GEOLOGIC CONSIDERATIONS IN UMTRA PROJECT ALTERNATE SITE SELECTION PROCESS

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ABSTRACT

A phased approach was used to select potential sites for disposal of contaminated materials from the Uranium Mill Tailings Remedial Action (UMTRA) Project site in Lakeview, Oregon. An 1800-square-kilometer area centered around the uranium mill site was the initial search region. Sixteen hundred square kilometers were eliminated from consideration with application of geologic, geotechnical, hydrologic, and environmental exclusionary criteria. With additional analysis of existing information, seven sections were selected for further consideration. These seven sites were visited by a team of experts. Potential 16-hectare disposal sites within each of the seven areas were chosen and numerically ranked using a set of geotechnical, geologic, hydrologic, engineering, and environmental inclusionary factors. Subsurface investigations were conducted at the two highest ranking sites. The rankings before and the rankings after the drilling programs and data analysis are compared for ten key geotechnical and geohydrologic factors at the two sites Conclusions are drawn regarding the appropriateness of the site selection criteria and procedures.

INTRODUCTION

On November 8, 1978, Congress enacted the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. Congress stated that uranium mill tailings "...may pose a potential and significant radiation health hazard to the public...and...that every reasonable effort should be made to provide for stabilization, disposal, and control in a safe and environmentally sound manner of such tailings in order to prevent or minimize radon diffusion into the environment and to prevent or minimize other environmental hazards from such tailings." The Environmental Protection Agency (EPA) was directed to establish "...standards of general application for the protection of public health, safety, and the environment" and the Department of Energy (DOE) was directed to conduct remedial actions at the designated inactive uranium processing sites to achieve compliance with the EPA standards.[1] The standards, promulgated by EPA in 1983, state that "control shall be designed to be effective for up to 1000 years to the extent reasonably achievable, and, in any case, for at least 200 years." (40 CFR 192.02)[2]

The inactive uranium mill site at Lakeview, Oregon is one of 24 sites scheduled for remedial action under the Uranium Mill Tailings Remedial Action (UMTRA) Project. This site is within a Known Geothermal Resource Area and within 0.8 kilometer of the Goose Lake Graben fault zone. As stated in a recent UMTRA Project report, "...significant changes in the character and surficial location of the geothermal activity in the Lakeview area can occur. As historically documented, these changes can be seismically induced or result from geothermal vent closure. Considering the close proximity of existing geothermal activity and the proven geothermal reservoir under the site, a distinct hazard exists which could jeopardize the integrity of the proposed stabilization of the Lakeview tailings. If surficial geothermal activity were to occur directly under the reclaimed site, the greatest consequence would probably be related to water-quality changes and off-site contamination of the surface water and ground water. Uncontrolled migration of surface water emanating from an on-site geothermal spring would probably be the most observable impact. The cover systems designed to reduce radon emanation and provide erosional protection could be compromised.... Considering the 200- to 1,000-year, no-maintenance design life of the reclamation procedure, the geothermal hazard is too great to allow stabilization in place. It is recommended that the tailings be relocated to a location which does not possess the geothermal characteristics of the present Lakeview site."[3]

The conclusions of this study were accepted by the Department of Energy (DOE) and tailings and other contaminated materials will be relocated to a disposal site. A formal site selection process was developed to identify suitable disposal sites. Key factors in this process are regional and site-specific geotechnical and geohydrologic considerations. The sequential selection process includes:

- Designation of the search region.
- Elimination of unsuitable areas based on review of available information.
- Selection of general site areas within the remaining suitable areas.
- Selection of smaller areas within the general areas.
- Quantitative ranking of sites according to specific criteria.
- Use of conventional geotechnical and geohydrologic techniques to characterize the two highest ranking sites.

PHASED SITE SELECTION PROCESS

Phase I, the designation of the search region, was based on two nontechnical criteria, which were disposal within Lake County, Oregon, and inclusion of the two mine sites which produced the uranium ore. The region chosen to fulfill these criteria was a circle of 24-kilometer radius centered on the existing tailings pile.

Phase II, elimination of unsuitable areas based on available information, consisted of two parts. The first part was development of regional screening guidelines consisting of geotechnical, geologic, hydrologic, and environmental factors. The regional screening guidelines were developed by DOE with consideration of reviews and comments by the Nuclear Regulatory Commission, the Bureau of Land Management, the Forest Service, the State of Oregon, and the Lakeview Community Task Force on Uranium Tailings Disposal. The 23 screening guidelines are listed and described on Table I.

TABLE I

Regional Screening Guidelines[4]

Characteristic	Criteria Definition (Buffer Zones)
Geologic faults	Areas within 0.43 kilometer of Holocene or Recent faulting.
Liquefaction potential	Within 0.43 kilometer of areas having saturated loose sands or visible surface indications of disrupted drainage or broken ground.
Landslides	Areas within 0.43 kilometer of visible indications of slope instability.
Geothermal activity	Within 3.2 kilometers of Known Geothermal Resource Areas, as identified by the Oregon Department of Geology and Mineral Industries, and other evidence of geothermal activity.
Volcanic activity	Areas within 3.2 kilometers of exposed Late Quaternary volcanic deposits.
Erosive soils	Areas of known highly-erosive soils.
Slope and escarpments	Slopes steeper than 33 percent grade; or areas from the top of an escarpment in excess of 3 meters in height.
Goose Lake	Areas lower in elevation than 1.5 meters above the historic high-water level (1,549 meters).
Water bodies	Lakes, ponds, reservoirs, rivers, or perennial streams.
Wetlands	Wetlands as defined by the Oregon Department of Fish & Wildlife Habitat Protection Plan for Lake County.
Floodplains	100-year floodplains as defined by the HUD, or within 0.21 kilometer of stream centerline.
Aquifers	Principal recharge areas and transition zones for sole source aquifers or other areas of potential water use.
Surface drinking-water supplies	Areas within 1.7 kilometers of surface drinking water supplies.
Communities	Areas within 1.7 kilometers of community limits (legal boundary).
Mineral resources	Significant known recoverable resources of oil, gas, coal, and other minerals (except uranium and gravel).
Subsidence areas	Within 0.43 kilometer of areas susceptible to subsidence by natural or man-made causes.
Transportation and communication corridors	Areas within the rights-of-way of state, Federal, and county roads, and Lake County Airport.
Archaeological & historical resources	Within 33 meters of archaeological or historical districts and sites on the National Register of Historic Places.
Prime farmland	Areas designated by the SCS as being within the Class II soil capability classification.
State & National Parks	Within 0.43 kilometer of Parks and Monuments under Federal, state, or local jurisdiction.
Wilderness & natural areas	Within 0.43 kilometer of Wilderness Areas, Natural Areas, areas of critical environmental concern, and proposed RARE II areas.
Wildlife refuges	Within 0.43 kilometer of wildlife refuges and designated migratory bird feeding areas.
Critical habitat	Within 0.43 kilometer of designated critical habitat for threatened or endangered species, fishery resource areas, and botanically and geologically sensitive areas; within 0.86 kilometer of known bald eagle or osprey nests and sage grouse strutting grounds.

The second part of Phase II was application of the guidelines to the 1800-square-kilometer area surrounding the present mill site. Geotechnical engineers, geologists, hydrologists, seismologists, and environmental scientists reviewed topographic maps, aerial photographs, the Lake County Comprehensive Plan, and technical reports from the Oregon Department of Geology and Mineral Industries (DOGAMI), U.S. Bureau of Land Management, U.S. Forest Service, U.S. Soil Conservation Service (SCS), U.S. Department of Agriculture, and the U.S. Geological Survey (USGS) for the screening. The lands within the buffer zones, as defined on Table I, were identified and plotted on topographic maps. Phase II resulted in the elimination of 1600 square kilometers from further consideration. The remaining 200 square kilometers were considered in Phase III. On Fig. 1, the excluded areas are darkened and the remaining areas are white.

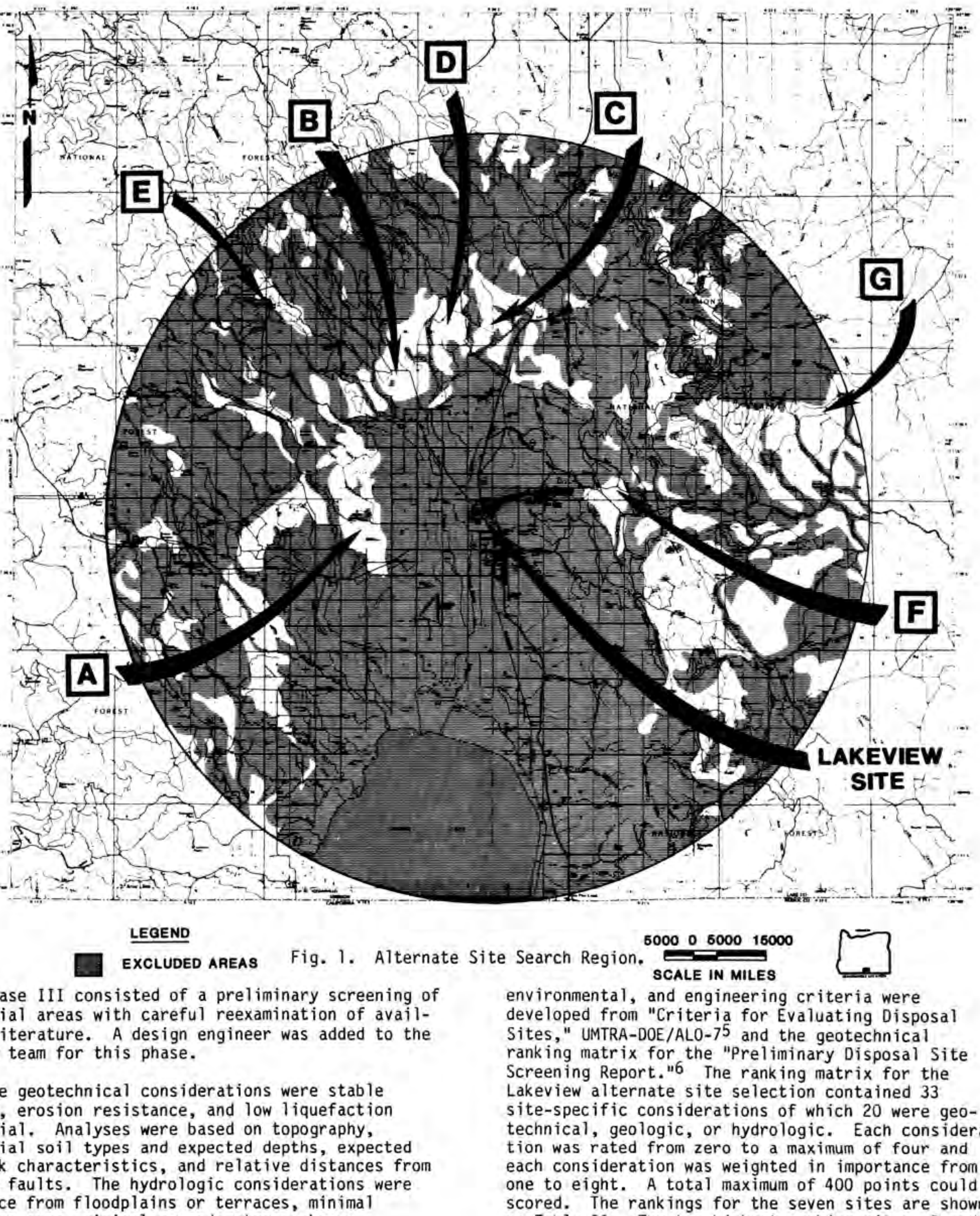

Fig. 1. Alternate Site Search Region.

Phase III consisted of a preliminary screening of potential areas with careful reexamination of available literature. A design engineer was added to the review team for this phase.

The geotechnical considerations were stable slopes, erosion resistance, and low liquefaction potential. Analyses were based on topography, surficial soil types and expected depths, expected bedrock characteristics, and relative distances from active faults. The hydrologic considerations were distance from floodplains or terraces, minimal drainage area, minimal ground-water recharge potential, and expected depth to ground water.

Phase III resulted in the selection of six sections for further consideration. At the request of the State of Oregon and the Lakeview Community Task Force the mine sites also were included. These seven areas, the six chosen areas and the mine sites, are identified as areas A through G on Fig. 1.

Phase IV consisted of on-site evaluations. Specific geotechnical, geologic, hydrologic, environmental, and engineering criteria were developed from "Criteria for Evaluating Disposal Sites," UMTRA-DOE/ALO-7[5] and the geotechnical ranking matrix for the "Preliminary Disposal Site Screening Report."[6] The ranking matrix for the Lakeview alternate site selection contained 33 site-specific considerations of which 20 were geotechnical, geologic, or hydrologic. Each consideration was rated from zero to a maximum of four and each consideration was weighted in importance from one to eight. A total maximum of 400 points could be scored. The rankings for the seven sites are shown on Table II. The two highest ranking sites, B and G, were chosen for geologic field investigations. No subsurface investigations were planned for the five other sites.

FIELD INVESTIGATIONS AND RESULTS

Site B is six miles northwest of Lakeview, Oregon, and adjacent to the Fremont Mountains. The site has gentle to moderate slopes ranging from 20 percent near the topographic high of Augur Peak, downward to the west where the slopes flatten to approximately 5 percent. The drainage area above the site is approximately 7.7 hectares. The drainage is towards Camp Creek which is approximately 900 meters southwest of the site and 15 meters below the site. Ground cover consists of sagebrush and bunch grasses.

The field program at site B consisted of 16 borings and 12 test pits, with nine of the borings completed as monitor wells. The boring locations are shown on Fig. 2. The test pits were between the rows of borings. The borings and test pits were lithologically logged, disturbed and undisturbed soil samples were taken, and slug tests performed in five monitor wells. Wells were sampled two weeks after development and ground-water levels will be monitored at least through June, 1985.

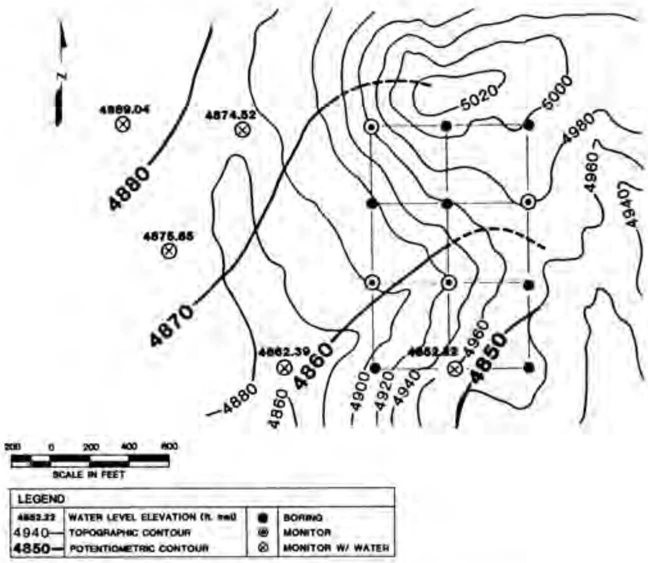

Fig. 2. Site B Field Investigation.

Soils encountered at the site consist of interfingered lenticular zones of silty sands, sands, and low and high plasticity silts (SP, SM, ML, and MH). These materials are dense to very dense although occasional lenses of medium dense soils were encountered. Although the soils are highly variable, as exhibited by a wide range of densities and moisture contents, even the low density (0.72 grams per cubic centimeter) and high moisture content soils (100 percent) exhibited high strength and low compressibility. This unusual characteristic is attributed to a partial cementation within the soils. The flatter portions of the site are underlain by a dense sand and gravel outwash alluvium.

Bedrock was not encountered in borings as deep as 39 meters. The site is located in a structural graben and based upon the depth of sediments along the eastern edge of the Goose Lake Basin, the depth to bedrock is estimated as at least 300 meters beneath the site.

Ground water was encountered in five of the nine borings completed as monitor wells. Four shallow wells in the valley, just west of the site boundary, show water-table conditions with depths to ground water from 2.1 to 5.5 meters (December 1984). One 24-meter well drilled near the course of a broad surface swale on the southwest slope of Augur Hill showed ground water at 23 meters below ground surface. Based upon the five measured water levels (in December, 1984) a potentiometric map was constructed (Fig. 2). Ground water moves from northwest to south-southeast under a hydraulic gradient of approximately 0.018. The ground-water flow direction appears to be opposite the topographic slope indicating most recharge is from the Fremont Mountains to the west, rather than the small areal drainage divide immediately above the proposed disposal site. From five slug tests, the calculated values of hydraulic conductivity ranged from 4×10^{-5} cm/sec to 5×10^{-4} cm/sec with an average of 3.5×10^{-4} cm/sec.

Five ground-water samples and one surface-water sample were collected and analyzed for chemical and radiological parameters. Existing shallow ground water exhibits low TDS, high pH, and high silica, typical of ground water encountered in volcanic host rock. The chemical composition of the ground water clearly shows that the major source of shallow ground water is from the volcanic Fremont Mountains, rather than local recharge through the lacustrine, alluvial deposits at the site.

Site G is approximately 37 road kilometers to the northwest of Lakeview at the edge of the Warner Valley. The site is relatively flat with slopes of approximately two percent to the northeast. The drainage area above the site is approximately 20 hectares. The nearest surface flow, Mapes Creek, is over 1.6 kilometers from the site and 60 meters below the site. The site supports a substantial cover of sagebrush and bunch grasses.

At site G, a similiar field program was conducted. This program consisted of 16 borings and nine test pits, with one boring completed as a monitor well. The boring locations are shown on Fig. 3.

Fig. 3. Site G Field Investigation.

Soils were from 1.2 to 1.8 meters thick. These soils consist of well-graded sandy, gravelly clays suitable for cover and liner material. The soils are underlain by Miocene and Pliocene basalt flows that compose the Warner Mountains horst block.[7] Borehole logs up to 46 meters show that the soils rest upon a series of thin (six to 11 meters) basalt flows. The upper half of each flow consists of moderately to very weathered, reddish brown, fractured basalts, and the lower half is composed of dark grey vesicular, slightly to very fractured basalts with some voids up to one meter. Below a depth of six meters, fractures are clay filled.

All 16 boreholes drilled on a 366-meter grid at site G encountered no ground water. The lithologic log of the 46-meter monitor well showed that vesicular zones, highly weathered zones, and unhealed cooling fractures and voids are potential pervious zones for water movement. The apparent absence of shallow ground water may indicate that most local precipitation and snowmelt is lost through evaporation and surface-water runoff.

RESULTS AND CONCLUSIONS

Although rankings were estimated prior to drilling, ten of the geotechnical and geohydrologic criteria from Table II require subsurface investigations for determination. These ten criteria were reconsidered for sites B and G. The results follow:

- Soil type and geotechnical properties (surficial materials lithology). The near-surface soils of both sites are suitable as radon cover material, although the limited depth of soil at site G may require borrowing from outside the disposal area. The high strength and low compressibility of the foundation soils at site B are suitable characteristics for disposal site construction, although a more detailed stability analysis is needed than at site G, which is founded on bedrock. Both sites scored 3.

- Thickness of soil (surficial materials thickness). The assumption for this criterion is that a site with shallow bedrock is inherently better than a site with deep soil. There is no reason for such preferential treatment. Site B scored 0 and site G scored 3.

- Host rock type and geotechnical properties (host rock lithology). This ranking criterion assumes sedimentary rock forms and precludes a deep soil site. The criterion was modified to consider sites with deep soils and sites with igneous or metamorphic rocks. Site G has a foundation of relatively durable and strong volcanic rocks. However, this rock is open and porous. Therefore, site G scored 0. Bedrock at site B does not cause foundation problems because it is deep. Therefore, site B scored 4.

- Host rock thickness. The thicker the host rock, the higher the ranking. The host rock at site G is at least 46 meters thick and probably much thicker. The bedrock at site B is deep and would not affect the repository performance. Both sites scored 4 for this criterion.

- Presence of fracturing. A highly fractured foundation rock is less desirable than a tight, unfractured rock. Shallow bedrock also is assumed for this criterion. Site B was ranked 4 due to the great depth to bedrock. Site G, with its high degree of fractures, ranked 0.

- Susceptibility to natural slope failures, subsidence or hydrocompaction. The bedrock at site G has numerous shallow voids and wide fractures, creating a subsidence potential. For full evaluation, additional field investigation would be needed. For this reason, site G was reranked as 3. Site B, with its high strength and low compressibility foundation soils, was ranked as 4.

- Aquifer characteristics of surficial material. The surficial materials at site B produce moderate quantities of high-quality water. The surficial materials at site G produce no water. Site B was reranked as 1 and site G was 4.

- Aquifer characteristics of host rock. The host rock at site B is not a viable source of ground water due to its depth. The bedrock at site G is unsaturated to at least 46 meters. Both sites scored 4.

- Ground-water recharge. Both sites have limited drainage areas. The minimal ground-water recharge around site G is supported by the deep ground-water conditions. That the slope of the water table is opposite the topography suggests limited recharge at site B. Both sites scored 4.

- Depth to first important bedrock aquifer. No bedrock aquifers were encountered at either site. Both sites scored 4.

The preference of the geotechnical ranking criteria for shallow bedrock sites cannot be justified from a performance basis. Because some of the criteria applied only to sites with shallow bedrock, it was assumed that if bedrock was deep, then the site was ranked highly. This bias and assumption resulted in a more subjective and less than optimal site selection process. A more definitive set of criteria that would rank a broader range of site conditions is suggested. Such criteria would rate directly performance factors such as foundation soil/rock hydraulic conductivity, compressibility, and strength. Because soil is needed for cover and possibly liner material, thicker soils should rank high instead of low as in the present ranking system.

Considering the more objective geotechnical ranking criteria and reranking the geohydrologic factors following data analysis, site B scores higher than site G as a disposal site. Before the field investigations, site B scored 61 and site G scored 93 on the subset of geotechnical/geohydrologic criteria requiring field investigations for determination. After the field investigations, site B scored 84 and site G scored 82.

In retrospect, the site selection process could be improved by conducting a preliminary drilling program at each of the selected sites rather than concentrating on a large program at only two of the sites. As can be seen in the comparison of the rankings before and after data acquisition, significant changes in the expected suitability of the site can occur between actual subsurface conditions and those determined from surface examinations of each site. This preliminary program also would serve to lessen the potential of encountering a "fatal flaw" during the final in-depth data gathering effort for the preferred alternative.

Table II

Rankings of Phase IV Sites

Ranking Criteria and Weightings	A	B	C	D	E	F	G
	Site Designations and Rankings						
Land Slope (1)	4	4	4	0	0	4	4
Lithology of Surficial Materials (1)	2	1	0	1	3	1	3
Thickness of Surficial Materials (2)	0	8	6	8	4	8	8
Lithology of Host Rock (2)	4	0	0	0	4	4	6
Thickness of Host Rock (1)	4	4	4	4	4	4	4
Joint Spacing or Shear Zones (1)	4	4	4	4	0	3	2
Distance from Active Faults (4)	8	8	4	4	8	8	12
Slope Failure/Subsidence (4)	16	16	16	4	4	16	16
Erosion/Deposition (3)	9	9	12	6	0	6	12
Geomorphic Stability (4)	12	16	16	12	4	12	16
Surficial Aquifer Characteristics (4)	12	16	16	12	16	16	16
Host Rock Aquifer Characteristics (4)	0	12	0	4	4	12	16
Recharge (4)	0	0	0	4	0	8	16
Depth to First Important Aquifer (2)	0	0	2	0	0	2	6
Distance to Surface Water (2)	2	6	4	4	0	2	4
Drainage Area Above Site (2)	8	8	8	8	2	8	8
Potential Evaporation/Precipitation Ratio (1)	2	2	2	2	0	0	3
Distance to Geothermal (4)	4	8	16	16	16	8	16
Distance to Quaternary Volcanic Exposures (1)	4	4	4	4	2	4	2
Mineral Conflict (1)	4	4	4	4	0	4	4
Geotechnical/Geohydrologic Subtotal	99	130	122	101	71	130	174
Population (4)	16	16	16	16	16	16	16
Farmland Potential (4)	2	12	2	2	16	16	12
Irrigable Lands (3)	9	12	9	12	12	12	12
Transportation Corridor (3)	12	9	9	9	6	12	12
Historical Significance (4)	---	---	---	---	---	0	---
Threatened and Endangered Species (4)	16	16	16	16	16	16	12
Scenic and Recreational (3)	9	9	9	9	6	3	9
Land use (4)	16	16	16	16	16	8	16
Environmental Subtotal	80	90	77	80	88	83	89
Distance from Exising Site (8)	24	24	16	16	16	8	0
Distance to Borrow Site Fine Materials (2.5)	10	10	10	10	10	7.5	10
Distance to Borrow Site Coarse Materials (2.5)	10	7.5	10	10	10	10	10
Land Ownership (6)	12	18	18	12	18	12	18
Existing Road Networks (4)	16	16	16	12	4	8	16
Engineering Subtotal	72	75.5	70	60	58	45.5	54
Total Ranking	251	295.5	269	241	217	258.5	317

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