SITE SELECTION FOR LOW LEVEL RADIOACTIVE WASTE DISPOSAL SITES

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INTRODUCTION

The enactment of the Low-Level Radioactive Waste Policy Act (Public Law 96-573) delegates the responsibility for the disposal of low-level radioactive waste to the states. This law enables states to form compacts with other states to create regional disposal sites. The disposal sites within a region thus created would only be available to the states participating in the compact. In order to provide adequate burial space one or more burial sites will have to be created within each region. Since the provisions of this act allow states within a region to exclude waste generated outside the region after 1986 a concerted effort will have to be made during the next few years to locate new low level radioactive waste disposal sites.

Guidance on the selection of sites for low level radioactive waste disposal is contained in the proposed rule, "Licensing Requirements for Land Disposal of Radioactive Waste" 10 CFR61 issued by the NRC. Section 61.50 of that rule contains requirements for suitability of a disposal site (Table I). These criteria contain requirements which the NRC feels must be satisfied to ensure that the overall performance requirements contained in 10CFR 61 can be satisfied.

Table I

10CFR 61 SITE SUITABILITY CRITERIA

1. Capable of being characterized, modeled, analyzed and monitored.

2. Projected population growth should not adversely affect ability to meet performance objectives.

3. Avoid areas having significant natural resources.

4. Well drained and outside of 100 year flood plain.

5. Minimize upstream drainage areas.

6. Provide sufficient depth to the water table.

7. Ground water discharge must not originate within the hydrogeologic unit used for disposal.

8. Avoid areas subjected to seismic activity or vulcanism.

9. Avoid areas subjected to surface geologic processes such as mass wasting, erosion, slumping, landsiding, or weathering.

10. Avoid nearby facilities or activities which could adversely impact performance.

While these criteria are necessary to ensure that the site will be suitable for the disposal of radioactive waste there are additional criteria which must be considered when determining the best overall site within a region. These additional criteria ensure that there is a adequate consideration of engineering/economic, environmental, and sociological criteria as required by the National Environmental Policy Act of 1969. These additional criteria include issues such as the availability of transportation to the site, overall capacity for a site, construction costs, the presence of endangered species, and land use.

Nuclear waste disposal siting, like the siting of airports or nuclear power plants, generates considerable public interest. It is therefore important that the site selection consultant, in cooperation with the governing agency, make an objective, thorough and well documented analysis so that proposed sites will have the best chance for public acceptance.

Though this objective appears formidable, it can be approached if the lessons learned and the methodologies used in the siting of other controversial facilities are adapted to the specific problems associated with nuclear waste disposal siting. Sensitivity to environmental and sociological issues of concern to the general public is required, as well as to the traditional engineering and economic issues normally analysed. If all the issues are dealt with in a professional manner, based upon a balance of public interests and economic considerations, a reasonable case for a nuclear waste site recommendation will result.

SITE SCREEN METHODOLOGY

In the early 70's, Bechtel developed a computeraided siting methodology to equip its projects with effective tools for dealing with controversial siting problems in an era of increasing public awareness and participation. This methodology is called SITE SCREEN. It's generic techniques have been applied in the siting of nuclear and fossil fueled power plants, reservoirs and new communities. The criteria and weighting factors selected must be tailored to the specific facility being sited, be it an airport, a nuclear power plant, a radioactive waste disposal facility, or any other industrial plant. The SITE SCREEN procedure is structured so that at various points the study team is required to establish the project-specific criteria necessary to continue, and to assess or reassess the relative importance of the criteria used. As the need for new low level radioactive waste repositories grows, there is an obvious place for a methodology of this type to aid in the siting decisions to be faced by governments and communities.

An integral part of the SITE SCREEN methodology is the graphic documentation of the site selection process, including a clear statement of the siting criteria; definition of the territory to be studied; identification of candidate regions and preferred regions; and production of computer generated maps of the preferred regions portraying the important physical and sociological features. From these kinds of data, the process of decision making which leads to the identification of candidate sites, evaluation of candidates and selection of preferred sites can be effectively shown.

An overview of the SITE SCREEN procedure is illustrated in Fig. 1. It is an economical system, structured to meet the following objectives:

- o Screen large territories to identify the most acceptable regions for the proposed facility using readily available data
- o Identify ecomonically feasible alternative site areas, having high environmental and sociological acceptablilty
- o Select and rank the most acceptable sites, considering a balance of engineering/economic, environmental, and sociological factors in accordance with the National Environmental Policy Act.
- o Provide for economical future reevaluation of sites and updating of site rankings to account for changes in regulatory requirements or changed societal perceptions which may have evolved with the passage of time.

REGIONS

PRIMARY SCREENING

Primary screening covers the entire territory in which the site could be located.

CANDIDATE REGIONS

SECONDARY SCREENING

Secondary screening is conducted within the preferred regions identified in the primary screening process.

CANDIDATE AREAS

AREA SCREENING

The objective of site area screening is to identify a list of candidate sites for site evaluation.

CANDIDATE SITES

SITE EVALUATIONS

The objective of site evaluation is to identify a preferred site and establish a list of prime alternative sites.

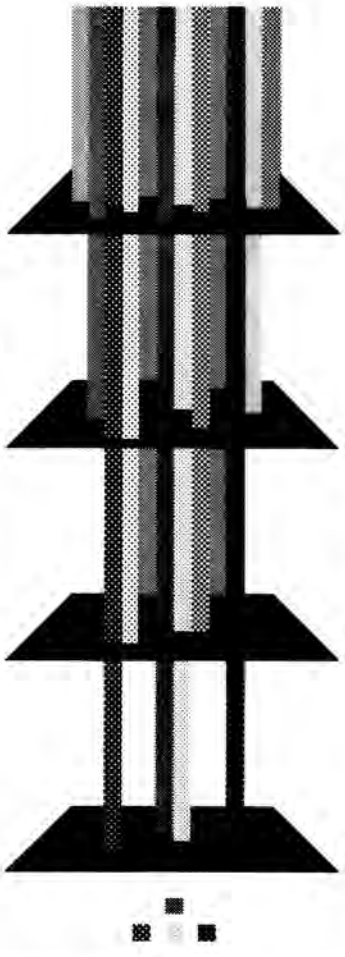

Fig. 1 **Site Screen Methodology**

The documentation of siting decisions provided by the Site Screen Methodology is complete, graphic, and flexible to changes. The more complete the documentation, the more useful it can become in satisfying inquiries by the client, goverment, and the public. The essential elements of complete documentation for site selection and evaluation include at least the following:

- o Definition of the limits of the territory which shall be considered
- o Selection of the most suitable regions within that territory
- o Distribution of engineering/economic, environmental, and sociological attributes within those regions
- o Criteria used for site selection
- o Importance given to each criterion used
- o Identification of potential sites considering the stated criteria and importance values
- o Evaluation of each potential site against the stated criteria
- o Final selections and rationale.

EXAMPLE SITING STUDY

The purpose of the following example will be to show how the Site Screen Methodology could be applied to the location of a low level radioactive waste disposal site to serve a hypothetical region in the U.S. The first step is to define the limits of the study territory. The outer limits of this territory are found by establishing a criterion which locates the geographical boundaries which may be defined by legal requirements or governmental agreements among neighboring political entities. The inner limits of the territory are found by defining the obvious exclusion areas (e.g., cities and their surroundings). For this example, these territorial limits are identified in Fig. 2.

Primary Screening

The primary screening of the territory starts with dividing the territory into regions. Regions are defined by considering existing natural or man made barriers such as rivers, interstate highways, major suburbs, terrain, or national forests, etc. Fig. 3 shows the example territory divided into 51 regions.

The criteria for regional selection for the waste site are then developed based on 10CFR61 Site Suitability Criteria (Table I), NEPA requirements and any special regional considerations.

For this example siting study, the above considerations were used to develop a set of Regional Screening Criteria as shown in Table II. The criteria are listed in the three groups shown so that regions, and subsequently sites can be adequately evaluated in response to NEPA requirements.

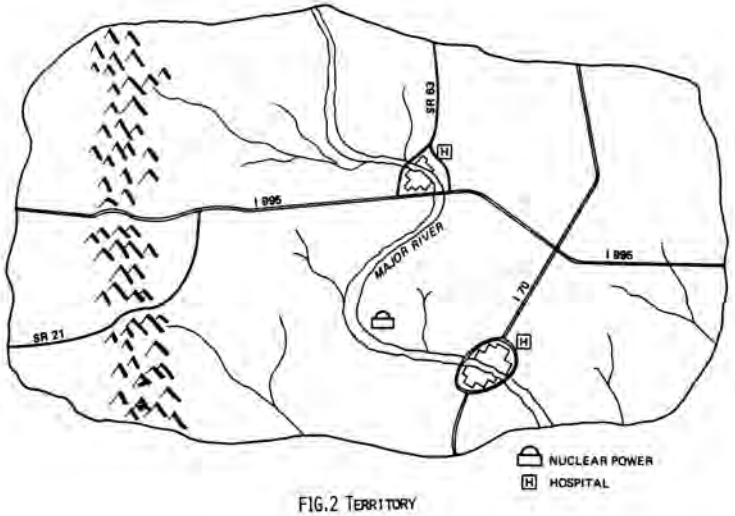

FIG.2 TERRITORY

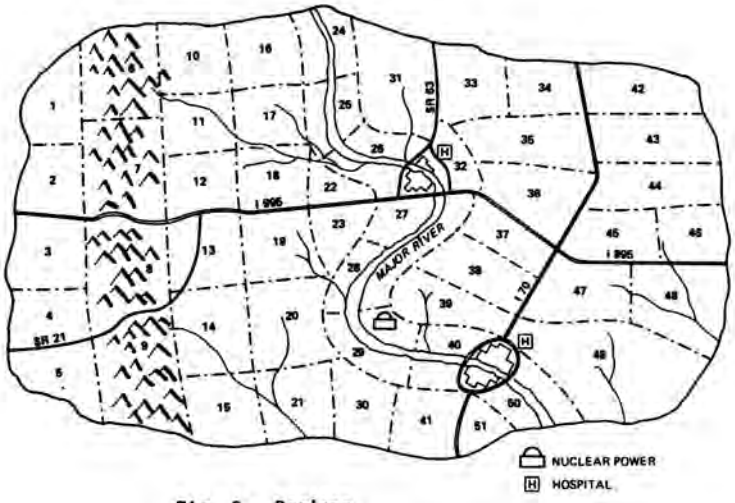

Fig. 3. Regions.

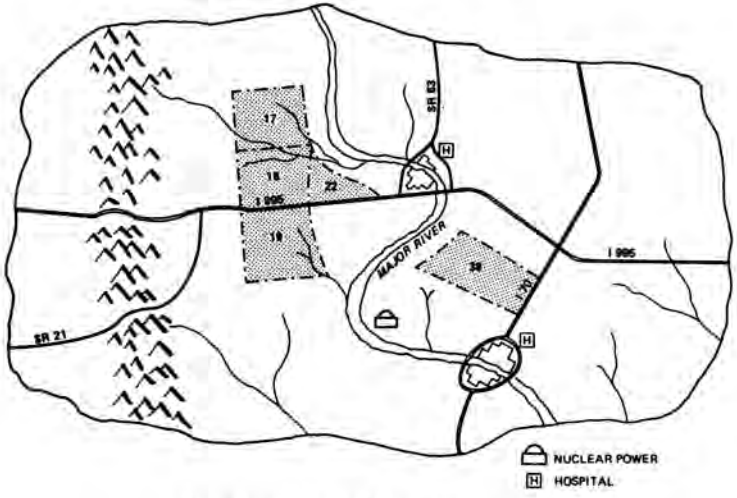

Fig. 4. Selected Regions.

Table II

REGIONAL SCREENING CRITERIA

FOR A LOW LEVEL RADIOACTIVE WASTE DISPOSAL SITE

ENGINEERING/ECONOMIC CRITERIA

1. Geology
2. Hydrology
3. Drainage Basin
4. Surface Waters & Flooding
5. Transportation
6. Construction Cost

ENVIRONMENTAL CRITERIA

1. Terrestrial Habitats
2. Natural Vegetation
3. Migration Routes
4. Endangered Species
5. Erosion Potential

SOCIOLOGICAL CRITERIA

1. Demography
2. Natural Resources
3. Land Use
4. Argiculture
5. Public Acceptance

It should be noted that not all of the requirements contained in 10CFR 61 are addressed in Table II. The list of criteria is limited because not all criteria are relevant for a regional screening. For instance, a regional screening can determine areas subjected to seismic activity and flooding. However the suitability of the site related to erosion, ground water, and drainage cannot be adequately determined on a regional basis. Similarly while the overall construction costs will vary from one region to another, specific construction features cannot be assessed until specific sites are selected.

Regions which do not satisfy certain essential criteria will be excluded during the regional screening. Many of the criteria identified in 10CFR 61 are go or no-go criteria. If the criteria is not satisfied then siting in the region will automatically be excluded. For instance areas subjected to seismic activity or flooding will be excluded. Other criteria such as the presence of significant natural resources or general land use will be assigned a weighting factor to be used in the evaluation.

Once the criteria are established and the weighting factors are assigned, all regions are then evaluated and a regional merit (RM) numerical score for each region is developed in the following manner:

a. Determine a regional rating for each region being considered for each criterion identified, using a subjective numerical rating scale or objective scales defined on the basis of cost, acres of land, miles, etc.

b. Calculate the regional merit (RM) value for each region being considered with the Site Screen computer program using the following equation:

$$RM_k = \sum_{i=1}^{3} W_i \sum_{j=1}^{b_i} W_{ij} \quad R_{ijk} \qquad (1)$$

where:

RM_k	=	Regional Merit (0 to 1000) for Region k
k	=	Region Number
i	=	Criteria Group Number
W_i	=	Criteria Group Weighting Factor (0 to 1)
b_i	=	Number of Criteria Within Criteria Group i
j	=	Criterion Number
W_{ij}	=	Criterion Weighting Factor (0 to 100)
R_{ijk}	=	Rating of Region k Against Criterion j in Criteria Group i (0 to 10)

c. Rank regions in descending order by regional merit (RM) value.

d. Conduct sensitivity analysis to determine the sensitivity of the regional ranking to changes in weighting factors.

A typical ranking of regional merit values which could result from the analysis for the regions shown in Fig. 3 is:

Region	RM	Region	RM
22	721	17	533
19	694	13	452
38	605	34	439
18	561	42	404
		All Others	< 380

It is apparent that regions 22,19,38,18 and 17 are those in which the most suitable sites for a Low Level Radioactive Waste Disposal Site will be found. At this level of the study the approximately 100,000 + square mile territory has been reduced by a factor of 12, to approximately 8,000 square miles. These regions, shown shaded in Fig. 4, are then ready to be studied in greater detail by means of the Secondary Screening process.

Secondary Screening

The objective of Secondary Screening is to identify potential plant site areas within the candidate regions. Information on significant attributes within these regions is entered into a bank of data which is used for the production of graphic computer maps. These computer-generated maps serve as an interactive tool used by the site selection team for identifying the best site areas within the selected regions. They also serve as a method for documenting the judgments made by the site selection team, and as a means for efficiently using the various government sponsored geocoded information systems being developed throughout the U.S.

For the Example, the five regions selected for further study are comprised of approximately 8,000 square miles. A study of an area of this size at a significant depth of detail is easily accomplished through the Secondary Screening process of the SITE SCREEN Methodology.

To facilitate the computer mapping, a coordinate system and grid cell size must be established. Grid cell size should be selected as a compromise between a maximization of data resolution and a minimization of the amount of interpatation required to fit the existing data to the grid cell size selected. For these regions, the U.S.G.S. Township, Range, and Section geographical system with 1-mile square grid cells would be appropriate.

The data recorded for each cell would be very similar to that listed in Table III and includes various aspects of land use, zoning, transportation system, geology, etc. The data entered into the computer program. Can then be retrieved in either map form, showing any number of grid cells, or report form which lists the attributes recorded in any one cell or group of cells. The Secondary Screening computer program package calculates the values specified by the numerical factor weighting functions and produces multiattribute maps. Multiattribute maps, as shown in Fig. 5 are an aid to the study team in identifying the most suitable areas for the waste disposal site within the regions. The multiattribute maps highlight these suitable areas and conveniently serve to document the logic used to arrive at these decisions.

Area Screening

For this example, it is assumed that eight potential site areas have been identified and documentation of the selection process has been accomplished by the Secondary Screening study. The Area Screening required to reduce these eight potential sites to four candidate sites uses the generic Equation (1), shown under Primary Screening, to calculate an "area merit" score for each of the site areas.

Table III

EXAMPLE INPUT DATA TYPES AND VALUE SCALES
FOR SECONDARY SCREENING IN CANDIDATE REGIONS

FROM USGS MAPS AND/OR COUNTY ROAD MAPS

Data Type	Example Input Value
	1 2 3 4 5
Population	None/Dwellings/Minor/Major/Institution
	1 2 3 4
Parks	None/Regional/State/National
	1 2 3 4 5
Forests	None/Minor/Major Woods/State/National
	1 2 3 4
Lakes, Ponds	None/Minimal/Minor/Major
	1 2 3 4
Rivers, Streams	None/Creek/River/Major River
	1 2 3
Wetlands	None/Minor/Major
	1 2 3
Airports	None/Minor/Major
	1 2 3 4
Railroads	None/Spur/Branch/Mainline
	1 2 3 4 5
Roads	None/County/State/U.S./Interstate
	1 2
Pipeline	Absent/Present
	1 2
Cemeteries	Absent/Present
	1 2 3 4
Resources	None/Dumps/Quarries/Mines

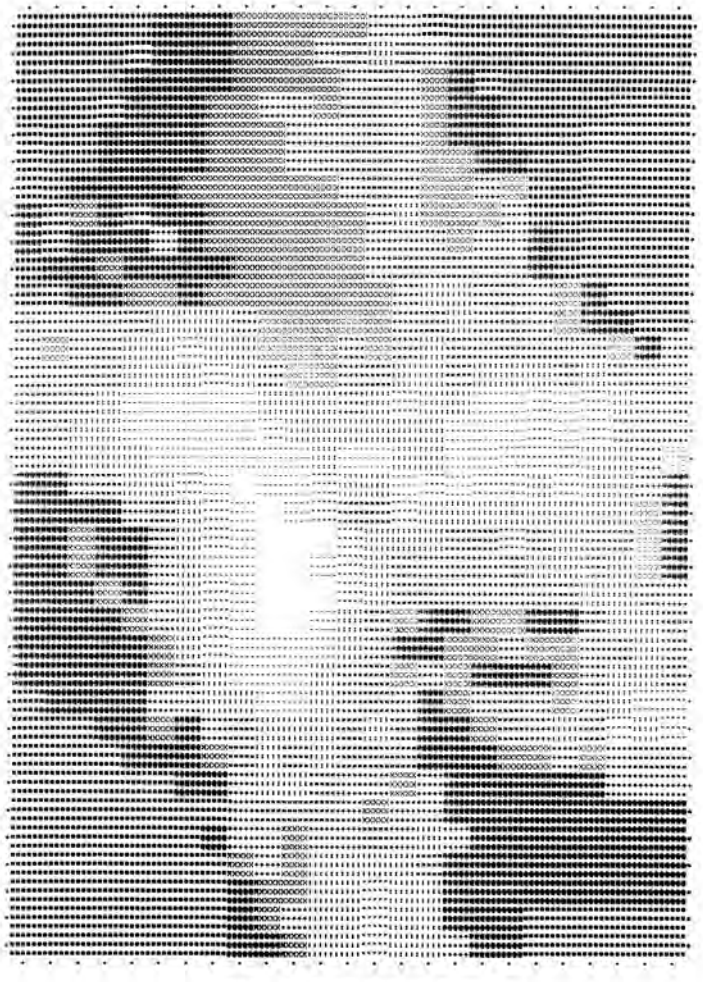

Fig. 5 **Multiattribute Map**

At this level of the study, the original 100,000 + square mile territory has been reduced by a factor of 2500 by means of the first two levels of screening to eight areas of about 5 square miles each. In addition, the study team has become familiar with the region and gained a better knowledge of the importance of the various criteria and how much weight should be given to each criterion. The team can now define the criteria for area screening and evaluate the eight site areas against those criteria. The basic criteria used in the primary and secondary screening levels are retained or revised and additional criteria are added to provide an in-depth evaluation of the sites. Specialists in all the engineering, economic, environmental, and sociological disciplines evaluate and rate each site area against the site area criteria. From these ratings, area merit (AM) scores are calculated in the same manner as that shown for regional merit (RM), and the areas ranked in order of preference, as follows:

Site Area	Area Merit (AM)	Site Area	Area Merit (AM)
Appleton	595	Glen Ellen	488
Burgville	621	Evans	473
Dover	570	Herndon	446
Centerville	539	Foster	422

Final Site Evaluation

From the area merit rankings, the four top-ranked sites are selected as candidate sites for final site evaluation. The criteria used in area screening are reviewed again and revised if appropriate. Much of the data needed for the final site evaluation are available from the area merit procedure already completed for these sites. Additional data may be called for in some areas and conceptual designs may be required to arrive at the differential ratings between candidate sites in this final phase of the study. On-site environmental surveys and transportation studies of the surrounding areas and access corridors may be appropriate. The essence of all the data, surveys, and studies are then incorporated by the specialists into a final site evaluation and rating

of each candidate site. The generic merit equation and sensitivity analysis are again used to calculate the "final site merit" (FSM) of each candidate site. Table IV shows the example criteria used is the Final Site Merit evaluation, the criteria weight, the ratings of each site, and the Final Site Merit score for each site. The sites are then ranked in descending order of FSM score to arrive at the final recommendation for preferred site and alternative sites, as follows:

Candidate Site	FSM
Appleton	678
Burgville	619
Dover	567
Centerville	545

Note that the FSM scores shown above will vary from the AM scores calculated for the same sites in the area screening phase of the study. This is expected since the FSM evaluation is a total reevaluation of each candidate site using refined criteria and weighting factors, more data in some cases, and the results of conceptual designs and more complete onsite surveys. It is not unexpected that the ranking of two sites, closely rated at the area screening level, may reverse in the final site ranking.

The Final Site Merit scores shown above were calculated with fixed Criterion Group Weighting Factors as follows: Engineering/Economic = 1/2, Environmental = 1/4, Sociological = 1/4. A graphical sensitivity analysis can be constructed to demonstrate how the the ranking of the final four candidate sites would vary as the Criterion Group Weighting Factors are varied. For the example site study, this is demonstrated in Fig. 6. This type of graphical sensitivity analysis can be useful in communicating to non-technical audiences the dynamics of site ranking and site selection as influenced by the importance or weighting factors assigned to the engineering/economic, environmental and sociological criteria.

Table IV

FINAL SITE MERIT SCREENING CRITERIA AND EVALUATION

	CRITERIA	WEIGHT	APPLE	BURGV	CENTR	DOVER
	ENGINEERING/ECONOMIC	(0.50)				
1.	Geology	15	7	6	4	9
2.	Hydrology	15	6	5	5	4
3.	Site Drainage	11	4	7	4	5
4.	Flooding	11	9	4	3	4
5.	Water Table	12	8	5	4	6
6.	Surface Waters	8	5	8	5	4
7.	Erosion	8	9	6	3	3
8.	Transportation	10	4	7	9	10
9.	Capacity	5	6	5	5	10
10.	Construction Cost	5	7	6	8	9
	CRITERIA GROUP TOTAL	100	651	583	479	617
	ENVIRONMENTAL	(0.25)				
1.	Terrestrial Habitats	18	9	7	5	4
2.	Natural Vegetation	18	8	9	6	5
3.	Migration Routes	10	4	6	7	5
4.	Endangered Species	15	7	8	3	3
5.	Water Quality	12	9	7	6	7
6.	Erosion Potential	15	6	8	9	5
7.	Groundwater	12	7	7	10	4
	CRITERIA GROUP TOTAL	100	733	756	640	464
	SOCIOLOGICAL	(0.25)				
1.	Demography	30	7	7	8	6
2.	Natural Resources	9	8	4	5	4
3.	Present Land Use	12	5	3	7	1
4.	Future Land Use	9	5	8	3	3
5.	Cultural Resources	6	6	5	5	4
6.	Argiculture	9	8	4	8	4
7.	Social Effects	9	8	6	7	6
8.	Public Acceptance	16	7	5	7	7
	CRITERIA GROUP TOTAL	100	679	553	673	481
	FINAL SITE MERIT (FSM)		678	619	567	545

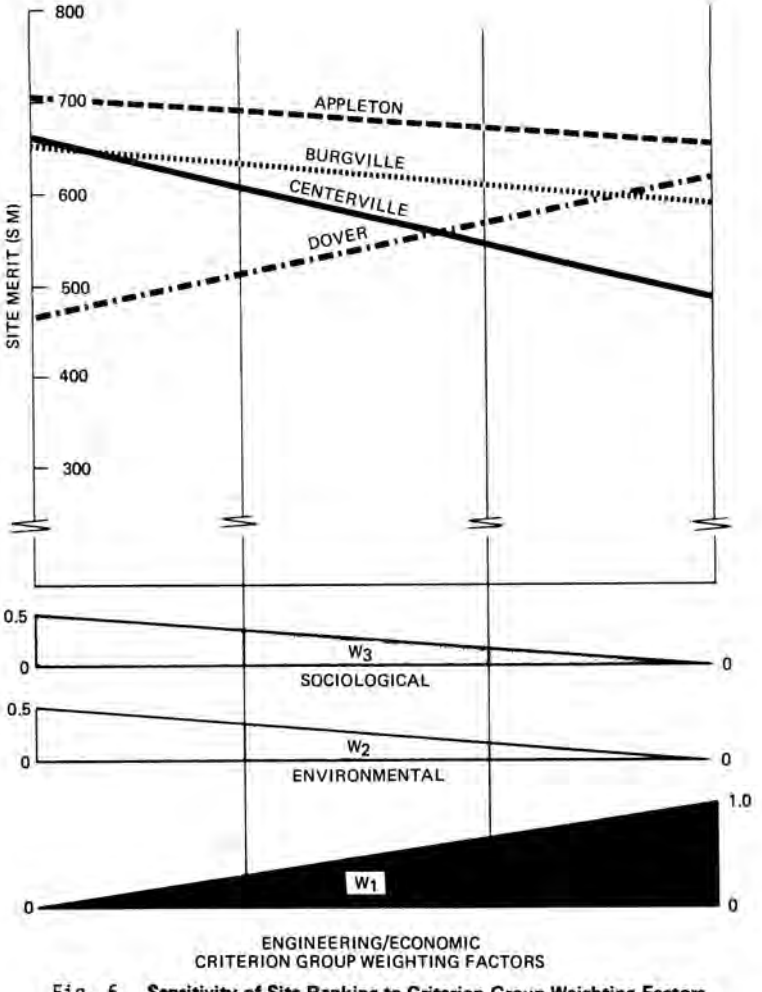

Fig. 6 **Sensitivity of Site Ranking to Criterion Group Weighting Factors**

CONCLUSION

Through employment of a siting methodology such as SITE SCREEN, the report prepared to document the above site study can confidently recommend the Appleton site for the proposed Low Level Radioactive Waste Disposal Site. The Burgville site can be used as an alternate. The results of the study are not likely to come as a surprise to any group actively involved with the planning process, since consensus is built among client, consultant, agency, and public interest groups over the course of the study. The use of this methodology does not, of course, guarantee that everyone will agree with the recommendation. It can, however, demonstrate to all concerned that the site study consultant has made a thorough, well documented, and easily understood study which has responded to all significant issues.