EPA's Suite of Tools for Managing Waste Following a Large-Scale Incident

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ABSTRACT

Large-scale disasters have the potential to generate a significant amount of waste. For example, Hurricane Katrina and the Joplin Missouri tornado resulted in 100 million and 1.5 million cubic yards of waste respectfully. Man-made chemical, biological, radiological or nuclear (CBRN) incidents either by way of terrorism, war, or accidents have the potential to generate as much or more hazardous waste.

Recovery is profoundly impacted by waste management issues. The quantification, segregation, transportation, and storage of waste can be an arduous and costly undertaking. Furthermore, these processes are intricately linked with decisions made throughout the recovery timeline. Therefore, the remediation, including waste management, must be holistically considered. Understanding these complex interactions can be facilitated by using models and tools that adhere to the "system-of-systems" approach. To better understand and predict waste management issues the Environmental Protection Agency's (EPA's) Homeland Security Research Program (HSRP) is developing a suite of tools and resources for planning and recovery purposes. The waste management suite consists of four tools:

- Incident Waste Decision Support Tool (I-WASTE): characterizes and produces order-of-magnitude estimates for the weight and volume of waste materials that may require management and/or disposal, as well as identifies and locates potential treatment and disposal facilities.
- Waste Estimation Support Tool (WEST): estimates waste generated from remediation and cleanup activities following a wide-area radiological or biological incident;
- Waste Storage and Staging Tool: identifies and prioritizes potential locations for staging and storing waste;
- Waste Logistics Tool: estimates optimal routes with consideration to cost, time, and logistical requirements (e.g., resource demand, transportation type, access limitations, etc.) associated with transporting large volumes of waste from disaster-stricken areas to intermediate waste staging/temporary storage/on-site processing sites to off-site waste management facilities; and

This paper will present EPA's waste management suite of tools, their purpose and application to large-scale incidents, and a case study demonstrating their use in a hypothetical scenario.

INTRODUCTION

Decontamination efforts following a large-scale radiological incident have the potential to generate a significant amount of waste and are resource intensive in terms of cost, time, and infrastructure [1]. For instance, it is estimated that radiological cleanup efforts following the Fukushima incident will generate up to 30 million cubic yards of radioactive waste, take over 30-40 years for disposal, and cost $600 billion to fully remediate [2,3]. These estimates are largely a result of decontamination and waste management strategies, policies, timelines, available resources, and public sentiment. Large-scale recovery efforts, such as Fukushima, require significant planning efforts to fully understand the overall waste management implications and associated processes with regards to other aspects of cleanup [4]. Tools, models, and supporting datasets are used to guide decision makers in selecting the most optimal cleanup approach with reference to cost, time, and efficiency.

EPA HSRP is developing a suite of tools to (1) estimate the amount, characteristics, and activity of waste as a function of decontamination; (2) identify potential waste staging/storage sites; and (3) estimate and optimize the resource and logistical demands associated with transporting large volumes of waste. These tools can be used in combination to make predictions and to evaluate decisions regarding large-scale cleanup efforts with an emphasis on developing optimized decontamination strategies so that decision makers can effectively prioritize and select options for both planning purposes and during an actual incident.

The objectives of this paper are threefold: 1) provide an overview of EPA's suite of waste management tools; 2) introduce EPA's systems approach to waste management; and 3) apply EPA's waste management tools and systems thinking to a hypothetical radiological scenario to demonstrate the complexity and importance of waste management as a significant driver of recovery costs and timelines.

EPA WASTE MANAGEMENT TOOLS

Waste management is an integral part of the planning and recovery process. The decisions made early on can have significant impacts on the waste streams and can have effects lasting decades or longer; therefore, it is critical to understand the impact of these decisions (e.g., segregation strategies, decontamination methods, sampling methods, waste classification, etc.) prior to implementation [4]. To aid in this process, EPA has developed a series of novel tools that assist users in the estimation and management of waste following a large-scale chemical, biological, radiological or nuclear (CBRN) incident. Although the tools described in this section were designed and implemented separately, they can be used in a systematic way to gain insight and ultimately guide users through the entire waste management process.

I-WASTE

To facilitate the proper management of incident-derived waste, EPA developed the Incident Waste Decision Support Tool (I-WASTE). I-WASTE was developed by the U.S. EPA's HSRP in partnership with EPA program and regional offices, other U.S. government agencies, industry, and state and local emergency response programs.

I-WASTE is an online web-based suite of tools that provides quick and easy access to information needed for making decisions associated with handling, transport regulations, treatment, and disposal of waste and disaster debris. I-WASTE includes calculators to rapidly generate rough estimates of the quantities and characteristics of waste that would be produced by incidents of national significance and subsequent cleanup activities in various building types and outdoor areas. It provides location-specific information to identify specific treatment and disposal facilities and key contacts for managing waste and debris. The key contacts include both local and state regulatory decision makers but also contacts for facilities, since the waste management facilities are key participants in the waste management decision making process during an incident. I-WASTE provides references to technical information addressing waste management issues, regulations, and other information that is important for the protection of public health, first responders, and the environment.

WEST

The Waste Estimation Support Tool (WEST) is a novel application based on the Federal Emergency Management Agency's (FEMA) Hazus-MH software. WEST enables users, in a geographically specific manner, to estimate the characteristics, amount, and residual contamination of waste generated from remediation and cleanup activities after a radiological or biological incident. These waste estimates are generated as a function of extensive selectable decontamination techniques, are specific to a geographic location, and are tied to the affected infrastructure in that geographic location. The waste estimates account for the infrastructure's materials of construction, indoor/outdoor footprint(s), and the purpose for which the infrastructure is used (i.e., occupancy classification).

Waste Storage and Staging Tool

The Waste Storage and Staging Tool is a GIS-based decision support tool for identifying and prioritizing potential waste staging and storage sites for CBRN contamination incidents. Using a site suitability analysis, the tool, in combination with the Waste Logistics Tool, considers implicating factors such as natural or manmade environments to avoid, and topographic features and transportation-related infrastructure which have favorable characteristics for storage and staging sites. Users may input the estimated waste volume (if known) to determine the total required candidate site land area. If waste volumes are not known, then the tool can analyze the various siting criteria for a specified geographic area to identify candidate sites and their total available land surface areas. These criteria can be ranked according to degree of importance and automatically evaluated according to "best fit."

Waste Logistics Tool

Managing and transporting large volumes of debris and waste following a CBRN incident is a challenging process. EPA's HSRP is currently developing a GIS-based tool to support estimating resource demands and logistics planning associated with transporting large volumes of waste. The tool uses GIS to apply spatial information and analysis technologies to locate and prioritize optimal transportation routes to waste staging, storage and/or waste management and disposal sites.

Waste transportation estimates consider the amount of waste to be transported, points of origin (i.e., generation points, staging locations), and potential disposal sites. The results are visually represented on a map as potential routes along a street network. Route attributes contain a route name, length, cost, travel time estimate, and number of stops. Potential routes can be evaluated according to resource demand, proximity to sensitive locations, non-interference with routes related to other aspects of the response/recovery operations, and quickest or shortest path. Both the Storage and Staging Tool and the Waste Logistics Tool provide decision makers with a defendable and agile approach for waste storage and staging site selection.

SYSTEMS APPROACH TO WASTE MANAGEMENT

The following sections describe efforts that HSRP is undertaking to better connect and convey its decision support tools. Currently, these tools operate on a point-to-point integration where information is communicated by the end-user or directly imported from a prior model run or instance. Although this approach allows decisions and data to be systematically considered, it is inefficient from a systems integration and information sharing perspective. Tools that are centrally connected (i.e., through a hub-and-spoke or cloud-based approach) present additional opportunities for solving large-scale problems by modeling the interactions of primary drivers (e.g., resource availability, logistics, storage limitations, etc.). Future iterations of waste management tools will fully incorporate the "systems approach", to include the system of systems concept and information sharing framework and platform.

System of Systems

For wide area incidents, response and recovery efforts may begin without collecting or considering essential information. Decisions related to the decontamination, waste management, and disposal strategy will affect the cost, duration, and effectiveness of response. The process of understanding how these response activities influence one another and contribute to the overall solution is referred to as a systems approach. The systems approach recognizes that each response activity is coupled with another, where decisions made for one response action impact decisions and options that exist for another. For example, this dynamic is observed where the amount of waste to be managed is profoundly impacted by the decontamination approach that is selected, or when waste management constraints may drive decontamination decisions. While EPA waste tools encourage a phased and cohesive approach (i.e., decontamination, waste estimation, and disposal), the tools compile and display results in a way that allows users to see the "big picture" and how minute changes in these approaches can greatly impact each individual response activity. This "big picture" approach facilitates planning through scenario-based analyses that can increase preparedness, identify problematic scenarios, and ultimately identify effective solutions in advance of an incident.

Despite best efforts to include all relevant considerations into these tools, there is no way to anticipate all potential situations that might arise during the progression of an incident's timeline. Social factors such as public opinion on selection of remediation approaches or staging site locations, are not easily incorporated into tools that are largely based on technical criteria. In addition, decision makers are not interested in having a computer program tell them what to do. Therefore, as a general approach, all the EPA HSRP tools present and prioritize options, along with advantages and disadvantages, to support decision makers in making informed decisions grounded by science that take into account unforeseen factors.

Information Sharing Framework and Platform

Improving the way in which information is shared amongst decision makers, responders, and stakeholders, as well as models and decision support systems is critical to the success of any response or recovery operation. Building this capability would allow for the immediate distribution of up-to-date research amongst stakeholders to enable more efficient and better-informed decision making. Such a capability would also greatly enhance communicating the latest response technology performance metrics and therefore better estimate the resources necessary to characterize and cleanup a contaminated area.

In many cases, legacy tools developed by HSRP (and elsewhere within the federal government) tend to rely on static data that are stored within each individual tool and are therefore susceptible to becoming out-of-date as improved data become available. To confront this issue, HSRP is developing the Remediation Data Repository (RADAR), a searchable database for accessing multi-hazard research and operational data conducted by the EPA and other federal and international partners. The tool acts as a central repository (i.e., database) that stores data derived from HSRP literature reviews, research, and tools. RADAR will allow EPA's homeland security specific research and operational guidance to be shared among partners and a broad array of users by way of an online platform – an offering that currently does not exist. RADAR is being designed to provide users access to data both through a user-friendly searchable interface and via an application programming interface (API) to facilitate consumption of data through web services by other HSRP tools. This capability will greatly reduce the cost of updating models and tools and ensure end-users are referencing the most up-to-date information, all the while significantly reducing development and maintenance costs.

CASE STUDY

Scenario Description and Assumptions

The hypothetical scenario assumed an incident at the Shearon Harris Nuclear Power Plant located in New Hill, NC. Cesium 137 (Cs-137) was selected as the principal source of contamination. While it is acknowledged a myriad of radioisotopes would be released if such an incident took place, Cs-137 was chosen due to its half-life and relevancy to other radiological incidents (e.g., nuclear power plants, radiological dispersal devices (RDDs) and nuclear weapons).

The hypothetical contamination extent and defined levels of surface contamination are shown in Figure 1. The following contamination levels were assumed: zone 1 = 2000 microcuries per square yard (µCi/yd^2), zone 2 = 200 µCi/yd^2, and zone 3 = 20 µCi/yd^2 as illustrated by different colors (e.g., zone 1 appears as red, zone 2 as orange, and zone 3 as yellow). Zones 1, 2 and 3 cover an area of 2, 16, and 45 square miles respectively. The hypothetical plume shown in Figure 1 was generated by considering values from previous national level exercise and was used to define the extent and contamination level of the contamination.

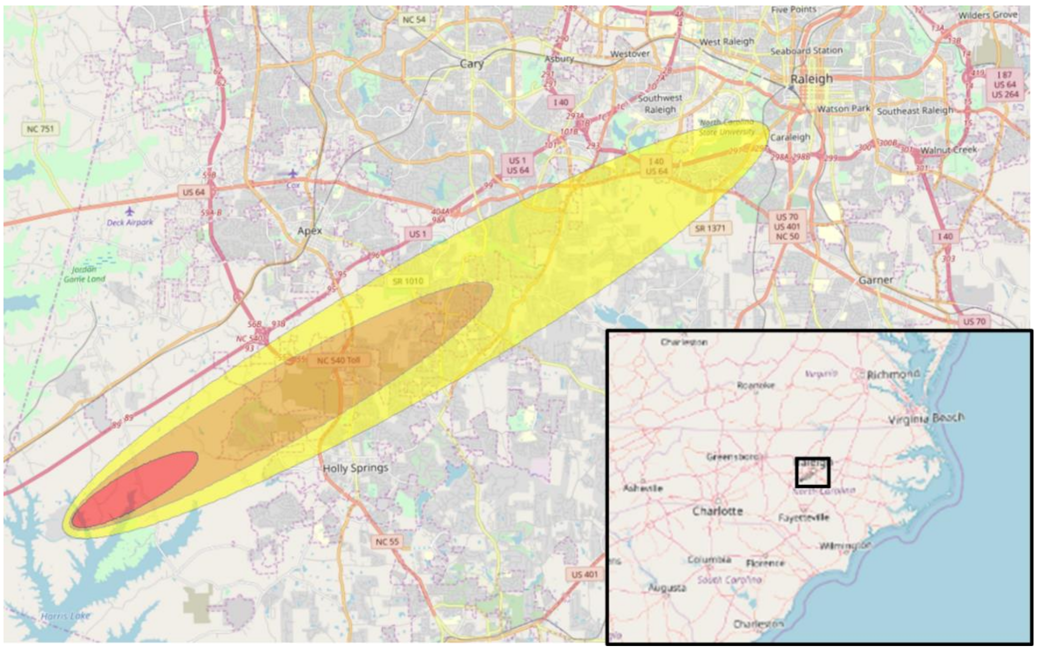

Figure 1. Shearon Harris Hypothetical Scenario Deposition Map

Decontamination & Waste Results

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 the quantity and rate of waste generation as a result of decontamination activities. WEST was used to estimate the amount of waste generated based on two separate decontamination approaches: 1) Decontamination Strategy 1: primarily dry decontamination technologies; and 2) Decontamination Strategy 2: combination of wet and dry decontamination technologies. The distribution of decontamination technologies by zone, building, and ground surface for Decontamination Strategy 1 and 2 can be found in Tables 1 and 2 respectively.

Table 1. Decontamination Strategy 1: Dry

Decon Technology	Zone	Percentage of Surface Decontaminated Using Decon Technology (%)	
		Buildings	Ground Surfaces

		Exterior Walls, Excluding Roofs	Interior Floors	Interior Walls, Including Ceilings	Roofs	Soil	Streets - Asphalt	Streets/ Sidewalks - Concrete
Low Volume Foam/Rinse	1	50	100					
Surface Brushing	1	50						
Polymer/Gel	1			100				
Brushing & High-Pressure Washing	1							
Grinding	1				100			25
Excavation/Physical Removal - Manual Removal	1					100		
Excavation/Physical Removal - Machine Assisted	1						75	
Road Sweeper	1						25	
Abrasion	1							75
Low Volume Foam/Rinse	2	25	100					
Surface Brushing	2	75						
Polymer/Gel	2			50				
Grinding	2				50			50
Water Blasting	2				50			
Excavation/Physical Removal - Manual Removal	2					25		
Excavation/Physical Removal - Machine Assisted	2					25	10	
Soil Inversion	2					50		
Road Sweeper	2						90	
Abrasion	2							50
Surface Brushing	3	100						
Low Volume Foam/Rinse	3		100					
Polymer/Gel	3			25				
Grinding	3				50			90
Excavation/Physical Removal - Manual Removal	3					25		
Soil Inversion	3					75		
Road Sweeper	3						100	
Abrasion	3							10

Table 2. Decontamination Strategy 2: Wet

Decon Technology	Zone	Percentage of Surface Decontaminated Using Decon Technology (%)						
		Buildings				Ground Surfaces		
		Exterior Walls, Excluding Roofs	Interior Floors	Interior Walls, Including Ceilings	Roofs	Soil	Streets - Asphalt	Streets/ Sidewalks - Concrete
Low Volume Foam/Rinse	1	50	100					
Water Blasting	1	50					25	25
Polymer/Gel	1			100				
Brushing & High-Pressure Washing	1				50			
Grinding	1				50			
Excavation/Physical Removal - Manual Removal	1					100		
Excavation/Physical Removal - Machine Assisted	1						75	
Abrasion	1							75
Low Volume Foam/Rinse	2	75	100					
Water Blasting	2	25			50		40	50
Polymer/Gel	2			50				
Brushing & High-Pressure Washing	2				50			
Excavation/Physical Removal - Manual Removal	2					25		
Excavation/Physical Removal - Machine Assisted	2					25	10	
Soil Inversion	2					50		
Road Sweeper	2						50	
Abrasion	2							50
Low Volume Foam/Rinse	3	100	100					
Polymer/Gel	3			25				
Brushing & High-Pressure Washing	3				50			
Excavation/Physical Removal - Manual Removal	3					25		
Soil Inversion	3					75		
Road Sweeper	3						50	

Water Blasting	3						50	90
Abrasion	3							10

The waste estimates for Decontamination Strategies 1 and 2 are shown in Tables 3 and 4. Decontamination Strategy 1 resulted in a total of 2.97 million tons of solid waste and 20.7 million gallons of aqueous waste. Whereas, Decontamination Strategy 2 resulted in a total of 2.97 million tons of solid waste and 533 million gallons of aqueous waste. Decontamination Strategy 2 generated significantly more aqueous waste than Decontamination Strategy 1. This contrast was a result of using decontamination technologies that required a significant amount of wash water to implement (e.g., dust suppression). Therefore, when solely considering waste amounts, Decontamination Strategy 1 would likely be the most logical choice (i.e., Decontamination Strategy 1 produced significantly less aqueous waste).

This estimate did not consider cost, time, or efficacy of decontamination. While, these criteria are critical in the selection of a decontamination strategy, WEST is currently limited to estimating waste amounts. It is recommended that all criteria be equally considered and evaluated by subject matter experts before deciding on a specific approach.

Table 3. Waste Results Decon Strategy 1

Zone Number	Solid Waste Mass (US Ton)	Liquid Waste Mass (US Ton)	Solid Waste Volume (yd3)	Liquid Waste Volume (gal)
1	2.69E+05	3.73E+02	2.15E+05	2.42E+06
2	1.25E+06	6.61E+04	9.79E+05	1.58E+07
3	1.45E+06	1.00E+04	1.13E+06	2.41E+06
Total	2.97E+06	7.65E+04	2.33E+06	2.07E+07

Table 4. Waste Results Decon Strategy 2

Zone Number	Solid Waste Mass (US Ton)	Liquid Waste Mass (US Ton)	Solid Waste Volume (yd3)	Liquid Waste Volume (gal)
1	2.69E+05	1.46E+05	2.15E+05	3.74E+07
2	1.25E+06	5.63E+05	9.79E+05	1.35E+08
3	1.45E+06	1.50E+06	1.13E+06	3.60E+08
Total	2.97E+06	2.21E+06	2.33E+06	5.33E+08

Staging Site Selection

The selection of short- or long-term staging and storage sites is typically not part of the pre-planning process. This might be an acceptable approach for some non-CBRN incidents. However, when considering CBRN agents, the fate and transport of contaminants can be a significant concern, especially when limiting the impact of contaminated areas, preventing re-contamination, and minimizing exposure to workers and inhabitants. Several criteria must be considered as part of the site selection process, such as proximity to people and infrastructure, environmental factors, and degree and extent of contamination.

EPA’s Waste Storage and Staging Tool was used to identify potential waste staging sites. Four criteria were considered as part of this study: 1) proximity to largest volume of waste by census tract; 2) sites with high and level elevation; 3) surface types that are ubiquitous to urban areas (i.e., presence of concrete and asphalt); and 4) hydrological features that might redistribute contaminants during precipitation or flood events. The current version of the tool uses an elimination process for determining optimal sites (i.e., locations representing less desired criteria are iteratively removed from the area of interest). The final product identifies locations that are most optimized for staging waste per the end-user’s defined criteria. The area for consideration or area of interest (AOI) is defined by the end-user. For this case study, the plume or contamination extent was used (i.e., waste will be temporarily stored within the contaminated area). Figure 5 shows the input layers and the resulting “Location-Allocation” analysis for each criterion. AOI layers that are labeled with the letter “A” represent the criterion that were evaluated, and AOI layers that are labeled with the letter “B” represent areas that are most optimal for staging waste based on the “Location-Allocation” analysis (colored in green).

The results of this analysis show that a total area of 0.25 square miles is available, from a total AOI of 63 square miles, for staging waste per the established waste criteria. When compared with the estimated volume of waste for both Decontamination Strategies 1 and 2 totaling 2.33 million cubic yards, the identified waste staging areas likely lack the necessary capacity for staging the predicted volume of waste. Therefore, a larger AOI, less restrictive site criteria, or a more effective decontamination strategy would need to be considered by either reducing the amount of waste generated or increasing the capacity of potential staging areas to meet the projected waste estimates.

It is important to consider that large-scale incidents may require more stringent waste staging criteria, in addition to public and political implications (e.g., eminent domain issues and state and local laws). These considerations would likely result in fewer options (i.e., less area) for staging waste. The criteria considered as part of this study were selected solely for illustrative purposes and do not represent EPA’s or the federal government’s approach to selecting potential staging sites. Alternatively, there may be government-owned land that might be able to be used for an incident-specific staging/storage/disposal site. I-WASTE includes a database of federally-owned facilities that might be potentially used for such purposes.

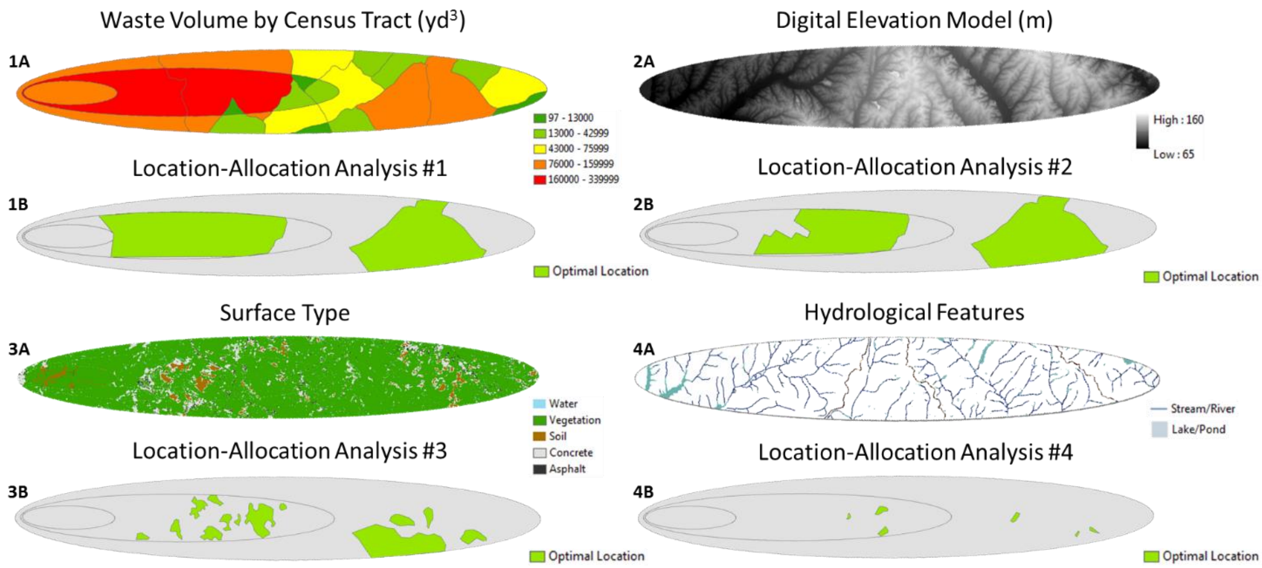

Figure 2. Location-Allocation Criteria

Logistics and Disposal

The logistics and disposal of waste are critical, albeit often underestimated elements of the recovery process. In most situations these elements can be the costliest part of recovery and therefore should be considered along with decontamination strategy and waste estimation efforts. For example, an efficacious decontamination strategy that generates minimal waste may still require extensive transportation and disposal efforts, which may require a greater emphasis on on-site waste minimization or storage options.

To determine potential disposal sites and resulting transportation routes, I-WASTE was used to query potential disposal sites that were licensed under the Resource Conservation and Recovery Act (RCRA) Subtitle C, as well as commercial and private radioactive waste disposal facilities. The search for RCRA facilities was limited to North Carolina, and high-level federal and commercial facilities were queried for the entire continental U.S. Table 5 shows the facilities that met these criteria. The search resulted in a total of 15 facilities, including: four (4) RCRA, six (6) commercial radioactive waste, and five (5) federal radioactive waste disposal facilities.

Several of the resulting facilities were more than 500 miles away from the point of origin. It was assumed this distance was not practical due to safety, cost, and regulation concerns. Therefore, a proximity analysis (a function built into the Waste Logistics Tool) was performed to determine which disposal facilities were within close proximity (i.e., driving duration and distance) to the designated waste staging sites. This method determines the most optimal "trucking" route, driving distance, and duration. Of the total of 15 facilities, two (2) RCRA, one (1) commercial, and one (1) federal high-level disposal facilities were found to have the least amount of travel time and distance from the designated waste staging sites. The selected RCRA and commercial and federal radioactive waste disposal facilities were on average 150 and 300 miles in distance, respectively. Municipal solid waste (MSW) facilities were not included due to the sheer number of results and the potential for outdated information. It was assumed that MSW landfills within a radius of 50 miles could meet the necessary disposal requirements. Table 5 shows disposal facilities sorted by trucking time. Figure 3 shows these locations on a map.

It is important to note that in most situations, disposal site selection cannot solely be based on safety, cost, and regulation concerns alone. Site capacity, acceptance, and political or public perception will also play a major role in site selection; however, these criteria were not considered as part of this study. Furthermore, this study did not consider input from state/locals, facility owners, permitting issues, etc.

Table 5. Potential Waste Disposal Sites[1]

Disposal Facility	Facility Type	Trucking Time (Minutes)	Trucking Distance (Miles)	Map ID
Veolia ES Technical Solutions	Resource Conservation and Recovery Act (RCRA)	51	42	16
Dart Acquisitions	Resource Conservation and Recovery Act (RCRA)	203	165	6
ECOFLO	Resource Conservation and Recovery Act (RCRA)	261	253	15
US DOE Savannah River	Federal Radioactive Waste Disposal Facilities	272	290	13
Detrex Corporation	Resource Conservation and Recovery Act (RCRA)	285	245	14
Chem-Nuclear Systems	Commercial Radioactive Waste Disposal Facilities	300	303	1
Oak Ridge	Federal Radioactive Waste Disposal Facilities	398	392	11
U.S. Ecology Texas LP	Commercial Radioactive Waste Disposal Facilities	1377	1415	4
Waste Control Specialists LLC	Commercial Radioactive Waste Disposal Facilities	1504	1596	9
U.S. ISO Pant	Federal Radioactive Waste Disposal Facilities	1561	1646	12
Energy Solutions	Commercial Radioactive Waste Disposal Facilities	1999	2156	2
Idaho National Laboratory	Federal Radioactive Waste Disposal Facilities	2075	2240	10
U.S. Ecology Idaho	Commercial Radioactive Waste Disposal Facilities	2250	2434	3
US Ecology Washington	Commercial Radioactive Waste Disposal Facilities	2531	2721	5
Hanford Site	Federal Radioactive Waste Disposal Facilities	2620	2745	0

[1] Note: I-WASTE facility data were last updated in December 2016.

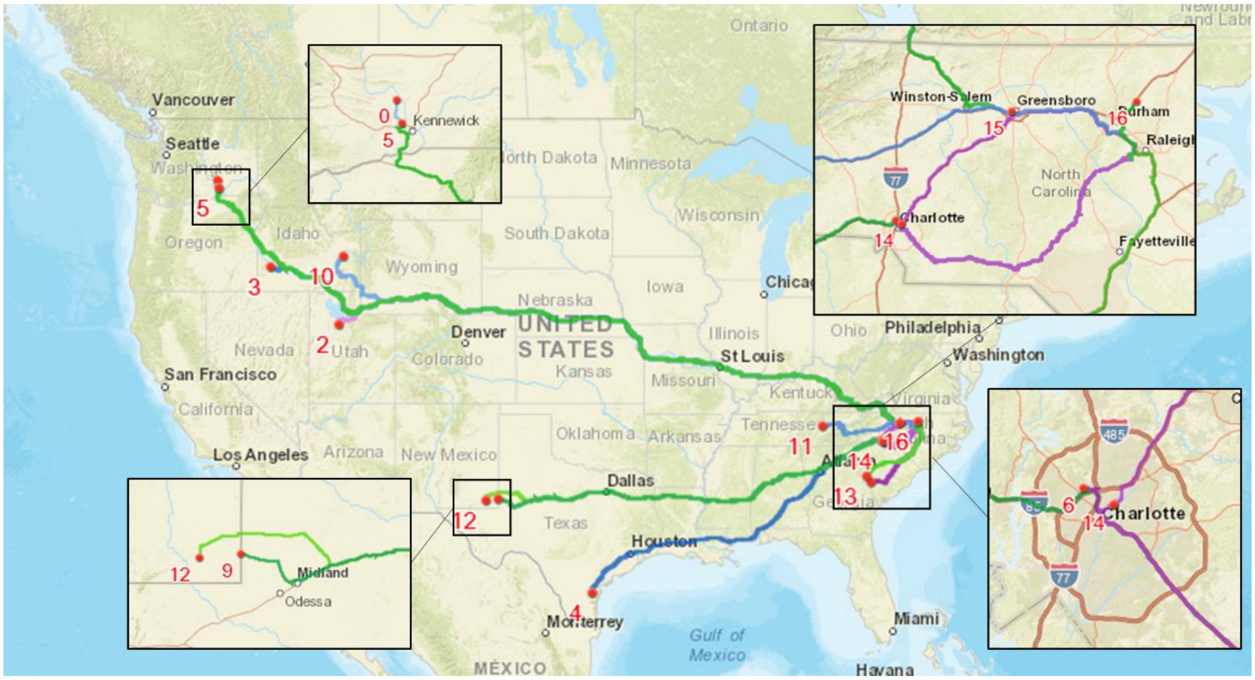

Figure 3. Map of Potential Low- and High-Level Waste Disposal Sites

For the purposes of this scenario, it was assumed that waste minimization efforts would allow approximately 60% of the resulting waste to be disposed of as MSW, 40% disposed of as low level low-level radioactive waste (LLRW). It is important to note that the characteristics and activity of waste can vary significantly and depend on many factors. The cost and efficacy of waste minimization technologies were not considered in this study but can significantly alter the waste streams (for better or worse).

The EPA Waste Logistics Tool was used to estimate the total cost and time necessary to transport and store waste according to decontamination strategy and disposal type. It was estimated that Decontamination Strategy 1 would necessitate an approximated cost of $75 million and a total of 261 days to complete (assuming the highest possible duration with resources distributed evenly). Decontamination Strategy 2 would cost significantly more at approximately $224 million and a total of 1,226 days to complete. The stark difference between Decontamination Strategies 1 and 2 is due to the amount of aqueous waste generated by the technologies used in Strategy 2. Table 6 shows disposal cost and duration per disposal type and decontamination strategy.

Table 6. Waste Transport and Logistics Results

Decon Strategy	C&D Landfills, MSW Landfills, and Large Landfills		Resource Conservation and Recovery Act (RCRA)		Federal Radioactive Waste Disposal Facility	
	Total Cost ($)	Total Time (days)	Total Cost ($)	Total Time (days)	Total Cost ($)	Total Time (days)
Decon Strategy 1 Solid Waste (US Tons)	28,102,602	234	18,046,539	261	22,875,142	174
Decon Strategy 1 Liquid Waste (gal)	NA	NA	4,543,424	43	906,423.57	11
Decon Strategy 2 Solid Waste (US Tons)	28,102,602	234	18,046,539	261	22,875,142	174
Decon Strategy 2 Liquid Waste (gal)	NA	NA	131,431,175	1226	23,332,435	263

DISCUSSION

Large-scale disasters have the potential to generate a significant amount of waste. Recovery from such disasters is largely driven by waste management issues and related decisions. These issues extend from decontamination and staging, transportation, and final disposal of waste, among others. Even minor anomalies in the planning or management of waste can result in significant impacts to cost, timeliness, and overall success of response and recovery as demonstrated in the contrast between Decontamination Strategies 1 and 2. To address these issues, EPA HSRP has been developing a series of waste management tools for systematically evaluating the waste management paradigm with the purpose of optimizing decisions with consideration to large-scale recovery efforts.

A successful decision support system is one that shares data and solutions across multiple platforms and is available through a single point of access; references a consolidated and living source; and informs (but does not instruct) the user through a phased, yet flexible approach that identifies problems that would otherwise be elusive if their interactions were modeled separately. EPA HSRP is working towards integrating this approach into its decision support tools.

A case study was conducted to demonstrate the importance and interdependencies of waste management issues with reference to the suite of tools and approach as previously described. The case study assumed a hypothetical incident at a nuclear power plant that impacted a semi-urban area with an area of 63 square miles. Two decontamination strategies were evaluated (i.e., dry vs. combination of wet and dry) along with their impacts on waste management process. The following bullets summarize the observations and gaps identified by this case study:

- This case study evaluated two separate decontamination approaches following a hypothetical nuclear power plant incident. Decontamination Strategy 1 (i.e., dry decontamination) resulted in considerably lower levels of aqueous waste when compared to Decontamination Strategy 2 (i.e., combination of wet and dry decontamination). The results of this comparison demonstrate the significant impacts that even minor deviations in decontamination strategy can have on the overall waste stream, and ultimately the entire response and recovery process.

- The evaluation and ultimate selection of short- and long-term waste staging areas should take into consideration a number of health, environmental, and regulatory factors. In fact, the criteria evaluated as part of this study represent a small, and probably selective sample of what would be considered in a real-world event. Even when working with limited criteria and a relatively large area of interest (as demonstrated in this case study), very few locations met the prescribed waste staging criteria. The findings of the staging site selection portion of this study are likely synonymous to real-world events: wide-ranging waste staging criteria would likely require an abundance of land to enact; otherwise, less stringent waste staging criteria or more extensive waste transportation efforts would be necessary. This highlights the importance of waste management pre-planning efforts which should take into consideration some of the potential limitations noted with waste staging. Furthermore, this study demonstrates the significance of pre-selecting waste staging and storage areas before an incident occurs (as part of a routine planning process).

- The logistics and final disposal of waste remains a poorly understood and ill-practiced topic. The hypothetical incident featured in this case study, though small in scale, managed to generate at least 2.33 million cubic yards of solid waste and between 20.7 and 533 million gallons of aqueous waste. The cost of transporting and disposing of this amount of waste would be between $75-224 million and require between 260 and 1,220 days to complete. The stark difference between these scenarios further demonstrates the need for a systematic approach when evaluating decontamination and waste management options. The resources necessary to dispose of waste are largely a function of the size and level of contamination of an incident, but also the amount of waste generated by decontamination. As demonstrated in this case study, minor changes in the decontamination strategy resulted in a difference of 150 million and over 1,000 days when considering transport and disposal.

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