The Transportation Factor in Site Evaluations for Spent Nuclear Fuel Storage and Disposal Facilities – 15460

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ABSTRACT

New facility siting studies will be necessary to fulfill the Blue Ribbon Commission (BRC) on America's Nuclear Future 2012 recommendation to develop consolidated interim storage (CIS) for spent nuclear fuel in the next decade. Future site evaluations for used nuclear fuel (UNF) storage and disposal facilities must address transportation requirements, especially access to mainline railroads, early in the site selection process. The U.S. Department of Energy (DOE) in 2013 proposed a strategy for managing spent nuclear fuel in accordance with the BRC recommendations by establishing a pilot interim storage facility by 2021 and a consolidated interim storage facility by 2025. The authors demonstrate that currently available geographic information systems and already adopted siting criteria (defining favorable and unfavorable conditions) allow the identification of the transportation portion of a storage facility siting process to begin without delay.

Ready access to the mainline rail system is absolutely critical since existing rail access, or easily constructed access, is a highly favorable condition for successful siting. Despite widespread rail abandonments over the past three decades, vast areas of the United States retain mainline rail service or could connect to existing mainlines by building new rail spurs of less than 25-50 miles. This precondition for transportation planning is critical. Planners need to start with the beginning – availability of rail transportation to and from the interim storage facility/facilities.

A second step in transportation screening would be to evaluate those potential site locations within 50 miles of existing mainline railroads using other appropriate variables. This effort could begin with the application of the 1984 repository siting guidelines for transportation (10 CFR 960.5-2-7)[1]. Repository surface facilities have essentially the same transportation requirements as storage facilities. The guidelines in 10 CFR 960 provide a readily available template for evaluating sites based on transportation risks, impacts and costs. Initial site screening, after considering proximity to mainline railroads as the precursory step, should evaluate: 1) proximity to highly populated areas; 2) proximity to interstate highways; 3) proximity to environmentally sensitive areas and lands protected by federal, state, or tribal

governments; and 4) proximity to military installations, hazardous materials facilities, or other facilities that might impact transportation safety and security.

Several challenges exist which prevent effective transportation planning. The diversity of canister and cask types and SNF characteristics and conditions, the increasingly limited rail access at the shipping sites and the ease with which public attention can be marshalled against a waste management program, all suggest that future efforts need to identify potential storage sites that reduce transportation impacts and costs by reducing near-site transportation construction and reduce total system transportation impacts. This can most easily be accomplished by reducing shipping distances in a process that is easily defined and implemented. The paper concludes that the DOE should develop a site screening and evaluation program with transportation as a central consideration.

INTRODUCTION

The DOE’s Office of Nuclear Energy (ONE) is currently sponsoring studies that will support the development of an interim storage facility for used nuclear fuel (UNF) [2]. In order to make progress, a vital first step will be to identify suitable locations. No program for UNF storage can make substantial progress without the identification of a storage site. Very little other work is possible unless a storage site is identified. For example, stakeholders cannot be identified, section 180c funding cannot be tested, training cannot be performed, and engineering studies cannot be performed until this work is done. Most importantly, consent cannot be obtained without a site. A site is the *sine qua non* of any program for the storage of UNF in the U.S.

Existing transportation siting guidelines that can provide a useful foundation in identifying a site are embodied in 10 CFR 960.5-2-7. This paper describes a geographic information system (GIS) process to identify feasible sites for a CIS. This work is done by translating the siting criteria into data and rules that can be used in a GIS. The rules are then applied to the coterminous United States to find an optimum location for the interim site. In using existing federal regulations as the foundation of a siting process, this paper demonstrates a straightforward way to identify acceptable locations for a possible pilot study for the storage of spent nuclear fuel.

The failure of the Yucca Mountain repository shows that assessing transportation access (and transportation system requirements and impacts) in the earliest phases of site screening is vital. Congressional designation of Yucca Mountain as the only repository candidate site in 1987 ignored known problems with rail access construction and adverse impacts, as well as challenging highway access. DOE had previously evaluated Yucca Mountain in accordance with the repository siting guidelines for transportation (10 CFR 960.5-2-7). That study indicated that the site exhibited **no favorable** conditions for rail construction and presented three potentially adverse conditions: relatively high construction costs; relatively difficult terrain; and local conditions (proximity to military facilities and potential military aircraft over-flights) "that could cause the transportation-related costs, environmental impacts, or risk to public health and safety from waste transportation operations to be significantly greater than those projected for other comparable siting options"[3]. Had the siting guidelines been applied earlier, Yucca Mt. could have been excluded from consideration.

In order to reorient the nation’s UNF management program, the administration established the BRC [4]. The final report from the BRC recommends a process that requires the consent of the affected parties, with the ability to withdraw from the process (similar to the process adopted by the United Kingdom)

(BRC final report). This paper demonstrates that it is possible to identify a range of potentially acceptable locations for one or more interim storage facilities using existing data and publically available software.

ORPHAN SITES AND DOE

The current DOE program is aimed at locating an interim site for UNF from so-called "orphan sites." These orphan sites are locations where a reactor once operated, but now only the spent fuel storage facility remains. There are currently eleven of these sites across the United States.

Fig. 1. Current US orphan sites

An important, yet often unstated aspect of the DOE program is that in order to contain the costs, a site should be selected that will support both the pilot project as well as a likely follow-on program for the remaining waste. To support this, a pilot site should be evaluated on proximity to the geographic center of the UNF currently in storage. This will reduce transportation, emergency management, and other program costs. An analysis of the geographic center of the orphan sites (when adjusted for the volume of UNF at each site) can be used as a preliminary step to determine where an optimal site might be.

Fig. 2. Geographic Center of the UNF in the US, Weighted by Numbers of Shipments

The geographic center of the stored UNF was calculated using both the orphan sites and all of the power plants weighted by the number of shipments. That number of shipments was obtained from the Final Supplemental Environmental Impact Statement for Yucca Mountain. Trojan and Rancho Seco, both orphan sites, pull the weighted center west and north of the original site. This provides a useful guide for understanding that the DOE CIS pilot program should consider sites that are suitable for both the orphan sites and all plants.

TRANSPORTATION AS AN ESSENTIAL STEP

The authors suggest a site selection process that begins by ensuring transportation access is readily available. Site selection for a UNF interim facility should reflect lessons learned from the experience with Yucca Mountain. To help overcome the risk, impact and cost issues that arose from such conflicts over Yucca Mountain, this paper suggest the following process.

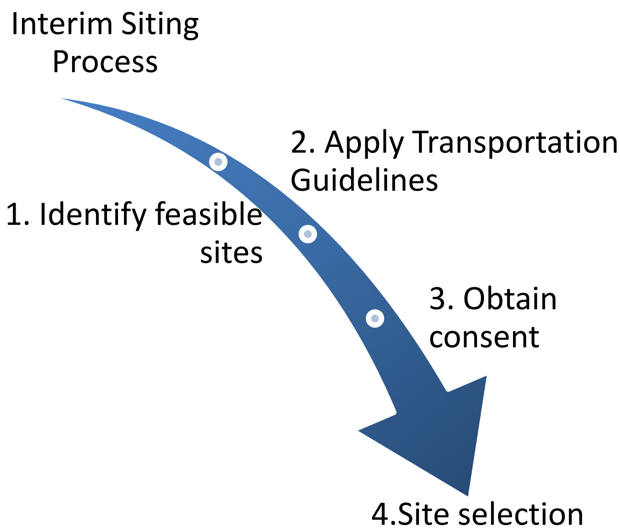

Fig. 3. Proposed Siting Process

The authors suggest a process that begins by identifying sites that are not too remote from existing transportation infrastructure but not too close to certain sensitive areas. In order to implement the process, it is necessary to convert data from a variety of different types into a consistent format. As noted, the process rests on siting guidelines. The siting guidelines list: 1) minimum acceptable conditions, 2) favorable conditions, and 3) adverse conditions. Transportation siting guidelines contained in 10 CFR 960.5-2-7 can be translated from these general guidelines into specific pieces of data that can then be used to optimize site selection using a GIS informed process. That is illustrated as follows.

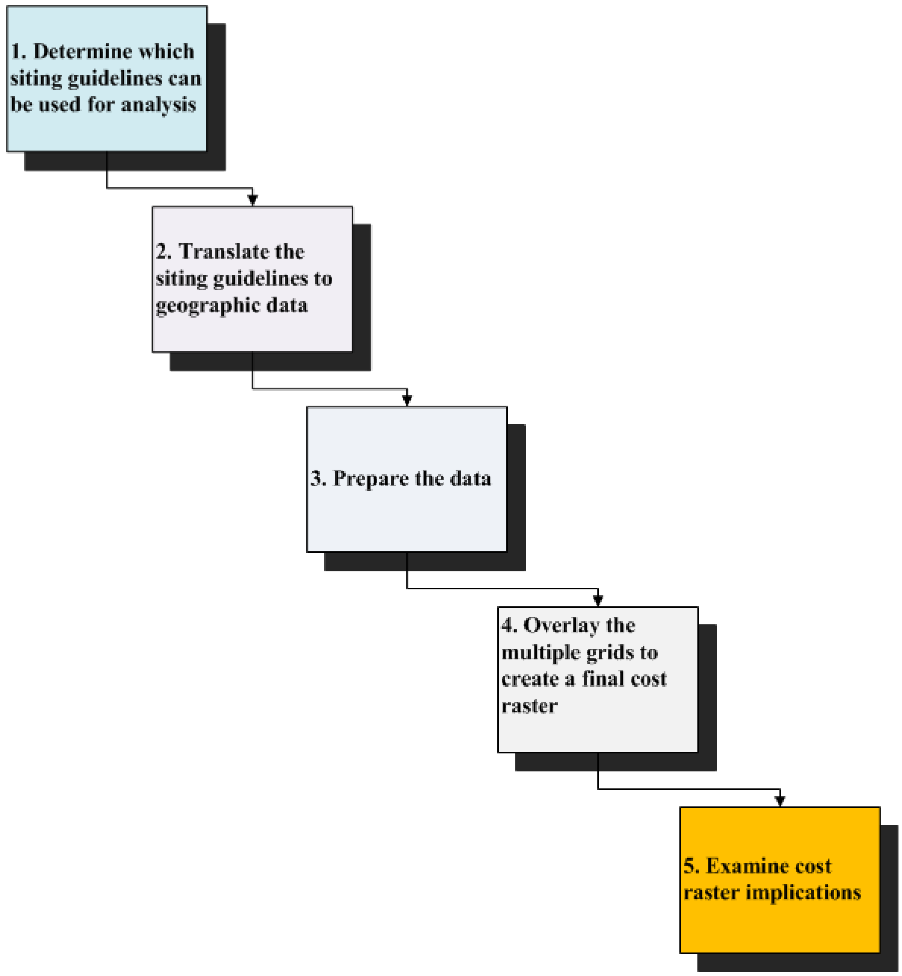

Fig. 4. Data Conversion Process

This process is then accomplished by placing the data into a density grid. Each density grid represents a single data value. Some of the conditions do not translate readily into geographic data. These are shown as "not indicated" in the tables. Furthermore, some of the siting conditions are repetitive. Siting conditions were not added multiple times.

For purposes of these guidelines, Environmentally Sensitive Areas (ESA's) are areas defined in the US Intermodal Surface Transportation Enhancement Act (ISTEA). Data was obtained from the National Transportation Atlas 2013, published by the US Department of Transportation (DOT) [5] and from the United States Geological Survey (USGS) tunnel database [6]. The open source GIS software QGIS (version 2.60) was used for this analysis [7]. It is worth noting that this was a deliberate choice. The authors wanted to ensure their work could be easily repeated by others. This work was not done in a "black box."

INITIAL SCREENING

An important initial step in screening for possible sites is to identify a site that would not exhibit prohibitive transportation costs. This consideration is reflected in 10 CFR 960.5-2-7. To implement this condition, a 50-mile buffer on either side of every Class I rail line and every interstate highway was used.

The length of the buffer is not set in stone, but it does provide a useful basis for discussion. This is particularly true due to the rapid decline of near-site infrastructure. When rail and highway buffers are combined, the buffer is shown below.

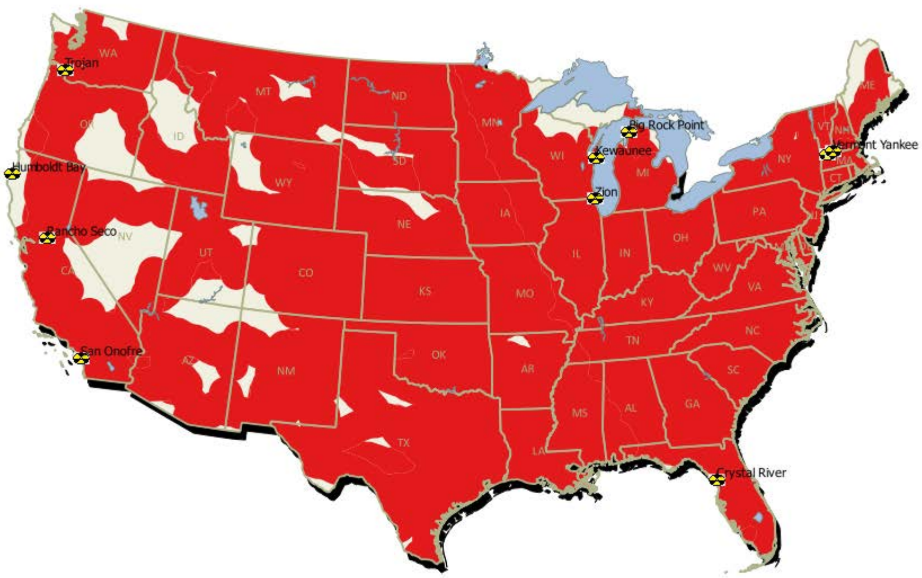

Fig. 5. 50-Mile Buffer around every Class I Rail Line and Interstate Highway

This shows that only 11% of the continental US is excluded from consideration using a 50-mile buffer. Additionally, an analysis of the roughness of the terrain using Digital Elevation models reveal that 40% of the remaining 11% is not suitable because of slope.

MINIMUM CONDITIONS

The minimum conditions defined in 10 CFR 960.5-2-7 are:

> *The access routes constructed from existing local highways and railroads to the site Will not conflict irreconcilably with the previously designated use of any resource listed in Sec. 960.5-2-5(d) these are indicated by the presence of tribes, environmentally sensitive areas, parks, and military reservations can be designed and constructed using reasonably available technology;*
>
> *will not require transportation system components to meet performance standards more stringent than those specified in the applicable DOT and NRC regulations, nor require the development of new packaging containment technology;*
>
> *will allow transportation operations to be conducted without causing an unacceptable risk to the public or unacceptable environmental impacts, taking into account programmatic, technical, social, economic, and environmental factors.*

When rendered into geographic data the minimum conditions are shown in Table 1 below:

Table 1. Minimum Siting Conditions

Minimum Conditions	**Geographic Data Used:**
Conflict irreconcilably with the previously designated use of any resource	Tribes, ESA, parks, and military reservations
Constructed with reasonably available technology	Not indicated
Not require more stringent construction than other transportation system	Not indicated
Does not create extra risk	National Bridge Inventory, USGS tunnel

FAVORABLE CONDITIONS

The favorable conditions listed in 10 CFR 960.5-2-7 are:

Availability of access routes from local existing highways and railroads to the site which have any of the following characteristics:

Such routes are relatively short and economical to construct as compared to access routes for other comparable siting options.
Federal condemnation is not required to acquire rights-of-way for the access routes.
Cuts, fills, tunnels, or bridges are not required.
Such routes are free of sharp curves or steep grades and are not likely to be affected by landslides or rock slides.
Such routes bypass local cities and towns.

Proximity to local highways and railroads that provide access to regional highways and railroads and are adequate to serve the repository without significant upgrading or reconstruction.

Proximity to regional highways, mainline railroads, or inland waterways that provide access to the national transportation system.

Availability of a regional railroad system with a minimum number of interchange points at which train crew and equipment changes would be required.

Total projected life-cycle cost and risk for transportation of all wastes designated for the repository site which are significantly lower than those for comparable siting options, considering locations of present and potential sources of waste, interim storage facilities, and other repositories.

Availability of regional and local carriers--truck, rail, and water--which have the capability and are willing to handle waste shipments to the repository.

Absence of legal impediment with regard to compliance with Federal regulations for the transportation of waste in or through the affected State and adjoining States.

Plans, procedures, and capabilities for response to radioactive waste transportation accidents in the affected State that are completed or being developed.

A regional meteorological history indicating that significant transportation disruptions would not be routine seasonal occurrences.

When rendered into geographic data, the favorable conditions are shown in Table 2 below:

Table 2. 10 CFR 960.5-2-7 Favorable Conditions

Favorable Conditions	**Geographic Data Used:**
Availability of access routes from local existing highways and railroads to the site which have any of the following characteristics	Rail and Highway networks
Short and economical	Distance grid
Federal condemnation not required	Minimize Federal Land
Cuts, fills, tunnels and bridges not required	National Bridge Inventory, USGS tunnel
Free of sharp grades and turns	Slope
Bypass local cities and towns	Population density
Distance to mainline	Distance
Minimum interchanges	Not indicated
Total projected life-cycle cost	Distance
Absence of legal impediments	Tribes, environmentally sensitive areas, parks, and military reservations
Meteorological Conditions	

UNFAVORABLE CONDITIONS

Unfavorable conditions identified in the CFR as potentially adverse conditions are:

Access routes to existing local highways and railroads that are expensive to construct relative to comparable siting options.

Terrain between the site and existing local highways and railroads such that steep grades, sharp switchbacks, rivers, lakes, landslides, rock slides, or potential sources of hazard to incoming waste shipments will be encountered along access routes to the site.

Existing local highways and railroads that could require significant reconstruction or upgrading to provide adequate routes to the regional and national transportation system.

Any local condition that could cause the transportation-related costs, environmental impacts, or risk to public health and safety from waste transportation operations to be significantly greater than those projected for other comparable siting options.

These conditions were matched to available geographic data. When rendered into geographic data, the unfavorable conditions are shown in Table 3 below:

Table 3 10 CFR 960.5-2-7 Unfavorable Conditions

Unfavorable Conditions	**Indicated by:**
Expensive	Distance
Easy terrain	Grade
Significant construction costs	Distance
Local conditions	Tribes, ESA, parks, and military reservations

METHODOLOGY

Map features are depicted in a GIS in one of three ways, as points, lines, or polygons. Points are used to depict features like wells, dams, and positions of buildings. Railroads, highways, and rivers are depicted as lines. Polygons are used to represent areas: e.g. forests, lakes, urban areas, etc…

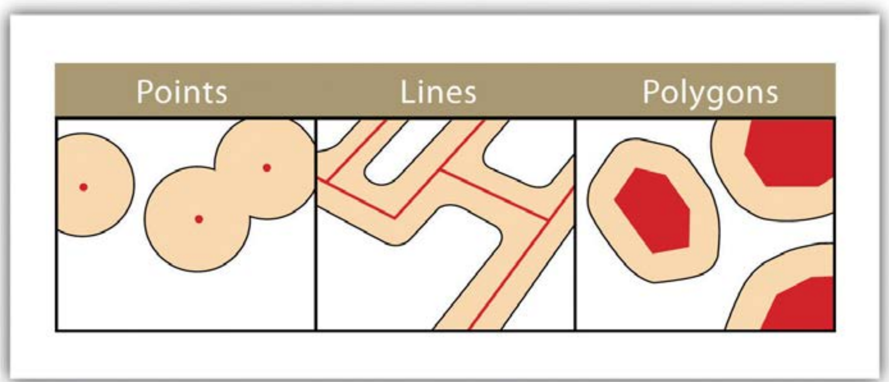

Fig. 6. Points, Lines and Polygons depicting Features in a GIS

Each of the features is converted into points. For example, a railroad, depicted in a GIS as a line, is converted into a series of points that follow the course of the same line - so this linear feature becomes a point feature.

All of the data used in the analysis is converted from its original source as either a point, line or polygon form into points. Using the points, it is possible to create a grid. The grid is a fixed set of squares that each contain data (in this case, it is a count of the number of features in each cell). For example, a grid with four cells appears as:

2	4
3	1

Fig. 7. Density grid count

The individual cells can be colored to depict the number of features in them.

2	4
3	1

Fig.8. Shaded density grid

It is then possible to perform mathematical operations on the numbers contained in multiple density grids.

2	4	+	1	5	=	3	9
3	1		1	2		4	3

Fig 9. Example of a mathematical operation on a density grid

The extent of grids can be made uniform so combinations and calculations can be performed with the data in any cell in any grid. This makes it possible to combine dissimilar data. The advantage of this approach is that it makes it possible to combine different kinds of geographic data in ways in which they would otherwise be incompatible. This makes it possible to combine a variety of different types of features as noted in the data charts above.

Once the grids have been prepared, it is possible to add and include or remove individual grids. It is also possible to apply weights to the individual grids to give the siting condition reflected in the grid extra significance in the analysis. For the purposes of this analysis, the grids for minimum, favorable, and unfavorable conditions are combined to provide a final raster that contains all of the siting conditions. In GIS parlance, this is referred to as a cost-raster.

ANALYSIS

A density grid was prepared for each applicable condition of the siting guidelines. The grids for each condition were set within the minimum, favorable, and unfavorable tables and then they were added together (without weights) to create a grid that reflected each of the table properties. That is, a final minimum conditions grid was created by adding together the minimum conditions grids. The same creation of a final grid was performed for the favorable and unfavorable grids. In each of the grids and maps below, the darker colors indicate favorable conditions. No color indicates an absence of data-sites that are of no value.

MINIMUM SITING CONDITIONS

For minimum conditions, the desirability was assessed by combining density grids that minimized impacts on tribes, military installations, parks, and environmentally sensitive areas. An example of the grids used is indicated by the grid showing the density of Indian tribes in the US.

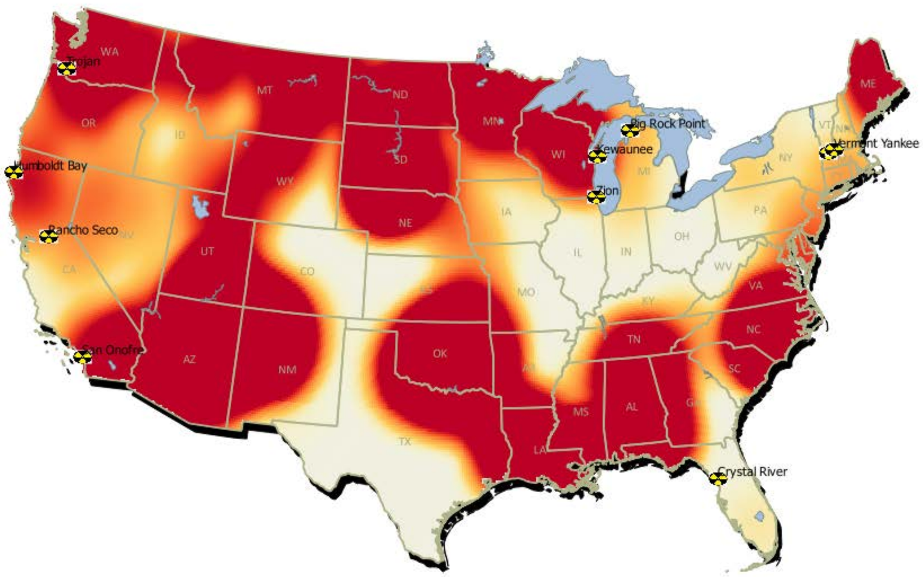

Fig. 10 Density grid of US Indian tribes

When combined, the density grids provide a clear indication of areas where minimum siting conditions have been met.

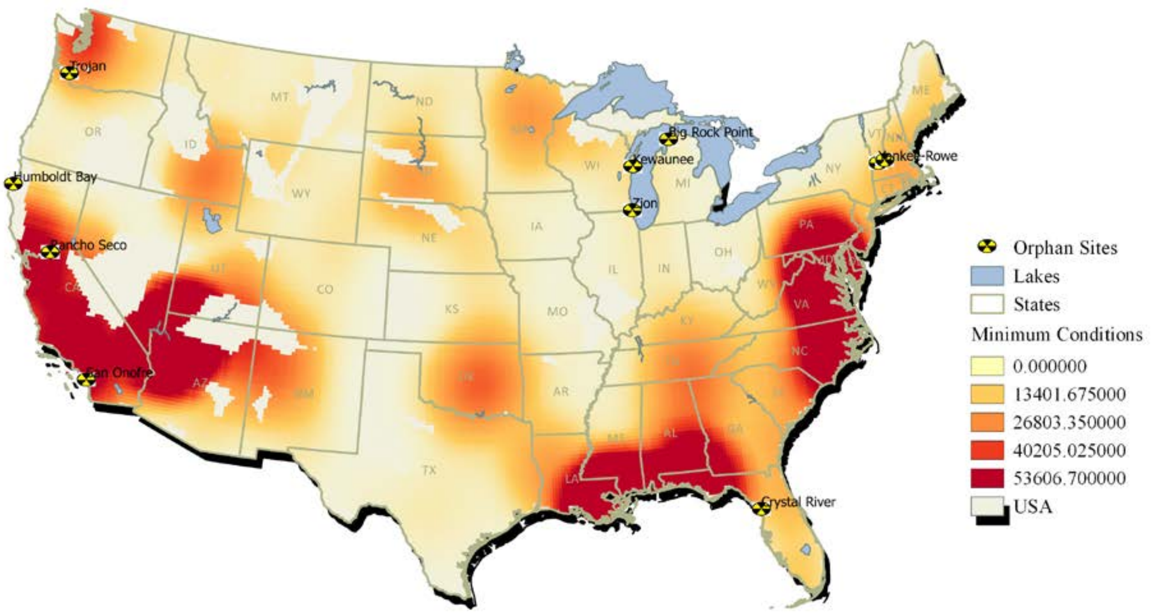

Fig. 11. Density grid of minimum conditions

The minimum conditions grid depicts the areas that fulfill the minimum conditions identified in the siting guidelines. The darker colors indicate more suitable areas. This first level of analysis indicates many potentially suitable areas. But additional information can improve the site screening process.

FAVORABLE SITING CONDITIONS

The favorable siting conditions were rendered into a series of density grids. In each case the darker color represents areas where more favorable siting conditions exist. As an example of the density grids, a grid depicting the density of highways and freeways is illustrated in the figure below.

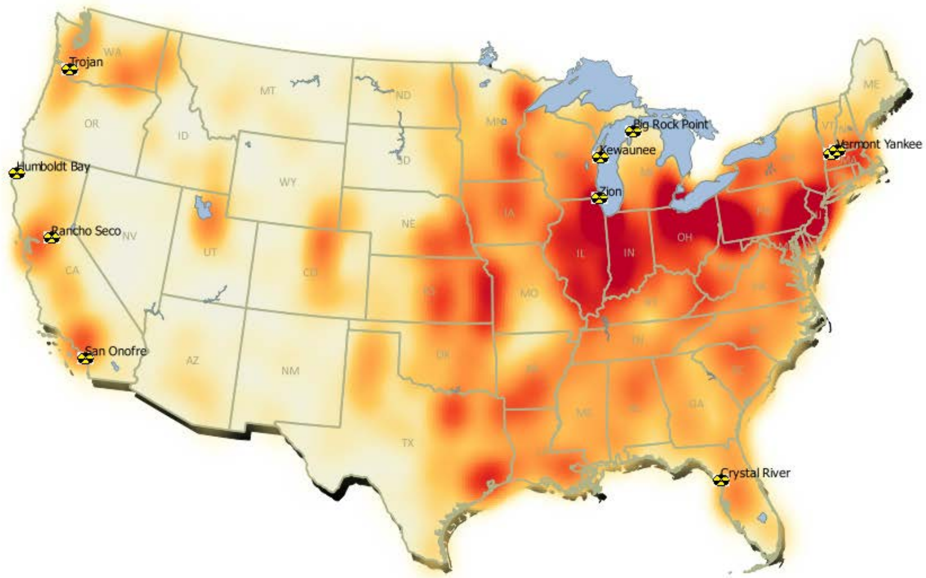

Fig. 12. Density grid of Class I railways

In the next step, shown in Figure 13, the density grids for all of the favorable conditions are combined. These grids depict the areas that fulfill the favorable conditions identified in the siting guidelines. The darker colors indicate more suitable areas. Once again, there are many potentially suitable areas. But once again, additional information can refine the site evaluation process.

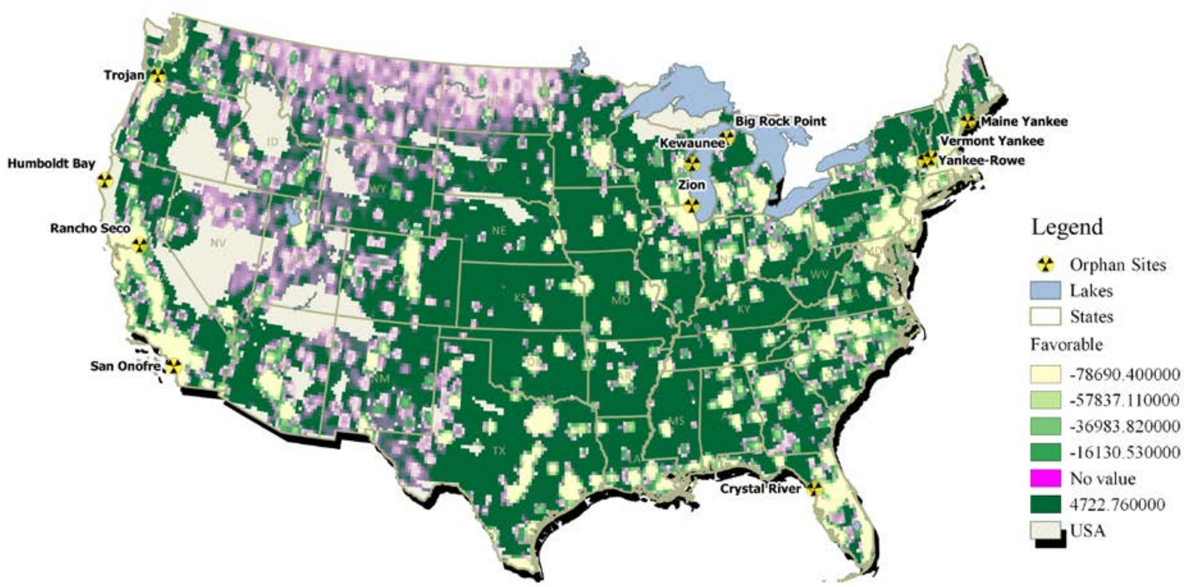

Fig. 13. Favorable conditions for interim facility

In this case, the darker area shows the more favorable locations.

UNFAVORABLE SITING CONDITIONS

The unfavorable siting conditions were rendered into a series of density grids. In each case the darker color represents areas where more of the unfavorable siting condition exists. As an example, Figure 15 depicts the density grids depicting the rail and highway tunnels.

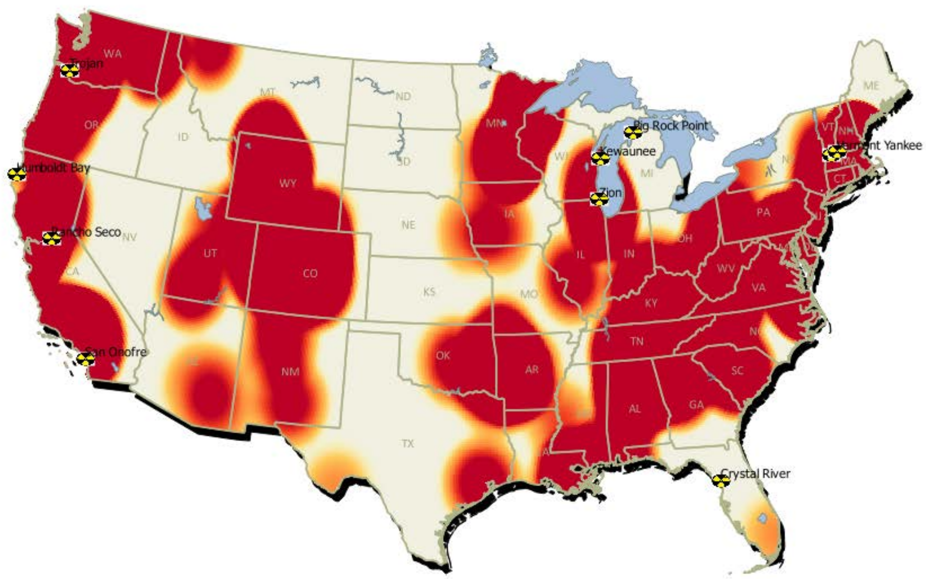

Fig. 14. Density grid of tunnels

Figure 16, below, shows the combined density grid of unfavorable conditions. Many areas of the country indicate conditions for siting that are not favorable.

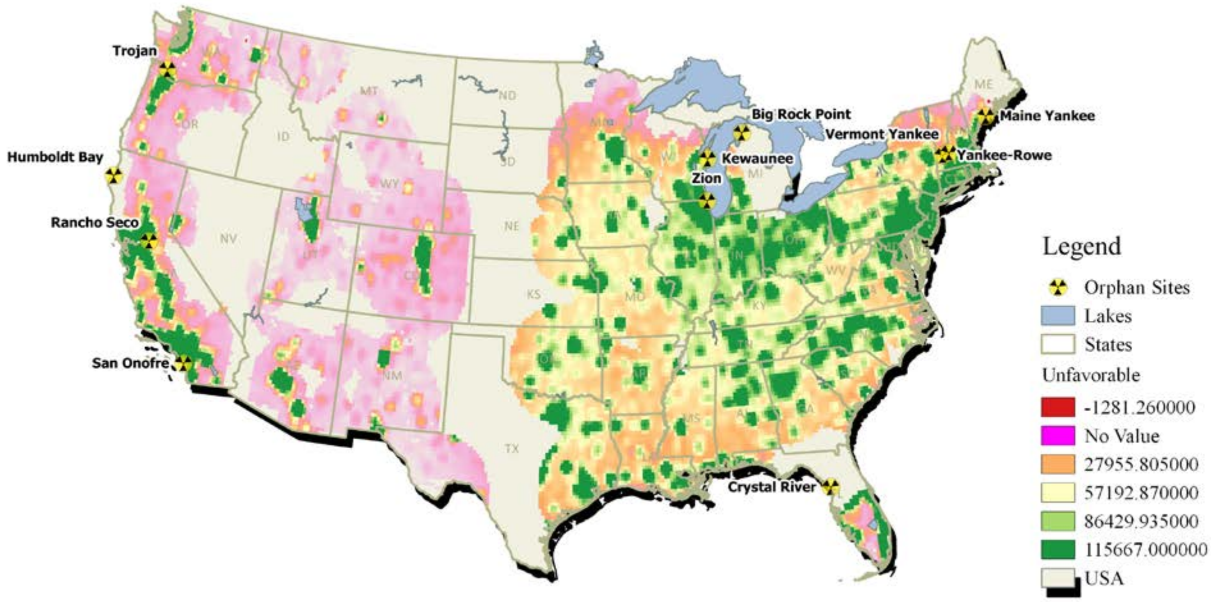

Fig. 15. Combined unfavorable density grid

For the final step in this analysis, Figure 17 combines the grids for minimum, favorable, and unfavorable conditions to provide a final raster that contains all of the siting conditions. In GIS parlance, this is referred to as a cost-raster. The combined density grid shows that there are numerous areas where conditions for siting an interim storage facility are not desirable. These areas can be removed from consideration early in the screening process. Efforts at obtaining consent for CIS sites should be focused on areas of the country where transportation access is not needlessly complex or expensive.

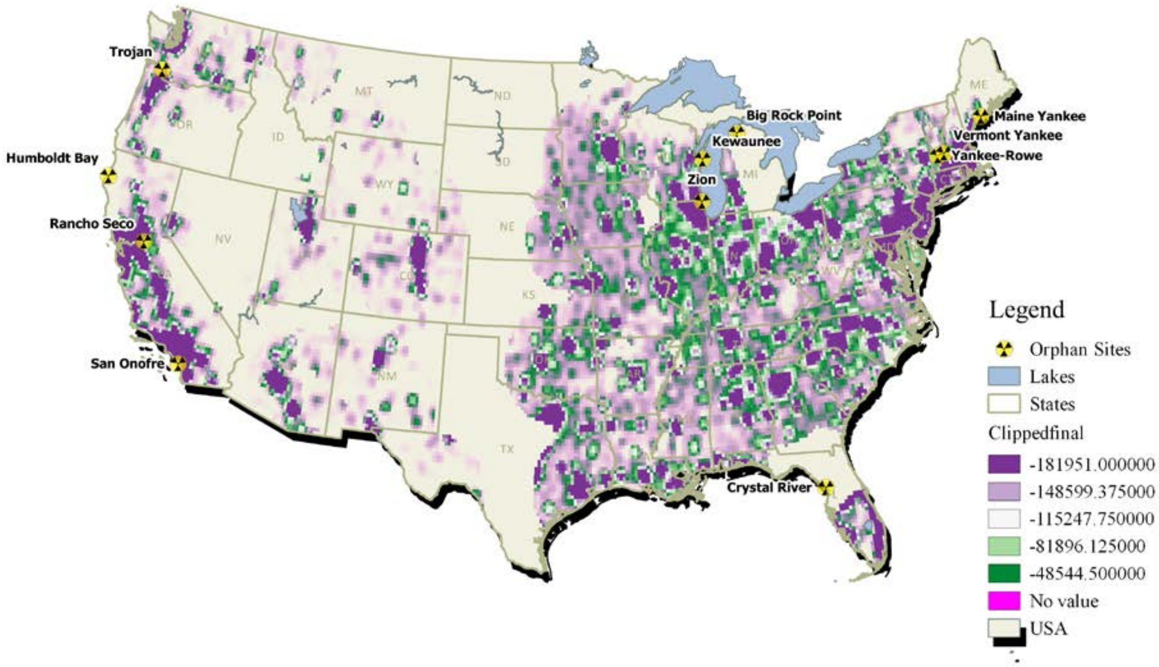

Fig.16. Final cost raster of favorable and unfavorable conditions

This analysis highlights several important points. The first is that the Yucca Mountain site does not meet any of the minimum or favorable siting conditions contained in 10 CFR 960.5-2-7. It could have been removed from consideration in a technically objective siting process. Second, this type of analysis can be an important risk management tool. For example, an important finding from the work done by the NRC in the Package Performance Study (PPS) reveals that probably the greatest accidental threat to a UNF cask will occur in a tunnel. This type of analysis can be used to find locations and routes that will minimize the use of tunnels, thereby reducing risk. This type of analysis is also valuable for making explicit choices made by program managers. The UNF siting problem has suffered from on-again, off-again procedures that conceal, rather than highlight, the direction the program is taking. A clear cut expression of this type of analysis makes it easier to comprehend. Finally, this type of analysis enables stakeholders to make choices and express preferences between various siting choices. It can help all involved make clear what can be accomplished. Past efforts at siting UNF facilities have foundered due to poor interactions between the states and Federal government. This problem suggests that this kind of analysis can readily identify optimal states for siting facilities. This is an essential and missing truth about UNF site identification in the United States. That is, the state is more important than the site.

CONCLUSION

Transporting UNF to an interim storage facility is an essential part of a storage program. The siting guidelines contained in 10 CFR 960.5-2-7 provide a useful framework for evaluating SNF transportation risks, impacts, and costs, and should be applied early in the site screening process for an interim storage facility or facilities. The process herein can be used to determine which areas are NOT suited for an interim storage site. An optimal site from a transportation perspective can be readily identified. This paper applies a straightforward process that can be successfully used to identify the potential areas for a possible interim site.

Efforts to achieve the BRC's goal of consent based siting will require a more nuanced and politically sensitive approach than a GIS analysis can provide. However, by identifying areas that are not suitable, it becomes easier to focus on places that may have more favorable characteristics. This process was not applied to the Yucca Mountain Project, where the site was so unsuited to transportation that it would have incurred billions of dollars in additional costs and added economic security and health risks throughout the United States.

This paper demonstrates that the template for choosing a site based on favorable transportation considerations already exists. It is possible, using open source software and readily available data sources to conduct a very sophisticated pre-screening for potentially suitable sites. This pre-screening can help focus attention on areas where a UNF interim site is technically feasible. The real test, however, will be to achieve consensus among stakeholders at the regional, state and local levels.

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