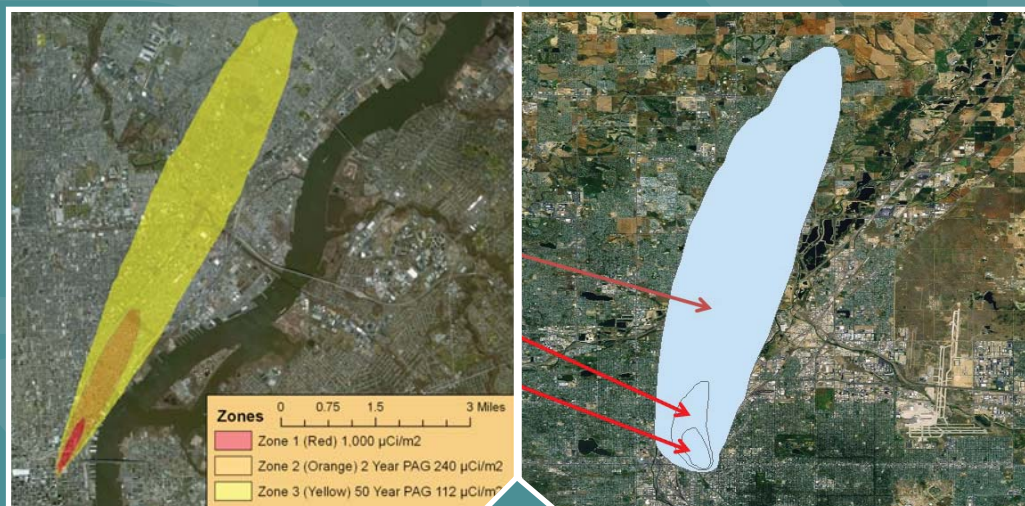


RDD Waste Estimation Support Tool Report

Version 1.2



RDD Waste Estimation Support Tool Report

Version 1.2

National Homeland Security Research Center

Office of Research and Development

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

Acknowledgments

The authors would like to acknowledge the support of Dan Schultheisz and Tom Peake of EPA/ORIA, who provided partial funding for this effort. In addition, there are several individuals whose input was particularly valuable in the development of the Waste Estimation Support Tool, including Bill Steuteville of EPA/Region 3, Jim Michael and Mario Ierardi of EPA/ORCR, Cayce Parrish of EPA/OHS, Emily Snyder of EPA/ORD, and Paul Kudarauskas of EPA/OEM.

Disclaimer

The U.S. Environmental Protection Agency (EPA), through its Office of Research and Development, funded and managed the research described here under EPA Contract Number EP-C-07-015, Work Assignment Number 4-14, with Eastern Research Group and Interagency Agreement DW89922983 with the Oak Ridge Institute for Science and Education. This document has been subjected to the Agency's review and has been approved for publication. Note that approval does not signify that the contents necessarily reflect the views of the Agency. Mention of trade names or commercial products in this document or in the methods referenced in this document does not constitute endorsement or recommendation for use. EPA does not endorse the purchase or sale of any commercial products or services.

Table of Contents

Acknowledgments.....	i
Table of Contents.....	iii
List of Figures.....	v
List of Tables	viii
Acronyms, Abbreviations, and Glossary	ix
Executive Summary.....	1
1.0 Introduction.....	3
1.1 Background.....	5
1.2 Purpose.....	6
1.1.1. Liberty RadEx.....	8
2.0 Description.....	10
2.1 Approach	11
2.2 GIS Data Analysis Tools.....	12
2.3 Image Analysis Tool	14
2.3.1 Artificial Neural Networks.....	17
2.3.2 Ground Surface Estimation	18
2.4 Database Tool.....	20
2.5 Waste Estimation Spreadsheet Tool.....	22
3.0 System Requirements.....	25

4.0 Instructions for Generating Waste Estimate	26
4.1 Instruction for Operating the RDD Waste Estimation Spreadsheet Tool	44
5.0 Results – Liberty RadEx Example.....	60
6.0 Conclusions.....	64
6.1 Looking Forward.....	64
7.0 References.....	66

List of Figures

Figure 1. Data Aggregation Methodology	1
Figure 2. Graphical Depiction of Methodology.....	2
Figure 3. Liberty RadEx Plume Shapefiles.....	9
Figure 4. Preliminary Data Aggregation Methodology	10
Figure 5. Graphical Depiction of Methodology.....	12
Figure 6. Surface Color Palette.....	15
Figure 7. Surface Media Classification.....	16
Figure 8. Feed Forward Neural Network.....	18
Figure 9. Hazus-MH Database Tool Output.....	22
Figure 10. Example Inventory Relationship of Model Building Type and Occupancy Class [3]	24
Figure 11. Liberty RadEx Plume Zones	27
Figure 12. Hazus-MH Startup.....	28
Figure 13. Accessing WEST.....	29
Figure 14. Set Default Directory Button.....	29
Figure 15. Create Neural Network Training Set Button.....	30
Figure 16. Train Neural Network Button.....	31
Figure 17. Show/Hide ArcToolBox Window Button	31
Figure 18. Add WEST Toolbox.....	32
Figure 19. Unload Table To Text Properties	32
Figure 20. Clear Selected Features Button	33
Figure 21. Add Data Button.....	33
Figure 22. World Imagery Layer	33

Figure 23. Repair Geometry Location	34
Figure 24. Rejuvenate 1 Script.....	34
Figure 25. Rejuvenate 2 Script.....	35
Figure 26. Zoom To Selected.....	36
Figure 27. Export TIF Menu	36
Figure 28. Image Zone 1 Script	37
Figure 29. Export BMP Menu	38
Figure 30. Intersect 1 Script.....	39
Figure 31. Intersect 2 Script.....	40
Figure 32. Convert Square Footages Button.....	40
Figure 33. Hazus Database Tool Button	41
Figure 34. Select Hazus Folder	41
Figure 35. Select Inventory.....	42
Figure 36. Hazus Database Tool.....	43
Figure 37. ID Surfaces Button	43
Figure 38. RDD Waste Estimation Spreadsheet Tool Main Screen	45
Figure 39. Security Alert – Macro Screen	45
Figure 40. Waste Estimation Spreadsheet Tool Main Screen Start Button	46
Figure 41. RDD Waste Estimation Spreadsheet Tool Home Screen.....	46
Figure 42. Scenario Basic Information Screen	48
Figure 43. File Import Status Screen	51
Figure 44. Partitioning and Remaining Activity Screen – Activity at Deposition	51
Figure 45. Partitioning and Remaining Activity Screen – Remaining Activity at Time t.....	52

Figure 46. Source Partitioning Factors and Weathering Correction Factors Screens.....	53
Figure 47. Accessing Decon/Demo Parameters Screen from Partitioning and Remaining Activity Screen.....	54
Figure 48. Decontamination/Demolition Parameters Screen.....	54
Figure 49. Accessing Default Parameter Screens	56
Figure 50. Accessing Waste Results from Decontamination/Demolition Parameters Screen.....	57
Figure 51. Waste Results Screen	57
Figure 52. Accessing Waste Graphs from Waste Results Screen.....	58
Figure 53. Waste Graphs Screen.....	58
Figure 54. Save Scenario Option	59

List of Tables

Table 1. List of WEST GIS Scripts	13
Table 2. Media segregation parameters used in the Liberty RadEx Scenario	61
Table 3. Example Waste Quantity Estimation from Liberty RadEx Scenario	62
Table 4 Example Waste Activity Estimation from Liberty RadEx Scenario ($\mu\text{Ci}/\text{m}^3$)	63

Acronyms, Abbreviations, and Glossary

AI – Artificial Intelligence

ANN – Artificial Neural Network

ArcGIS – A complete software system, published by ESRI, for designing and managing solutions through the application of geographic knowledge

Beta Test – A limited release testing phase

BP – Back Propagation

Bq – Becquerel (a measure of radioactivity)

C&D – Construction and Demolition

CBRN – Chemical, biological, radiological, and nuclear

Census Tract – Small relatively permanent geographical subdivisions of a county

Chernobyl disaster – A nuclear disaster that occurred at the Chernobyl Nuclear Power Plant in Ukraine on April 26th, 1986

Ci – Curie(s) (a measure of radioactivity – 1 Ci = 37 billion Bq)

Comprehensive Data Management System – A complementary tool for Hazus-MH that provides users with the capability to update and manage statewide datasets.

Contiguous Albers Equal Area Conic Projection – A conical equal area map projection that uses two established parallels.

Cs-137 – Radioactive isotope of cesium with a half-life of 30 years

CSV – A file format based on comma-separated values or character-separated values

DHS – U.S. Department of Homeland Security

Dirty Bomb – A radiological weapon that combines explosives with radioactive material

DoD – U.S. Department of Defense

DoE – U.S. Department of Energy

EPA – U.S. Environmental Protection Agency

ESRI – Geographic information systems mapping software company based in Redlands, California

FEMA – Federal Emergency Management Agency

FLIR - Forward looking infrared

FRMAC – Federal Radiological Monitoring and Assessment Center

Fukushima Disaster – A nuclear disaster that occurred at the Fukushima Daiichi Nuclear Power Plant in Japan on March 11th, 2011

G – Graphical Programming Language

GAO – U.S. Government Accountability Office

Geospatial – Relating to or denoting data that are associated with a particular location

GIS – Geographic Information System

GPS – Global Positioning System

GUI – Graphical User Interface

Hazus-MH Database Tool – A database tool used to query the Hazus-MH databases based on census tract data.

Hazus-MH – Hazus-MH is a nationally applicable standardized methodology, published and supported by FEMA, which is used to estimate potential losses from earthquakes, floods, and hurricanes.

IC – Incident Commander

IND – Improvised Nuclear Device

LabVIEW – A graphical programming environment published by National Instruments Corporation of Austin, Texas

Land Cover – Physical material located on the earth’s surface

Landsat – a series of Earth-observing satellite missions jointly managed by NASA and the USGS

Layer – Set of thematic data characterized and stored in a map library

Liberty RadEx – A national Tier 2 full-scale exercise conducted in April 2010, based on a fictional terrorist attack involving a radiological dispersal device in the city of Philadelphia, PA.

LLRW – Low Level Radioactive Waste

MLP – Multi-Layer Perceptron

MSW – Municipal Solid Waste

NARAC – National Atmospheric Release Advisory Center

NASA – National Aeronautics and Space Administration

Neural Network – A data analysis and pattern-recognition tool that mimics the behavior of neurons found in the nervous system

Neuro-fuzzy Method – A combination of artificial networks and fuzzy logic

NHSRC – EPA National Homeland Security Research Center

NI – National Instruments

NRC – United States Nuclear Regulatory Commission

NRF – National Response Framework

NSSIPC - National Security Staff Interagency Policy Coordination

OEM – EPA Office of Emergency Management

ORD – EPA Office of Research and Development

ORIA – EPA Office of Radiation and Indoor Air

ORISE – Oak Ridge Institute for Science and Education

OSC – On-Scene Coordinator

PAGs – Protective Action Guides

PE – Processing Element

Python – General-purpose, high-level programming language

QA – Quality Assurance

QAPP – Quality Assurance Project Plan

QC – Quality Control

RDD – Radiological Dispersal Device

RGB – Red, Green, and Blue

Shapefile – A geospatial file format that stores non-topological geometry and attribute information for the spatial features in a data set

SQL – Structured Query Language, an international standard database manipulation query language

TAD – Threat Agent Disposal (workgroup)

Thematic Mapping – A map designed to portray a particular theme

TM – Thematic mapping

TXT – file format used to designate a text file

US – United States

USACE – U.S. Army Corps of Engineers

USGS – U.S. Geological Survey

VB – Visual Basic, an event driven programming language developed by Microsoft

VI – Virtual Instruments

WARRP – Wide Area Recovery and Resiliency Program

WEST – Waste Estimation Support Tool

Executive Summary

Historically, Radiological Dispersal Device (RDD) planning scenarios have primarily focused on response efforts, giving little attention to the recovery and management of debris and waste that would likely consume significant state and federal resources. The U.S. EPA's RDD Waste Estimation Support Tool (WEST) is a planning tool for estimating the potential volume and radioactivity levels of waste generated by a radiological incident and subsequent decontamination efforts. WEST supports decision makers by generating a first-order estimate of the quantity and characteristics of waste resulting from a radiological incident, and allows the user to evaluate various decontamination/demolition strategies to examine the impact of those strategies on waste generation.

The WEST is composed of two processes, preliminary data aggregation and the generation of waste inventories (separately known as the *Waste Tool*) as depicted in Figure 1. To function properly, the waste tool requires three important inputs from the preliminary data aggregation process: geographic information, surface media, and building stock (i.e., building quantity, size, square footage, and construction materials).

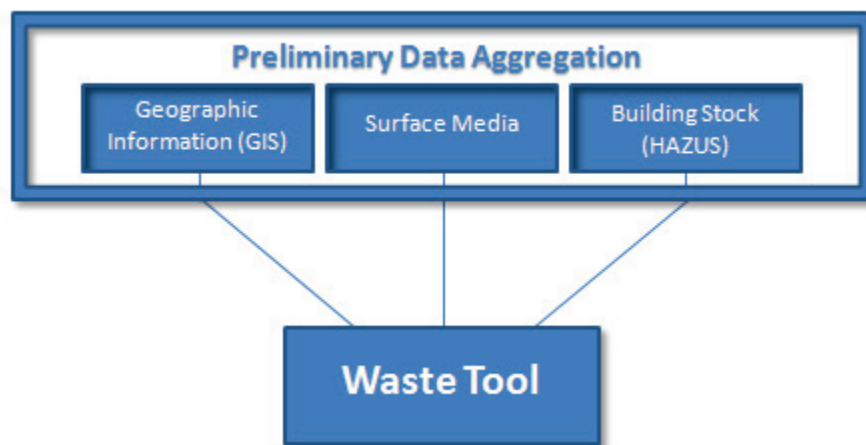


Figure 1. Data Aggregation Methodology

As shown in Figure 2, the WEST utilizes multiple platforms to assess the environmental and structural composition of an area to estimate the quantity, characteristics, and activities of waste and debris. The general approach to creating an RDD scenario begins by classifying geographical areas by level of contamination (i.e., using a dispersion plume shapefile). Based on the underlying building stock inventory and outdoor surface media, the waste tool calculates the amount and characteristics of debris resulting from the initial RDD blast and waste/debris resulting from building demolition and/or ground surface and selected decontamination techniques, including estimates of wastewater. The resulting data support the development of integrated response strategies that take different considerations into account (e.g., demolition, decontamination, and disposal) within a relatively short period of time.

Methodology

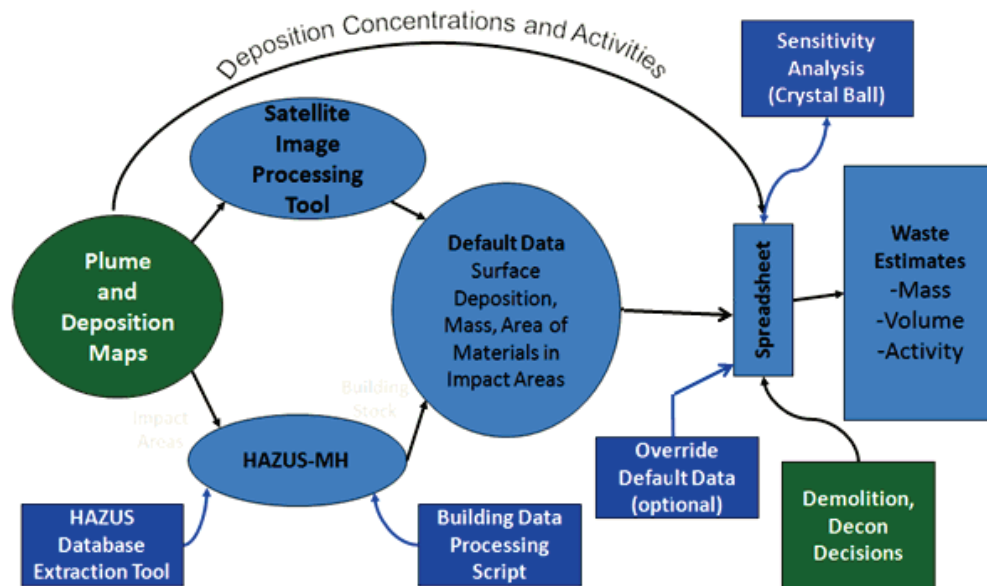


Figure 2. Graphical Depiction of Methodology

1.0 Introduction

Radioactive materials have a wide range of benevolent uses, especially in the purviews of medicine, industry, and research. However, conventional radioactive materials can also be used for sinister purposes such as radiological dispersal devices (RDDs) [1]. An RDD is a type of chemical, biological, radiological, and nuclear (CBRN) weapon in which radioactive material is combined with a dispersal device e.g., explosive. When detonated, the RDD, coupled with atmospheric transport, has the potential to disperse radioactive material over a wide area, contaminating exposed surfaces [1]. RDDs differ from traditional nuclear weapons: where nuclear weapons are capable of instantly incinerating a measurable area, RDDs are typically armed with a conventional explosive, resulting in a much smaller area of direct blast damage. However, both are capable of spreading radioactive particulates over a large area. Casualties from an RDD would initially remain relatively low [1]. Decontamination and remediation are the most arduous tasks associated with detonation of an RDD. As the radioactive particulate matter settles, its behavior will be influenced by the type of surface material. Depending on the radionuclide, permeable surfaces can act as a sponge, absorbing the radionuclide, making it difficult to decontaminate [2]. Decontamination resulting from a RDD that uses cesium may be financially exhaustive, potentially requiring extended recovery efforts. Efforts to mitigate the risk arising from RDDs entail securing radioactive sources, developing and deploying detection measures, and utilizing intelligence and counterterrorism resources [1]. Measures used to plan or prepare for detonation of an RDD are complex in number and typically involve event modeling in addition to response and recovery exercises. [1, 3, 4]

The modeling of atmospheric products generated by an RDD is described as one of the key planning factors by the *Planning Guidance for Response to a Nuclear Detonation Report*

developed by the National Security Staff Interagency Policy Coordination (NSSIPC) Subcommittee [3]. The NSSIPC further recommends that, in uncertain situations where technical information is limited, modeling should be used to the fullest possible extent [3]. Predictive plume and deposition models, however, are limited and tend to use postulated environmental inputs, which inhibit accuracy [4]. Accuracy in modeling, specifically in expedited response scenarios, is typically forfeited. Exploring capabilities for autonomous prediction of environmental inputs to aid in the generation of CBRN models addresses a major knowledge gap.

Modeling the distribution of the radionuclides in the plume is only the beginning of the remediation process. Contaminated areas are better defined through sampling and characterization processes that eventually supersede the initial plume modeling. However, a number of days or weeks may elapse before the affected area is fully characterized and, to minimize remediation timelines, initial development of remediation strategies must start immediately following the contamination event. This process includes identification of the materials found in both the indoor and outdoor portions of the affected areas and developing approaches for optimal cleanup of those surfaces and materials. Supplying the incident commander (IC) with decision making tools to prioritize remediation processes as soon as possible is a key element of a rapid, effective remediation that minimizes economic and health impacts to the affected community.

The Waste Estimation Support Tool (WEST) supports this process by exploiting plume models distributed by the National Atmospheric Release Advisory Committee (NARAC) depicting deposition and concentration levels, land cover classification capabilities using feed-forward neural network derived pattern recognition algorithms, and building stock values

including square footage and building counts and composition estimates as generated by the Federal Emergency Management Agency's (FEMA's) Hazus-MH software [5]. Using these modules, researchers have developed a suite of applications for rapidly estimating waste inventories and levels of radioactivity generated by detonation of an RDD as a function of user-defined decontamination and demolition approaches. This report begins by describing the background of the WEST and the need for estimating waste inventories generated by a RDD. Furthermore, this report describes the WEST and its supporting applications.

1.1 Background

For emergency planners and federal responders to scope out the waste and debris management issues resulting from a radiological response and recovery effort, it is critical to understand not only the quantity, characteristics, and level of contamination of the waste and debris but also the implications of response and cleanup approaches regarding waste generation. Until recently, pre-operational efforts, considering a large scale radiological event, were focused on the immediate response and early recovery phases, ignoring the issues associated with long term recovery. Though the activities associated with disaster response are crucial, the resulting recovery efforts tend to be the most arduous and time consuming in nature, especially in the purview of remediation.

In response to these shortfalls, the EPA conducted a series of exercises focusing on the longer-term recovery issues in addition to the formation of the Threat Agent Disposal (TAD) workgroup which examined the disposal of chemical, biological, and radiological threats. One of the most prominent national level exercises, Liberty RadEx, held in Philadelphia in April of 2010, was labeled as a drill to test the country's capability to clean up and help communities

recover from a dirty bomb terrorist attack. The WEST was developed to generate first-order estimates of a waste inventory for the RDD described in the exercise scenario.

1.2 Purpose

The purpose of this report is to describe the need for estimating the waste inventory generated by an RDD event, how the WEST and its supporting applications function, and lastly how to operate the tool itself. The recovery phase of an RDD event has largely been underestimated, particularly in the realm of debris management. Without proper planning, the management of debris would likely exhaust state and federal resources [6]. Further, waste management decisions are often controversial and need to be supported with the best information available. The WEST provides a better understanding of the recovery process by generating qualitative and quantitative estimates of debris and waste resulting from an RDD.

The detonation of an RDD in an urban area by terrorists is one of the National Planning Scenarios for which the U.S. Department of Homeland Security (DHS) is coordinating activities of various government agencies with response preparation requirements [7]. A recent survey by the Government Accountability Office (GAO) found that almost all city and state governments would be overwhelmed by an RDD response and would request aid from the Federal government [6]. Roles and responsibilities of the various government agencies during emergency response activities are described in the National Response Framework (NRF) [6, 8]. Under the NRF, the EPA is the lead agency for cleanup activities in the aftermath of an RDD event, including decontamination and waste disposal. Other Federal agencies, including the U.S. Department of Energy (DOE), U.S. Department of Defense (DoD) through the U.S. Army Corps of Engineers (USACE), and the U.S. Nuclear Regulatory Commission (NRC) also have major roles in an RDD cleanup [9].

Numerous exercises have been performed by agencies at the federal, state, and local level to help prepare for an RDD incident. However, GAO noted that in spite of over 70 RDD and improvised nuclear device (IND) exercises over the last several years prior to 2009, only three have included interagency recovery discussions following the exercise, and none have directly included activities related to the disposal of contaminated waste and debris in the exercise activities [6].

An integrated RDD response will require inclusion of many competing considerations, including risk to occupants and residents from post-cleanup radiation levels, prioritization of cleanups, costs associated with cleanups, speed of cleanup, decisions to demolish/remove or decontaminate, economic impacts created from denial of access to facilities and businesses, waste/debris treatment, transportation, and disposal costs. Determination of waste characteristics and whether the generated waste is considered to be construction and demolition (C&D) debris, municipal solid waste (MSW), hazardous waste, mixed waste, or low level radioactive waste (LLRW), and characterization of the wastewater that is generated from the incident or subsequent cleanup activities will influence the cleanup costs and timelines. Selected decontamination techniques to meet the cleanup level goals, whether they involve chemical treatment, strippable coatings, abrasive removal, or aqueous washing, will also influence the types and amounts of waste generated and associated cleanup costs and timelines. For emergency planners and federal responders to scope out the waste and debris management issues resulting from an RDD response and recovery effort, it is critical to understand not only the quantity, characteristics, and level of contamination of the waste and debris, but also the implications of response and cleanup approaches regarding waste generation. This lesson has been learned during recent cleanups of naturally-occurring *Bacillus anthracis* resulting from contaminated

animal hides. The best course of action in the cleanup was determined to be to produce as little waste as possible during the response and recovery. As the waste management issues are raised to a heightened degree of visibility from a planning standpoint, there is a critical need to scope out the magnitude and characteristics of the waste and debris so that staging/storage areas and treatment/disposal pathways can be identified. This report describes an effort to develop a first order estimate of a waste inventory based on the RDD scenario and plume maps utilized in the Liberty RadEx National Level Exercise from April 2010 [10].

1.1.1. Liberty RadEx

The Liberty RadEx drill, a national Tier 2 full-scale RDD exercise conducted in Philadelphia in April of 2010, was the largest drill of its kind to test the country's capability to clean up and help communities recover from a dirty bomb terrorist attack. The scenario involved a large truck bomb carrying 2,300 curies (Ci) of Cs-137 in the form of cesium chloride that was hypothetically detonated in downtown Philadelphia, with ensuing atmospheric transport and deposition creating a large area of contamination. Some of the products developed by the IC, using the NARAC prior to and during the exercise, were the GIS shapefiles which described the predicted deposition plume from the RDD as it moved downwind from the blast event. These shapefiles included predictions of ground-level deposition of Cs-137 in terms of aerial activity, or the activity of the ground surface following deposition in terms of microcuries per square meter ($\mu\text{Ci}/\text{m}^2$). The predicted deposition activities were segregated into three different levels designated high, medium, and low, reflecting the isopleths at 37, 8.8, and 4.1 MBq/m^2 (1,000, 240, and 112 $\mu\text{Ci}/\text{m}^2$) predicted surface activities. These surface activities are designated in the tables below as "Zone 1," "Zone 2," and "Zone 3," respectively, and are shown in Figure 3. The outer two zones in Figure 3 are based on Protective Action Guides (PAGs) which represent

radiation levels that help state and local authorities make radiation protection decisions, such as evacuations.

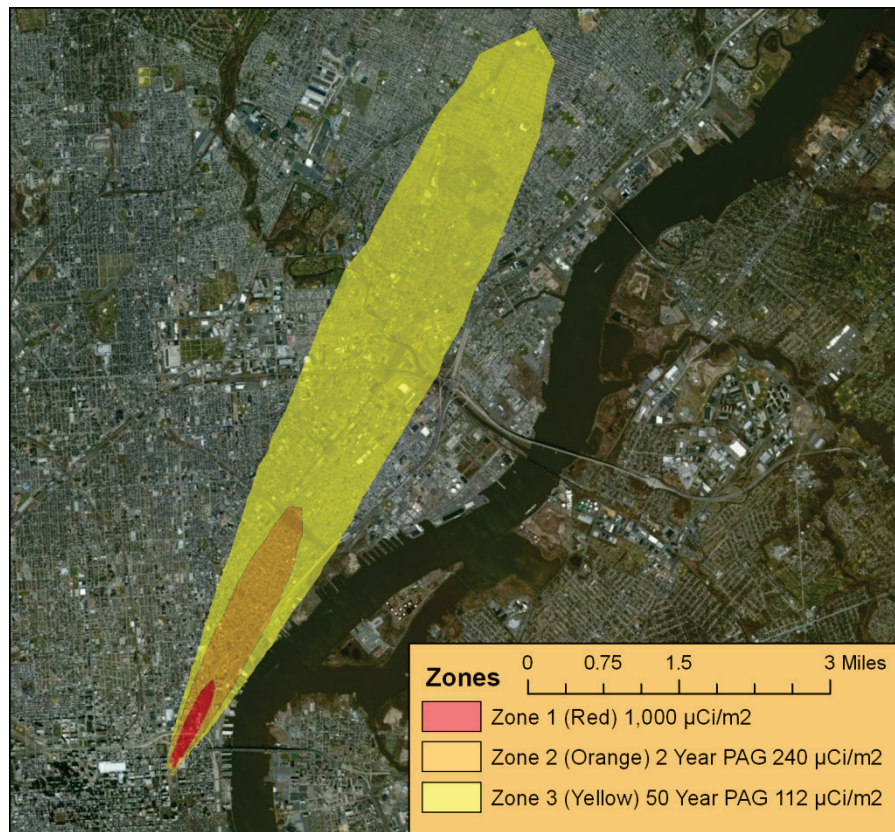


Figure 3. Liberty RadEx Plume Shapefiles

2.0 Description

The WEST is fundamentally composed of two processes, preliminary data aggregation and the generation of waste inventories (separately known as the *Waste Tool*) as depicted in Figure 4. To function properly, the waste tool requires three important inputs from the preliminary data aggregation process: geographic information, surface media, and building stock.

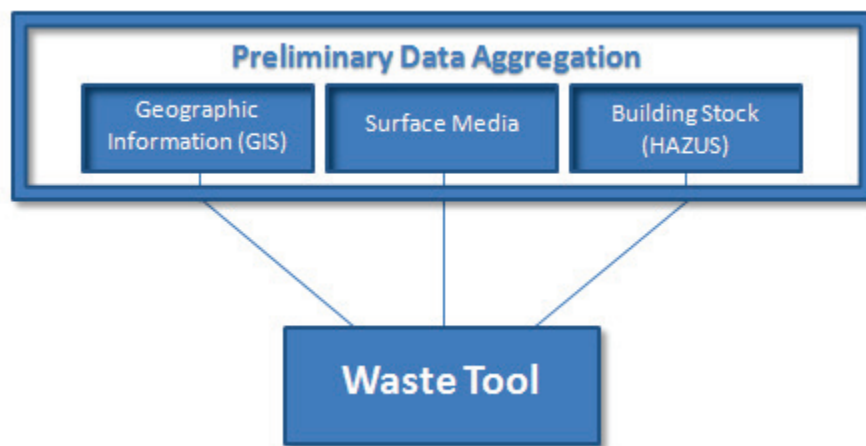


Figure 4. Preliminary Data Aggregation Methodology

The preliminary data aggregation process generates the following:

- Surface media statistics
- Building counts
- Building square footage
- Census tract/zone intersect percentages
- Zonal plume area

The Hazus-MH tool also produces supplemental infrastructure data, not used by the WEST directly. The supplemental infrastructure data are potentially important to the user and may be used in future versions of WEST to enhance the analysis of decontamination strategies.

Each of the three processes requires a separate application to generate the required output. The preliminary data aggregation processes in addition to the Waste Tool are explained in greater detail further on in this section.

2.1 Approach

The general approach that was used for developing the WEST is as follows [11]:

- Define the geographical areas affected by the hypothetical radiological contamination incident and subsequent radionuclide deposition using the geographic information system (GIS) shapefiles created during exercise modeling efforts by the Federal Radiological Monitoring and Assessment Center (FRMAC) supporting the Liberty RadEx exercise;
- Generate an inventory of building structures and other items within the affected geographical areas using the Hazus-MH software developed by FEMA;
- Estimate the outdoor ground media (asphalt, concrete, vegetation/soils) surface area using overhead satellite imagery;
- Based on the inventory of buildings, outdoor areas, and other items, use a database and spreadsheet to calculate an estimate of the amount and characteristics of debris resulting from the initial RDD blast and waste/debris resulting from building demolition and/or ground surface and selected decontamination techniques, including estimates of wastewater; and
- Since this approach uses MS Excel spreadsheets to perform the calculations of decontamination and demolition decisions, Excel plug-ins like Crystal Ball (Oracle Inc., Santa Clara, CA) can be used to perform sensitivity analysis on the parameters to find out which decontamination option had the largest influence on cost or waste quantities.

A comprehensive depiction of the methodology behind the tool is shown in Figure 5.

Methodology

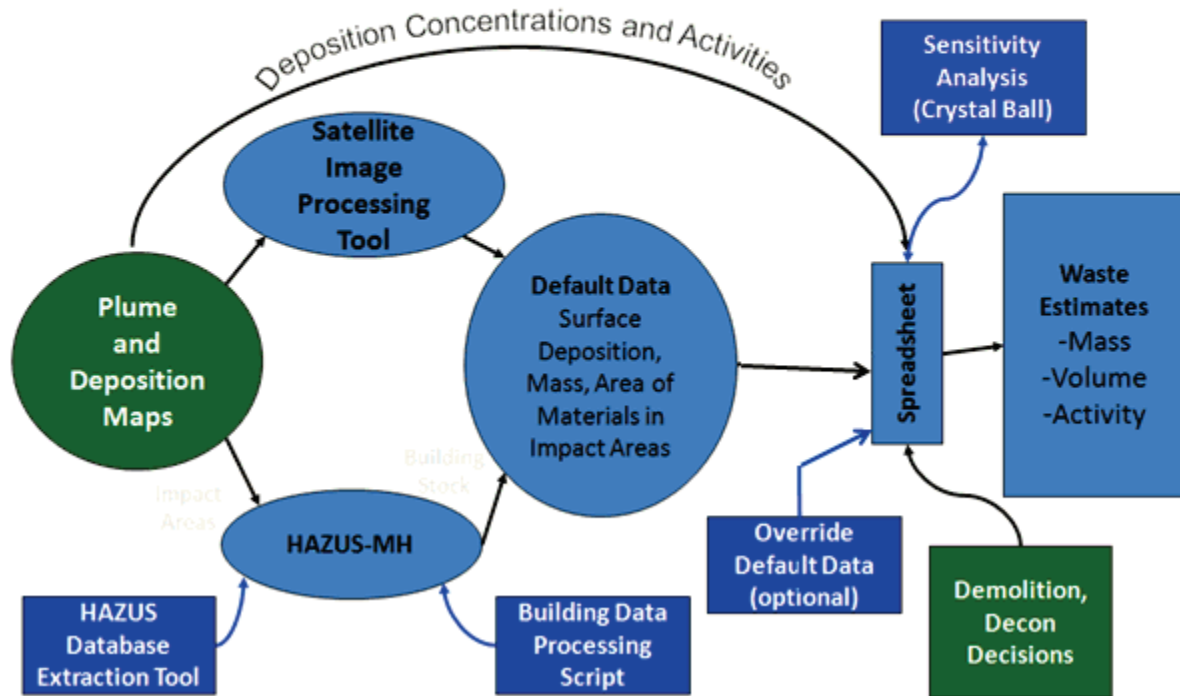


Figure 5. Graphical Depiction of Methodology

2.2 GIS Data Analysis Tools

When working with wide area events, it is important to understand the infrastructure and geographical qualities of a specific area. The entire process begins by generating a geographic area that completely encompasses the event. This process is often referred to as geospatial analysis and is systematically automated using a geographic information system such as ESRI's ArcGIS (ESRI Inc., Redlands, CA). ArcGIS has various extensions available to extend its functionality. One of the most acclaimed extensions for modeling potential loss of infrastructure is FEMA's Hazus-MH. Formally used to model earthquakes, floods, and hurricanes, Hazus-MH

operates using building stock databases that are applicable to other large scale disasters including those that involve radiological events.

Due to the steep learning curve associated with Hazus-MH and ArcGIS, the process of generating a scenario has been extensively automated by creating a script, otherwise known as a Toolbox in ArcGIS, to generate the needed results quickly with minimal input from the end user. The script can easily be installed as an add-on feature within ArcGIS by using the “Add Toolbox” function. Two inputs are needed for the script to function, a census layer derived from Hazus-MH and a plume layer.

The Toolbox houses seven scripts that perform three basic functions:

- Geometry and attribute modifications
- Census and geometry extraction
- Satellite imagery extraction

Table 1 provides a brief synopsis of each script within the Toolbox.

Table 1. List of WEST GIS Scripts

Script Name	Summary
Rejuvenate 1	<ol style="list-style-type: none">1. Merge three plume shape files into one.2. Add new field titled “Line_ID” for identification.
Rejuvenate 2	<ol style="list-style-type: none">1. Create Identifiers for the Line_ID field.2. Assign zones 001 – 003 for future reference.
Intersect 1	<ol style="list-style-type: none">1. Project both plume and census shapefiles.2. Establish area of plume before and after intersect.3. Establish area of census tract shapefile.4. Area of plume is exported using the unload table to text script.
Intersect 2	<ol style="list-style-type: none">1. Create new field for recording duplicates.2. Execute “loCount” script to record the number of duplicates.3. Delete duplicates.4. Export all census tracts in the table as a .csv file.5. Execute “iDup” script to record fields with equal areas.6. Delete duplicates.7. Export reaming (diverging) census tracts as a .txt file.

Image Zone 1	<ol style="list-style-type: none"> 1. Select and clip level001 from plume. 2. User selected satellite imagery is clipped using level001 plume. 3. Resulting image is saved at user's preference.
Image Zone 2	<ol style="list-style-type: none"> 1. Select and clip level002 from plume. 2. User selected satellite imagery is clipped using level002 plume. 3. Resulting image is saved at user's preference.
Image Zone 3	<ol style="list-style-type: none"> 1. Select and clip level003 from plume. 2. User selected satellite imagery is clipped using level003 plume. 3. Resulting image is saved at user's preference.

Although the GIS portion of the WEST is specific to the United States (US), since Hazus-MH is used to generate the building stock data needed for the waste estimate, the waste estimation spreadsheet itself is generic and applicable to a wide variety of situations. To use the WEST on an area not in the US, the geospatial data needed for import would have to be reproduced from whatever source the user has access to and reformatted to be suitable for import into the waste estimation spreadsheet. The use of census tracts as the smallest unit area for estimating waste is not hard coded into the WEST; other geographical units could be used.

2.3 Image Analysis Tool

A key component of estimating decontamination, demolition, and waste/debris disposal options from a wide area radiological event is to be able to classify outdoor media in an expedited manner. By analyzing satellite imagery of a selected area, the Image Analysis Tool classifies outdoor surface areas by type, e.g., soil, asphalt, or foliage. As demonstrated in Figure 6, surface classification is achieved by measuring the range fluctuations between Red, Green, and Blue (RGB) color codes for each individual pixel within a satellite image. These values range from 0 to 255, providing 16,581,375 color variations for the satellite image processing tool to examine.
































Color	Red	Green	Blue	Surface
	128	128	128	ASPHALT
	150	150	150	ASPHALT
	51	51	51	ASPHALT
	255	255	255	CONCRETE
	255	255	204	CONCRETE
	204	255	204	CONCRETE
	255	204	153	CONCRETE
	192	192	192	CONCRETE
	0	0	0	CONCRETE
	0	255	0	VEGETATION
	0	128	128	VEGETATION
	153	204	0	VEGETATION
	51	153	102	VEGETATION
	0	128	0	VEGETATION
	0	51	0	VEGETATION
	51	51	0	VEGETATION
	30	128	0	VEGETATION
	40	255	204	VEGETATION
	45	255	153	VEGETATION
	53	153	51	VEGETATION
	204	255	255	WATER
	0	204	255	WATER
	153	204	255	WATER
	51	102	255	WATER
	51	204	204	WATER
	0	255	255	WATER
	0	102	204	WATER
	0	0	255	WATER
	0	0	128	WATER
	0	51	102	WATER
	51	51	153	WATER

Figure 6. Surface Color Palette

Using the GIS tools described above to generate the imagery, the user uploads the resulting bitmap to the Image Analysis Tool. The tool then decodes the bitmap into an RGB format. Once the color ranges have been segmented and calibrated, the image is then redrawn according to surface type. The tool individually redraws each surface material that was pre-trained or defined by the user. An example is shown in Figure 7.

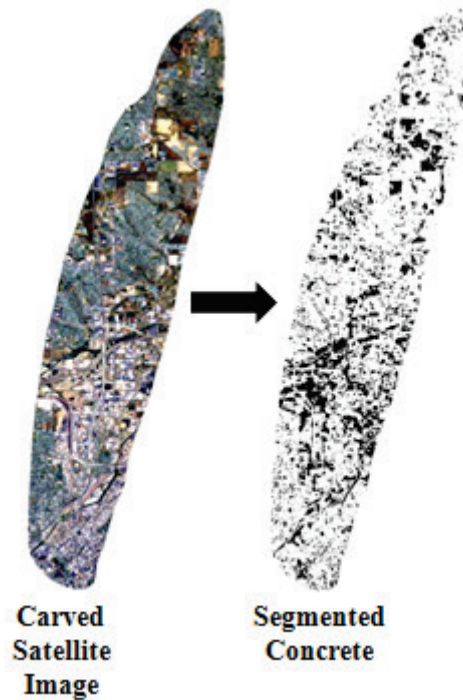


Figure 7. Surface Media Classification¹

The Image Analysis Tool functions using a form of artificial intelligence called Artificial Neural Networks (ANNs). ANNs are well known as pattern recognition algorithms.

Understanding the composition of surfaces within the contours of a plume resulting from an RDD is essential when assessing the makeup of debris, establishing decontamination parameters, and ultimately plays a key role in the remediation process. Though the classification of surfaces is crucial when determining waste characteristics, the process of manually analyzing wide area events is nearly impossible to accurately accomplish in a short period of time. However, by harnessing machine vision utilizing an ANN, surfaces can quickly be analyzed and classified based on color. By automating surface classification, the composition of surfaces over a wide area can quickly be determined, providing a more accurate estimation of surface contamination.

¹ The carved multispectral Landsat image depicts a plume covering Denver, Colorado. The segmented concrete image is the result of processing the carved satellite image using the Image Analysis Tool. The black pixels in the carved satellite image represent concrete, while the white pixels represent non-concrete surfaces.

Both ANNs and the image classification process are explained in greater detail in the following sections.

2.3.1 Artificial Neural Networks

Formally designed as a data analysis and pattern recognition tool that mimics the behavior of neurons found in the nervous system, ANNs outperform all other traditional classification methods and have been widely used in the realm of pattern recognition [12, 13]. By means of computerized artificial intelligence (AI), ANNs offer pattern recognition similar to human intelligence in addition to managing fallible data [14, 15]. Visually speaking, a neural network can be depicted graphically using numerical values coupled with nodes that utilize message-passing algorithms to identify patterns. The nodes within the graph act as input or output sources, while the graph itself works as a medium for networking or linking the various nodes. In essence, the architecture of a neural network mimics the architecture of a statistical processor by making analytical conjectures about data, capable of computing various relationships in a short duration with the convenience of decreased execution time compared to other means [16].

Nature-inspired and modeled based on the human brain, neural networks are composed of interconnecting nodes called processing elements (PEs) [14, 17]. Each PE exhibits a distinct behavior based on an assigned parameter and linkage [17]. The linkages between the PEs are assigned weights that act as constants, which can be adjusted using a learning algorithm [13]. There are many types of ANNs; one of the simplest being the feed-forward network, which is utilized by the Image Analysis Tool. The feed-forward network operates using one input layer,

hidden layer(s) also known as weights, and one output layer as shown in Figure 8.

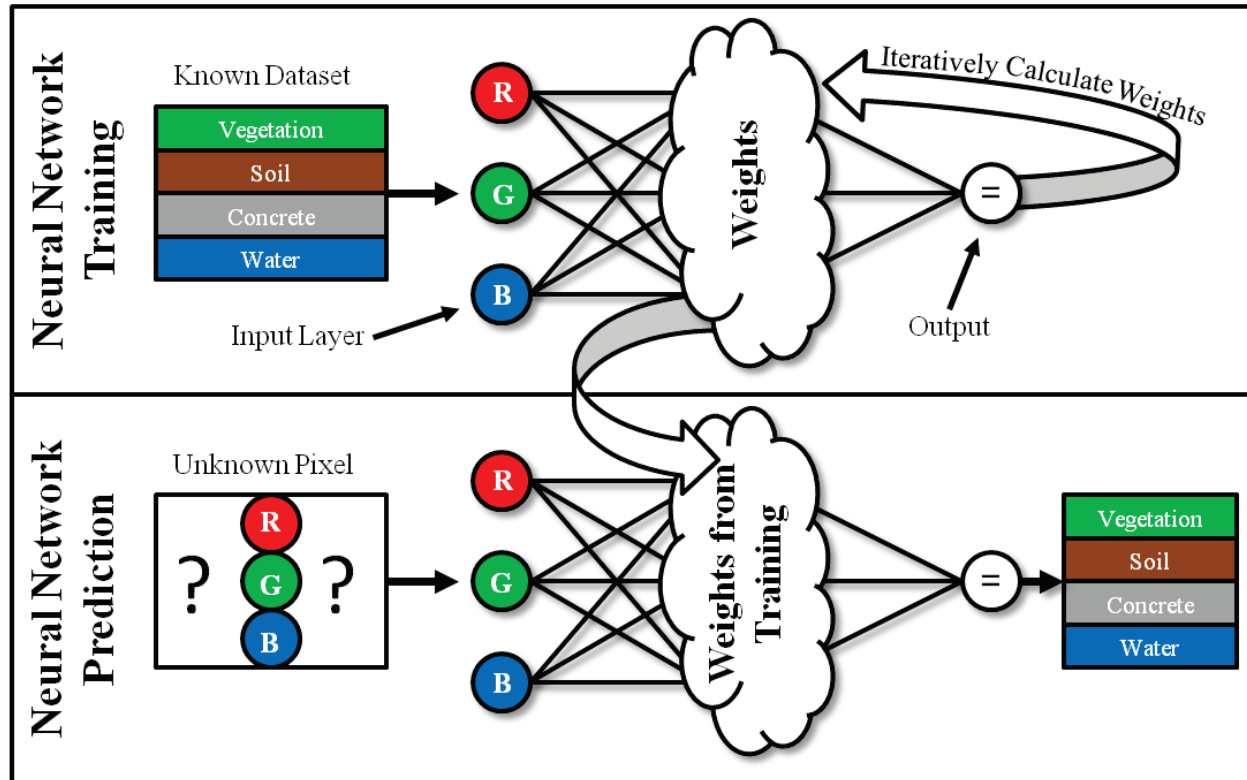


Figure 8. Feed Forward Neural Network

ANNs fundamentally learn by environmental exposure (comparison of known inputs and known outputs) and adjustment of interneuron synaptic weights. There are various learning methods available, each with its own specialty. The Image Analysis Tool for example, utilizes a backpropagation learning algorithm.

2.3.2 Ground Surface Estimation

As previously mentioned, the ability of ANNs to classify surface composition is a crucial component in the purviews of RDD waste estimation; however, the task of associating a group of symmetrically related pixels retaining analogous colors is primarily a human concept, easily expressed as linguistic terms and often a matter of postulation [18]. Significant improvements have been made in the realm of machine vision and image processing technology in the past few

years, reducing the amount of speculation and time associated with manually classifying imagery [16].

A body of research exists on both the classification of satellite imagery using neural networks and texture analysis based on pixel values. The ANN backed Image Analysis Tool works specifically at the pixel level, detecting discrete changes in color values in satellite imagery, often referred to as texture classification [15]. A generic term, texture classification is defined as the process of segmenting images into homogeneous textured sections based on a sequence of trained textures [19]. Texture has been described as having two separate dimensions: one for describing primitive features and the other for representing interactions between those features [15]. By applying dimensional separations, classification networks are able to segment textures based on learned samples.

Neural Networks have been widely used in the classification of land cover for the purposes of monitoring and planning for land use. One particular study focused on developing an automated ANN classification system using a supervised Multi-Layer Perceptron (MLP) network module, one of the most commonly used modules in land cover classification. The MLP-based ANN was engineered to classify urban areas, forest, planted crop fields, grass, fallow areas, transitional areas, wetlands, and water features from Landsat imagery. Training was completed using the supervised back propagation (BP) algorithm, which consisted of one input layer, one or more hidden layers, and one output layer that used a total of 3,360 training pixels and 360 testing pixels. Upon completion, the MLP network module had a classification accuracy of 88.13%. Researchers noted that the module was suitable for land cover mapping using remotely sensed data, and would be particularly favorable when the distribution of the data are not normal [12, 16].

The ability of ANNs to work with poorly organized datasets in an expedited manner makes them perfect solutions for classifying land cover. Applying the proficiencies of ANNs to resolve land cover to estimate debris resulting from CBRN weaponry is a relatively new concept. One of the few studies that employed a neural network is the work of Kanvesky et al., (1996) using an ANN to predict radioactive fallout resulting from the Chernobyl disaster. This study, however, failed to address surface deposition. To date, models that address the deposition of radioactive particles largely omit the specific identification of surface media found within a study area, instead assigning generic environmental conditions for a specified area (e.g., wooded or urban settings) [20]. ANNs have demonstrated obvious successes in identification of terrain by means of remote sensing imagery, indicating an opportunity to apply ANN texture classification capabilities to RDD deposition and debris modeling [18]. In the absence of literature, vast research and development opportunities exist for the application of ANNs to CBRN dispersion modeling.

2.4 Database Tool

Possibly the most arduous element of the waste estimation process is the acquisition and analysis of building stock data (i.e., building quantity, size, square footage, and construction materials) over a wide area. The Hazus-MH Database Tool confronts this issue by utilizing FEMA's Hazus-MH building stock database. Hazus-MH, FEMA's loss estimation software, is considered the leading entity for estimating building stock counts for rural and urban environments. Originally designed to estimate the loss inflicted by floods, hurricanes, and earthquakes, the Hazus-MH building stock data is used by WEST to generate square footage and building count estimates. One of the unique functions of the Hazus-MH Database Tool is the ability to extract building stock data directly from the Hazus-MH databases automatically

without navigating Hazus-MH or FEMA's Comprehensive Data Management System. By automating the building stock extraction process, the time required to produce the waste estimates is greatly reduced, and the universe of potential users is expanded beyond those with significant GIS expertise.

The Hazus-MH Database Tool functions as a standalone executable using the LabVIEW runtime engine. By applying census tracts derived from the previously mentioned GIS functions, the Database Tool queries over sixty tables for matching census identifications located in various databases (a complete listing of table and database names is found in Appendix B). Once allocated and filtered, the results are uploaded to local tables for further examination by the user. The Database Tool also queries a number of databases relating to infrastructure and demographics. A complete listing of the exported data is shown in Figure 9. Upon execution of the Database Tool, two general building stock databases are exported to the Waste Tool: a) Square Footage by Building Type; and b) Building Count by Building Type. Additional infrastructure and demographic information is provided for informative purposes only, and to date, is not used by the tool, although this information may be used in the future.

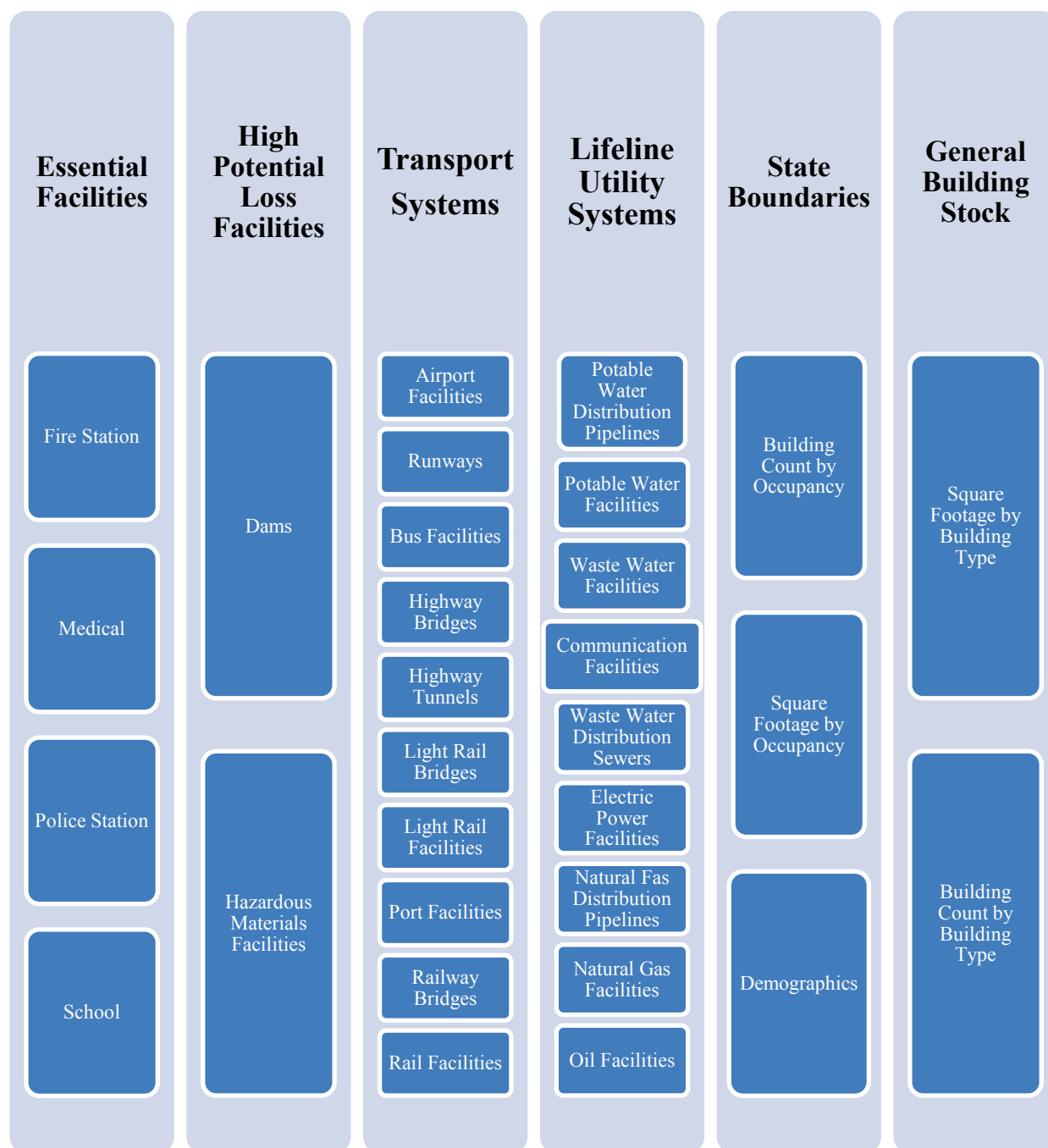


Figure 9. Hazus-MH Database Tool Output

2.5 Waste Estimation Spreadsheet Tool

The RDD Waste Estimation Spreadsheet Tool (Waste Tool) is a Microsoft Excel 2007 application that was created to process the data generated using the GIS data analysis tools (see

Section 2.2), the Image Analysis Tool (see Section 2.3), and the Hazus-MH Database Tool (see Section 2.4). The Waste Tool will use those data to generate waste estimates. The Waste Tool consists of two separate Microsoft Excel files, a calculation file and an application (user interface) file. The Waste Tool provides a simple and intuitive interface for users to specify various required inputs and to modify preprogrammed default parameters. The Waste Tool performs numerous calculations based on the data described above and additional user inputs to describe waste tradeoffs by:

- Total number and total square footage of all affected structures in each contamination zone (Hazus-MH);
- Interior surface areas of buildings (Hazus-MH);
- Exterior surface areas of buildings (Image Analysis Tool);
- Quantities of structural and non-structural demolition debris (WEST);
- Quantities of waste resulting from decontamination activities (WEST); and
- Initial radionuclide activity on various building and ground surfaces (WEST) – based on initial deposition estimates from NARAC.

The Waste Tool also contains reference tables consisting of default data and information derived from Hazus-MH on:

- Descriptions of model building type and specific occupancy type as defined by Hazus-MH. An example of available building and occupancy types is shown in Figure 10;

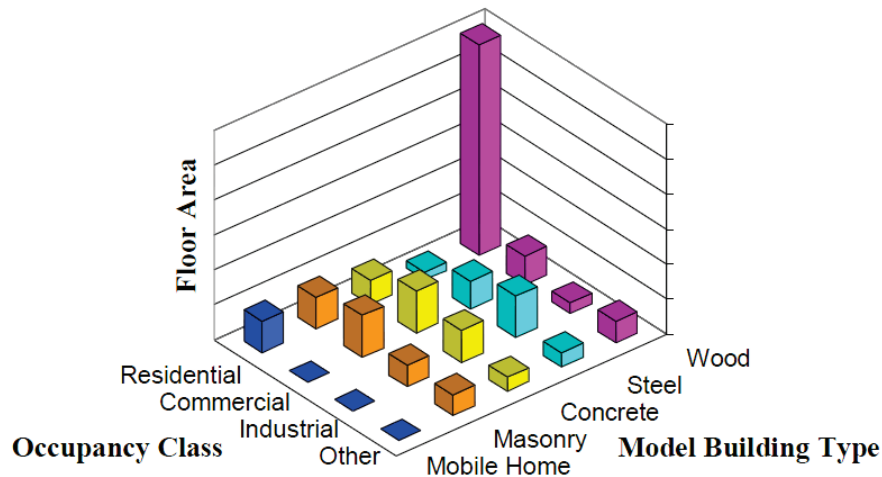


Figure 10. Example Inventory Relationship of Model Building Type and Occupancy Class

[3]

- Debris factors;
- Typical building heights; and
- Typical number of stories for each model building type.

Default data for decontamination technologies, surface material densities, building geometry calculations, and unit conversion factors are also included in the tool.

The Waste Tool performs the following calculations based on the total square footage and building counts for each model building type (i.e., in terms of building use, occupancy class, and structural system) located in each census tract that crosses one or more of the three contamination zones:

- Average square footage per building;
- Roof area per building;
- Interior floor area per building;
- Exterior surface area per building, excluding roof area;

- Interior surface area per building, excluding floors; and
- Structural and non-structural debris for each debris type (brick, wood, and reinforced concrete and steel) and for each model building type.

Once the preliminary data have been generated and imported into the tool, users can specify the type of decontamination technology to be used in each deposition zone, or can choose to model the demolition of all buildings in any given zone. Once the demolition and/or decontamination parameters have been specified, the Waste Tool estimates the amount of contaminated waste that would be generated. The waste estimates include building materials and ground surface materials, as well as the water that is generated during decontamination activities.

3.0 System Requirements

The following specifications are required in order to run the WEST and its supporting software. Operating the WEST below the suggested user requirements may cause system errors or freezes.

Required software:

- Hazus-MH MR5 2.0
- ArcGIS 9.3
- Microsoft Office 2007 or later
- LabVIEW 2010 runtime (included)
- Waste Estimation Support Tool (included)
- Google Earth (optional)

Suggested system requirements:

- Processor: Pentium 4/M or equivalent
- RAM: 2 GB

- Screen Resolution: 1024 x 768 pixels
- Operating System: Windows XP
- Disk Space: 45 GB (includes required software)

4.0 Instructions for Generating Waste Estimate

The following text describes a general approach for generating preliminary datasets used by the Waste Tool. The subsequent procedures should take approximately one hour.

1. Retrieve shapefiles from provided source.
2. Create Hazus-MH Scenario encompassing study region.
3. Set up the WEST folder.
4. Load the WEST Scripts into ArcGIS.
5. Combine plume shapefiles.
6. Generate satellite imagery of plume shapefiles.
7. Process study regions to generate square footage and building stock info.
8. Process satellite imagery to generate outdoor surface estimates.
9. Import building count and outdoor surface descriptor files into RDD Waste Estimation Spreadsheet.

Plume Shapefiles

Retrieve shapefiles for the provided scenario (e.g., LRE or WARRP) from an appropriate source, such as NARAC. The plume must be segmented into three zones (the maximum that can be handled by the current version of WEST). If four or more zones exist within the plume, delete the unused contours so that three remain. Figure 11 shows the plume used in the Liberty RadEx scenario.

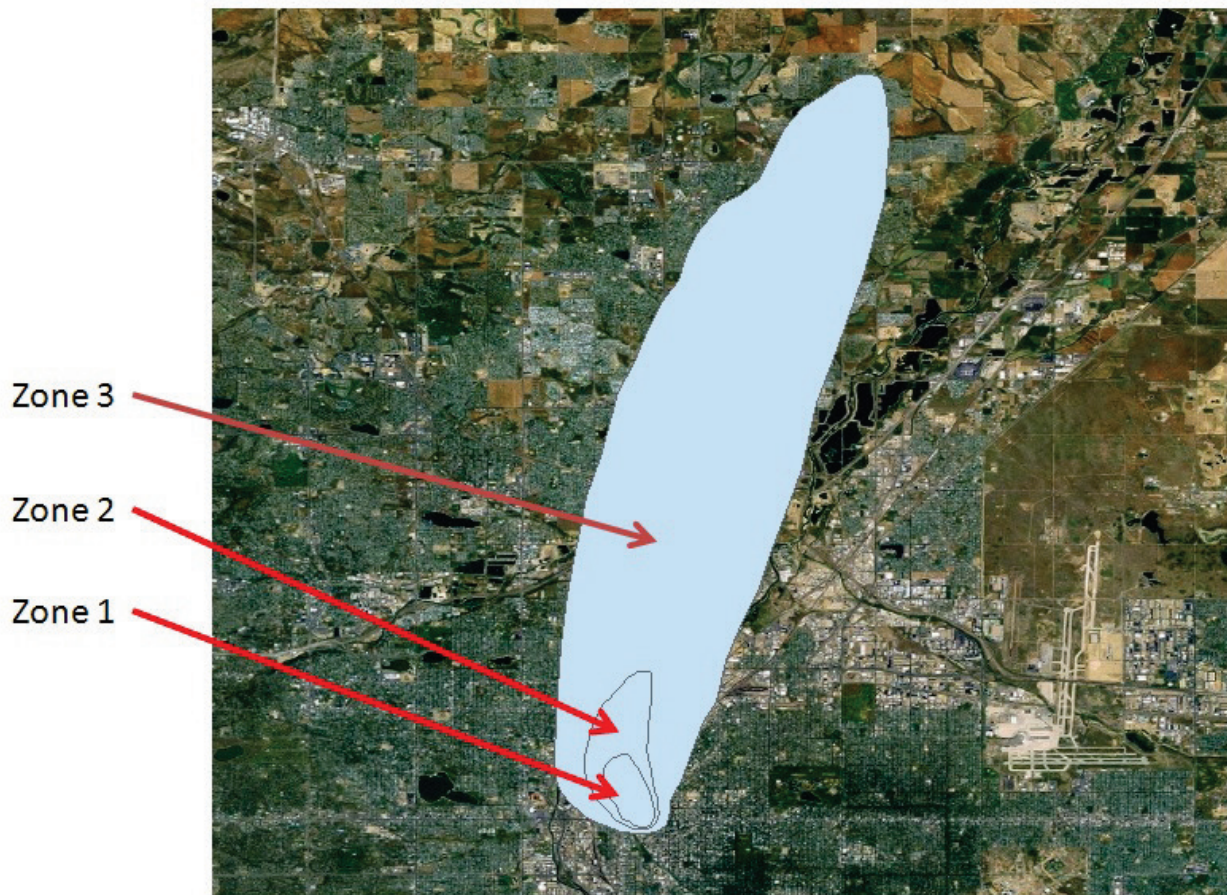


Figure 11. Liberty RadEx Plume Zones

HAZUS Scenario

Before generating a scenario in Hazus-MH, be sure to extract the necessary state inventory file from the Data Inventory DVD. To make the default inventory data accessible to Hazus-MH (in order to create new study regions), do the following:

1. Navigate to the compressed state data file on your DVD.
2. Select the file (CA.exe for example) and double-click to uncompress it.
3. When prompted for the 'Extract to' folder, enter the path to the Hazus-MH Data Path folder. By default, this folder is C:\Program Files\HAZUS-MH\Data Inventory.

From the Hazus-MH startup menu, create an earthquake scenario at the county level that encompasses the plume (tip: by selecting “Show map” you can view/select the preferred state and county). By adding the plume shapefile using the add data button from the “Show map” screen, you can view the underlying county(s). Be sure that the entire plume lies within the study region. Figure 12 (below) depicts the necessary steps for creating a study region (be sure to select “Earthquake” as hazard type).

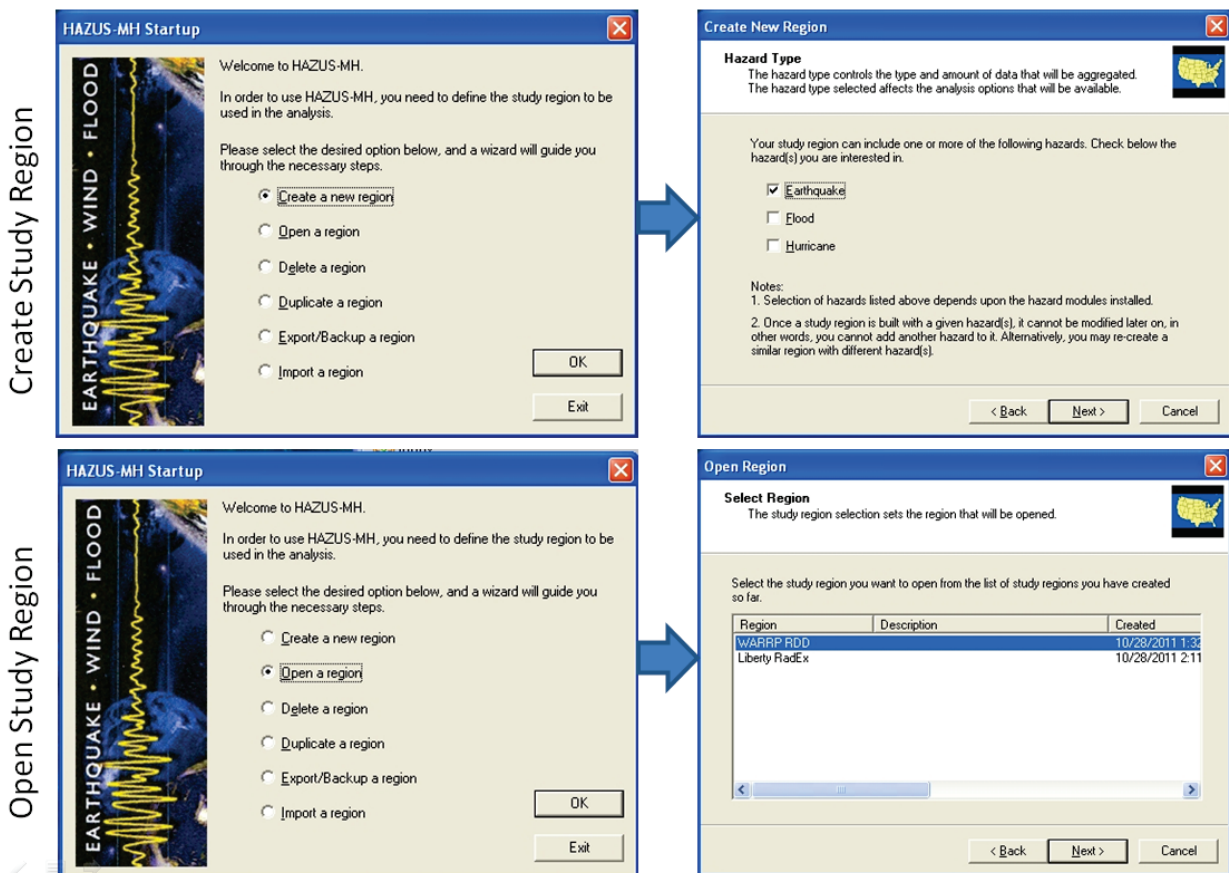


Figure 12. Hazus-MH Startup

WEST. Graphical User Interface (GUI)

The WEST GUI functions as a “point and click” interface intended to guide the user through the data aggregation process using a series of icons that function as application shortcuts. The WEST GUI can be accessed by clicking “**Start→All Programs→WEST**”.

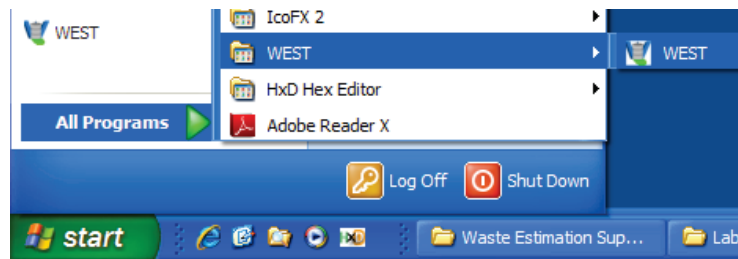


Figure 13. Accessing WEST

WEST Folder

The following procedures describe the steps necessary to establish the WEST directory. The directory will be used to store files associated with the WEST.

1. Create a folder to receive all the data – (e.g., Desktop\WEST).
2. To establish a WEST default directory/folder, click the **Set Default Directory** button.



Figure 14. Set Default Directory Button

3. Select the folder created in Step 1.

Copy/Train Neural Network

The following procedures describe the steps necessary to copy or create a new neural network training set. It is important to note that a pre-trained neural network is included with the WEST.

Step 2 only applies if you want to create a custom training set.

1. Copy the provided WESTTrainingSet.txt and WESTTrainingSet-Trained.txt files (located in default WEST installation directory) into the WEST folder.
2. Alternatively, if the training sets are unavailable, you may create your own.
 - a. To create a neural network training set that will be used to train the neural network, click the **Create Neural Network Training Set** button.



Figure 15. Create Neural Network Training Set Button

- b. When prompted to select a surface color map click **Default** (alternatively you may create your own color map by selecting **Custom**; however, this process tends to be complex and tedious and is beyond the scope of this document).
 - c. Save the file as “**WESTTrainingSet.txt**” within the WEST installation directory
 - d. To train the neural network that will be used to classify the satellite imagery, click the **Train Neural Network** button.



Figure 16. Train Neural Network Button

- e. The Train Neural Network application will open and begin training the neural network by accessing the WESTTrainingSet.txt file created in the previous step. Once the training has been completed, save the file as “**WESTTrainingSet-Trained.txt**” within the WEST installation directory.

Load Scripts

The following procedures explain how to add the WEST Toolbox, a suite of ArcGIS scripts used to automate the geospatial processes.

1. Open the scenario you just created in Hazus-MH.
2. Toggle the “**Show/Hide ArcToolBox Window**” button to display the ArcToolBox pane.



Figure 17. Show/Hide ArcToolBox Window Button

3. Right click **ArcToolbox**, select “**Add Toolbox**” and add the WEST Toolbox (in the WEST Apps folder).

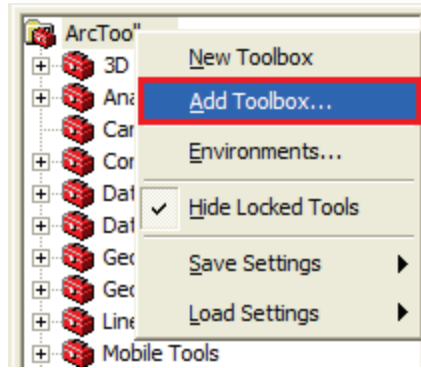


Figure 18. Add WEST Toolbox

4. In ArcToolbox, expand WEST Toolbox, right click “**unload table to text**”.
5. Select “**Properties**”.
6. Select **Source Tab**.
7. Navigate to “**unload table to text.py**” script (in the WEST Apps folder).

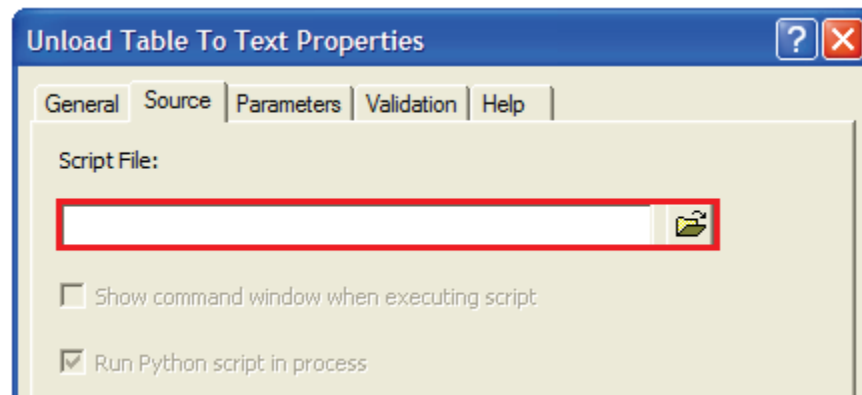


Figure 19. Unload Table To Text Properties

8. Hit “**Apply**” then **OK**.

Combine Shapefiles

The subsequent procedures are used to intersect the plume and census shapefiles within Hazus-MH. By combining the shapefiles, data within the shapefiles are merged for easier analysis.

1. Clear selected features by pressing the “**Clear Selected Features**” button. A grayed out button indicates that no features are currently selected. Be sure that no features are selected before and after each script is executed.

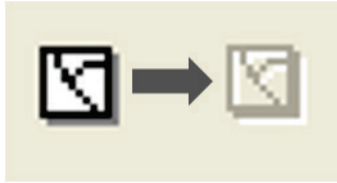


Figure 20. Clear Selected Features Button

2. Using the “**Add Data**” button, load the plume shapefile(s) (Shapefiles are not provided, you must either create or own or retrieve them from an official source e.g., NARAC).



Figure 21. Add Data Button

3. Select “**Add Data**” and load the provided satellite imagery (Located in default WEST installation directory or alternatively select “**File→Add Data From ArcGIS Online**” if you don’t have it).



Figure 22. World Imagery Layer

4. Validate the integrity of the shapefiles.
 - a. Run ArcGIS Script “**Data Management Tools→Features→Repair Geometry**” on each shapefile.

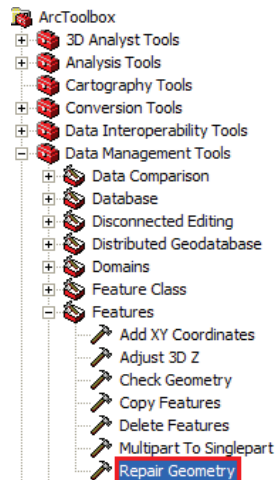


Figure 23. Repair Geometry Location

5. If the plume shapefiles you got from NARAC for Zones 1-3 are already combined into a single shape file then skip to Step 8, otherwise continue with Step 6.
6. Run “**WEST Toolbox → Rejuvenate1**”.
 - a. **WEST Folder:** the WEST folder you created.
 - b. **Select plumes:** corresponding to Zones 1, 2, and 3 – make sure Zone 3 is largest, Zone 2 is second largest, and Zone 1 is smallest and click “**OK**”.

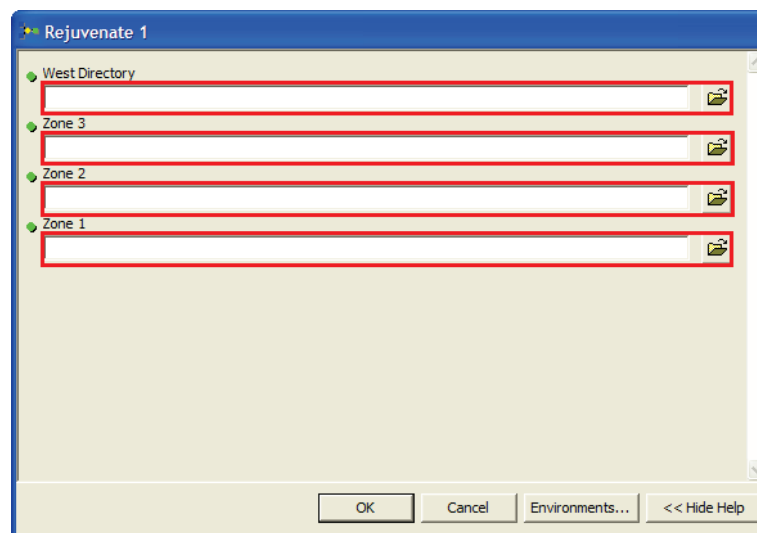


Figure 24. Rejuvenate 1 Script

7. Select “**Add Data**” and import the newly created shape file that is in the WEST folder. It will be named the same as the Zone 3 plume shape file with the word “merge” following.
8. Run Rejuvenate2.
 - a. **WEST Folder**: the WEST folder you created.
 - b. “**Shapefile_Merge**”: the merged shapefile from Step 5.

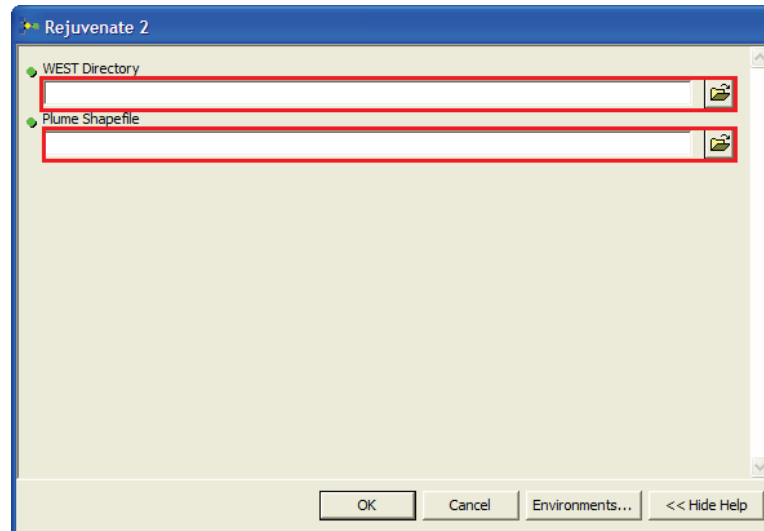


Figure 25. Rejuvenate 2 Script

9. A merged shapefile with all the plumes has now been created in the WEST directory. It is named the same as the previous merged shape file.

Satellite Imagery

The next steps describe how to dissect satellite imagery from the zonal areas. The resulting imagery will subsequently be classified according to surface type.

1. Confirm the merged shapefile created during Step 8 “Run Rejuvenate2” has been added.
2. Right click on the merged shapefile and select “**Open Attribute Table**”; Right click on the left box on the line for Zone 1 (line ID = Level001) and select “**Zoom to Selected**”; Close window.

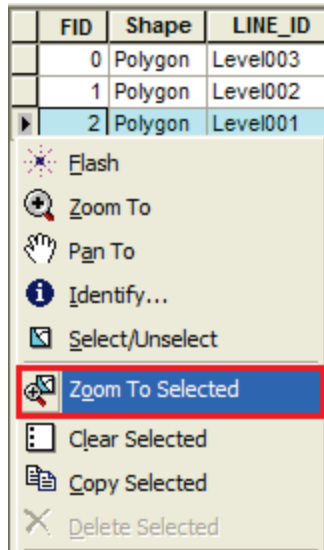


Figure 26. Zoom To Selected

3. **Hide all Layers** except “**Imagery**”; you should now see the satellite image area encompassing Zone 1.
4. **Select Menu File→”Export Map”**; Export the image as a **TIF file** at **200 dpi resolution**, with the “**Write GeoTIFF Tags**” option checked on the “Format” tab; Name the file “**Zone1**”; Save the file into the WEST folder.

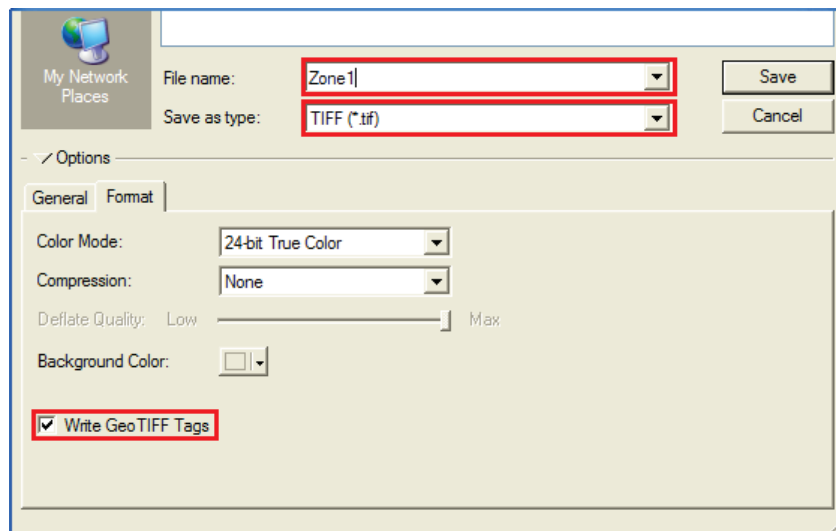


Figure 27. Export TIF Menu

5. Select “**Add Data**” and import the Zone1.tif file you just created.
6. Under the ArcToolbox, go to “**WEST Toolbox→Image Zone1**”.
 - a. **Plume**: the merged shapefile.
 - b. **Satellite Image**: Zone1.tif.
 - c. **Save Image As**: “Zone1.img” – use the file dialog to save that into your WEST folder.
 - d. **WEST directory**: your WEST directory you created.

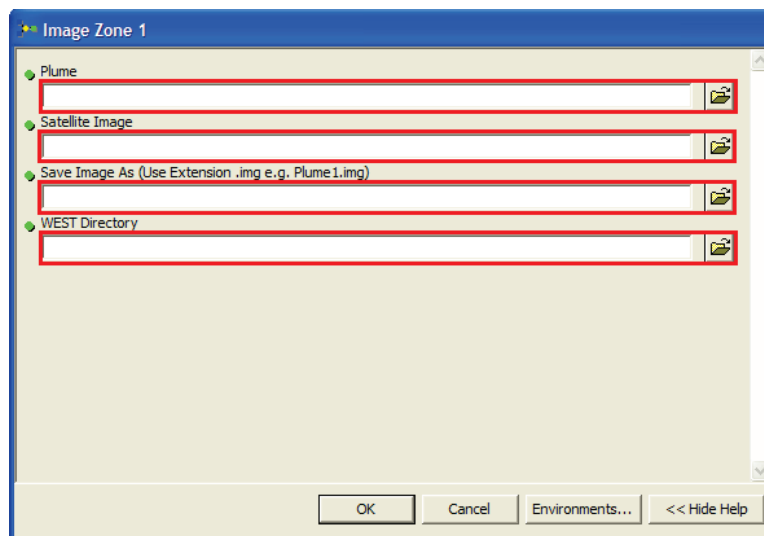


Figure 28. Image Zone 1 Script

7. Select “**Add Data**” and import the Zone1.img file that was created in your WEST folder.
8. Hide all layers except Zone1.img; -- you should see the satellite imagery for the irregularly shaped Zone 1.
9. **Select Menu File→”Export Map”**; Export the image as a **BMP file at 200 dpi resolution**; Name the file “**Zone1.bmp**”.

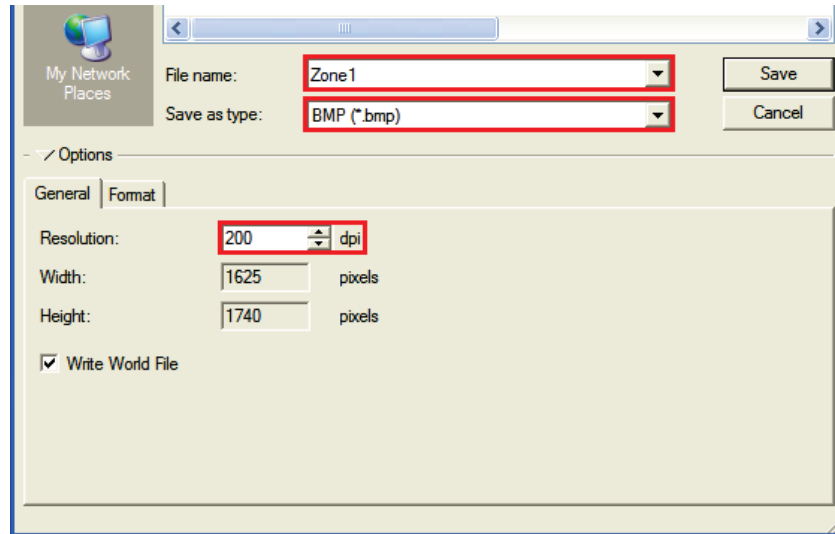


Figure 29. Export BMP Menu

10. Repeat this process for Zones 2 and 3 (Zone 2 line ID = Level002 and Zone 3 line ID = Level003).

Process Study Regions

The following procedures describe how to process the study regions using the intersect scripts.

Upon execution of the scripts, a statistical reference is derived for calculating the building stock.

1. Under the ArcToolbox, go to “**WEST Toolbox→ Intersect 1**”.
 - a. **Census Data**: Study Region Tract.
 - b. **Plume Data**: the merged shapefile.
 - c. **WEST Folder**: the WEST folder you created.
 - d. **PLUMEAREA.csv** : save the file as “PLUMEAREA.csv” in your WEST folder.

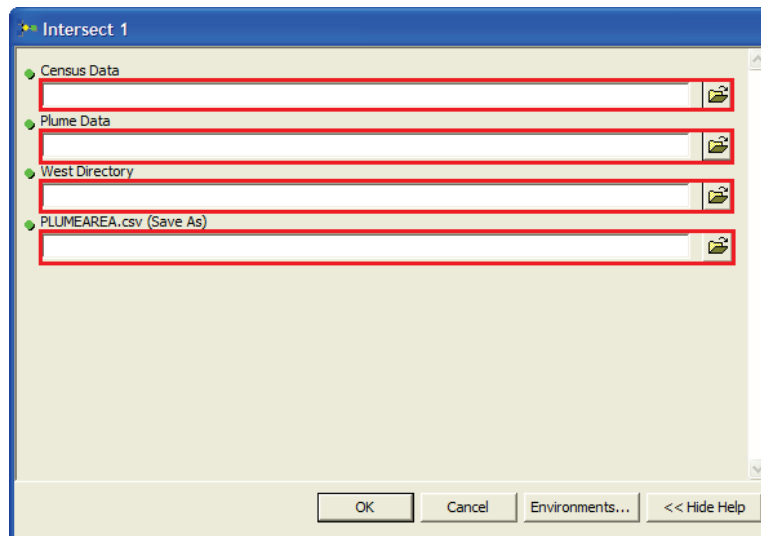


Figure 30. Intersect 1 Script

2. Intersect1 created a new shapefile in the WEST Directory called
 “hztract_Project_Intersect.shp”. Add this file using the “**Add Data**” button.
3. Under the ArcToolbox, go to “**WEST Toolbox→ Intersect 2**”.
 - a. **Intersected Shape File:** hztract_Project_Intersect .
 - b. **OUTPUT.csv:** save the file as “OUTPUT.csv” in your WEST folder.
 - c. **CENSUS.txt** : save the file as “CENSUS.txt” in your WEST folder.

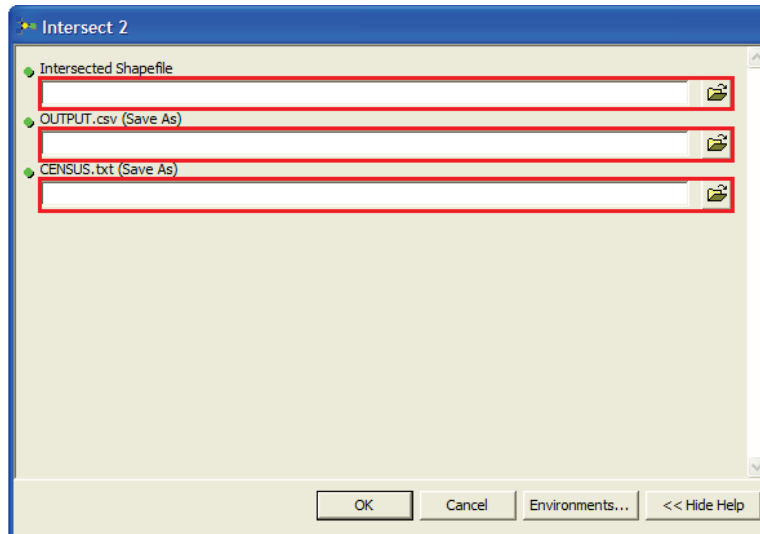


Figure 31. Intersect 2 Script

Convert Zone Square Footages

The following procedures describe how to convert the square footages extracted during the GIS portion.

1. To convert the zone square footages, click the **Convert Zone Square Footages** button.



Figure 32. Convert Square Footages Button

2. The Convert Zone Square Footages application automatically locates and converts the required values. Click the **Ok** button to close the application.

Process Building Stock

The following procedures describe how to extract the building stock inventory using the Hazus Database Tool.

1. To process building stock inventories, click the **Hazus Database Tool** button.



Figure 33. Hazus Database Tool Button

2. Step 1: locate Hazus-MH directory.
 - a. **Select the Hazus-MH Folder:** default location: C:\Program Files\HAZUS-MH
(tip: to select the folder currently being viewed, select the “**Select Current Folder**” button.)
 - b. If Hazus-MH folder is located outside of default directory, check box and select your “**HazusData**” folder, otherwise click “**OK**” to continue.

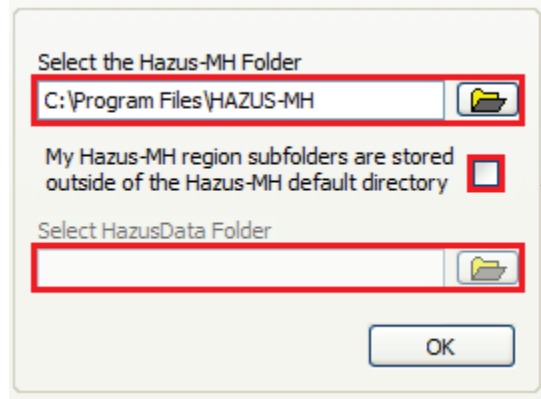


Figure 34. Select Hazus Folder

3. Step 2: select state inventory and region.
 - a. Select **State Data Inventory Database:** the state of your study region.
 - b. Check **Include General Building Stock.**
 - c. Check **Export Data to WEST.**

- d. **Select Region**: the name of the study region you created in Step 2.
- e. Click **Execute**.

Hazus-MH Version: MR5 2.0

Select State Data Inventory Database

CO

Include General Building Stock (Requires Hazus-MH): ☒

Export Data to WEST: ☒

Select Region

WARRP Demo 10-24

Execute

Figure 35. Select Inventory

- 4. The required building stock files, i.e., building count and square footage values are extracted to the pre-established working directory. Optionally, the Database Tool has embedded functionality to further assist in site assessment:
 - a. Browse critical infrastructure and building stock.
 - b. Export infrastructure and building stock tables for separate analysis by clicking the **Export Table to Excel** button.
 - c. Plot infrastructure and building stock data in Google Earth by clicking the **View Features in Google Earth** button (must have Google Earth installed).

Home Essential Facilities High Potential Loss Facilities Transportation Systems Lifeline Utility Systems State Boundaries General Building Stock (Requires HAZUS-99)						
Fire Station Medical Police Station School						
Tract	Name	Address	City	Zip code	State	Contact
08031001101	HORACE MANIN MIDDLE SCHOOL	4130 NAVAJO STREET	DENVER	80211	CO	
08031001102	BRYANT WEBSTER ELEMENTARY SCHOOL	3635 QUIVAS ST	DENVER	80211	CO	
08031001500	GARDEN PLACE ELEMENTARY SCHOOL	4425 LINCOLN STREET	DENVER	80216	CO	
08031001600	INNER-CITY CHRISTIAN SCH PARTN	2609 LAWRENCE STREET	DENVER	80205	CO	
08031001702	EMILY GRUFFITH OPPORTUNITY SCHOOL	1250 WELTON STREET	DENVER	80204	CO	
08031001800	DEL PUEBLO ELEMENTARY SCHOOL	750 GALAPAGO	DENVER	80204	CO	
08031001900	GREENLEE/METRO LAB ELEMENTARY SCHOOL	1150 LIPAN STREET	DENVER	80204	CO	
08031002000	P. S. I CHARTER SCHOOL	1080 DELAWARE STREET	DENVER	80204	CO	
08031002403	GILPIN ELEMENTARY SCHOOL	2949 CALIFORNIA STREET	DENVER	80205	CO	
08001008505	HULSTROM ELEMENTARY SCHOOL	10604 GRANT DRIVE	NORTHGLENN	80233	CO	
08001008507	MALLEY DRIVE ELEMENTARY SCHOOL	1300 EAST MALLEY DRIVE	NORTHGLENN	80233	CO	
08001008508	WOODGLEN ELEMENTARY SCHOOL	11717 NORTH MADISON STREET	THORNTON	80233	CO	
08001008524	BRIGHT HORIZONS PRE-KINDERGARTEN SCHOOL	5321 EAST 136TH AVENUE	BRIGHTON	80601	CO	
08001008525	STARGATE CHARTER SCHOOL	3951 COTTONWOOD LAKES BOULEVAR	THORNTON	80241	CO	
08001008529	CHILDRENS WORLD	12290 PENNSYLVANIA ST	THORNTON	80241	CO	
08001008530	SHADOW RIDGE MIDDLE SCHOOL	12551 HOLLY STREET	THORNTON	80602	CO	
08001008531	CHERRY DRIVE ELEMENTARY SCHOOL	11500 CHERRY DRIVE	THORNTON	80233	CO	
08001008534	RIVERDALE ELEMENTARY SCHOOL	10724 ELM DRIVE	THORNTON	80233	CO	
08031000201	BEACH COURT ELEMENTARY SCHOOL	4950 BEACH COURT	DENVER	80221	CO	
08031000202	REXINGTON ELEMENTARY SCHOOL	4735 PECOS STREET	DENVER	80211	CO	
08031000401	COLUMBIAN ELEMENTARY SCHOOL	2925 WEST 40TH AVENUE	DENVER	80211	CO	
08031000402	CONTEMPORARY LEARNING ACADEMY HIGH SCHOO	2211 WEST 27TH AVENUE	DENVER	80211	CO	
08031000600	FRED N THOMAS CAREER EDUCATION CENTER	2650 ELIOT STREET	DENVER	80211	CO	
08031003500	SWANSEA ELEMENTARY SCHOOL	4650 COLUMBINE STREET	DENVER	80216	CO	
08001008901	ADAMS CITY MIDDLE SCHOOL	4451 EAST 72ND AVENUE	COMMERCE CITY	80022	CO	
08001008952	MAPLETON PRESCHOOL	602 EAST 64TH AVENUE	DENVER	80229	CO	
08001009001	MONTREY ELEMENTARY SCHOOL	2201 MC ELWAIN BOULEVARD	DENVER	80229	CO	
08001009002	CORONADO HILLS ELEMENTARY SCHOOL	8300 DOWNING DRIVE	THORNTON	80229	CO	
08001009003	SKYVIEW NEW TECHNOLOGY HIGH SCHOOL	1200 E 78TH AVENUE	DENVER	80229	CO	

Figure 36. Hazus Database Tool

Process Satellite imagery

Once the satellite images have been dissected according to zone, the resulting imagery must now be classified according to surface type.

1. To process satellite imagery, click the **ID Surfaces** button.



Figure 37. ID Surfaces Button

- a. **Select** the Zone1.bmp file created during the Satellite Imagery process.
- b. When it asks you if the study region is rectangular select the “**No**” option.
- c. Repeat this process for Zones 2 and 3.

Import Files

Up to this point, all files used to create a scenario within the waste tool have been generated.

Before continuing, ensure the following files have been created in the WEST directory:

- Ground Surface Percentage Data = RDD Tool Ground Surface Data.csv
- Building Count Data = BldgsinCensusTract.csv
- Census Tract/Zone Percentage Data = TRACT_AREAS.CSV
- Building Square Footage Data = SqFtofBldgsinCensusTract.csv
- Zone Area Data = Plumearea.csv

TRACT_AREAS.csv, BldgsinCensusTract.csv, and SqFtofBldgsinCensusTract.csv should contain the same number of entries. Four bitmap files have also been generated. Check images for classification accuracy.

4.1 Instruction for Operating the RDD Waste Estimation Spreadsheet Tool

Once the generated files have been checked for compatibility (i.e., the number of records in the import CSV files are the same, the data structures of the import CSV files are consistent with what is needed by the spreadsheet), they are now ready to be uploaded to the waste tool. The following steps explain how to install and operate the Waste Tool.

1. Install the two RDD Waste Estimation Spreadsheet Tool files into the same directory of your choosing:

RDDToolApp_20120815_V1.2.xlsm

RDDToolData.xlsx

2. Open the **RDDToolApp_20120815_V1.2.xlsm** file. The following screen will appear.

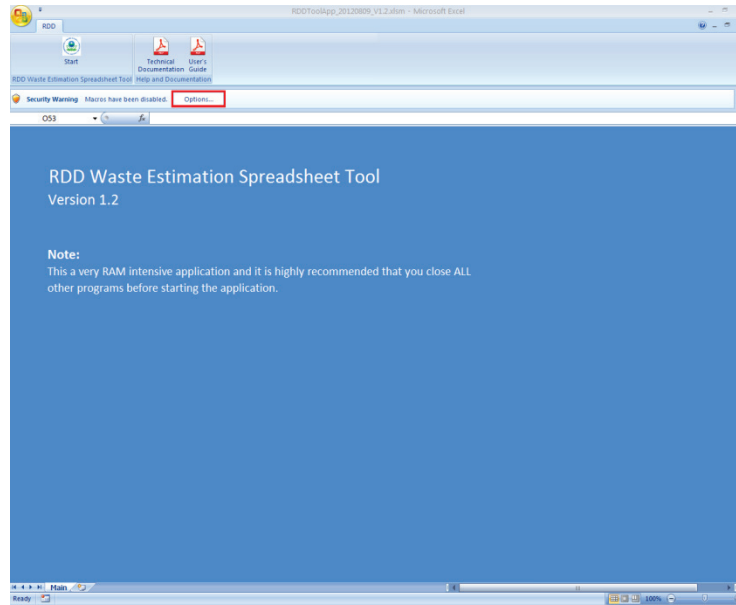


Figure 38. RDD Waste Estimation Spreadsheet Tool Main Screen

3. Enable Macros. Click the **Options...** box. The Microsoft Office Security Options window appears.



Figure 39. Security Alert – Macro Screen

4. Click the **Enable this content** radio button, then click the **OK** button.
5. Click **Start** on the top left side of the Microsoft Excel toolbar ribbon.

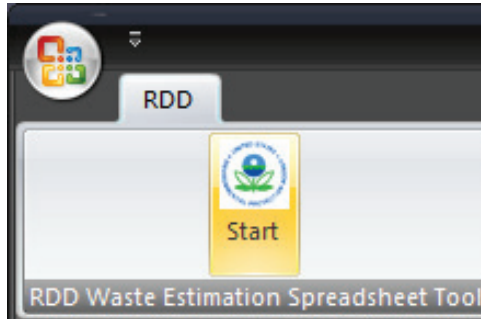


Figure 40. Waste Estimation Spreadsheet Tool Main Screen Start Button

6. The RDD Waste Estimation Tool Home window appears.

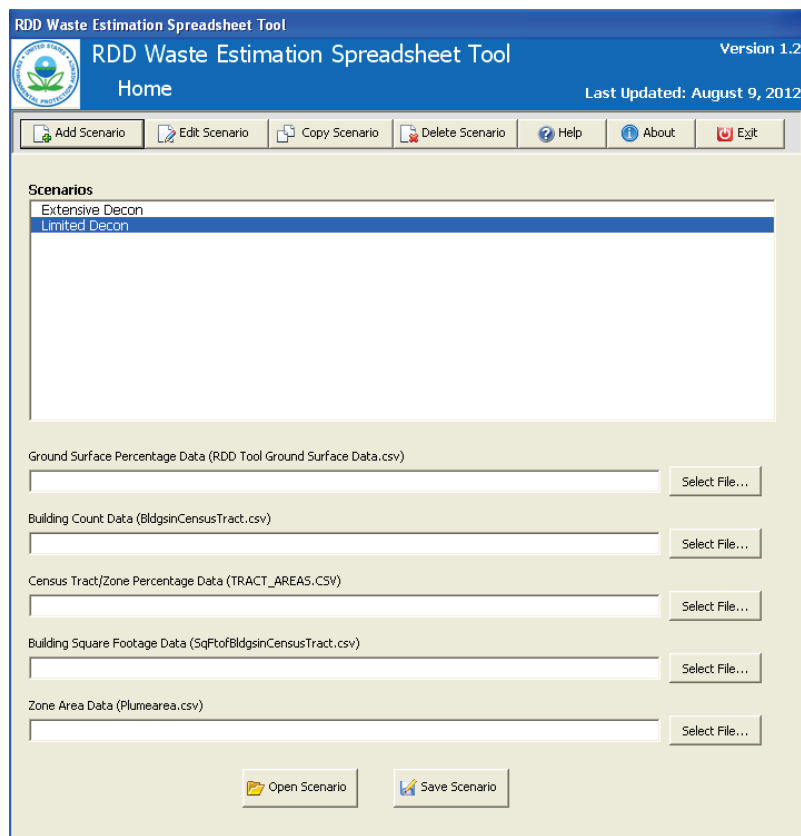


Figure 41. RDD Waste Estimation Spreadsheet Tool Home Screen

Two pre-existing scenarios are provided in the Tool: Extensive Decon and Limited Decon. Any other user created scenarios will also be listed in the Scenarios list on the Home window. The two default scenarios cannot be deleted. From the Home window, you can:

- Add a new scenario.
- Edit an existing scenario.
- Copy an existing scenario.
- Delete an existing scenario.
- Open an existing scenario.
- Save an existing scenario.

You do not need to import data to **add**, **edit**, **copy**, or **delete** an existing scenario. You can create multiple scenarios and import different data sets to apply to one or more of the scenarios.

When you **Open** or **Save** a scenario, you must import the five data files created from previous steps in the methodology.

- a. To **add a new scenario** from the Home window, click the Add Scenario button. The Scenario Basic Information window appears.

RDD Waste Estimation Spreadsheet Tool Version 1.2
Scenario Basic Information New Scenario

Home Save Undo Help

Scenario Name

Comments

Time Elapsed Since Initial Deposition days

Total Affected Area Scaling Factor

Initial Ground Surface Activity at Deposition

Select area activity unit per

Radionuclides Present

Radionuclide	Zone 1 Activity	Zone 2 Activity	Zone 3 Activity	Activity Includes Daughter
Am-241	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="checkbox"/>
Ba-140/La-140	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="checkbox"/>
Ce-141	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="checkbox"/>
Ce-144/Pr-144/Pr-144m	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="checkbox"/>
Cf-252	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="text" value="0"/>	<input type="checkbox"/>

Figure 42. Scenario Basic Information Screen

- i. Give the scenario a unique name.
- ii. Enter the number of days that have elapsed since initial deposition.
- iii. The default affected area scaling factor is 1. Changing this factor allows you to adjust the total area of each affected zone by the factor specified. For example, if the total affected area is 1,000,000 m², entering a scaling factor of 1.5 will adjust the total affected area to 1,500,000 m². All subsequent calculations will be based on the scaled area.
- iv. Specify the areal activity units that will be associated with the activity values that will be entered for each radionuclide.

- v. Specify the radionuclides present at deposition by entering the ground surface activity for those radionuclides for each zone. If the activity includes the contribution from the daughter product(s), then check the **Activity Includes Daughter** box. If this box is not checked, the tool will calculate the activity contribution from any daughter products. See the Technical Documentation or click on the **Help** button for more information on which daughters are included in the calculations.
 - vi. Once all of the information has been entered, click the **Save** button. To return to the Home window, click the **Home** button.
- b. To **edit an existing scenario**, highlight the scenario name in the Scenarios box and click Edit Scenario. The Scenario Basic Information window will appear. Make any desired changes to the scenario and then click the Save button. To return to the Home window, click the Home button.
- c. To **copy an existing scenario**, highlight the scenario name in the Scenarios box and click Copy Scenario. A new scenario will automatically be created and will be listed in the Scenarios box with the default scenario name “Copy of...” To change the name of the copied scenario or to make any other changes to the scenario basic information, highlight the copied scenario in the Scenario box and then click the Edit Scenario button. The Scenario Basic Information window will appear. Make any desired changes to the scenario and then click the Save button. To return to the Home window, click the Home button.
- d. To **delete an existing scenario**, highlight the scenario name in the Scenarios box and click the Delete Scenario button. This action will permanently delete a scenario and cannot be undone.

7. Open or Save a Scenario

- a. To open or save a scenario, you must have at least one scenario created and available in the Scenarios box. The procedure for opening or saving a scenario is as follows:
- b. Highlight the scenario in the Scenarios box to which you want to apply the geographic data.
- c. The five geographic data files that must be imported and applied to the scenario were created in previous steps and were saved in a directory. The files must be provided in the following order:
 - Ground Surface Percentage Data = RDD Tool Ground Surface Data.csv
 - Building Count Data = BldgsinCensusTract.csv
 - Census Tract/Zone Percentage Data = TRACT_AREAS.CSV
 - Building Square Footage Data = SqFtofBldgsinCensusTract.csv
 - Zone Area Data = Plumearea.csv
- d. Import each of those five files by clicking on the respective **Select File...** button at the bottom right of the Home window. A **Select File** dialogue box will appear. Navigate to the location of the data file and select the data file to import. Then click Open. The directory path and filename will appear on the Home window.
- e. Once the five geographic data files have been selected, click the **Open Scenario** button or the **Save Scenario** button. If you choose to save a scenario, a Save File dialogue window opens where you can specify the location to export a copy of the Microsoft Excel data file.
- f. A status window will appear that will show the progress of the data import.

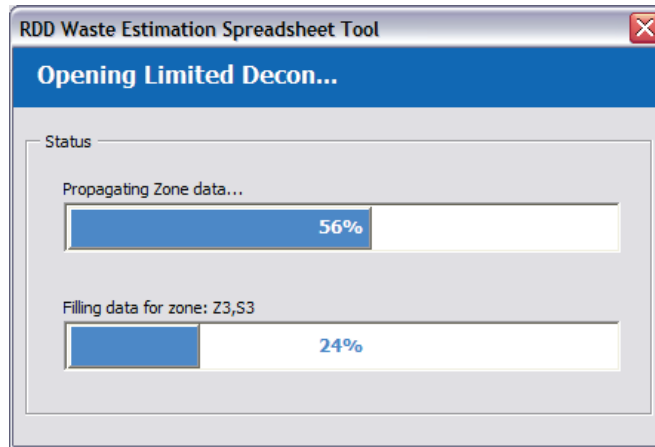


Figure 43. File Import Status Screen

Once the data import is complete, the geographic data are applied to the scenario. If you chose to save the scenario, the Microsoft Excel data file was exported to the directory that you specified in Step 7.e above.

If you chose to open a scenario, the Partitioning and Remaining Activity window appears.

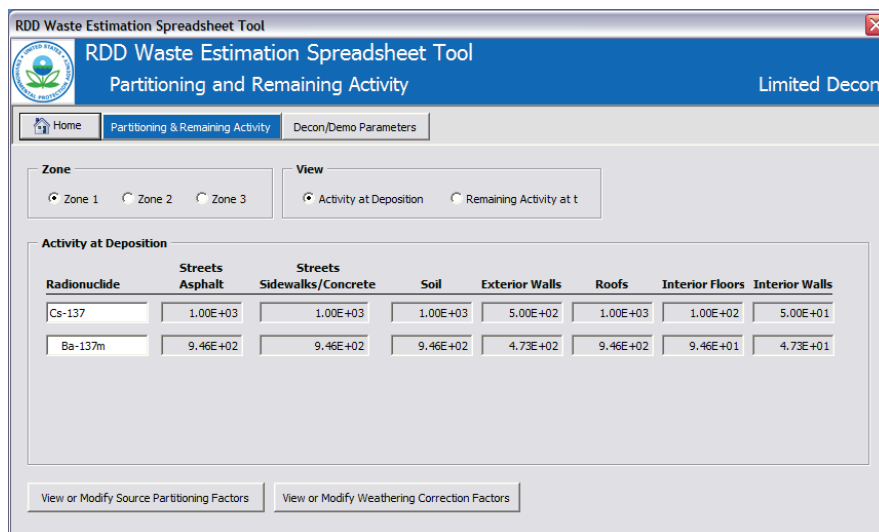


Figure 44. Partitioning and Remaining Activity Screen – Activity at Deposition

This window presents the results for the activity at deposition and the activity remaining at the number of days specified since initial deposition for all radionuclides for which an initial ground surface activity was specified on the Scenario Basic Information window. The deposition and

remaining activities are calculated for all three zones and for various structural and non-structural surface types.

RDD Waste Estimation Spreadsheet Tool
Partitioning and Remaining Activity
 Limited Decon

Home Partitioning & Remaining Activity Decon/Demo Parameters

Zone: ☒ Zone 1 ☐ Zone 2 ☐ Zone 3

View: ☐ Activity at Deposition ☒ Remaining Activity at t

Remaining Activity at t

Radionuclide	Streets Asphalt	Streets Sidewalks/Concrete	Soil	Exterior Walls	Roofs	Interior Floors	Interior Walls
Cs-137	8.60E+02	8.60E+02	9.80E+02	4.73E+02	9.90E+02	8.60E+01	4.73E+01
Ba-137m	8.14E+02	8.14E+02	9.27E+02	4.48E+02	9.37E+02	8.14E+01	4.48E+01

View or Modify Source Partitioning Factors View or Modify Weathering Correction Factors

Figure 45. Partitioning and Remaining Activity Screen – Remaining Activity at Time t

The activities are calculated based on the specified initial ground surface activity, source partitioning factors, and weathering correction factors. For more information on these factors and details on the activity calculations, please refer to Appendix D.

8. To view or modify the default source partitioning factors, click the **View or Modify Source Partitioning Factors** button.
9. To view or modify the weathering correction factors, click the **View or Modify Weathering Correction Factors** button.

RDD Waste Estimation Spreadsheet Tool

RDD Waste Estimation Spreadsheet Tool
Partitioning and Remaining Activity

Limited Decon

Home Partitioning & Remaining Activity Decon/Demo Parameters

Zone: ☒ Zone 1 ☐ Zone 2 ☐ Zone 3

View: ☒ Activity at Deposition ☐ Remaining Activity at t

Activity at Deposition

Radionuclide	Streets Asphalt	Streets Sidewalks/Concrete	Soil	Exterior Walls	Roofs	Interior Floors	Interior Walls
Cs-137	1.00E+03	1.00E+03	1.00E+03	5.00E+02	1.00E+03	1.00E+02	5.00E+01
Ba-137m	9.46E+02	9.46E+02	9.46E+02	4.73E+02	9.46E+02	9.46E+01	4.73E+01

View or Modify Source Partitioning Factors View or Modify Weathering Correction Factors

RDD Waste Estimation Spreadsheet Tool

Source Partitioning Factors

Close & Save Close & Cancel Restore Default Values Help

Factor

Streets

Soil

Exterior Walls

Roofs

Interior Floor

Interior Walls

RDD Waste Estimation Spreadsheet Tool

Weathering Correction Factors

Close & Save Close & Cancel Restore Default Values Help

	Mobile Fraction (a)	Shorter Half Life ln 2/b (yr)	Longer Half Life ln 2/c (yr)
Vertical Walls	<input type="text" value="0.2"/>	<input type="text" value="0.2"/>	<input type="text" value="20"/>
Roof With Tiles	<input type="text" value="0.5"/>	<input type="text" value="4"/>	<input type="text" value="50"/>
Paved Areas	<input type="text" value="0.5"/>	<input type="text" value="0.2"/>	<input type="text" value="2"/>
Lawns	<input type="text" value="0.46"/>	<input type="text" value="1.5"/>	<input type="text" value="50"/>

Figure 46. Source Partitioning Factors and Weathering Correction Factors Screens

10. After any changes have been made to the Source Partitioning Factors or Weathering Correction Factors, click the **Decon/Demo Parameters** button.

RDD Waste Estimation Spreadsheet Tool
 Partitioning and Remaining Activity
 Limited Decon

Home Partitioning & Remaining Activity **Decon/Demo Parameters**

Zone: ☒ Zone 1 ☐ Zone 2 ☐ Zone 3

View: ☒ Activity at Deposition ☐ Remaining Activity at t

Radionuclide	Streets Asphalt	Streets Sidewalks/Concrete	Soil	Exterior Walls	Roofs	Interior Floors	Interior Walls
Cs-137	1.00E+03	1.00E+03	1.00E+03	5.00E+02	1.00E+03	1.00E+02	5.00E+01
Ba-137m	9.46E+02	9.46E+02	9.46E+02	4.73E+02	9.46E+02	9.46E+01	4.73E+01

View or Modify Source Partitioning Factors View or Modify Weathering Correction Factors

Figure 47. Accessing Decon/Demo Parameters Screen from Partitioning and Remaining Activity Screen

The Decontamination/Demolition Parameters window appears.

RDD Waste Estimation Spreadsheet Tool
 Decontamination/Demolition Parameters
 Limited Decon

Home Partitioning & Remaining Activity **Decon/Demo Parameters** Waste Results Waste Graphs

Zone: ☒ Zone 1 ☐ Zone 2 ☐ Zone 3

View or Modify Surface Material Properties View or Modify Decontamination Technique Properties

Ground Surfaces Buildings

Percent of Total Ground Area Comprised of:

Asphalt %

Concrete %

Soils %

Select Media

☒ Streets - Asphalt

☐ Streets/Sidewalks - Concrete

☐ Soil

Enter Data

Figure 48. Decontamination/Demolition Parameters Screen

Decontamination and demolition parameters can be specified for each zone. Decontamination parameters apply to ground surfaces and building surfaces, and demolition parameters apply to buildings. You can easily navigate between data input screens for each of the three zones by

clicking the desired radio button at the top left side of the screen. The data input screens for each zone are exactly the same and are organized as follows:

A. Ground Surfaces.

- a. Percent of Total Ground Area Comprised of Asphalt, Concrete, and Soils.
- b. Decontamination Parameters for Ground Surface Media.
 - i. Streets – Asphalt.
 - ii. Streets/Sidewalks – Concrete.
 - iii. Soil.

B. Buildings

- a. Percentage of Buildings to Decontaminate.
- b. Percentage of Buildings to Demolish.
- c. Decontamination Parameters for Building Surfaces.
 - i. Exterior Walls.
 - ii. Roofs.
 - iii. Interior Floors.
 - iv. Interior Walls.

Certain parameters are global and apply to all zones. These parameters include:

- Surface material densities;
- Decontamination technique parameters;
- Building parameters; and
- Dust suppression technology parameters.

11. You can view or modify parameters for each of the above four categories by selecting the appropriate button on the Decontamination/Demolition Parameters window. The **View or Modify Building Parameters** and **View or Modify Dust Suppression Technology Parameters** buttons are available only when entering data for buildings.

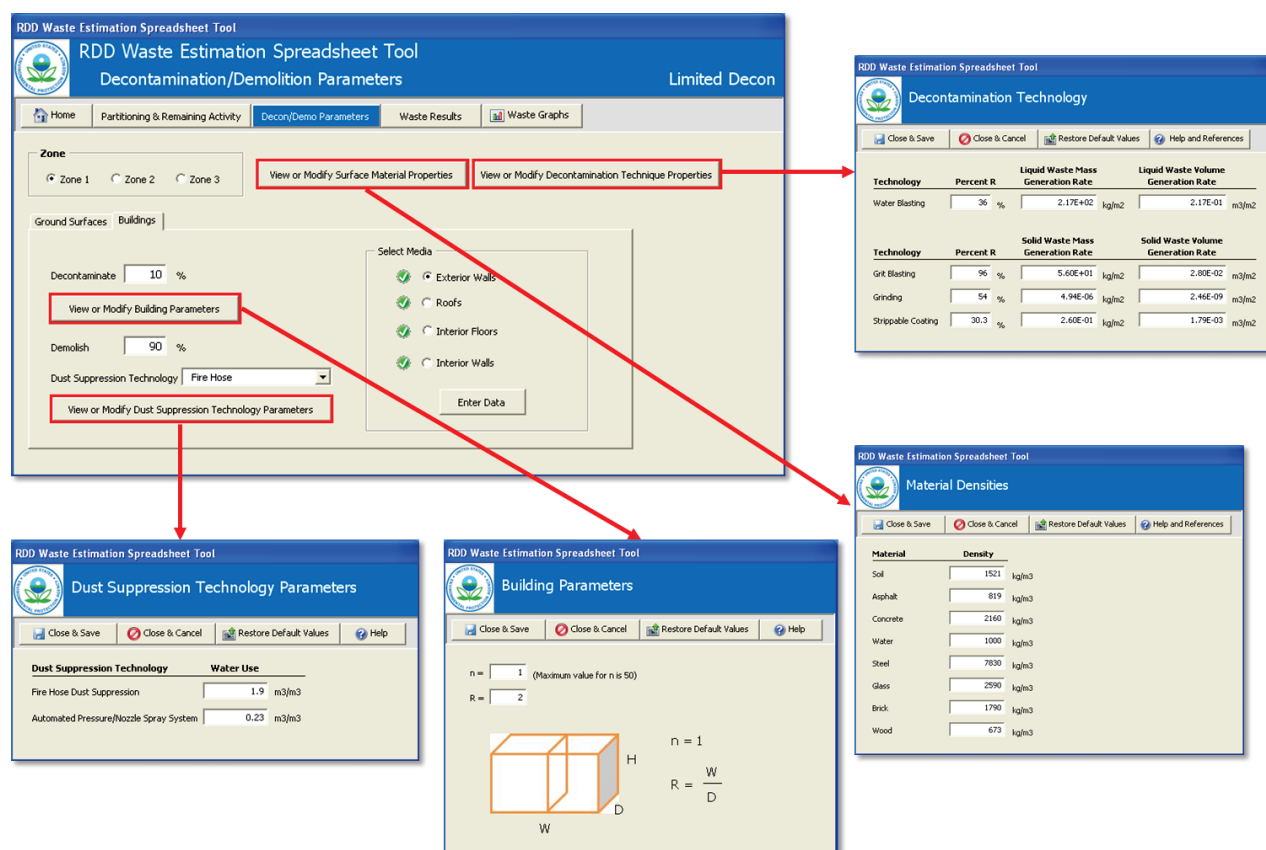


Figure 49. Accessing Default Parameter Screens

12. Once all of the parameters have been entered or modified, click **Waste Results**.

Figure 50. Accessing Waste Results from Decontamination/Demolition Parameters Screen

Waste results are presented in three formats: summary, demolition detail, and decontamination detail. Users can choose to view the results in various mass, volume, and activity units.

	Mass	Volume
Decontamination Waste	4.87E+06	1.04E+09
Solid Waste	1.61E+06	2.60E+08
Liquid Waste	3.27E+06	7.82E+08
Demolition Waste	1.32E+06	2.26E+08
Solid Waste	7.47E+05	8.85E+07
Liquid Waste	5.73E+05	1.37E+08
Total	6.19E+06	1.27E+09

Figure 51. Waste Results Screen

Waste results can be graphically represented by clicking the **Waste Graphs** button.

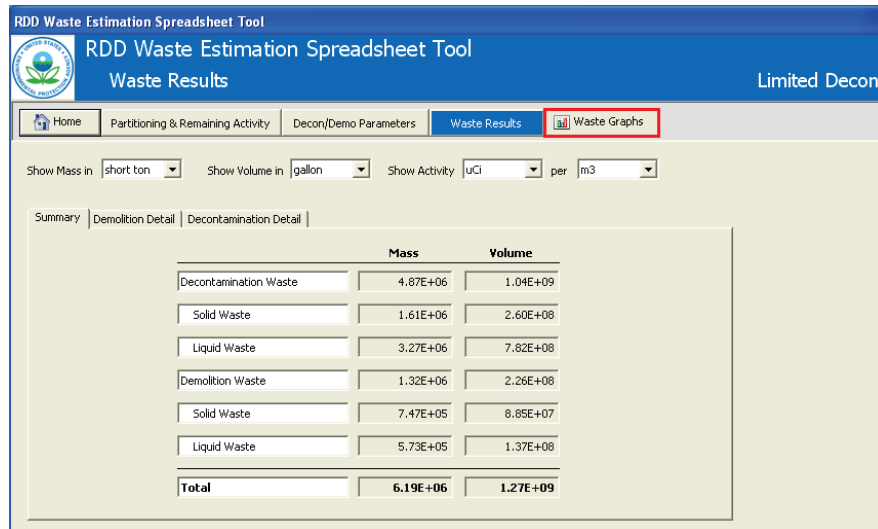


Figure 52. Accessing Waste Graphs from Waste Results Screen

Waste results are graphed based on four outputs: solid waste volume percentage, liquid waste volume percentage, estimated solid waste activity, and estimated aqueous waste activity.

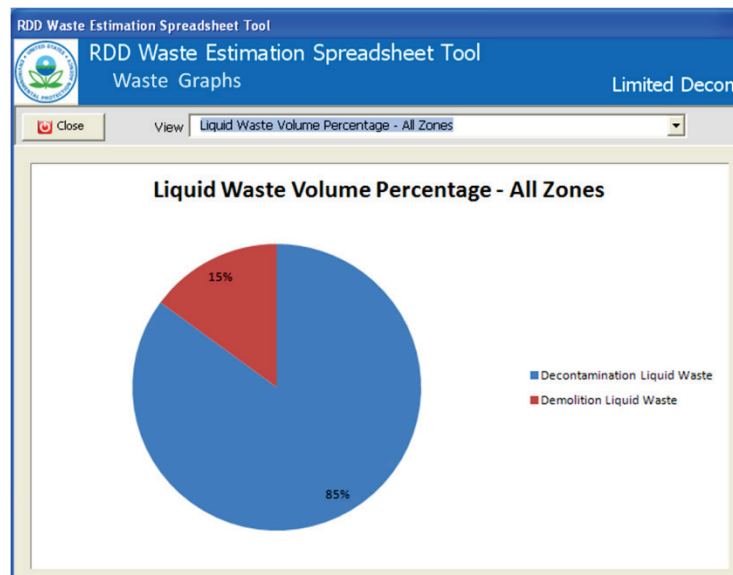


Figure 53. Waste Graphs Screen

13. To return to the tool home screen, click **Close** to return to the Waste Results window and click **Home**.
14. To export the graphs/spreadsheet for further analysis, click the **Save Scenario** button.

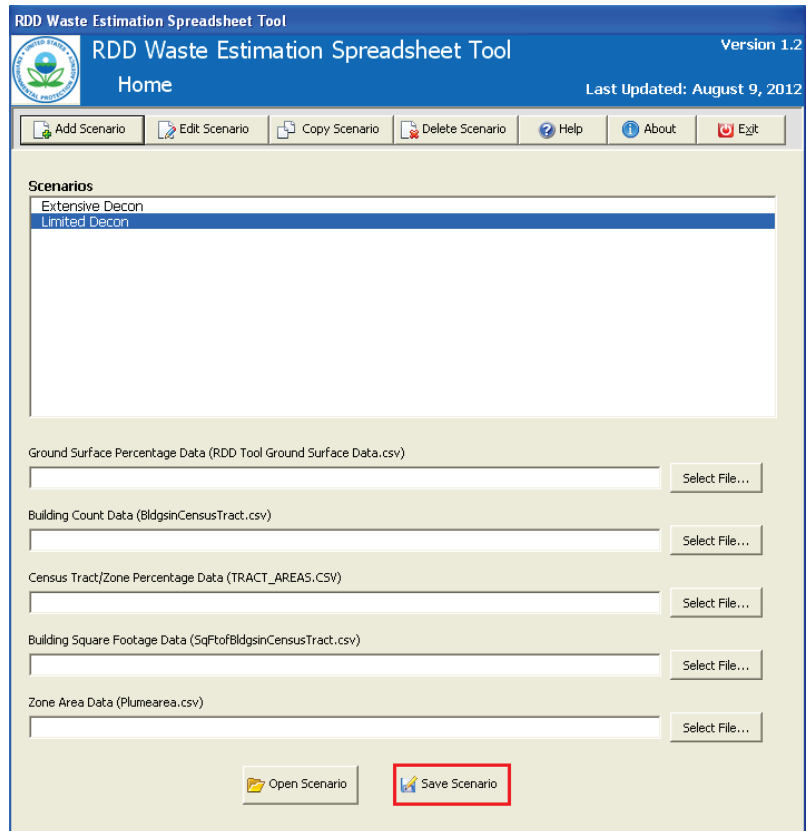


Figure 54. Save Scenario Option

5.0 Results – Liberty RadEx Example

In the event of an RDD incident, several options for decontamination of building and urban materials exist, including strippable coatings, chemical decontamination technologies, washing and cleaning, and various abrasive techniques such as scabbling. Each of these techniques removes the contaminated material and potentially some of the underlying substrate, producing varying amounts of waste in solid and/or liquid form. There is a complex relationship between decontamination method selection, waste generation rates, as well as technical, regulatory, and political considerations that drive the selection of the remediation strategy that results in the most cost-effective and rapid return to normalcy. The decision-making process for the overall remediation effort will need to consider several issues, including human health risk, effectiveness of the decontamination technology, cost of application of the decontamination technology, rate at which materials can be decontaminated using that technology, and the quantity of waste (and level of contamination) produced by that technology and associated disposal costs. Some decontamination parameters may be defined by practical limits that occur during operational activities (e.g., minimum amount of soil that could be removed is six inches due to the degree of control operators have over the typical heavy equipment used for soil excavation).

Based on several decontamination technologies that EPA has identified that are likely to be used (the tool currently allows a user to select from strippable coatings, abrasive removal, washing, a “no decontamination” option, as well as a user-defined decontamination technology option) for various surface types, decontamination waste quantities and characteristics were estimated using a combination of default and user-adjustable parameters in the spreadsheet tool [21]. The estimates include:

- Contaminated material (e.g., the layer of radioactive material that must be removed from structures, roads, soil, etc);
- Residues from the decontamination technologies (e.g., removed strippable coatings); and
- Wastewater and sludges from onsite decontamination efforts.

Based on the Liberty RadEx scenario, a number of “best guess” assumptions were made for a hypothetical mitigation strategy for three affected geographical zones shown previously in Figure 3, including the fraction of buildings to be demolished versus the fraction to be decontaminated, as well as a potential mix of decontamination technologies that might be deployed. This process is demonstrated below in Table 2. The decontamination and demolition options selected in no way reflect EPA policy or even likely strategies that may be used in a real RDD incident.

Table 2. Media segregation parameters used in the Liberty RadEx Scenario

Media	Zone 1: 90% demolition, 10% decontamination	Zone 2: 10% demolition, 90% decontamination	Zone 3 10% demolition, 90% decontamination
Asphalt	1” removal	1” removal – 70% Wash – 30%	1” removal – 70% Wash – 30%
Concrete	1” removal	1” removal – 70% Wash – 30%	1” removal – 70% Wash – 30%
Soil	6” removal	6” removal	6” removal
External Walls	1 mm removal	1 mm removal – 20% Wash – 80%	Wash
Roofs	1 mm removal	1 mm removal – 20% Wash – 80%	1 mm removal – 20% Wash – 80%
Interior Walls	1 mm removal	1 mm removal – 20% Wash – 30% Strippable Coating – 50%	1 mm removal – 20% Wash – 30% Strippable Coating – 50%

Floors	1" removal	1" removal	1" removal – 50% Wash – 50%
--------	------------	------------	--------------------------------

Based on the assumptions and analyses described above and in Section 2, the waste estimation spreadsheet produces an estimate of both waste quantity and activity. The results of the estimated waste quantities from this example scenario are shown in Table 3, and estimates of activity are shown in Table 4. Estimations of certain quantities (e.g., liquid wastes) make no assumptions as to the availability of resources (e.g., wash water) necessary to produce those quantities of wastes. In fact, one of the useful outputs of the tool is a gross indication of the theoretical viability of certain strategies (e.g., where water supplies are limited, using washing as a decontamination option may not be possible).

Table 3 demonstrates the amount of waste generated by demolition and decontamination measures. Note the total waste produced (approximately 1.3 million metric tons) and the amount of liquid waste generated as a result (approximately 41 billion liters).

Table 3. Example Waste Quantity Estimation from Liberty RadEx Scenario

	Zone 1	Zone 2	Zone 3	Total	Units
<i>Solid Waste</i>					
Demolition	66,883	82,548	142,110	291,540	metric tons
Decontamination	22,060	308,651	681,265	1,011,976	metric tons
Total	88,943	391,199	823,375	1,303,516	metric tons
<i>Liquid Waste</i>					
Demolition	52,948,845	65,350,416	112,503,382	230,802,643	liters
Decontamination	-	16,425,394,718	24,797,444,633	41,222,839,351	liters
Total	52,948,845	16,490,745,134	24,909,948,015	41,453,641,994	liters

Table 4 depicts the amount of waste radioactivity by media type. Overall, activity is minimal, demonstrating the possible use of LLRW or MSW depositories.

Table 4 Example Waste Activity Estimation from Liberty RadEx Scenario (μCi/m3)

Media	Zone 1	Zone 2	Zone 3
<i>Demolition</i>			
All Debris	4.62E+01	1.53E+01	6.63E+00
Liquid Waste	5.62E+03	1.87E+03	8.10E+02
<i>Decontamination</i>			
Asphalt	3.82E+04	9.18E+03	4.28E+03
Concrete	3.82E+04	9.18E+03	4.28E+03
Soils	6.56E+03	1.57E+03	7.34E+02
Exterior Walls - Porous	4.98E+05	1.19E+05	
Exterior Walls - Nonporous	4.91E+05	1.18E+05	
Roofs - Porous	9.98E+05	2.40E+05	1.12E+05
Roofs - Nonporous	9.98E+05	2.40E+05	1.12E+05
Interior Walls - Porous	4.98E+04	1.19E+04	5.58E+03
Interior Walls - Nonporous	4.91E+04	1.18E+04	5.50E+03
Interior Floors	3.82E+03	9.18E+02	4.28E+02
Liquid Waste		3.87E+01	1.45E+01
Coating Waste		4.41E+03	2.06E+03

6.0 Conclusions

The EPA has developed a GIS-based tool to estimate the quantity, characteristics, and activities of waste and debris resulting from an RDD or other radiological release event. The tool uses a combination of the Hazus-MH software, Microsoft Access, and a suite of internally developed tools to produce the waste inventories. Adjustable parameters allow the user to estimate the impacts on the waste streams of different demolition and decontamination strategies. Characteristics of waste and wastewater generated from the incident or subsequent cleanup activities will influence the cleanup costs and timelines. Federal responders and decision makers using this tool may be better able to implement an integrated response by effective analysis of many competing considerations, resulting in optimal decision making capabilities. Use of this tool may be a useful task to include with cities' planning activities to accompany the background radiation surveys that are being performed.

6.1 Looking Forward

Multiple avenues for future enhancements exist from aggregating the preliminary data to calibrating the estimates produced by the tool. In addition to being a waste estimation apparatus for radiological events, the underlying methodology remains the same relative to chemical and biological events as well, ultimately enabling the WEST to function as a CBRN waste estimation tool.

In light of recent events in Japan, the application of the WEST to incidents outside the United States is pragmatically evident. The tool utilizes infrastructure databases that are specifically attuned to the United States, so international compatibility is currently not possible.

However, efforts are being made to resolve this issue. Additional future enhancements to the tool include:

- Evaluation of available decontamination options per scenario.
- Costs and time associated with each decontamination method.
- Transportation cost, logistics, and time according to destination.
- Ability to update the image analysis pattern recognition algorithm for improved accuracy.
- Customizable surface detection for increased classification capacity.
- Automated building stock aggregation using remote sensing resources.
- Topographic outputs for geospatial interpretation.

7.0 References

1. Medalia, J.E., *Dirty Bombs: Background in Brief*, in *CRS Report for Congress*, R41891/2011, Library of Congress. Congressional Research Service
2. Andersson, K.G., *Airborne Radioactive Contamination in Inhabited Areas*. 2009: Elsevier Science.
3. National Security Staff Interagency Policy Coordination Subcommittee, *Planning Guidance for Response to a Nuclear Detonation*, 2010.
4. Yu, C., et al., *Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident*, 2009.
5. FEMA. *The Federal Emergency Management Agency's (FEMA's) Methodology for Estimating Potential Losses from Disasters*. 2009 [cited September 28], 2009; Available from: <http://www.fema.gov/protecting-our-communities/hazus>.
6. Government Accountability Office, *Combating Nuclear Terrorism: Preliminary Observations on Preparedness to Recover from Possible Attacks Using Radiological or Nuclear Materials*, 2009: Washington, DC.
7. U.S. Department of Homeland Security. *National Preparedness Guidelines*. 2007 [cited 2009 October 27]; Available from: http://www.dhs.gov/xlibrary/assets/National_Preparedness_Guidelines.pdf.
8. U.S. Department of Homeland Security. *National Response Framework*. 2008 [cited 2009 October 27]; Available from: <http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf>.

9. Demmer, R.L., *Large Scale, Urban Decontamination; Developments, Historical Examples and Lessons Learned*, in *Proceedings of the WM07 Conference* 2007: Tucson, AZ.
10. U.S. EPA. *Liberty RadEx*. 2010 May 26, 2011]; Available from: <http://www.epa.gov/libertyradex/>.
11. Lemieux, P., et al. *A First-Order Estimate of Debris and Waste Resulting from a Hypothetical Radiological Dispersal Device Incident*. in *Proceedings of the WM2010 Conference*. 2010. Phoenix, AZ.
12. Yuan, H., C. Van Der wile, and S. Khorram, *An Automated Artificial Neural Network System for Land Use/Land Cover Classification from Landsat TM Imagery*. *Remote Sensing*, 2009. **1**(3): p. 243-265.
13. Jordan, M.I. and C.M. Bishop, *Neural Networks*. *ACM Computing Surveys*, 1996. **28**(1): p. 73-75.
14. Mas, J.F. and J.J. Flores, *The Application of Artificial Neural Networks to the Analysis of Remotely Sensed Data*. *Int. J. Remote Sens.*, 2008. **29**(3): p. 617-663.
15. Miller, D.M., E.J. Kaminsky, and S. Rana, *Neural Network Classification of Remote-Sensing Data*. *Comput. Geosci.*, 1995. **21**(3): p. 377-386.
16. Yang, C.-C., et al., *Application of Artificial Neural Networks in Image Recognition and Classification of Crop and Weeds*. *Canadian Agricultural Engineering*, 2000. **42**(3): p. 147-152.
17. Aleksander, I. and H. Morton *An Introduction to Neural Computing*. 1995: International Thomson Computer Press. 284.

18. Stathakis, D. and A. Vasilakos, *Satellite Image Classification Using Granular Neural Networks*,. International Journal of Remote Sensing, 2006. **27**(18).
19. Greenspan, H. and R.M. Goodman, *Remote Sensing Image Analysis via a Texture Classification Neural Network*, in *Advances in Neural Information Processing Systems 5, [NIPS Conference]1993*, Morgan Kaufmann Publishers Inc. p. 425-432.
20. Hill, A., *Using the Hazard Prediction and Assessment Capability (HPAC) Hazard Assessment Program for Radiological Scenarios Relevant to the Australian Defence Force*, 2003, DSTO Platforms Sciences Laboratory: Victoria.
21. Drake, J., R. James, and R. Demmer. *Performance Evaluation of Decontamination Technologies for Dirty Bomb Cleanup*. in *Proceedings of the WM 2010 Conference*. 2010. Phoenix, AZ.

SCIENCE



PRESORTED STANDARD
POSTAGE & FEES PAID
EPA
PERMIT NO. G-35

Office of Research and Development (8101R)
Washington, DC 20460

Official Business
Penalty for Private Use
\$300