Specific Grid Element Determination

When a census data point is found to lie within the longitudinal and latitudinal boundaries of the grid, a SecPop algorithm calculates the surface distance (the distance measured along the surface of the earth) between the census data block center point and the site center point. If the distance is less than the outer radius of the grid, then the census block lies within the region of interest. Surface distance is calculated using the Pythagorean theorem based on longitudinal and latitudinal distances. Longitudinal distance is calculated by multiplying the difference in

longitudes between the site and the element by the value of DPDLON calculated for the site. Similarly, latitudinal distance is calculated by multiplying the difference in latitudes by an average DPDLAT. Since values for DPDLAT vary significantly with latitude, the value used is the average of the value calculated at the site and the value at the census block. The census data element is then located within a radial ring based on this surface distance. This method essentially introduces a local flat plane approximation to earth's surface.

Once it is determined that a census block lies within the grid, it is then necessary to determine in which of the grid elements the census data point lies. The angle (measured clockwise from true north) of a line from the site center to the census block is found from Equation 3-5:

$$\theta_{de} = \tan^{-1}\left(\frac{x}{y}\right) \qquad \text{Equation 3-5}$$

Where

θ_{de} = the angle made between a line from the site to the data element and true north
x = the distance from the longitude of the data element to the longitude of the site
y = the distance from the latitude of the data element to the latitude of the site

This value, θ_{de}, is then used to determine the specific grid element in which the census block is located.

3.2 Land Fraction Algorithms

In addition to location and population, every record in the block-level database also includes the land area of the block and a code to indicate which county in the U.S. the block resides. In addition, the 2010 census file contains water area for each census block. Total area of the block is the sum of land and water areas. This additional information allows for a finer granularity of land-fraction data than was available with previous census data. This information is used by both the land-fraction algorithm and the economic-factors algorithms to estimate land fractions and economic factors, respectively.

County-level databases contain the land-fraction data for every county in the contiguous U.S. The sources for the economic factors and the sources of the data are described in Table 3-1.

With the 2000 and earlier census files, the area of the census blocks cannot be used to determine section land fractions directly for two reasons. First, the area given is only the land area; no water area is included with the block-level data. Second, there is no simple way to aggregate the block areas to determine how much of a grid element they "fill up" since the geometry of the blocks is unknown. Instead the area of the blocks is used to weight the county-level land fraction data.

With the 2010 census data, this deficiency is resolved. Data at the census-block level contains both land and water areas, so land fraction data at the county level are not needed. This allows a higher level of granularity with the 2010 data.

Table 3-1 County Level Data File Variables and Data Sources

Variable	Description	Source for COUNTY2002.DAT (compatible with 2000 census file)	Source for COUNTY2007.DAT (compatible with 2010 census file)	Source for COUNTY2012.DAT (compatible with 2010 census file)
FRMFRC	Fraction of land devoted to farming in the region	2002 Census of Agriculture Data Files Supplied by the U.S. Department of Commerce Economics and Statistics Administration Bureau of the Census	2007 Census of Agriculture Data Files Supplied by the U.S. Department of Commerce Economics and Statistics Administration Bureau of the Census	2012 Census of Agriculture Data Files Supplied by the U.S. Department of Commerce Economics and Statistics Administration Bureau of the Census
DPF	Fraction of farm sales resulting from dairy production in the region			
ASFP	Annual average farm sales for the region ($/hectare)			
VFRM	Average farmland value for the region ($/hectare)			
VNFRM	Average non-farm value for the region ($/person)	2003 and 2004 Statistical Abstract of the United States, U.S. Dept. of Commerce, Economics and Statistics Admin., Bureau of the Census 2004 County and City Data Book, U.S. Dept. of Commerce, Bureau of the Census, Data User Services Div.	2008 and 2009 Statistical Abstract of the United States, U.S. Dept. of Commerce, Economics and Statistics Admin., Bureau of the Census 2009 County and City Data Book, U.S. Dept. of Commerce, Bureau of the Census, Data User Services Div.	2013 and 2014 Statistical Abstract of the United States, U.S. Dept. of Commerce, Economics and Statistics Admin., Bureau of the Census 2014 County and City Data Book, U.S. Dept. of Commerce, Bureau of the Census, Data User Services Div.

During a site-specific calculation, a running sum for each grid element is made of the total area of the blocks that lie within each section and a running sum is made of all the weighted land fraction data. At the end of the calculation, the sum of the weighted land fractions is divided by the sum of the block areas. For the 2000 (and older) census data, this is equivalent to the following formula for the land fraction for grid element i, j:

$$FRCLND\_2000(i,j) = \frac{\sum_{n} LA_{Block} \times FRCLND\left(County_{Block}\right)}{\sum_{n} \left(LA_{Block}\right)} \qquad \text{Equation 3-6}$$

Where

$FRCLND(i,j)$ = the estimated land fraction for the grid element defined by sector *i* and the area between radii *j* and *j-1* (where $j = 0$ refers to the center of the grid, i.e., a radius of zero),

$FRCLND(County_{Block})$ = the land fraction of the county in which the present census block resides,

LA_{Block} = the land area of a census block whose centroid is within grid element (i,j), and

n = the number of census blocks that resides in grid element (i, j).

For 2010 census data, the algorithm takes account of the additional information provided in the database by using the following equation to estimate land fraction for a grid element:

$$FRCLND\_2010(i,j) = \frac{\sum_{n} LA_{Block}}{\sum_{n} (LA_{Block} + WA_{Block})} \qquad \text{Equation 3-7}$$

Where

WA_{Block} = the water area of a census block whose centroid is within grid element *(i,j)*.

Note that in areas where census blocks tend to be large, e.g., lakes, deserts, national and state parks, it is possible that no census block centroid lies within a grid element and the resulting land fraction is estimated to be 0. While this is appropriate for a lake, it may not represent desert regions accurately. The user may need to edit the output data manually in such cases to obtain a better estimate for areas that do not contain census block centroids. Whenever the denominator of Equation 3-6 or 3-7 is zero, the estimated value is assigned to be zero. The current version of SecPop clearly identifies grid elements with land but no population by assigning them an economic region index of 3. When the entire area of the grid element is water, the economic region index is set to 2.

3.3 Economic Factors Algorithms

SecPop estimates the economic factors that are defined in the Site Data File. The economic factors are calculated for the user-defined economic regions. The user can define the number of rings that comprise the exclusion area, and this region is assigned an economic region index of 1. The economic values assigned to this region are zeros.

The algorithm used to calculate the economic factors is very similar to that used in Section 3.2. The only difference is that the values are accumulated for each economic region instead of each grid element. The county-level database has values for each economic factor by county. The Economic Factor (*EF*) for each economic region, *i*, is calculated using the following equation:

$$EF(i) = \frac{\sum_{n} LA_{Block} \times EF(County_{Block})}{\sum_{n} LA_{Block}} \qquad \text{Equation 3-8}$$

Where

$EF(i)$ = the estimated economic factor for economic region i,
$EF(County_{Block})$ = the economic factor of the county in which the census block resides,
LA_{Block} = the land area of a census block that lies within an economic region i,
n = the number of census blocks that belong to economic region i.

The exception to using Equation 3-8 to estimate economic factors is for the average nonfarm value for a region, VNFRM, when calculated in conjunction with 2010 census data. In this case, the weighting is based on population rather than land area. The weighting is based on land area (Equation 3-8) when using 2000 census data for compatibility with older versions of SecPop. For this one specific case, Equation 3-8 is replaced with Equation 3-9 below.

$$VNFRM\ (i) = \frac{\sum_{n} POP_{Block} \times VNFRM\ (County_{Block})}{\sum_{n} POP_{Block}} \qquad \text{Equation 3-9}$$

Where

$VNFRM(i)$ = the estimated average per capita nonfarm value for economic region i,

$VNFRM\ (County_{Block})$ = the per capita nonfarm value of the county in which the census block resides, and

POP_{Block} = the population of a census block that belongs to economic region i.

3.4 Database Structure

The five database files that are distributed with SecPop are the block-level census files, Census00.bin and Census2010.bin, and the county-level files, County2002.dat, County2007.dat, and County2012.dat. The 2000 and 2010 block-level census databases contain nearly eight million and eleven million records, respectively corresponding to the number of census blocks at the time of each census. The county-level census database contains over three thousand records, one for every county in the contiguous U.S. Only subsets of the possible combinations of census and county files are allowed because of changes in the sets of counties included circa 2000 and circa 2010. Specifically, Census00.bin is compatible with County2002.dat and Census2010.bin is compatible with County2007.dat and County2012.dat. The sections below describe the databases in more detail.

3.4.1 Block-Level Database

The 2000 and 2010 block-level census data are stored in binary files, Census00.bin and Census2010.bin. The 2000 data contain 8,164,718 records (census blocks); the 2010 data contain 11,007,989 records. The data used by SecPop are subsets of the original census data because they exclude Alaska, Hawaii, and the US territories. Each record is 12 bytes long and contains the following five pieces of information:

(1) a 2-byte integer code for the longitude of the geometric centroid of the census block,
(2) a 2-byte integer code for the latitude of the geometric centroid of the census block,
(3) a 2-byte integer for the residential population that resides within the census block,
(4) a 4-byte integer for the land area (0.001 km^2) of the census block, and
(5) a 2-byte integer code for the county in which the census block resides.

The integer codes for the longitude and latitude were derived to reduce the storage required for the block-level database. The longitude can be calculated using the following formula:

longitude = (integer_code + 91993) / 1000.0

The latitude can be calculated using the following formula:

latitude = (integer_code + 16610) / 1000.0

The integer code for the county is the index to the county-level database and is the first field in each record of that database. More information on the county-level database can be found in the next sub-section. Details on how the block-level databases were constructed and verified can be found in the appendices.

3.4.2 County-Level Database

The county-level data are stored in a fixed-width format ASCII text file. The file County2002.dat is used with the year 2000 census data files. The County2007.dat and County2012.dat files are used with the year 2010 census data files. The county-level database files contain a line of data for each of the 3109 counties in the contiguous United States. The data in these files are preceded by one header line.

The 2007 and 2010 county data files contain only non-census information. These county data files contain the following fields for each county:

FIPS Code	standard US federal code that identifies the state and county
State	two-letter abbreviation of the state in which the county lies
County Name	name of the county
FRCLND	fraction of area that is land in the county
FRMFRC	fraction of land devoted to farming in the county
DPF	fraction of farm sales resulting from dairy production in the county
ASFP	annual-average farm sales for the county ($/hectare)
VFRM	average farmland value for the county ($/hectare)
VNFRM	average non-farm value for the county ($/person)
Notes	comma separated fields describing data exceptions. Exceptions are listed in the order of FRMFRC, DPF, ASFP, FVFRM and VNFRM.

- "-" signifies that the data are listed in the agricultural census table with a value of zero for the respective field
- "d" signifies that the data are listed in the agricultural census table but data was withheld by the census bureau for confidentiality purposes
- "ex" signifies that the data are not listed in the agricultural census table and for this reason was assigned value of zero
- "b" signifies that farm area reported slightly exceeds county land area, and for this reason was assigned the value of one
- "pci" signifies that BEA combined an independent city and its neighboring county with a single PCI so the same value is applied to each
- "IC" signifies that the county is actually an independent city that has its own FIPS code

A sample of the 2012 database is shown in Table 3-2. The 2007 database follows the same format.

Table 3-2 Excerpt From the 2012 County-Level Database

Fips	State	County	FRCLND	FRMFRC	DPF	ASFP	VFRM	VNFRM	Notes
53001	WA	Adams	0.997475	0.841711	0	1025	3657	385355	, d, , , ,
53003	WA	Asotin	0.993084	0.64632	0	193	2718	360268	, -, , , ,
53005	WA	Benton	0.966126	0.64646	0	3243	7380	400593	, d, , , ,
53007	WA	Chelan	0.975498	0.040564	0	6729	22263	401322	, -, , , ,
53009	WA	Clallam	0.650904	0.021249	0	1113	31415	384099	, d, , , ,

The census specific fields, namely the population and the area, are written to an auxiliary file used by SecPop when the 2007 or 2012 county data are used. This information is created from the census database. This file, Census2010.aux, contains the following fields for each county:

FIPS Code	standard US federal code that identifies the state and county
State	two-letter abbreviation of the state in which the county lies
County Name	name of the county
LandArea	county land area in m**2
WaterArea	county water area in m**2
Population	county population

A sample of the Census2010.aux data file is shown in Table 3-3.

Table 3-3 Excerpt From the 2010 Census Auxilliary Database

Fips	State	County	Land Area	Water Area	Population
53001	WA	Adams	4.99E+09	1.26E+07	18728
53003	WA	Asotin	1.65E+09	1.15E+07	21623
53005	WA	Benton	4.40E+09	1.54E+08	175177
53007	WA	Chelan	7.56E+09	1.90E+08	72453
53009	WA	Clallam	4.50E+09	2.41E+09	71404

The 2002 county data file contains similar data. However, an additional county index needed for the previous software, SecPop2000, is included in the file. Because the census population and area information is included in the 2002 county data file, it is not necessary to have an auxiliary file containing the census specific information.

4.0 REFERENCES

[1] NUREG/CR-6525, SAND93-4032, "SECPOP90: Sector Population, Land Fraction and Economic Estimation Program," U.S. Nuclear Regulatory Commission, Washington, DC, 1993 (ADAMS ML18053A699).

[2] NUREG/CR-6525, Rev. 1, "SECPOP2000: Sector Population, Land Fraction, and Economic Estimation Program," U.S. Nuclear Regulatory Commission, Washington, DC, 2003 (ADAMS ML032310279).

[3] NUREG/CR-4551, SAND86-1309, Vol. 2, Rev. 1, Part 7, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters," U.S. Nuclear Regulatory Commission, Washington, DC, December 1990 (ADAMS ML100110319).

[4] NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC, December 1990.

[5] NUREG/CR-6613, "Code Manual for MACCS2: User's Guide," Volume 1, U.S. Nuclear Regulatory Commission, Washington, DC, December 1998 (ADAMS ML110030976).

Appendix A Coordinate (.Sit) Files

Table A-1 lists all the coordinate files provided with SecPop in the SecPop\Sites directory. The coordinates provided with each site were obtained from aerial views using publicly available software. For precise estimates, users should confirm site specific coordinates.

Table A-1 SecPop Coordinate (.Sit) Files

Operating Power Reactor Sites		
Arkansas.sit	Ft Calhoun.sit	Point Beach.sit
Beaver Valley.sit	Ginna.sit	Prairie Island.sit
Braidwood.sit	Grand Gulf.sit	Quad Cities.sit
Browns Ferry.sit	Hatch.sit	River Bend.sit
Brunswick.sit	Hope Creek.sit	Robinson.sit
Byron.sit	Indian Point.sit	Salem.sit
Callaway.sit	Joseph M Farley.sit	Seabrook.sit
Calvert Cliffs.sit	Lasalle.sit	Sequoyah.sit
Catawba.sit	Limerick.sit	Shearon Harris.sit
Clinton.sit	Mcguire.sit	South Texas.sit
Columbia Gen Sta.sit	Millstone.sit	St Lucie.sit
Comanche Peak.sit	Monticello.sit	Surry.sit
Cooper.sit	Nine Mile Point.sit	Susquehanna.sit
Crystal River.sit	North Anna.sit	Three Mile Island.sit
Davis-Besse.sit	Oconee.sit	Turkey Point.sit
Diablo Canyon.sit	Oyster Creek.sit	Virgil Summer.sit
Donald C Cook.sit	Palisades.sit	Vogtle.sit
Dresden.sit	Palo Verde.sit	Waterford.sit
Duane Arnold.sit	Peach Bottom.sit	Watts Bar.sit
Fermi.sit	Perry.sit	Wolf Creek.sit
Fitzpatrick.sit	Pilgrim.sit	
Shutdown Power Reactor Sites		
Big Rock Point.sit	Maine Yankee.sit	Vermont Yankee.sit
Haddam Neck.sit	Rancho Seco.sit	Yankee Rowe.sit
Kewaunee.sit	San Onofre.sit	Zion.sit
Lacrosse.sit	Trojan.sit	
Fuel Cycle Facility Sites		
Advanced Medical Systems.sit	Idaho NatL Engineering And Environ.sit	Portsmouth.sit
Bwx Technologies.sit	Mallinckrodt.sit	Richland Framatome.sit
General Atomics.sit	Morris General Electric.sit	Safety Light Corp.sit
Hanford Meteorological Tower.sit	Nuclear Fuel Services.sit	Squibb.sit
Hematite - Combustion Engr.sit	Oak Ridge.sit	Westinghouse Elec Corp.sit
Honeywell.sit	Paducah.sit	Wilmington Ge.sit

Appendix B 2010 Census File

This section describes the development of the 2010 census file for the SecPop code. All information needed to create the 2010 census file was purchased from the U.S. Census Bureau. The data set was purchased from the US Census Bureau and includes extraction software, the interface of which can be seen below in Figure B-1 and subsequent figures in this appendix.

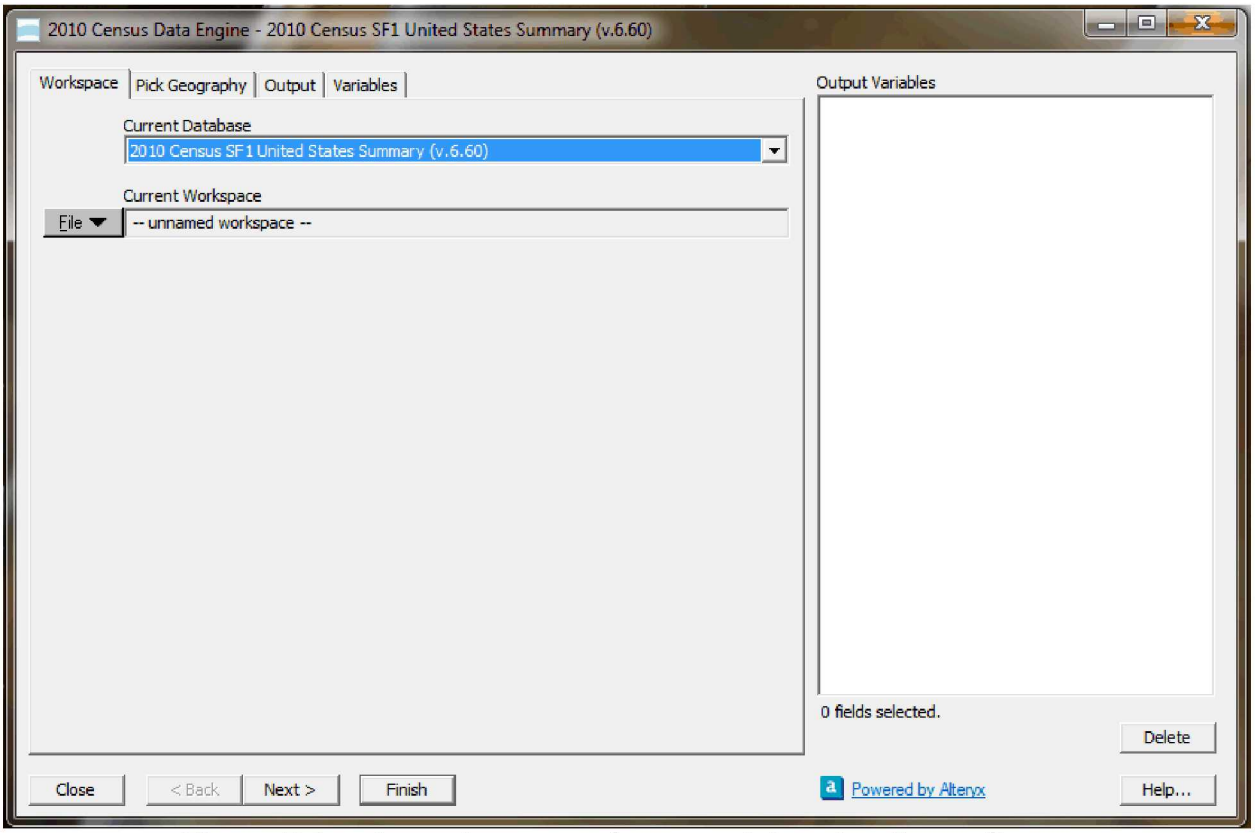


Figure B-1 Launch screen of census data extraction software

On the next screen in the "Pick Geography" tab (shown in Figure B-2), the Block (101) geography option was selected. This automatically writes the name of each block in the output file as well as a unique numeric key for each block that contains the 5-digit state and county FIPS code as the leading 5 digits.

There are 11,078,297 census blocks in the 2010 Census that cover the entirety of the United States, including national parks and other types of federal land. The SecPop database only includes the contiguous US, which has 11,007,989 census blocks. The difference between these two numbers corresponds to the number of census blocks in Alaska, Hawaii, Puerto Rico, and the other US territories.

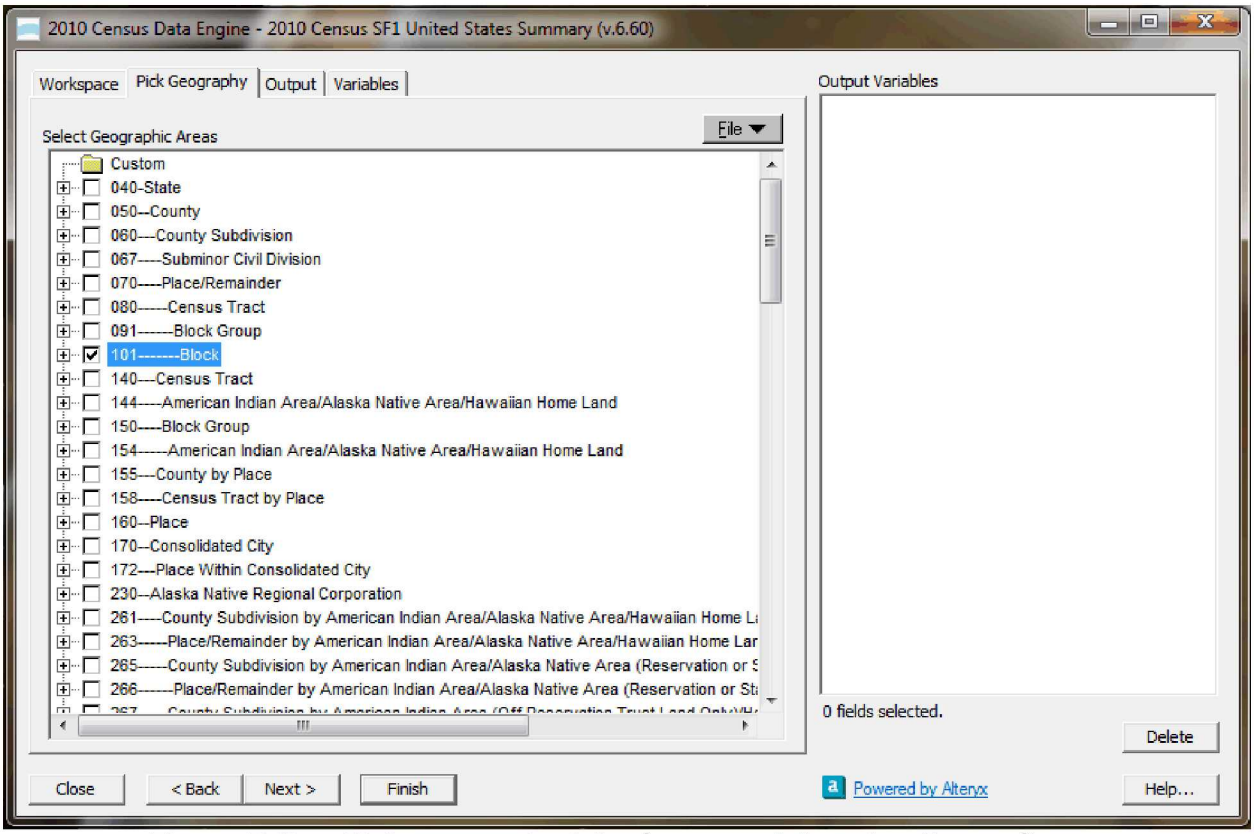


Figure B-2 Pick geography tab of census data extraction software

The next tab, “Output” (shown in Figure B-3), specifies the location and format of the output file or report. The Report option gives some pre-defined formats, but none of these were determined to be useful for this work, so the simpler File option was used. The file format used was to save directly as an Access database, which could then be manipulated using the Access query functionality. Another option was a comma separated text file (.csv) so that manipulation could be done in Excel. However, this file proved too large (over 11 million rows) to be processed with Excel.

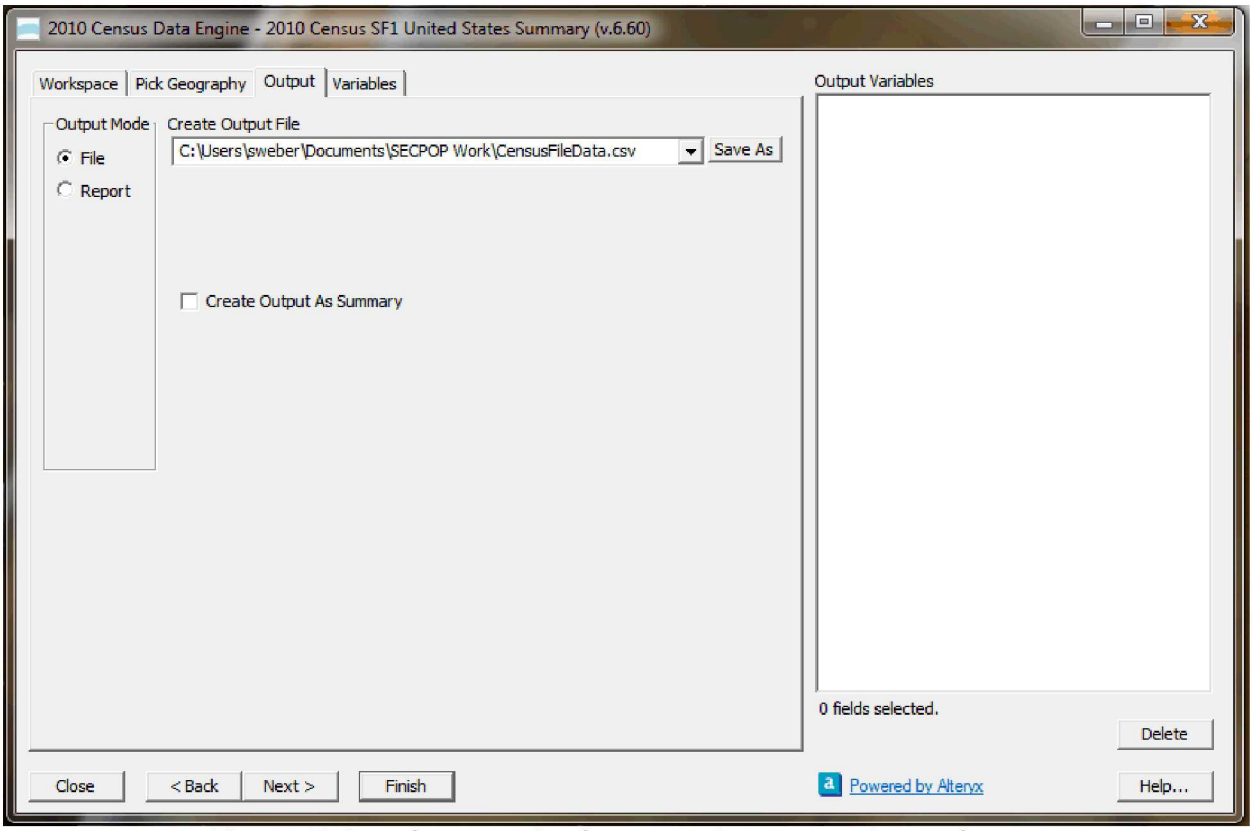


Figure B-3 Output tab of census data extraction software

The final step was to choose the output variables from the Variables tab, shown in Figure B-4. The five variables displayed in the window on the right side (land area, water area, latitude, longitude and population count) were used to create the census file. All five are contained within the Geographic Identifiers folder. Area (at least at the block level) is output in units of $1x10^{-6}$ km^2 (1 m^2). State (FIPS) and COUNTY could also be included to create the 5 digit FIPS code, if it was not extracted from the 24-digit block key that is automatically output.

Final formatting was done in Access and included the following:

- Extraction of the FIPS code from the long key
- Addition of a sequentially increasing ID (key field) for each census block for searching purposes
- Storage of latitudes and longitudes as 4-byte floating point numbers
- Sorting the data in descending order of longitude
- Writing a program to convert the data to a binary file, which is more efficient both in terms of file size and access speed than a text file

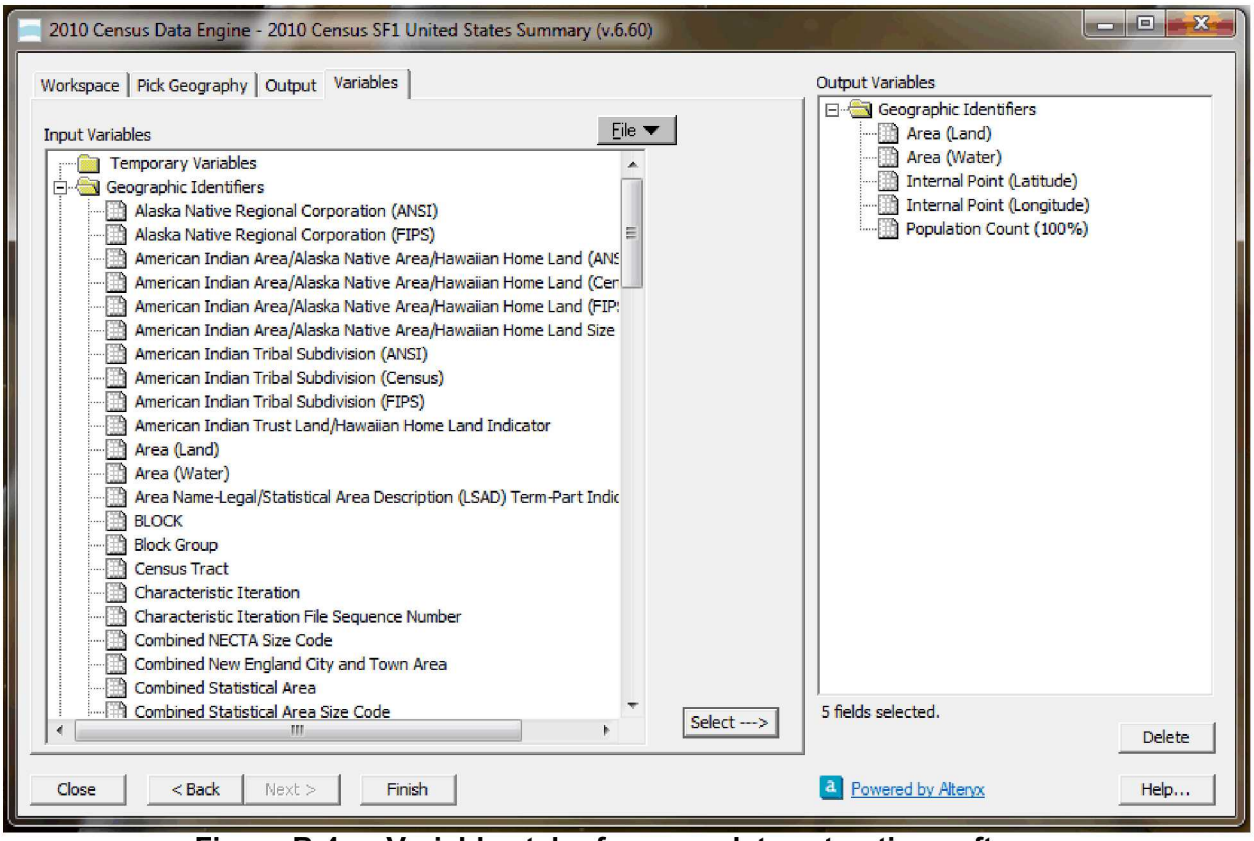


Figure B-4 Variables tab of census data extraction software

Appendix C 2007 County File

Table C-1 lists every field input into the 2007 county file (County2007.dat). Every value in the county file except FRCLND (land fraction) and VNFRM (non-farmland property value) (as well as most of the notes fields) came directly from the 2007 Agricultural Census. The raw data, along with a data query tool, was downloaded from the U.S. Department of Agriculture (USDA) 2007 Census website[5] [1].

Table C-1 Fields input in the 2007 county file

Field name	Explanation of field
FIPS	Unique identifier number for each county
STATE	Name of State
COUNTY	Name of County
FRCLND	Fraction of county's total area that is land as opposed to water (-)
FRMFRC	Fraction of county's total land area that is used for farming (-)
DPF	Fraction of farm sales resulting from dairy production in county (-)
ASFP	Total annual sales from all farms in a county ($/hectare of farmland)
VFRM	Farmland property value for the county ($/hectare of farmland)
VNFRM	Non-farmland property value for the county ($/person)
NOTES: -	Represents a value of 0
NOTES: b	Indicates that farm area from the 2007 Agricultural Census is slightly larger than land area from the 2010 Census. In these cases, the farm area is set equal to the land area.
NOTES: d	Indicates that data were withheld from 2007 Agricultural Census to avoid disclosing information for individual farms.
NOTES: ex	Refers to a county not listed in the 2007 Agricultural Census. It was therefore assumed that no agriculture exists in the county.
NOTES: IC	Means this county is actually an independent city that has its own FIPS code.
NOTES: pci	Means per capita income was combined for an independent city and its neighboring county. The same value for per capita income is used for both.

A screenshot of the data query tool from USDA is shown in Figure C-1.

[5] http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Desktop_Application/

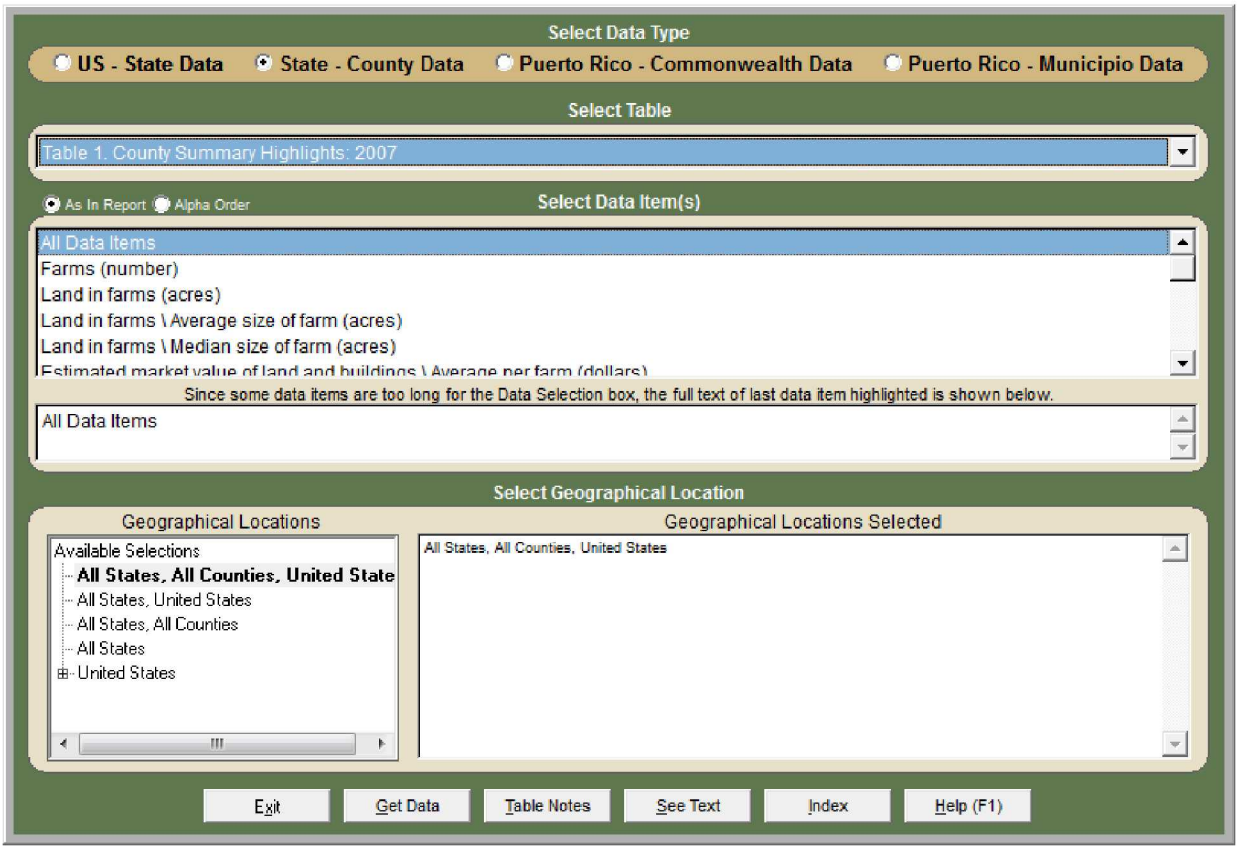


Figure C-1 Data query tool for 2007 Agricultural Census

The data sets that are needed from the Agricultural Census are shown in Table C-2. The name of the data type, table, and data item is an exact copy of what was displayed in the data query tool to obtain the needed data. Once the correct table and data item were chosen, the data was available by selecting "Get Data." After a new screen opened to display the data, "Export CSV" was selected to create a text file to be manipulated with Excel.

Table C-2 Data extracted from 2007 Agricultural Census

Field	Data Type	Table Name	Data Item
1	State – County Data	Table 1. County Summary Highlights: 2007	Land in farms (acres)
2	State – County Data	Table 2. Market Value of Agricultural Products Sold Including Direct Sales: 2007	Total Sales (see text) ($1,000, 2007)
3	State – County Data	Table 2. Market Value of Agricultural Products Sold Including Direct Sales: 2007	Total Sales (see text)\Value of sales by commodity or commodity group\Livestock, poultry, and their products\Milk and other dairy products from cows ($1,000, 2007)
4	State – County Data	Table 8. Farms, Land in Farms, Value of Land and Buildings, and Land Use: 2007	Farm and land in farms\Estimated market value of land and buildings ($1,000, 2007)
5	US – State Data	Table 1. Historical Highlights: 2007 and Earlier Census Years (Except AK & HI)	Estimated market value of all machinery and equipment 1/ ($1,000)

Once all the necessary data sets were extracted, some conversions and calculations were done to get the data into the proper format for the SecPop county file. The first step was to convert farm land from acres to hectares, using a factor of 0.404686 hectares per acre. The value for farm sales per hectare (ASFP) was calculated by dividing Field 2 (total sales) by Field 1 (land in farms after converting from acres to hectares). Dairy sales fraction (DPF) was calculated by dividing Field 3 (total sales – milk and other dairy products from cows) by Field 2 (total sales).

The final step was the calculation of farm property value (VFRM), which combines data from Field 4 and Field 5. To calculate this, first Field 5 (state level total for machinery and equipment) was converted to a county level amount by using the percentage of farmland in each county in the state. This value was then added to Field 4, the value of land and buildings available at the county level. Finally, the summed value was divided by Field 1 (county farmland converted to hectares). The value of machinery and equipment is about 10% of the value of land and buildings and was not included in the 2002 county file.

Farmland property values calculated using this method are 1.2 to 2 times higher in 2007 than in 2002. This is considered reasonable, considering inflation and changes to the market in this five-year period, as well as the addition of farm machinery and equipment to the calculation.

Land fraction (FRCLND) came directly from the 2010 U.S. Census. There were no major changes to county areas between 2007 and 2010. The process for extracting information from the U.S. Census software is described in Appendix B. Land fraction was calculated by dividing land area by the sum of land area and water area.

Farm fraction (FRMFRC) was calculated by dividing the farm area (Field 1) from the 2007 Agricultural Census by the land area from the 2010 U.S. Census. There were a few cases where the amount of farmland from the agriculture census slightly exceeded the county size from the census file, meaning essentially the entire county is farmland. For these cases, FRMFRC was set to a value of 1 and a note of “b” was entered in the corresponding notes field.

There needs to be a one-to-one correspondence between the FIPS codes in the county file and those in the census file. A cross-comparison was done between the 2010 census file and the 2007 county file, which revealed that there were a number of independent cities that have census data but were not present in the agriculture census, which are Baltimore, MD; St. Louis, MO; Washington, DC, and 36 cities in Virginia. A review of these cities concluded that they were omitted from the agricultural census because there was no agriculture to report, not that data were neglected. This conclusion was based on the fact that the three largest independent cities in Virginia were included in the agriculture census. Therefore, the other independent cities were added to the county file with values of zero for agricultural parameters (FRMFRC, ASFP, DPF, and VFRM) and a note of “ex” was entered in the corresponding notes fields. Additionally a note of “IC” was included in the City_notes field.

Two other notes relating to agriculture were included in the county file. A note of “-“ was entered to signify that no value was available for that field in the specific county, meaning that likely there was no agriculture in the county. The “d” code was entered to signify that the corresponding value was known, but was withheld to prevent confidential sales information from being revealed for a single farm. All counties with either “-” or “d” codes used a value of 0 for the agricultural parameters (FRMFRC, ASFP, DPF, and VFRM).

The above methodology produced every field needed for the county file except for non-farmland property value and its corresponding notes field.

Non-farmland Property Value

Calculation of VNFRM (county non-farmland property value per person) was the most complex step of the process. Exact county-level values are not readily available, so a calculation methodology was utilized. The overall approach was to use a set of known or readily accessible inputs defined in Table C-3 to first estimate the national-level non-farmland property value per person, $VNFRM_{US}$, and then to convert that to a county-level value, VNFRM, using a ratio of county per capita income, PCI_{CO}, to national per capita income, PCI_{US}. Equations C-1 and C-2 were used to estimate $VNFRM_{US}$. $VNFRM_{US}$ was then converted to a county-level VNFRM using Equation C-3. The definition and source of each input variable used in the calculations are provided in the following sections.

Table C-3 Inputs to calculations for non-farmland property value

Input	Definition of Input Acronym	2007 Value
FLV_{US}	Average fraction of home value due to land in U.S.	0.45
LPA_{US}	Average housing units per acre for the U.S.	5 units per acre
MHV_{US}	Median housing value in the U.S.	$191,471 per unit
PCI_{CO}	Per capita income for each county	various
PCI_{US}	Per capita income for the U.S.	$39,634 per person
POP_{US}	Population of the U.S.	301,621,157 people
RTW_{US}	Reproducible tangible wealth in the U.S.	$83,095 billion
UBL_{US}	Amount of urban and built-up land in the U.S.	111.2 million acres
VFA_{US}	Value of farm assets in the U.S.	$2,055,275,530,000
$VFHP_{US}$	Value of farm household possessions in the U.S.	$44.1 billion
$VNFRM_{US}$	Value of non-farmland per person for entire U.S. (calculated)	$427,655 per person
VSL_{US}	Value of suburban land in the U.S. (calculated)	$47,893 billion

$$VSL_{US} = UBL_{US} \times LPA_{US} \times FLV_{US} \times MHV_{US} \qquad \text{Equation C-1}$$

$$VNFRM_{US} = \frac{RTW_{US} - VFA_{US} + VFHP_{US} + VSL_{US}}{POP_{US}} \qquad \text{Equation C-2}$$

Having calculated a national average for non-farmland property value, $VNFRM_{US}$, a conversion was then made to a county-level value by using a ratio of each county's per capita income to the national per capita income (Equation C-3). This assumes that on the county level, property value is directly proportional to per capita income.

$$VNFRM_{CO} = VNFRM_{US} \times \left(\frac{PCI_{CO}}{PCI_{US}}\right) \qquad \text{Equation C-3}$$

This method of calculating a county-level value for non-farmland dates to the NUREG-1150 study [2]. A new methodology for non-farm property value was researched; however, no alternative was found for which the required information was readily available. The current method was reviewed by two Sandia National Laboratories economists and was determined to be applicable and defensible.

Values used in the calculation of Non-Farmland Property Value, VNFRM

The values for the variables RTW_{US}, PCI_{US}, and PCI_{CO} were obtained from the U.S. Bureau of Economic Analysis (BEA) through the Interactive Data tab on its website[6], a screenshot of which is shown in Figure C-2.

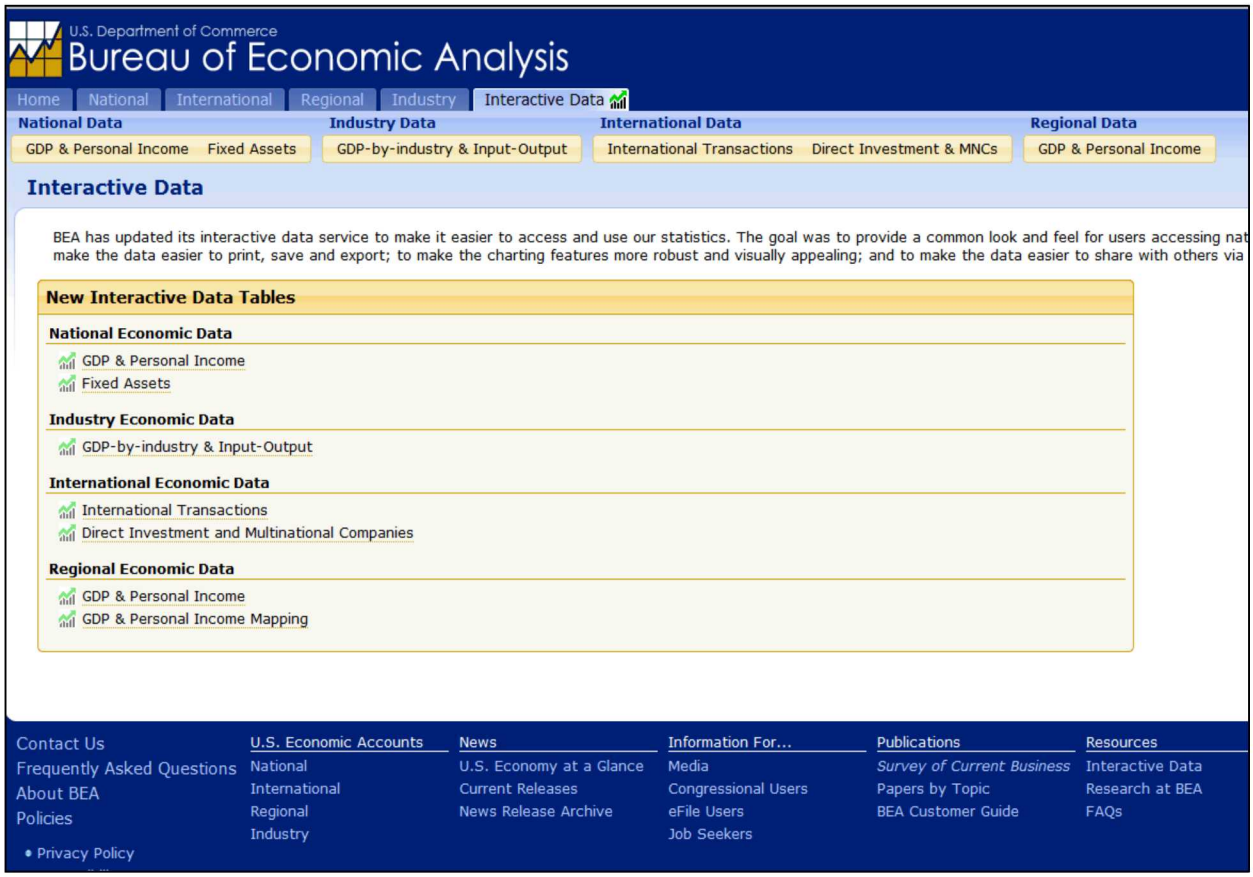


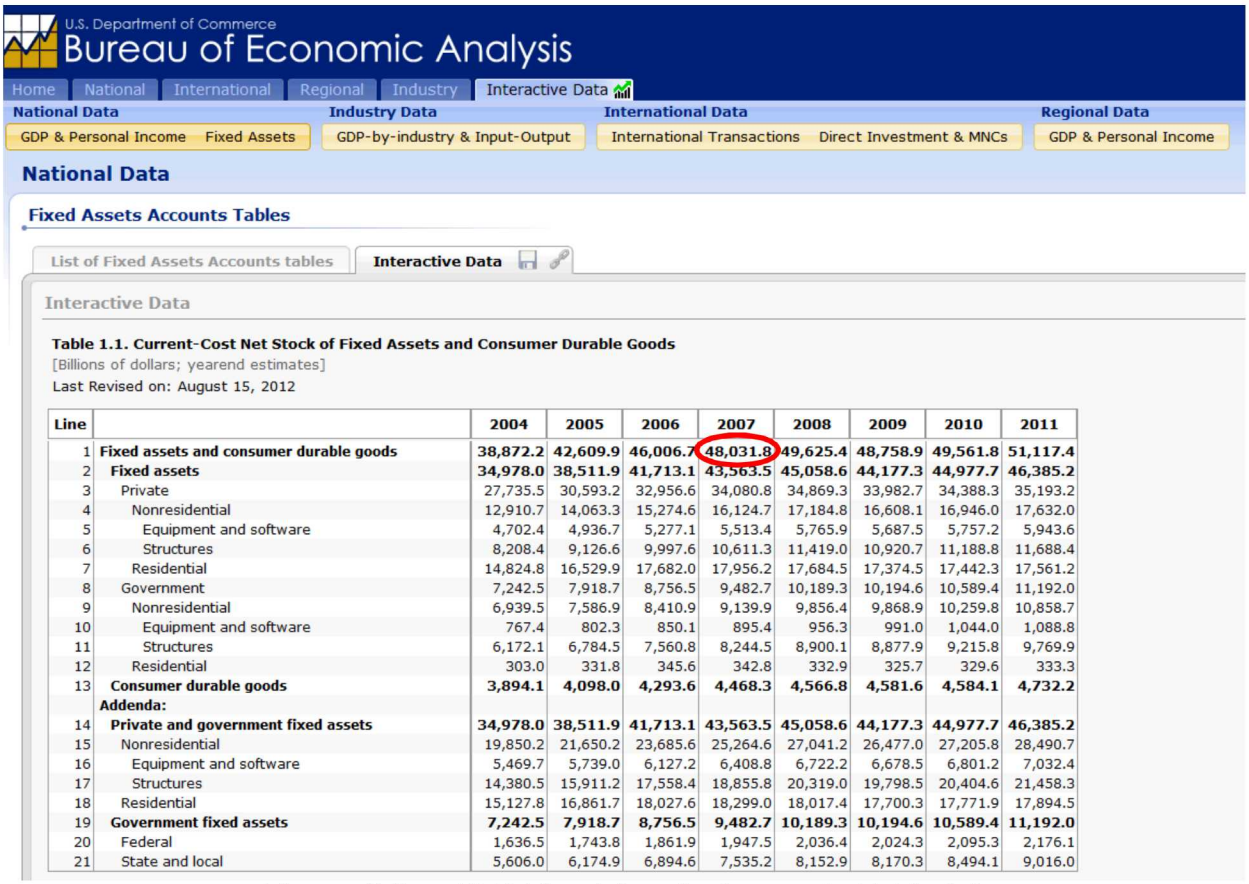
Figure C-2 BEA Interactive Data Website

Reproducible Tangible Wealth US (RTW_{US})

The definition of reproducible tangible wealth adopted in this document is the stock of privately owned and government-owned durable equipment and structures and of durable goods owned by consumers in the United States. The value assigned is used to capture the cost to recreate an area that becomes unusable. The word reproducible is an important part of the definition and thus it excludes the value of land. The term also excludes consumable goods.

The value of reproducible tangible wealth for 2007 was obtained by selecting "Fixed Assets" from Figure C-2, then "Begin using the data…", then selecting "Section 1 – Fixed Assets and Consumer Durable Goods", and then selecting "Table 1.1. Current-Cost Net Stock of Fixed Assets and Consumer Durable Goods (A)". The needed value appears in Line 1, "Fixed assets and consumer durable goods", which is displayed in Figure C-3.

[6] http://www.bea.gov/itable/



Line		2004	2005	2006	2007	2008	2009	2010	2011
1	**Fixed assets and consumer durable goods**	**38,872.2**	**42,609.9**	**46,006.7**	**48,031.8**	**49,625.4**	**48,758.9**	**49,561.8**	**51,117.4**
2	**Fixed assets**	**34,978.0**	**38,511.9**	**41,713.1**	**43,563.5**	**45,058.6**	**44,177.3**	**44,977.7**	**46,385.2**
3	Private	27,735.5	30,593.2	32,956.6	34,080.8	34,869.3	33,982.7	34,388.3	35,193.2
4	Nonresidential	12,910.7	14,063.3	15,274.6	16,124.7	17,184.8	16,608.1	16,946.0	17,632.0
5	Equipment and software	4,702.4	4,936.7	5,277.1	5,513.4	5,765.9	5,687.5	5,757.2	5,943.6
6	Structures	8,208.4	9,126.6	9,997.6	10,611.3	11,419.0	10,920.7	11,188.8	11,688.4
7	Residential	14,824.8	16,529.9	17,682.0	17,956.2	17,684.5	17,374.5	17,442.3	17,561.2
8	Government	7,242.5	7,918.7	8,756.5	9,482.7	10,189.3	10,194.6	10,589.4	11,192.0
9	Nonresidential	6,939.5	7,586.9	8,410.9	9,139.9	9,856.4	9,868.9	10,259.8	10,858.7
10	Equipment and software	767.4	802.3	850.1	895.4	956.3	991.0	1,044.0	1,088.8
11	Structures	6,172.1	6,784.5	7,560.8	8,244.5	8,900.1	8,877.9	9,215.8	9,769.9
12	Residential	303.0	331.8	345.6	342.8	332.9	325.7	329.6	333.3
13	**Consumer durable goods**	**3,894.1**	**4,098.0**	**4,293.6**	**4,468.3**	**4,566.8**	**4,581.6**	**4,584.1**	**4,732.2**
	Addenda:								
14	**Private and government fixed assets**	**34,978.0**	**38,511.9**	**41,713.1**	**43,563.5**	**45,058.6**	**44,177.3**	**44,977.7**	**46,385.2**
15	Nonresidential	19,850.2	21,650.2	23,685.6	25,264.6	27,041.2	26,477.0	27,205.8	28,490.7
16	Equipment and software	5,469.7	5,739.0	6,127.2	6,408.8	6,722.2	6,678.5	6,801.2	7,032.4
17	Structures	14,380.5	15,911.2	17,558.4	18,855.8	20,319.0	19,798.5	20,404.6	21,458.3
18	Residential	15,127.8	16,861.7	18,027.6	18,299.0	18,017.4	17,700.3	17,771.9	17,894.5
19	**Government fixed assets**	**7,242.5**	**7,918.7**	**8,756.5**	**9,482.7**	**10,189.3**	**10,194.6**	**10,589.4**	**11,192.0**
20	Federal	1,636.5	1,743.8	1,861.9	1,947.5	2,036.4	2,024.3	2,095.3	2,176.1
21	State and local	5,606.0	6,174.9	6,894.6	7,535.2	8,152.9	8,170.3	8,494.1	9,016.0

Figure C-3 BEA Fixed Assets Accounts Table 1.1

This value is a net stock value versus a gross stock value, which is what is needed in SecPop. Gross stock value refers to the original, total value, while net stock value accounts for the effects of depreciation. SecPop calculates a replacement cost, which is closer to the original value and so SecPop uses the gross, not net value. The BEA no longer reports gross stock value. To convert between net and gross, a conversion factor of 1.73 is used, yielding a value of $48,031.8 billion × 1.73 = $83,095.0 billion. The conversion factor comes from a BEA report from 1997 by Katz and Herman titled, "Improved Estimates of Fixed Reproducible Tangible Wealth" [3]. A more current reference was researched but not found. This report does not contain the factor of 1.73, but it can be derived by taking the ratio of gross to net stock values from this report.

Per Capita Income National Average (PCI_{US})

The process to extract this value was similar to the process for obtaining RTW_{US}. The value was obtained by selecting "National Data – GDP & Personal Income" from the same start screen, then selecting "Begin using the data...", then selecting "Section 2 - Personal Income and Outlays", and then "Table 2.1. Personal Income and Its Disposition (A) (Q)". The needed value was on line 1 "Personal Income", which is the total income for the entire U.S. population. Quarterly values are given but annual values and different time periods are available using the "modify" icon. The value obtained for 2007 was $11,954.4 billion corresponding to the third quarter. To convert this value into a per capita income, it was divided by the total U.S. population for 2007 (as described on the following page), 301,621,157, yielding a national average per capita income of $39,633.82 per person.

Per Capita Income on the County Level (PCI_{CO})
The process to extract this value was similar to the previous processes so no additional figures are displayed. The values were obtained by selecting "Regional Data - GDP & Personal Income" from the start screen, then selecting "Begin using the data...", then selecting "Local Area Personal Income and Employment", and then selecting the first choice, "Personal Income, Per Capita Personal Income and Population (CA1-3). Next, "county" was selected as the major area followed by "All counties in the U.S." Next, the Unit of Measure was selected as "Levels" and the Statistic was set to "Per capita personal income (dollars)". Finally, the year 2007 was selected and then the county data was downloaded as an Excel file. Because the values are already given per capita, no division by population was necessary.

U.S. Population (POP_{US})
U.S. population, both current and historical, can be found on the U.S. Census Bureau website[7]. This page is shown in Figure C-4.

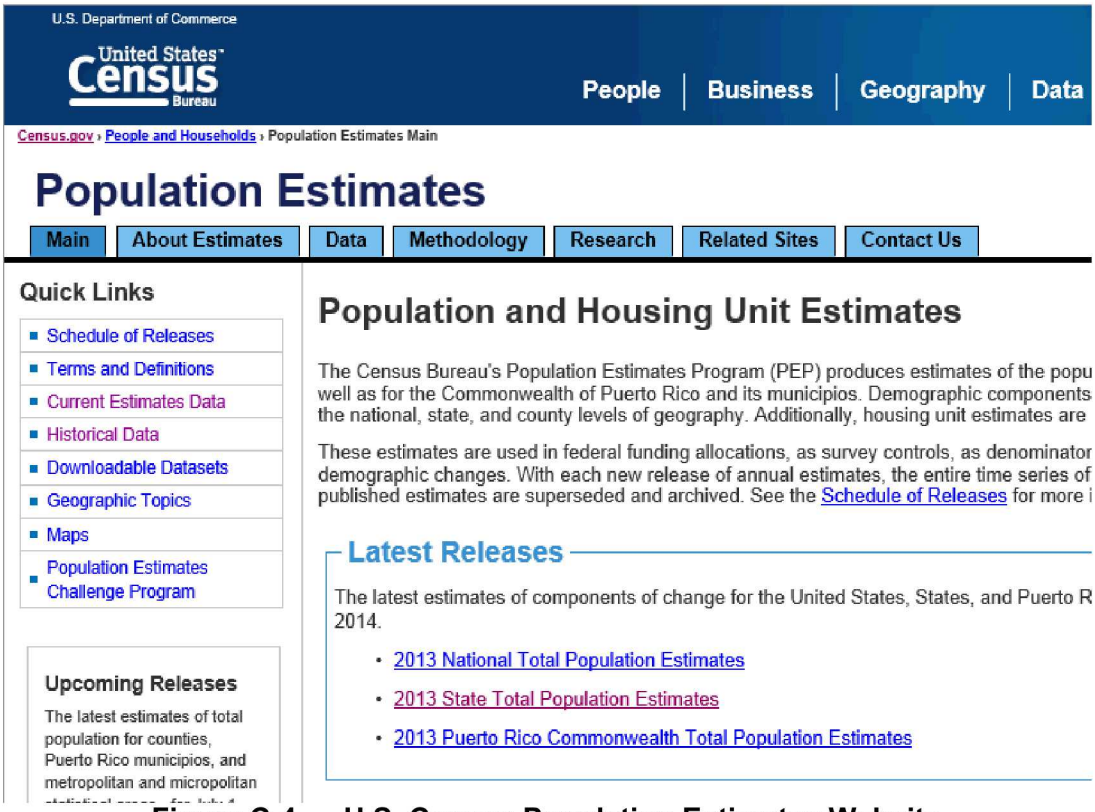


Figure C-4 U.S. Census Population Estimates Website

Under the Quick Links section on the far left of the page, "Historical Data" was selected. On the next page, the decade "2000s" was selected, followed, by the data year, 2007. "National Tables" was then selected and an Excel file was downloaded under the "Monthly Population Estimates" header. Since the national income data that were used for 2007 came from the 3rd quarter, the population total for the month of July was selected, 301,621,157.

Value of Farm Assets in the U.S. (VFA_{US})
The value of farm assets is available from the Economic Research Service[8], a branch of the U.S. Department of Agriculture (USDA). To obtain the value for 2007, the "U.S. farm sector balance sheet, 1960-2011" was opened as an Excel spreadsheet. The first line of the

[7] http://www.census.gov/popest/index.html
[8] http://www.ers.usda.gov/data-products/farm-income-and-wealth-statistics.aspx

spreadsheet is titled, “Farm Assets” which shows a nominal value of $2,055,275,530,000 for 2007. This is the needed value for the county file and includes real estate, livestock and poultry, machinery and motor vehicles, crops, purchased goods, and financial assets.

Value of Farm Household Possessions in the U.S. ($VFHP_{US}$)
No referenceable source was found for the value of farm household possessions. Because of this, an assumed value of $20,000 in possessions per farm was used and was multiplied by the number of farms in the U.S. in 2007, 2,204,950. The number of farms in the U.S. was obtained from the 2007 Census of Agriculture[9] [1]. The value of farm household possessions, $44.1 billion, is very small when compared to farm assets and reproducible tangible wealth, so the assumption has only a minor effect on the calculation. The 2002 county file used a value of zero, so even though the value per farm is an assumption, it is more credible than a value of zero.

Value of Suburban Land in the U.S. (VSL_{US})
This value is calculated using equation C-1 with the variables described above.

Amount of Urban and Built-up Land in the U.S. (UBL_{US})
The amount of urban and built-up land in the U.S. was found in the 2007 National Resources Inventory (NRI) report [4] which is produced by the Natural Resources Conservation Service (NRCS), a branch of the USDA. The report was downloaded from the NRI website[10]. The amount of developed land, 111.2 million acres, was found in the NRI report’s Table 1. This value includes large urban and built-up areas, rural transportation, and small built-up areas.

Average Housing Units per Acre in the U.S. (LPA_{US})
The value for housing units per acre was informed by data found in the American Housing Survey (AHS) [5], sponsored by the U.S. Department of Housing and Urban Development and conducted by the U.S. Census Bureau. The report is available from the U.S. Census Bureau website[11]. First, the “Data” tab was selected, then the year 2007, and then the National Summary Report and Tables – AHS 2007 was available for download. The AHS, in Table 1A-3. “Size of Unit and Lot – All Housing Units”, provides a median lot size for 1-unit structures, 0.35 acres per lot. The inverse of this is 2.86 housing units per acre. However this does not include multi-unit properties, which would certainly have the effect of increasing the number of units per acre.

In 2007, single unit properties were 68% of the total units. (AHS Table 1A-1 shows 80,406,000 detached 1-unit structures; 7,135,000 attached 1-unit structures; 8,705,000 manufactured/mobile homes or trailers; and 128,203,000 total units.) The remaining 32% contains multi-unit properties from 2 to 50 or more units. Assuming an average of 5 units per multi-unit property and the same median lot size as for 1-unit structures would give a total of 6.5 housing units per acre [(0.68 acres * 2.86 properties per acre * 1 unit per property) + (0.32 acres * 2.86 properties per acre * 5 units per property) = 6.5 units per acre.]

In the 2002 county file, a legacy value of 5 units per acre was used. Because the updated data provides a very similar value, the original value of 5 units per acre was continued in the 2007 county file and is considered reasonable.

U.S. Median Housing Value (MHV_{US})
The median housing value also used data from the American Housing Survey, which was discussed previously. Table 1A-7. “Financial Characteristics – All Housing Units”, gives a

[9] https://www.agcensus.usda.gov/Publications/2007/Full_Report/
[10] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/
[11] http://www.census.gov/programs-surveys/ahs/

median housing value of $191,417 for owner occupied homes. A median value was also provided for vacant for-sale units and vacant rented or sold units. However these values only represented about 2% of total units (3,097,000 units among 128,203,000 total housing units) and because they would not significantly change the value for owner occupied homes, the value of $191,417 was used.

Average Fraction of Home Value due to Land in the U.S. (FLV_{US})
In previous county files, an assumed value of 0.2 was used for the average fraction of home value due to the value of land. This was a legacy value that seems to date to about 1970. A more up-to-date discussion of this value was found in "The Price and Quantity of Residential Land in the United States", published in the Journal of Monetary Economics by authors Morris Davis and Jonathan Heathcote [6]. The article shows in its Figure 2, land's share of home value for 1975 to 2007. The 2007 value of 0.45 from the report is used in the 2007 SecPop county file. This input represents one of the largest differences used to compute VNFRM between the 2002 and 2007 county files.

Conclusions

This section lays out a method for a calculating a national average per capita value for non-farmland property. This is converted to a county-level value using a ratio of national per capita income to each county's per capita income as described in the equations above. This assumes that personal wealth and property values are directly proportional to income. It was found that for the independent cities in Virginia, BEA reported a single PCI for both the city and its neighboring or surrounding county. Since these are separate in the county file, the same PCI value was used to calculate non-farm property values for both the city and county and a code of "pci" was input in the "nonfarm_value_notes" field for each.

The final 2007 $VNFRM_{US}$ value ($427,655 per person), calculated using the above method and inputs, is about twice as large in 2007 as in 2002 ($232,300). The two factors with the largest impact on this increase are MHV_{US} and FLV_{US}. The median housing value is about two times higher in 2007. This is not unexpected since 2006-2007 represented the peak of the housing bubble in the United States. The fraction of home value due to land is also related, although not directly proportional, to the housing market. It is not surprising that the value would be significantly larger in 2007 than in 1970 as the housing market has increased consistently over this entire period. The two observations are logically justifiable and are also backed by available data.

The SecPop county file is only able to capture a snapshot in time for economic values. In this case, that snapshot is at the tail end of the housing bubble.

All the data sets described above were compiled in an Excel spreadsheet and then imported into Access. The query functionality in Access was then used to create the final text file needed for the SecPop code. Data for Alaska and Hawaii were removed from the county file, as neither of these is likely to be within the modeling domain for a MACCS analysis.

Note that the values for VNFRM calculated on a grid-element basis by SecPop are input to MACCS through the site file, however there is no direct MACCS input for VNFRM. Rather, MACCS requires an input value for an analogous value, VALWNF. While these two variables have equivalent units and definitions, they are used separately within the MACCS code. VALWNF has a single value for the entire grid and is used to determine whether decontamination is cost-effective (if the decontamination cost is less than VALWNF) or whether it is not cost-effective and the land is modeled as being condemned (decontamination cost is greater than VALWNF). If no site file is used, VALWNF is also used to calculate losses when

the property in a grid element is interdicted or condemned. If the site file is used, VNFRM is used to calculate losses when a grid element is interdicted or condemned. The same explanation is true for the MACCS variable VALWF and the SecPop variable VFRM. SecPop site files can be used to calculate a person-weighted average for VALWNF and a farm area-weighted average for VALWF. MACCS can run without the use of a site file when generic or site-independent analyses are required.

References

[1] U.S. Department of Agriculture, 2007 Census of Agriculture, United States Summary and State Data, Volume 1, Geographic Area Series, Part 51, AC-07-A-51, Issued February 2009, Updated December 2009. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/usv1.pdf

[2] US NRC, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, Vol. 1, U.S. Nuclear Regulatory Commission, Washington, DC, 1990.

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[6] Davis, M.A., and J. Heathcote, "The price and quantity of residential land in the United States", *Journal of Monetary Economics*, 54 (2595-2620), June, 2007. http://www.jonathanheathcote.com/land-final.pdf

Appendix D 2012 County File

This section describes the development of the 2012 county file (County2012.dat). The methodology generally follows that used to develop the 2007 county file. Therefore, this discussion focuses on changes in data sources and methodology relative to the 2007 county file development process.

The land fraction (FRCLND), dairy sales fraction (DPF), value for farm sales per hectare (ASFP), and the farm property values (VFRM) were all obtained using the same methods as the 2007 county data outlined in Appendix C. The 2012 note fields (b, d, ex, IC, and pci) are described in Appendix C since they have the same meaning as they did in the 2007 note fields. Table D-1 shows the inputs used in the calculation of VNFRM. The equations used to compute the national $VNFRM_{US}$ value and then to convert that to $VNFRM_{CO}$ are identical to Equations C-1, C-2, and C-3.

Table D-1 Inputs to calculations for non-farmland property value.

Input	Definition of Input Acronym	2012 Value
FLV_{US}	Average fraction of home value due to land in U.S.	0.28
LPA_{US}	Average housing units per acre for the U.S.	8.16 units per acre
MHV_{US}	Median housing value in the U.S.	$ 160,000 per unit
PCI_{CO}	Per capita income for each county	various
PCI_{US}	Per capita income for the U.S.	$44240.46 per person
POP_{US}	Population of the U.S.	313,914,040 people
RTW_{US}	Reproducible tangible wealth in the U.S.	$ 92,645.133 billion
UBL_{US}	Amount of urban and built-up land in the U.S.	118.31 million acres
VFA_{US}	Value of farm assets in the U.S.	$ 2,734,400,674 thousand
$VFHP_{US}$	Value of farm household possessions in the U.S.	$ 42 billion
$VNFRM_{US}$	Value of non-farmland per person for entire U.S. (calculated)	$ 424,329.80 per person
VSL_{US}	Value of suburban land in the U.S. (calculated)	$ 43,250.4 billion

The PCI_{CO}, PCI_{US}, POP_{US}, LPA_{US}, RTW_{US}, $VFHP_{US}$, $VNFRM_{US}$, and the VSL_{US} values were all obtained using the same process used in 2007 as outlined in Appendix C.

The following input used the same process as 2007 but pulled data from a different source:

- FLV_{US} – used the same process as 2007 but used 2012 data given by the same report author, John Heathcote [1].
- MHV_{US} – used the same process as 2007 but used a 2001 report [2] and 2013 data [3] to take the average for 2012.
- UBL_{US} – used the same process as 2007 but used a 2012 report [4] provided by the National Resources Conservation Service.
- VFA_{US} – used the same process as 2007 but used the 2011 – 2016 balance sheet [5].
- VSL_{US} – used same process as 2007 but used a 2012 Census of Agriculture report [6].

The $VNFRM_{US\text{-}2012}$ value shown in Table D-1 is $424,330 per person and is just slightly smaller than $VNFRM_{US\text{-}2007}$ value, $427,655. Although the value would normally be expected to be larger than the value for 2007 due to inflation, the $VNFRM_{US\text{-}2007}$ value was calculated at the peak of the housing bubble in the United States. In late 2007, the housing market collapsed, causing a recession in the United States economy. Based on data found from the U.S. Bureau

of the Census [7], the median sale price for new houses sold in the United States in 2007 is about $243,742 and the same value in 2012 is about $242,108. Overall, there was a slight decrease in median sale prices from 2007 to 2012. These values correlate reasonably well with the $VNFRM_{US}$ for the respective years.

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[3] US. Bureau of the Census, AHS 2013 National Summary Tables, U.S. Department of Commerce, January 4, 2016. http://www.census.gov/programs-surveys/ahs/data/2013/ahs-2013-summary-tables/national-summary-report-and-tables---ahs-2013.html

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Appendix E SecPop Verification Assessments

Test Plan for Development of SecPop 4.2.0

This section describes the verification assessments that were conducted to ensure that SecPop is functioning as intended. A summary of the tests is provided in Table E-1. SecPop passed all tests.

Table E-1 SecPop Verification Test Matrix

Test	Objective	Test Site	Test Area
1a	Verify consistency between v4.1 and v4.2 of each SecPop calculated variable for each grid element	Columbia	0-50 mi
1b		Oyster Creek	0-50 mi
1c		Columbia	0-1000 mi
1d		Oyster Creek	0-1000 mi
2	Verify consistency of SecPop calculations with radii distance units set in miles and kilometers	Dresden	0-64 km
3a	Verify consistency of SecPop calculated total population when using different number of compass sectors (16, 32, 48, and 64)	Columbia	0-50 mi
3b		Oyster Creek	0-50 mi
4a	Verify correct implementation of population multiplier and economic multiplier and consistency between v4.1 and v4.2	Columbia	0-50 mi
4b		Oyster Creek	0-50 mi
5	Verify that v4.2 correctly imports all data from existing SecPop project files (.spproj)	N/A	N/A
6a	Verify that SecPop calculated results for an individual grid element using 2007 county file are consistent with approximated spreadsheet calculations	Wolf Creek	95-100 mi
6b		Surry	120-125 mi
6c	Verify that SecPop calculated results for an individual grid element using 2012 county file are consistent with approximated spreadsheet calculations	Wolf Creek	95-100 mi
6d		Surry	120-125 mi
7a	Verify that changes in population and economic values are reasonable when comparing calculations using the 2000 census file and 2002 economic file to the 2010 census file and 2007 economic file	Columbia	0-50 mi
7b		Oyster Creek	0-50 mi
8	Verify that changes in county file parameters from 2007 to 2012 are reasonable	N/A	

A number of versions of SecPop were used in the testing process. Briefly, the distinguishing characteristics of these versions are described as follows:

Version 4.0	Internal (within Sandia) development version, not included in QA system and not used for testing
Version 4.1.0	Internal development version, initial development version after SecPop2000, included in QA system and used for testing
Version 4.1.1	Internal development version, same as version 4.2, interface changes for usability to correct issues noted in version 4.1.0, includes support for 2010 census data
Version 4.2.0	Same as version 4.1.1 (renamed)
Version 4.2.1	Includes correction for regional farm fraction
Version 4.2.2	Minor improvements, improved algorithm for assigning economic regions

Version 4.3.0 Minor usability improvements

Tests 1-5, 6a, 6b, and 7 were completed using various beta versions of SecPop 4.1.1. Once all code changes were completed, the final version became 4.2.0. To confirm that no bugs were introduced in the final version, regression testing was done using the sites and regions from Tests 6a and 7 and version 4.2.0. The extended site file and REAcct file were compared for both sites in each test between the beta version and the final version. The only difference when comparing the early beta versions, besides the version number, was land fraction. This is because the underlying calculation for land fraction was changed during the SecPop code development work. One sector from the Oyster Creek site was used to confirm that the new calculation was working as intended, and it was. This test shows there were no bugs introduced in the 4.2.0 SecPop version. Tests 6c, 6d, and 8 were added to test the 2012 county file and were run using version 4.3.0. Since the only change in this version was the ability to read in the 2012 county file, tests 1-5 were not repeated.

Test 1: Verify Consistency of Site Files Created Between SecPop 4.1.0 and 4.2.0

For these tests, the number of sectors was chosen to be 16 for comparison. Also, the 2000 census and 2002 county files were used because SecPop 4.1.0 was not compatible with the updated files.

The test used two sites in the contiguous U.S., Columbia Generating Station in Washington (46.471389, -119.333056) and Oyster Creek in New Jersey (39.814167, -74.206389) at 50 miles, then at a 1000-mile radius. The regions were set to be consistent between the 4.1.0 and 4.2.0 project files and then results were compared.

Test 1a and 1b

For each site, regions were created in SecPop 4.1.0 and for SecPop 4.2.0. The number of radii was limited to a set of 5 for the 50-mile test to easily facilitate the comparisons. These radii were 1, 5, 10, 25, and 50 miles. Economic regions were defined as the 0- to 1-mile area being the exclusion area with the remainder having exact economic values.

For Columbia in SecPop 4.1.0, it was identified that there was a total population of 4 inside this 1 mile exclusion zone in grid element [1, 4]. This was the same in version 4.2.0. For Oyster Creek, a population of 1,040 was identified in the 1 mile exclusion zone in grids [1, (2, 3, 6, 7, 10)], confirmed in 4.2. Both populations were dropped in creating the site files.

For Columbia, both population and economic results were identical. This was also true for Oyster Creek. The REAcct file showed the label change made from “Area” to “Land Area”.

Test 1c and 1d

These tests were identical to Tests 1a and 1b with an additional radius at 1000 mi (1609.3 km). At the Columbia site, there was a difference in population for one sector [6, 9]. The population in this sector was 24,818,452 in version 4.1.0 and 24,819,080 in version 4.2.0. This was for the interval between 50-1000 miles and the population in this sector was the only population that went to eight significant figures (ten million’s place). The population difference was not reflected in any differences in economic values. The population difference was also only seen in the site file, not the REAcct file.

At the Oyster Creek site, there were 4 sectors [6, (11-14)] with differences in population. Again, these were all sectors with populations in the ten-million’s place. However, for this site, there

were two sectors that were in the 10 million range that did not have a difference. A closer look showed that all sectors with differences had at least a population of 20 million. Also, as in Columbia, there were no economic differences and the population difference was seen only in the site file, not the REAcct file.

The code developers suspect that the difference stems from how data are stored between the two versions. In 4.1.0, the population was stored as a single precision number (maximum of 7 significant figures) and then added. Once the summed population increases over 7 figures (higher than 9,999,999) the calculation can lose small populations. In 4.2.0, the population is stored as double precision (maximum of 7 significant figures), added, and then the result is converted to single precision. In this case, the only loss can occur during rounding, not during the addition. This was confirmed by looking at the sector at Columbia that was different and manually summing the population of each census block. The result (24,819,079) is the same as the 4.2.0 value rounding to the nearest ten. This shows that the calculation in 4.2.0 is more accurate for sectors with population greater than 10 million.

Test 2: Verify Correct Implementation of Distance Unit Conversion

The Dresden site was used for this test, as was done in testing previous SecPop versions. The following distances were first entered in km, then converted to miles, and then converted back from miles to km. This gave the expected results as follows:

Table E-2 Distance Unit Conversions

Km	Convert column one to miles	Convert column two back to km
1	0.6213712	1
2	1.2427424	2
4	2.4854848	4
8	4.9709697	8
16	9.941939	16
32	19.883879	32
64	39.767757	64

A population calculation was run for the Dresden site for the units set in miles and then in km. The SecPop output files were compared and found to be identical.

Test 3: Verify consistency of SecPop calculated total population when using different number of compass sectors

The two sites and areas from Test 1a and Test 1b were run with 16, 32, 48, and 64 compass sectors. These tests used the 2010 census file and 2007 county file. Both the Columbia and Oyster Creek site tests showed the exact same total population, no matter what number of sectors was used. This shows that SecPop is dividing rings into sectors correctly.

Test 4: Verify correct implementation of population multiplier and economic multiplier and consistency between v4.1 and v4.2

The test sites and areas from Tests 1a and 1b were used with the 2000 census file and 2002 county file. SecPop 4.1.0 and 4.2 were run using population and economic multipliers of 2.0. The files created using population and economic multipliers with both SecPop version 4.1.0 and 4.2.0 were identical. This was confirmed using both the Columbia and Oyster Creek sites. The results show the multipliers were implemented the same way between the two code versions.

The Columbia site file generated from Test 4a was also compared to Test 1a files that had no economic multipliers. This comparison showed that all populations were increased by exactly 2, while economic values were increased by a factor ranging from 1.999805 to 2.00009. This slight deviation from 2 is likely due to a loss of significant digits through rounding and is considered acceptable. These results show that using a multiplier increases all relevant values appropriately.

Test 5: Verify that v4.2 correctly imports all data from existing SecPop project files

The MACCS site file varies in format with respect to the first two header lines. Because of this, it must be verified that the various formatted files can all be read by SecPop. The objective of this test was to verify that the radial distance, latitude, longitude, economic multiplier, population multiplier and economic region data (if available) were correctly imported.

The files were found in the following directory: \SecPop Acceptance tests\SiteFileFormats

Table E-3 Import check of MACCS site files

File name	Version of SecPop used to generate file	Imports correctly
SecPop 4.1.0	4.1.0	Yes
SecPop 3.13.1.inp	3.13.1	Yes
SecPop v3.12.inp	3.12	Yes
SecPop1980.inp	2.0	Yes

Test 6a and 6b: Verify that SecPop calculated results for an individual grid element using the 2007 county file are consistent with approximated spreadsheet calculations

Wolf Creek in Kansas was used as a low population test site. A SecPop project was configured to use 64 sectors with radii at 95 and 100 miles. Because of the large initial radius but small delta, as well as the minimal width because of using 64 sectors, sectors in the four primary compass directions approximate a rectangle, neglecting the effects of curvature of the sector. The radii of 95 and 100 miles were selected to maintain low population while having some water area in the sector of interest. Ring 1 from 0-95 miles was the exclusion zone for the test and exact economic values were used in the ring from 95-100 miles. The project file was changed to print out a dump of all census blocks in sector [2,1] which is due north from the site. Using Excel, the minimum and maximum latitude and longitude were found, which were set as the corners of the “rectangular” sector. In the original Access database of census data, a filter was applied to latitude and longitude to only keep results within this range and these census blocks were compared to those output by SecPop. There was one block given by SecPop but not by Access and two blocks vice versa. A closer look at the three blocks in question showed that for all three, the longitude was either at the top or bottom limit, meaning that the curvature of the sector calculated by SecPop would explain the differences. Because of the three blocks, there was a difference of 7 people (from 472 total) and 4.2×10^6 m^2 (from 1.24×10^8 m^2), orders of magnitude lower. The exact geometric area of the sector was also compared to the sum of all the census blocks, which was less than a 1% difference. This is considered a successful test.

This sector contains census blocks from two counties, with FIPS codes 20013 and 20085. This corresponds to Brown County and Jackson County in Kansas. To check the economic values in the site file, the population and area fraction for each county within the grid element were used to calculate a weighted average of their economic values from the county file, using the equations below. This is a slight simplification of the actual calculation done by SecPop but should be a reasonable approximation. It was found that using this method, calculated values

based on all the census blocks were much less than 1% different than what is in the SecPop file. To further confirm, the exact method used by SecPop was used to check non-farmland value. This gave the exact same result that is in the file.

Farmland Fraction: $$\frac{Sum_{region}(area_{frac} * county_{frmfrc})}{Sum_{region}(area_{frac})}$$

Dairy Sales Fraction: $$\frac{Sum_{region}(area_{frac} * county_{dpf})}{Sum_{region}(area_{frac})}$$

Agricultural Sales: $$\frac{Sum_{region}(area_{frac} * county_{asfp})}{Sum_{region}(area_{frac})}$$

Value of Farmland: $$\frac{Sum_{region}(area_{frac} * county_{vfrm})}{Sum_{region}(area_{frac})}$$

Value of Non-farmland: $$\frac{Sum_{region}(pop_{frac} * county_{vnfrm})}{Sum_{region}(pop_{frac})}$$

In the REAcct file, values given for each sector are all the counties that partially or fully lie within the sector as well as the population fraction and area fraction. Area fraction is just land area; water area is not included. These fractions are the fraction of the county's total population or land area that lie within the given sector. The values in the file were confirmed by using the population and land area from each individual census block in the sector, and the total county land area and population from the census auxiliary file, which summed values for counties. The population and land area fraction calculated by this method were exact matches to those values in the REAcct file.

For Test 6b, Surry in Virginia was used as the high population site as it is south of the Washington, DC/Baltimore, MD metropolitan area. The final ring used was from 120-125 miles in order to get a larger population in the due north sector (62,011 people in SecPop). This sector being in a large population area resulted in about 10 times more census blocks in the region compared to Test 6a with Wolf Creek, so it is expected there may be differences regarding individual blocks. Because of the larger number of census blocks, it was not attempted to resolve differences at the individual block level. However, the total population and area found by using this method were both 2-3% different than the SecPop values, which is considered very reasonable considering the effects of curvature.

The economic values and REAcct file were checked using the same method as Test 6a (Wolf Creek) above. Results were the same for Surry. Economic values were essentially the same using the simplified method. The actual method provided an exact match and the values for the REAcct file were also identical.

Test 6c and 6d: Verify that SecPop calculated results for an individual grid element using the 2012 county file are consistent with approximated spreadsheet calculations

The exact two sectors and methodology from Tests 6a and 6b were repeated with the 2012 county file. In both cases, like Tests 6a and 6b, there were only very small variations in values when using the simplified equations and an exact match when using the same equation for non-farmland value. The results of the tests are shown below.

Table E-4 Test 6c Results for Wolf Creek Site

Method	FRMFRC	DPF	ASFP	VFRM	VNFRM
Regional Economic Data from site file, Census Block 4 (MIX_CNTY04)	0.798	0.021	870.0	7058.8	401932.6
Test Results for Sector [2,1]	0.798	0.020	894.8	7183.3	404109.1

Table E-5 Test 6d Results for Surry Site

Method	FRMFRC	DPF	ASFP	VFRM	VNFRM
Regional Economic Data from site file, Census Block 43 (MIX_CNTY43)	0.094	0.000	471.1	23589.6	429222.6
Test Results for Sector [2,61]	0.093	0.000	465.9	23600.6	429116.6

Test 7: Verify that changes in population and economic values are reasonable when comparing calculations using the 2000 census file and 2002 economic file to the 2010 census file and 2007 economic file

Using SecPop 4.2.0 and the same location and sectors as Test 1a, populations and economic values were compared for calculations using the 2000 census and 2002 county files to calculations using the 2010 census and 2007 county file. Changes were expected, but on the order of 1-2x different, not 10x. The output files from calculations using the 2000 census file and 2002 county file were taken directly from Test 1a for Columbia and Test 1b for Oyster Creek.

With the 2010 census file and 2007 county file, Oyster Creek had 1075 people in the exclusion zone, as opposed to 1040, while Columbia had 0, not 4.

After doing a complete check of all values in the extended site files it was found that there were numerous fields where there was a nonzero value using 2002 data but not 2007 or vice versa. Anytime there was a nonzero value, this was excluded from the comparisons for population and economic values. Table E-6 and Table E-7 show the minimum, maximum and average percent difference when moving from the 2000 census and 2002 county files to the 2010 census and 2007 county files. Therefore, a positive change shows that the value increased in the newer files.

For the most part, the percentage changes seem very reasonable. There are a few things that stand out, however. There are some substantial changes in population. A closer look showed that these were all in sectors that had a very small 2000 population, so any change would be a large percentage of the total. Dairy fraction also had some very large changes for analogous reasons. Farm value and non-farm value both have significant changes. However, this was

expected due the inclusion of farm equipment and the fact that the data are captured during the housing market bubble. Important to note is that the average changes agree well between the two sites except for dairy sales fraction at Columbia, all variables had an average change less than a factor of 2 in either direction.

As the only crucial information in the REAcct file are population and area fraction, these files were not compared in this test since population and land fraction are in the site file. This assumes that the REAcct file is calculated correctly, as checked in test 6.

Table E-6 Percent differences for census and county values over set of grid elements for Columbia site

Variable	Minimum Percent Difference	Maximum Percent Difference	Average Percent Difference
Population	-81.8	229	10.5
Land Fraction	-0.3	1.2	-0.03
Farmland Fraction	-8.4	30.7	-0.2
Dairy Sales Fraction	-41.5	6634.8	375.9
Agricultural Sales	3.0	65.2	34.0
Farmland Value	27.9	68.6	53.4
Non-farmland Value	48.9	99.8	76.8

Table E-7 Percent differences for census and county values over set of grid elements for Oyster Creek site

Variable	Minimum Percent Difference	Maximum Percent Difference	Average Percent Difference
Population	-92.6	121.3	5.5
Land Fraction	-1.9	0.2	-1.0
Farmland Fraction	-25.6	-0.1	-17.0
Dairy Sales Fraction	-82.4	21.9	-55.5
Agricultural Sales	-20.0	75.4	36.5
Farmland Value	18.8	164.4	41.3
Non-farmland Value	64.0	92.0	76.3

Test 8: Verify that changes in county file parameters from 2007 to 2012 are reasonable

The first step of this test was calculating the ratio of each parameter for each county by simply dividing either the 2007 value by the 2012 value or the 2012 value by the 2007 value. The following equations were used:

$$Ratio = \frac{2007\ Value}{2012\ Value}$$

$$Ratio = \frac{2012\ Value}{2007\ Value}$$

By doing this two tables of ratios were made to see how much the values changed over time. The tables were then searched to identify if there were any large values that may be of concern. Although there were some large ratios these were seen to be with small changes to even

smaller economic values. With more typical economic values, there were no ratios that were of concern.

Next the percent difference for each county file variable was calculated for each county using the following formula:

$$\%\ Difference = \frac{|2012\ Value - 2007\ Value|}{\frac{2012\ Value + 2007\ Value}{2}}$$

It can be seen by observing this equation that if one of the values is zero and the other is nonzero, the percent difference is either -2 or 2. For this test to work properly every value of zero was changed to be 0.1. This was done to eliminate all of the division by zero errors that could occur when calculating the percent difference. This is small enough to where it would have very little effect on the final results. This test was used to find the percent difference between the 2007 data and the 2012 data indicating by how much each variable for every county changed. If there were generally more positive numbers for a certain variable then the average of all the percent differences for that variable should be positive as well, thus resulting in a general increase of that variable over the period. This was found to be the case.

Lastly, the minimum, maximum, and average percent difference were calculated for each county file variable among all counties. Table E-8 shows the results.

Table E-8 Percent differences for 2007 and 2012 county file parameters over entire set of counties

Variable	Minimum Percent Difference	Maximum Percent Difference	Average Percent Difference
Land Fraction	0	0	0
Farmland Fraction	-148	193	-1.3
Dairy Sales Fraction	-200	200	9.9
Agricultural Sales	-200	200	25.1
Farmland Value	-200	200	18.6
Non-farmland Value	-62.5	97.6	7.8

For the most part, the percentage changes seem very reasonable. In taking a closer look there are a few things that stand out. The minimum and maximum percent differences are both around -200% and 200% respectively. This occurs because there are some 2007 values that are zero and their corresponding 2012 value is non-zero or vice versa. However, since all the zeros were replaced with 0.1 (as mentioned above) the minimum and maximum differences were slightly different. However, this is the closest approximation that can be done. The average differences are very reasonable.

The 2007 and 2012 county files were also compared to each other using the average, minimum, maximum, and percentiles of each value. Table E-9 shows a comparison of land fraction, farm fraction, and dairy sales fraction. Table E-10 shows a comparison of annual farm sales, farmland value, and non-farmland value. Finally, Table E-11 shows how many of the 3,109 counties increased, decreased, or had no change when comparing a 2007 value to a 2012 value. Table E-11 also shows the largest individual increase and decrease among all 3,109 counties.

Table E-9 Comparison of 2007 and 2012 county file parameters FRCLND, FRMFRC, and DPF

	Land Fraction FRCLND (-)		Farm Fraction FRMFRC (-)		Dairy Sales Fraction DPF (-)	
	2007	2012	2007	2012	2007	2012
average	0.95	0.95	0.51	0.50	0.08	0.06
minimum	0.09	0.09	0	0	0	0
5th percentile	0.73	0.73	0.04	0.03	0	0
median	0.99	0.99	0.48	0.47	0.001	0
95th percentile	1.00	1.00	0.98	0.98	0.47	0.38
maximum	1.00	1.00	1.00	1.00	0.88	0.87

Table E-10 Comparison of 2007 and 2012 county file parameters ASFP, VFRM, and VNFRM

	Annual Farm Sales ASFP ($/ha)		Farmland Value VFRM ($/ha)		Non-farmland Value VNFRM ($/person)	
	2007	2012	2007	2012	2007	2012
average	1,241	1,467	9,156	10,860	339,311	368,331
minimum	-	-	-	-	160,318	170,165
5th percentile	36	42	1,501	1,721	240,146	255,318
median	677	918	7,034	8,123	324,240	347,283
95th percentile	4,042	4,246	19,392	21,606	482,166	545,825
maximum	227,337	60,721	1,130,477	508,539	1,345,966	1,164,792

Table E-11 Comparison of 2007 and 2012 county file parameters

	Land Fraction FRCLND (-)	Farm Fraction FRMFRC (-)	Dairy Sales Fraction DPF (-)	Annual Farm Sales ASFP ($/ha)	Farmland Value VFRM ($/ha)	Non-farmland Value VNFRM ($/person)
# Counties increase	-	1,313	350	2,552	2,409	2,474
# Counties no change	3,109	59	1,307	76	52	-
# Counties decrease	-	1,737	1,452	481	648	635
Maximum increase	N/A	0.31	0.57	$ 30,916	$ 440,651	$ 736,483
Maximum decrease	N/A	-0.63	-0.67	$ (227,337)	$ (817,979)	$ (369,127)

As expected, land fraction did not change for any county. The average farm fraction value decreased very slightly from 0.51 to 0.50 with more counties decreasing (56%) from 2007 to 2012 than increasing (42%). Dairy sales as a fraction of all agricultural sales decreased on average from 0.08 to 0.06 with about four times as many counties decreasing (47%) compared to those increasing (11%). For annual farm sales, farmland value, and non-farmland value, about 80% of counties increased from 2007 to 2012 while about 15-20% decreased. For these three parameters, the average, 5th percentile, median, and 95th percentile values all increased from 2007 to 2012 while the maximum value decreased for all three parameters.

Analysis of the county file showed that the largest increase in non-farmland value (VNFRM) was for Williams County, North Dakota. This county's 2007 value of $428,309 increased by

$736,483 to $1,164,792 in 2012. Like Williams, the next five largest increases were also in the western part of North Dakota (Dunn, Mountrail, Billings, McKenzie, and Slope counties). This seems completely reasonable and reflects the significant increase in per capita income from the rapid expansion of oil extraction from the Bakken formation. The largest decrease in VNFRM from 2007 to 2012 was for Loving County, Texas, which fell by $369,127, from $775,100 in 2007 to $405,973 in 2012. Loving County is noteworthy because it had the lowest population of all counties in the 2010 Census with just 82 people. The large decrease in VNFRM therefore seems reasonable and is magnified by the miniscule population.