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SITE SELECTION GUIDE
For
SOLAR THERMAL ELECTRIC GENERATING PLANTS

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16. Abstract

General site selection procedures and siting criteria for central power stations utilizing dynamic conversion of solar heat to electricity are defined. As an aid to implementing the guide, an exercise which resulted in the recommendation of a specific site for a 1000 MW(e) solar/electric power plant is described. Sources of information are included.

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FOREWORD

This report was prepared by Black & Veatch Consulting Engineers for Honeywell and NASA Lewis Research Center. It is one of four special reports being submitted by Honeywell to NASA under Contract NAS3-18014.* It is submitted in full compliance with Exhibit A of the contract Statement of Work, Task VI, C(2), viz., "A Design Handbook Specifying Site Criteria such as Solar, Meteorological, Geological, and Hydrological Criteria."

The three remaining special reports are identified as follows:

- Selecting Preferred Sites for a Solar Power Station Using Solar/Climatic Data, Honeywell Systems and Research Center, June 1974, NASA CR-134667.

- On-Site Survey of Candidate Solar/Electric Power Plant Sites, Honeywell Systems and Research Center and Black & Veatch Consulting Engineers, June 1974, NASA CR-134668.

- Executive Summary, Honeywell Systems and Research Center, NASA CR-134670.

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*Nine Monthly Technical Progress Narratives and three Design Review reports were also published. A final report (NASA CR-13475) is in progress.

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SECTION I
INTRODUCTION

Generating electricity from solar heat has yet to be accomplished on a scale commensurate with conventional generating station capacity, i.e., in the range 100-1000 MW(e). However, there appears to be no technological barrier to such an accomplishment. Such generating stations will become feasible upon development of efficient solar collector/concentrator/receiver systems and transport systems capable of delivering the collected heat to conventional turbo-generating machinery. In anticipation of these developments and as an aid to the engineering design analysis for such stations, consideration of potential sites becomes important.

Procedures and criteria have not been defined for selecting a site for the large-scale conversion of solar heat to electricity. Many of the criteria should, however, be similar to those used for siting fossil-fuel plants. These, together with the special requirements imposed by using solar energy as the primary heat source, can form the basis of site selection for solar-fuel plants.

SECTION II
OBJECTIVE

The principal objective of this guide is to provide general procedures and siting criteria for central power stations using the dynamic conversion of solar heat to electricity. The careful wording "dynamic conversion of solar heat to electricity" is used to distinguish these stations from those which may employ the direct photovoltaic conversion of solar radiation to electricity, or those which may convert solar energy to some intermediate energy source such as hydrogen, which can then be used to generate electricity. Having made this distinction at the outset, this rather cumbersome wording will not be used further. Rather, the shorter names "solar thermal electric generating stations" or simply "solar/electric power plants" will be used.

SECTION III
PLANT DESCRIPTION

The proposed solar/electric power plant must be specified in some detail to establish the criteria for site selection. Items which must be specified are described in this section.

3.1 PLANT CAPACITY, UTILIZATION AND OPERATING PHILOSOPHY

The desired electric generating capacity for the plant should be given. The basis for this rating should be clearly stated. For example, the plant may be rated in terms of peak generating capacity (kw(e)). (In this case, the average annual capacity and the total number of kilowatt-hours [electric] generated per year will be determined by annual insolation at the particular site chosen.) A design basis load model of the proposed plant should be provided. The operating philosophy for the plant, whether base load, intermediate, or peaking should be specified and the energy storage requirement stated in hours.

3.2 GENERAL PLANT DESIGN

The major systems of the proposed plant should be identified in a block diagram (see Figure 1). To help clarify the specific plant description, each system should be clearly specified in the appropriate block; e.g., "closed cycle helium gas turbine, 1000 psi/1400°F" in the prime-mover block.

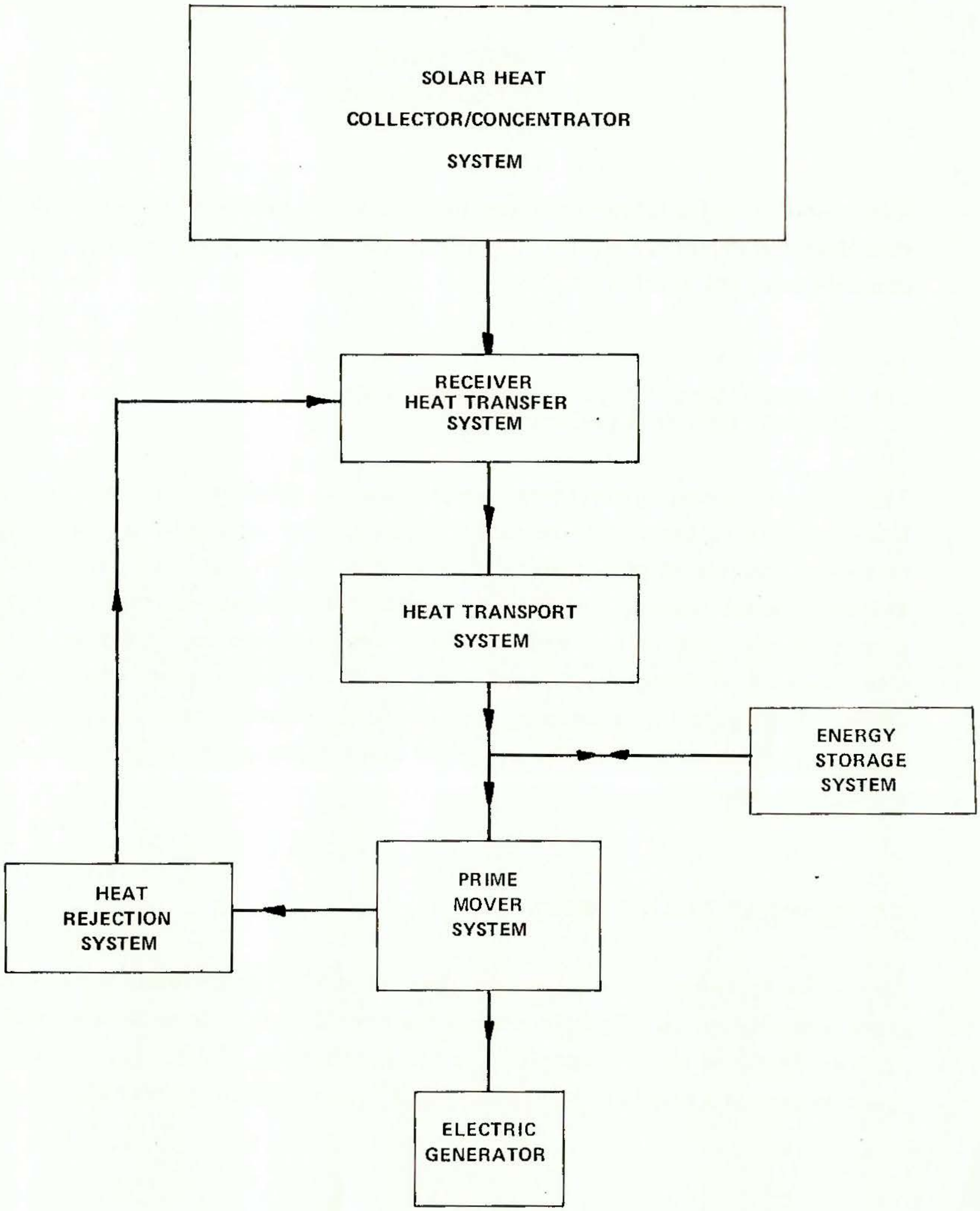

Figure 1. Generic Block Diagram of Major Plant Systems

3.3 COLLECTOR/CONCENTRATOR SYSTEM CONFIGURATION

This system may be either the distributed collector/concentrator type in which solar heat is collected and transferred to a heat transport medium at each individual collector/concentrator in the field, or the central-receiver type in which solar radiation is redirected by individual heliostats (flat mirrors) in the field and collected at one central receiver where heat transfer occurs.

Distributed systems use flat-plate, parabolic-trough and paraboloid-dish collectors. The collector type and array geometry should be specified. A drawing of a "unit cell" of the collector array should be provided and the ratio of collector area to total occupied land area (ground-cover ratio) stated.

Central receiver systems use an array of tracking heliostats (flat mirrors) to redirect sunlight to a central receiver, usually located on top of a tower. The heliostat design, array geometry, and ground cover ratio should be specified. The height of the receiver tower, as well as the construction and approximate weight of the receiver and other equipment mounted on the tower should be specified. Unusual design aspects of the receiver or tower should be described.

3.4 RECEIVER HEAT TRANSFER AND TRANSPORT SYSTEMS

For distributed systems, the method of heat transfer at the collector should be specified, e.g., heat pipe, and the fluid in the heat transport system specified, e.g., water, steam. A layout of the collector array and heat transport system should be provided. Modular arrays or unusual features should be described so that the proposed layout may be adapted to conform with site topography. It should be stated whether the heat transport system includes buried piping.

For central receiver systems, the method of heat transfer at the receiver should be described and the design and weight of the receiver specified. A layout of the piping configuration within the central tower and on the ground should be provided.

The location and design of major heat exchange equipment, e.g., steam generators, should be specified in the case of both distributed and central receiver systems.

3.5 PRIME MOVER

The working fluid and turbine size should be specified. The expected turbine (blade) efficiency and cycle efficiency should be given for peak load conditions. Turbine mounting and foundation requirements should be given.

3.6 HEAT REJECTION SYSTEM

The proposed method for dissipating rejected heat must be specified, e.g., wet or dry cooling towers, cooling lake, or river cooling. For the proposed plant, the penalties (e.g., heat-rate or efficiency) associated with alternate cooling systems should be stated. If the heat rejection system uses evaporative cooling, both peak and average makeup water requirements must be specified to determine water storage requirements. The approximate size of cooling towers, lake acreages, and other heat rejection system requirements must be stated. Sufficient information to establish the total land area must be specified.

3.7 ENERGY STORAGE REQUIREMENTS

The method of storing energy should be described, if storage is contemplated. The size and depth of excavations should be specified, as should soil, foundation or geological formation requirements.

3.8 LAND AREA REQUIREMENTS

The total land area required is determined primarily by the size of the distributed collector or heliostat field. Area requirements for heat transport, prime mover, heat rejection, and general plant services will normally be quite small compared to that required for the collector/heliostat field. To select a site it is generally sufficient to specify the field area requirement, unless cooling lakes or large cooling tower systems are required.

If necessary, this area may be closely approximated with the following information:

Q_s = Solar insolation (either peak or average) in kw/unit area

$W(e)$ = Plant capacity (either peak or average corresponding to the choice of Q_s) in kw(e)

η = Total plant efficiency (the product of collector/receiver, turbine, and cycle efficiency)

χ = Ratio of collector area to total occupied land area (ground cover ratio)

The total land area requirement is then

$$A_T = \frac{W(e)}{Q_s \eta \chi} ,$$

where the units depend on those used to express Q_s.

3.9 TOTAL WATER REQUIREMENTS

Water requirements of the plant, both peak and average for a 24-hour period, should be enumerated and totaled.

SECTION IV
SITE SELECTION PROCEDURES

Site selection is a process of evaluation of alternatives. At the outset, a siting region must be identified. Within the region, potential sites are selected and screened against certain general criteria to identify candidate sites. A relative evaluation of the technical, environmental and economic considerations for each candidate permits final site selection.

For this guide, the following overview is sufficient to illustrate these procedures. (An example application of the procedures is given in Appendix A.)

4.1 IDENTIFICATION OF GENERAL SITING REGION

4.1.1 Establish criteria
(Utility service area, boundary values of insolation)

4.1.2 Identify general siting region

4.2 SELECTION OF CANDIDATE SITES WITHIN THE REGION

4.2.1 Establish general screening and selection criteria
(Include plant description and requirements.)

4.2.2 Select candidate sites

4.3 EVALUATION AND COMPARISON OF CANDIDATE SITES

4.3.1 Establish specific evaluation criteria

(Breakdown of selection criteria into engineering, environmental and economic criteria.)

4.3.2 Evaluate and compare candidate sites

4.4 FINAL SITE SELECTION

4.4.1 Select top 2-3 candidate sites

4.4.2 Perform on-site inspection and data gathering

4.4.3 Identify intangible considerations

4.4.4 Select final site on basis of judgment of power plant owner, architect-engineer, and other consultants as required

SECTION V
SITING CRITERIA

The site selection procedures outlined in Section IV require establishing criteria for each step. This section defines these criteria. They are major siting criteria (for identifying siting regions), general selection/screening criteria (for choosing candidate sites), and evaluation criteria (for final site selection).

5.1 MAJOR SITING CRITERIA

There are two major site selection criteria: (1) high insolation, and (2) favorable meteorological conditions, e.g., minimal sky cover. These criteria are unique to solar/electric power plants and control the selection of a general siting region, consistent with the requirements of the utility service area and proximity to load centers (see subsection 5.3.1.6). The major siting criteria are in some respects analogous to fuel supply requirements of a conventional fossil fuel steam-electric generating plant.

5.1.1 Insolation

Solar energy striking the surface of the earth consists of direct and diffuse (scattered) radiation. Solar collectors which employ focussing to achieve energy concentration and heliostats which redirect sunlight use only direct radiation. Nonfocussing collectors, such as the flat plate, use both direct and diffuse radiation. Therefore, the collector system specified in subsection 3.2 determines which radiation component(s) are of interest. Having determined this, the insolation criterion is:

- Total annual insolation should be the maximum, consistent with other siting requirements.

Insolation is the most important site selection criterion. For a given plant generating capacity in kilowatt-hours per year, total plant cost is inversely proportional to the mean annual insolation. The higher the insolation, the lower the capital cost of the plant (see Section 5.3.1 for more detail).

5.1.2 Meteorological Conditions

The major meteorological criterion is:

- Meteorological records should demonstrate minimal insolation interruptions by clouds, fog, rain, or blowing dust and sand.

To meet this criterion, siting regions generally should be selected for which the mean sky cover, the number of days with thunderstorms and heavy fog, the wind speed, and total precipitation in the form of rain, snow and ice are all minimal.

The important meteorological information which should be gathered for each potential siting region is described in Table 1.

5.2 GENERAL SELECTION/SCREENING CRITERIA

Candidate sites within the siting region are selected and screened against a set of general criteria. (Note: The general selection/screening criteria introduced here are used again in much greater detail to evaluate the candidate sites in Subsection 5.3).

Table 1. Important Meteorological Information

Temperature:	Normal daily maximum Normal daily minimum Normal monthly Record high Record low
Precipitation:	Normal annual total Monthly maximum 24-Hr. maximum Snow: Mean total Monthly maximum 24-Hr. maximum
Humidity:	Hourly measurements
Wind:	Mean speed, prevailing direction Fastest speed, direction
Mean Sky Cover:	Expressed in tenths
Mean Number of Days With:	Thunderstorms Fog Temperature ≤32°F

5.2.1 Land Area and Topography

The land area criterion is straightforward.

- Candidate sites must satisfy the land area requirements for the proposed plant (see Subsection 3.8).

The topography of the land is important and must be compatible with plant requirements. Two general topographic criteria which may be used for candidate site selection and screening are:

- Avoid shading by ridges adjacent to site.
- Seek relatively flat areas with good drainage. Slopes which face south are acceptable, especially for central receiver system configurations.

5.2.2 Land Use

Land use planning is becoming increasingly an activity of governmental units, and candidate site selection must recognize existing land-use requirements. These requirements may be expressed as part of comprehensive land-use planning studies, or simply as zoning requirements. It is likely that the solar-electric power plant siting regions will fall within unincorporated areas not subject to existing local land-use regulations.

While Federal land-use planning does not presently exist, it is receiving the attention of the United States Congress. Site selection may, therefore, be subject to Federal land use planning. More specifically, the United States Congress has given increasing consideration to specific legislation dealing with power plant site selection. Although Federal power plant site selection statutes do not presently exist, solar thermal electric generating station siting may well be subject to such legislation in the future.

A general land-use criterion may therefore be stated:

- Candidate site selection must satisfy existing local, state, and Federal land-use statutes.

More specific land use criteria which are useful in the selection/screening stage are:

- Avoid urban areas, agriculturally productive areas, commercial and industrial activities including subsurface natural resources recovery.
- Avoid national, state, and local parks, American Indian land, wilderness areas, wildlife reserves and sanctuaries.
- Avoid proximity to airports and flight corridors.

5.2.3 Soils/Geology

For purposes of candidate site selection and screening, two general soils/geology criteria may be stated:

- Avoid dry lake playas, depressions, and areas of uncompacted sand and sand dunes.
- Avoid areas containing active seismic faults.

5.2.4 Water

The general water criterion is straightforward:

- Water supply (or feasible diversions) must meet the total plant requirements (see Section 3.9).

Recognizing that water is transportable, the water requirement is not as rigid as, for example, the requirement for land area. However, the site must permit means of delivering water. Such means may include pipelines, canals or other mechanisms.

Solar/electric power plant siting must also consider the question of water rights. The geographic regions of the United States best suited for siting lie generally in the southwestern United States where water is a valuable resource. Consequently, water is subject to strict controls in these regions. Prior allocations of water rights may eliminate suitable sources. Controversy regarding water appropriation rights could subject a solar/electric plant to operating delays. Therefore, it is essential that these rights be clearly established to avoid potential controversy.

5.2.5 Transportation Access

Construction of a solar/electric power plant will require the movement of man, materials, and equipment. Therefore, site accessibility by either highway or rail is essential. In the absence of suitable, existing access routes, new highway or spur rail line construction may be considered.

The general criterion for transportation access can therefore be stated:

- Access to the candidate site by paved highway or railroad should be possible with a minimum of secondary road improvement or spur line construction.

5.2.6 Electric Transmission

Transmission line facilities are essential for delivering electricity to the ultimate consumer. The site selection process should consider to some extent the availability of existing transmission facilities. However, the usefulness of existing transmission lines is largely dependent upon their capacity, and the size of the proposed solar/electric power plant may seriously limit their usefulness. In the absence of adequate transmission lines, the site selection may involve constructing new transmission lines leading either to a transmission substation or to the load center.

The general criterion for electric transmission may be stated:

- The location of a candidate site should minimize the construction of new transmission lines consistent with other siting constraints.

5.3 Evaluation Criteria

Final site selection requires evaluating all candidate sites in relation to detailed evaluation criteria. These criteria are all related to the general selection/screening criteria, but are more specific. The evaluation criteria are divided into three categories: engineering criteria; environmental criteria; and economic criteria. Systematically applying these criteria, as discussed below, permits an orderly evaluation of candidate sites.

5.3.1 Engineering Criteria

The major engineering factors are local insolation/meteorology, topography, soils/geology, water supply, road and railroad access, and electric transmission.

5.3.1.1 Local Insolation/Meteorology--Local insolation and meteorology are closely related, e.g., morning fog, afternoon thunderstorms, and inversion layers all reduce the available insolation. A complete evaluation of candidate sites requires local insolation and meteorological data. (Appendix C briefly describes the equipment necessary for obtaining these records.)

Accurate daily insolation records for a candidate site are important. Consider two candidate sites, the first having annual insolation of L_1 and the second L_2 where $L_1 > L_2$. Greater land area, a larger number of solar collectors/heliostats, and a larger turbine-generator capacity are required at the second site to generate the same number of kilowatt-hours per year as at the first site. Thus, total plant costs will be greater at the second site. The ratio of total plant costs, in terms of L_1 and L_2, is given approximately by:

$$\frac{C_2}{C_1} = \frac{L_1}{L_2} ,$$

provided L_1 and L_2 are not greatly different ($L_1/L_2 \lesssim 1.2$).

From this relation, each percentage point change in insolation increases or decreases total plant costs by an equal percentage.

The evaluation criterion for insolation is:

- Sites having the highest total annual insolation are strongly preferred.

Local meteorology, in addition to its direct influence on insolation, also determines (1) the frequency and intensity of blowing dust and sand which may degrade collector/heliostat reflecting surfaces, (2) the ambient temperature and humidity effects on thermal cycle efficiency, and (3) the frequency of severe weather such as hail, tornadoes, and flash flooding, all of which are detrimental to plant operation.

The evaluation criteria for meteorology are:

- The frequency of wind speeds sufficient to lift soil particles should be minimum.
- The frequency of high dry-bulb and wet-bulb temperatures should be minimum.

- The annual number of days with thunderstorms, hail, and precipitation exceeding 2 inches should be minimum.
- Precipitation as snow or ice should be minimum.

5.3.1.2 Topography--Topographic features may affect collecting and concentrating solar radiation, site preparation, drainage, and extended piping networks. The important topographic criteria are:

- Relatively flat areas are most acceptable because of collector layout flexibility, minimal shadowing, and minimal site preparation. Some slope is desirable, however, for drainage.
- South-facing slopes are acceptable because they may be used to compensate partially for the declination of the sun. The most favorable inclination of the slope will depend on the particular collector system configuration.
- Shading by ridges located south, east, or west of the site must be avoided.
- Topography should not require relocation of major natural drainage courses.

5.3.1.3 Soils/Geology--Soil properties such as particle size, consolidation, heaving capacity, and settlement should be determined.

The basic geologic formations should be identified within the site area and a description of stratigraphy within the formations prepared. The seismic activity and location of faults in the area should be identified.

Evaluation criteria are:

- Soil and geology of the site should be adequate for special structures such as reservoirs, cooling lakes, and turbine foundations.
- Fine, uncompacted sand should be avoided.
- Shifting sand dunes should be avoided.
- Areas of high seismic activity should be avoided.

5.3.1.4 Water Supply--The condenser cooling system must be specified and water requirements determined prior to evaluation of water supply sources (see Subsections 3.6 and 3.9). The plant's water requirements are primarily for cooling systems makeup and the plant's service water. The average annual water requirements for a 1,000,000 KW(e) solar power (steam) plant using evaporative (wet) cooling towers in the southwestern United States would be approximately 7,000 gallons per minute. In general, water requirements are directly proportional to the installed generating capacity.

Alternate water supply systems may be evaluated considering the following factors:

1. Quantity of surface water available
2. Quantity of ground water available
3. The quality of the supply
4. Present and projected uses of the proposed water supply
5. Stability of a sustained yield based on a statistical analysis of historical or simulated low flows and/or pump tests for ground water aquifer evaluation
6. Cost to import water as a function of transmission distance

7. Pumping requirements

8. Storage capability

9. The effects of ground water pumpage on aquifer drawdown or surface water withdrawal on low flows

Having determined the best water supply system, the evaluation criterion is:

- The water supply should be adequate to meet the design water requirements of the plant with water of adequate quality.

5.3.1.5 Road and Railroad Access--Transportation access to the solar plant site is required for construction, operation and maintenance. An economic evaluation of transportation alternatives and plant requirements will determine whether rail or highway transportation is appropriate.

Evaluation criteria are:

- Access to the site by highway or railroad should be possible with a minimum of secondary road improvement or spur rail construction.
- The site should be some distance from highly traveled public roads to avoid particulate matter settling on the collectors/ heliostats.

5.3.1.6--Electric Transmission--An important factor in selecting a solar plant site is the proximity of main electric transmission lines, substations and load centers. Candidate sites may be evaluated according to the following criteria:

- Sites for solar/electric plants of 300,000 KW(e) or larger should emphasize the proximity of load centers rather than existing transmission facilities.
- Sites for smaller plants should emphasize proximity to existing transmission facilities.

5.3.2 Environmental Criteria

The major siting criteria (high insolation and favorable meteorological conditions) constrain the candidate site locations for solar/electric plants to areas of relatively low population in the Southwestern United States. These same constraints favor regions of desert biome, which have generally uniform ecological characteristics. These conditions contrast with those associated with siting conventional fossil or nuclear fuel power plants, where high population densities and diverse ecological aspects can raise difficult environmental problems. For these reasons, environmental considerations are not expected to establish significant siting limitations for solar power plants. Nevertheless, the site selection analysis must recognize various environmental criteria.

Generalized environmental criteria for evaluating candidate sites are described in the following paragraphs.

5.3.2.1 Population --

1. Population Distribution -- Population is not a significant aspect of site analysis, since the favored siting regions are low in population. A general criterion can be stated as follows:

- Minimize the number of people displaced as a consequence of site selection.

2. Buffer Zones -- No specific criteria regarding buffer zones around a plant site are suggested. A general criterion can be stated as follows:

- Minimize the total population within 10 miles of the plant site.

5.3.2.2 Land Use--

1. Current Land Ownership--Specific site selection and evaluation must recognize existing land ownership.

In the favored siting region (Southwestern United States), the majority of the land is owned by the Federal government. This land is usually under the control of one of the following agencies: Bureau of Land Management; Department of Defense (Military Reservations); Bureau of Indian Affairs; or the National Park Service. The balance of the land is either privately owned or under control of the several states. Recognizing this ownership pattern, the following criteria are suggested for site selection:

- Bureau of Land Management land and private land offer the best potential for candidate sites.
- Military Reservations should be avoided unless specific communication with the commanding officer reveals a willingness on the part of the Department of Defense to cooperate.
- American Indian Land and National Park Service Land should be avoided (see 2 and 3 below).

2. Compatibility with Existing and Projected Uses--Land-use compabitility is an essential consideration. Specific criteria with regard to existing land use are:

- Avoid urban areas
- Avoid agriculturally productive areas
- Avoid or minimize effects upon highways, roads and railroads
- Avoid pipeline right-of-way

- Avoid American Indian land
- Avoid wildlife reserves and sanctuaries
- Avoid commercial and industrial activities

Criteria regarding projected land use are as follows:

- Avoid locations in areas of logical urban expansion
- Avoid areas suited to future agricultural development
- Avoid areas which overlie significant natural resources, such as oil and minerals

In some cases, the criteria stated above are merely recitals of factors inherent in the technical constraints on siting regions. For example, locations yielding the required combination of solar insolation and meteorology are generally not suited for agriculture. Similarly, urban development is not extensive in the most desirable solar plant siting regions.

3. Proximity to Recreational Facilities and Resources--Land used for recreation is inconsistent with solar plant siting. The following criteria are suggested:

- Avoid national, state and local parks
- Avoid wilderness areas
- Avoid sport fishing and hunting areas
- Avoid other known recreational areas

4. Proximity to Airports and Flight Corridors--The favored siting regions are within an area of military aircraft operations. No specific military criteria are presently known that might affect plant siting in relation to these aircraft operations. The following general criterion is suggested:

- Limit potential site locations to no nearer than about 20 miles from existing military airports

5.3.2.3 Water Use--As noted in Subsection 5.2.4, water rights in the regions favored for solar/electric power plants are carefully regulated. The potential for adverse effects resulting from plant water use should be eliminated by obtaining water rights for the plant.

In the absence of regulatory requirements, the following criteria are suggested:

- Avoid adverse effects upon surface water supplies
- Avoid adverse effects upon ground water supplies

There is the potential for effects upon recreational use of water resources; however, there are few water bodies in the favored siting regions that support recreational activities. The criteria for avoiding recreational areas (Subsection 5.3.2.2) should be applied to recreational water bodies.

5.3.2.4 Cultural and Aesthetic Features--Cultural and aesthetic features include historical and archaeological sites as well as scenic resources.

1. Involuntary Visual Impact--Aesthetic impacts are principally visual in character. A distinction is made between voluntary and involuntary visual impact. A solar plant will be of both scientific and general interest to the public. Such interest may prompt voluntary observation of the plant facilities. Involuntary visual impact is viewed as undesirable, and the following general criterion should be followed:

- Select site locations that will minimize significant casual, involuntary visual contact with the plant facilities.

2. Areas of Exceptional Scenic Value--In addition to avoiding general visual contact, truly scenic locations should also be avoided. Intrusion upon such areas can be minimized. The general criterion is as follows:

- Avoid site locations in areas of exceptional scenic value by site investigation.

3. Antiquities and Archaeology--The suggested criterion is:

- Avoid significant historical and archaeological sites. General application of this criterion is possible; however, specific site analysis is necessary.

5.3.2.5 Ecology--

1. Rare, Endangered, and Important Species--Impacts upon rare, endangered and important species have become an important siting consideration. The location of rare and endangered species must be determined by specific site investigations. The general presence in a region of such species may be known, but specific investigations at a site are essential. The suggested criterion is:

- Avoid areas of habitat known to support rare, endangered or important species.

2. Habitats--Wildlife habitat is a fundamental ecological consideration. A general criterion for site selection is as follows:

- Avoid destruction of significant wildlife habitat.

Application of this criterion requires site investigation.

5.3.3 Economic Considerations

The techniques for the economic evaluation of solar/electric power plant sites are no different than those normally used for evaluating conventional fossil or nuclear sites. In all cases, minimizing costs consistent with the technical requirements is the controlling criterion. Those items which contribute most significantly to the capital, operating and maintenance costs of a site are described in this subsection. Costs should be developed for each candidate site so that they may be compared.

5.3.3.1 Land--Land costs should be minimized consistent with satisfying the technical and environmental criteria. Because much of the land in Southwestern United States is owned or controlled by the Federal government, determining land acquisition costs may be difficult and require negotiations with the cognizant agency. Where possible, land acquisition costs should be determined for each candidate site.

5.3.3.2 Site Preparation--Site preparation costs include those for on-site inspection, surveying, soil boring and testing, excavation, and preconstruction and construction access.

5.3.3.3 Access Roads--Costs should be determined for developing new roads and/or the improvement of existing roads required for construction, operation and maintenance.

5.3.3.4 Water Supply--Determining the total water supply costs requires information on pumping, pipeline, intake, storage, treatment, and water rights.

5.3.3.5 Transmission Lines--The cost of adequate transmission lines assuming one line out of service, for loads varying between 100 to 1000 megawatts (by 100 megawatt increments) for varying distances are presented in Table 2.

Table 2. Cost - $ Millions (1973)

Load (MW)	10 Miles	20 Miles	50 Miles	100 Miles
100	1.7	2.9	6.5	12.5
200	1.7	2.9	7.4	16.2
300	2.0	3.4	8.5	16.2
400	2.3	3.9	8.5	18.7
500	2.3	3.9	8.5	18.7
600	2.3	3.9	10.0	18.7
700	3.1	4.8	10.0	18.7
800	3.1	4.8	10.0	28.1
900	3.1	4.8	10.0	28.1
1000	3.1	4.8	10.0	28.1

These costs do not include transformer capacity for the generating units, or switching gear and protective devices at distribution or terminal substations.

5.3.3.6 Engineering--Engineering costs may be considered essentially equal for all sites unless there are special features associated with a given candidate site (e.g., unusual topography, or a requirement for a water storage reservoir).

APPENDIX A

APPLICATION OF SITE SELECTION PROCEDURES AND CRITERIA TO THE SELECTION OF A SPECIFIC SITE

APPENDIX A

APPLICATION OF SITE SELECTION PROCEDURES AND CRITERIA TO THE SELECTION OF A SPECIFIC SITE

The procedures and criteria set forth in the main text of this guide form the basis for site selection and evaluation. As an aid to implementing the guide, this appendix describes an excercise which resulted in the recommendation of a specific site for a 1000 MW(e) solar/electric power plant.

PLANT REQUIREMENTS

A hypothetical plant with rather flexible requirements was assumed for this study.

Plant Capacity

Capacity was specified to be in the range 100-1000 MW(e). However, for purposes of land area, water, and other size-specific requirements, the upper figure of 1000 MW(e) was assumed.

Collector/Concentrator System Configuration

Both the distributed system and the central receiver system were considered in order to explore the problems of siting each concept. However, special site topography for the central receiver system was not specified.

Heat Transfer and Transport System

The heat transfer medium specified was water/steam. Whether the steam was generated at a collector or at a central point was not germane. A rectilinear array of collectors/heliostats was assumed. Piping from distributed collectors was to be above ground.

Prime Mover

Steam turbines in the size range 100-1000 MW(e) were specified. The distributed collector system used a saturated steam cycle operating at 985 psia/543°F throttle inlet conditions. For the central receiver, several prime movers were considered for their feasibility, and a steam cycle operating at 865 psia/900°F was chosen. (Note: Turbines operating at these conditions are not available above 200 MW(e). Larger plant sizes would consist of multiple units).

Heat Rejection System

Wet (evaporative) cooling towers were specified. Make-up water requirements were estimated at 7,000 gallons per minute for a 1000-MW(e) plant.

Energy Storage Requirements

No specific energy storage system was specified.

Land Area Requirements

Land area was 15-20 acres per megawatt (average) of electric power generated. For a base load plant which generates a daily average of 1000 MW(e) over a year, approximately 25 square miles is required. This figure was used to define the area requirement for site selection.

Total Water Requirements

Typical water requirements for a 1000 MW(e) generating plant operating at 0.5 capacity factor are:

	Peak gpm	Average gpm
Evaporative Cooling Make-up	13,700	7,000
Feed Water Make-up	200	100
General Service	200	100
Totals	14,100	7,200

IDENTIFICATION OF GENERAL SITING REGION

No particular utility service area was specified. The general siting region was therefore chosen to be that area of the United States having the highest, direct solar radiation. Figure A1 shows isopleths of direct solar radiation superimposed on a map of the continental United States. The area enclosed by the 350 Langley-per-day isopleth was chosen as the general siting region. The boundary of this region extends from the Arizona-Mexico border about

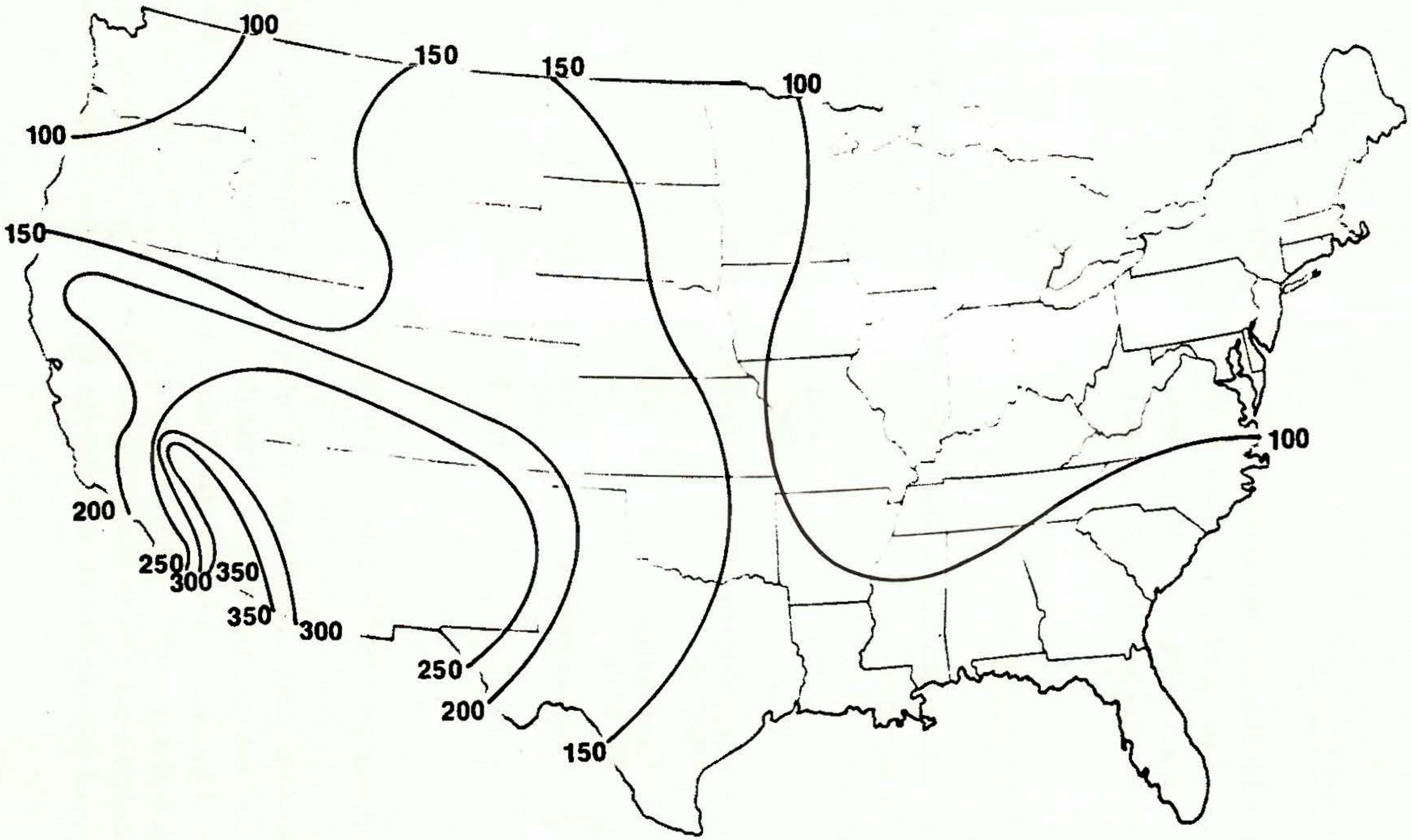

Figure A1. Isopleths of Mean Daily Direct Solar Radiation (Langleys)

100 miles east of Yuma in a northwesterly direction to the southern boundary of Death Valley National Monument. The boundary then circles to the southwest around Inyokern, California and extends southeast to the California-Mexico border near El Centro, California. A detailed map of the region is shown in Figure A2.

SELECTION OF CANDIDATE SITES

A map of Arizona, Nevada, and California with the scale of one inch = 8 miles was used to make an initial selection of acceptable siting areas within the general siting region. The applicable general selection/screening criteria were land area/topography and land use. These initial selections were then screened against the same two criteria by means of a closer inspection on U.S.G.S. 15-minute maps. The Cuddleback Lake area, the Bristol Lake area, and the Cadiz Lake area were rejected because of unsuitable topography. The region east of Yuma was rejected because the surrounding area is controlled by Luke Air Force Base and other military bases. The area west of Yuma was unsuitable because of shifting sand dunes. The area just west of Phoenix was rejected because of projected land use patterns and anticipated high land values. An Arizona site east of the Colorado River Indian Reservation did not offer any benefits greater than those of a site west of the river near Blythe, California. In addition, the Indian reservation lay between the potential Arizona site and available water sources.

Nine potential candidate sites satisfied the land area/topography and land-use criteria after inspection of the 15-minute maps. They were:

- Blythe (two alternate sites)
- Danby Lake (topography marginal for 1000 MW(e) distributed system)

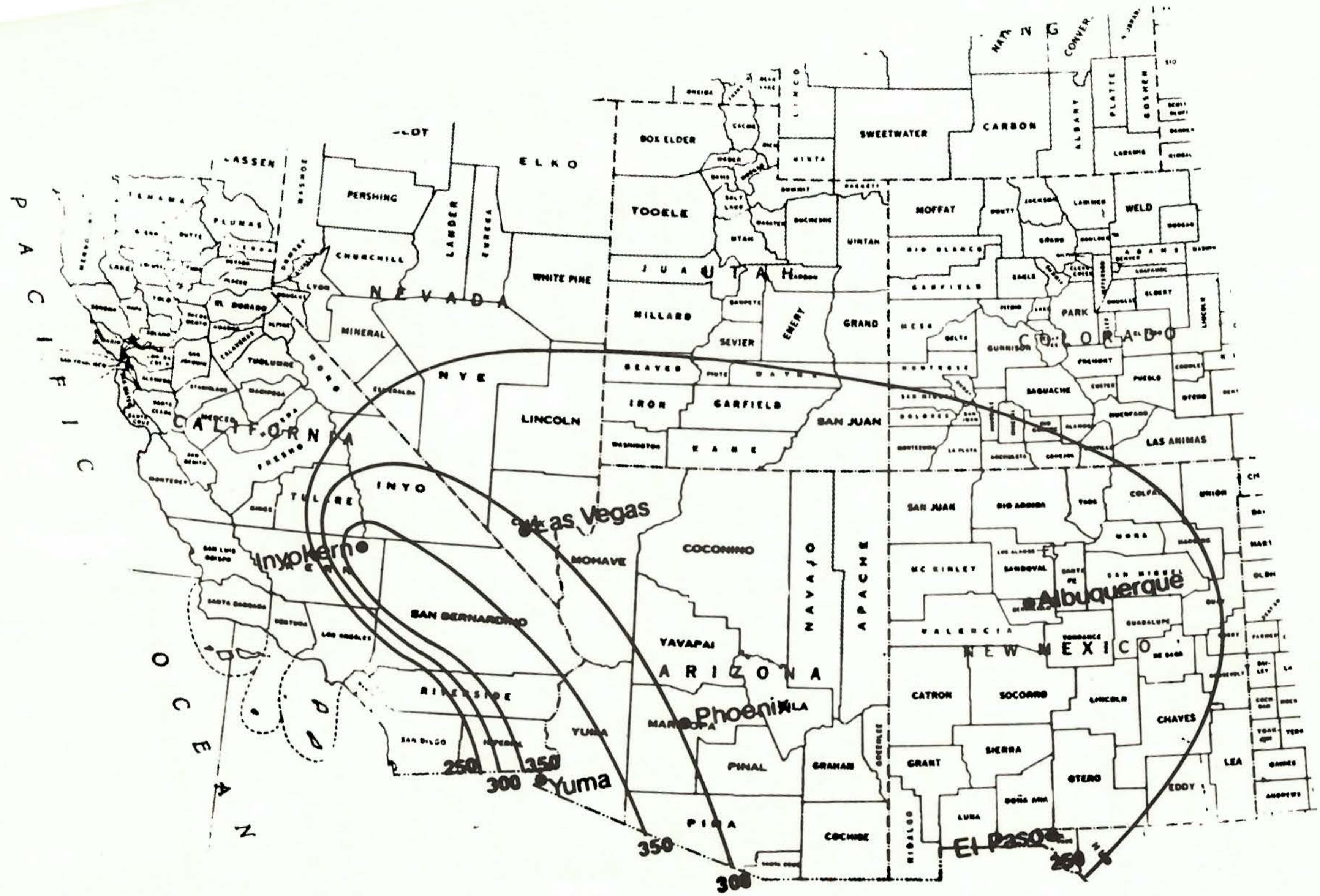

Figure A-2. Isopleths of Mean Daily Direct Solar Radiation in Basic Study Area

- Inyokern
- Inyokern South
- Manix
- Searles
- Soda Lake
- Superior Lake

The location of these areas is shown in Figure A3.

Of these nine, five met all of the general selection/screening criteria in varying degrees. The candidate sites were:

- Blythe (two alternate sites) - located approximately 15 miles and 25 miles west of Blythe, California
- Inyokern South - located approximately 6 miles southwest of Inyokern, California
- Manix - located approximately 10 miles northwest of Manix, California
- Searles - located approximately 20 miles due east of China Lake, California

Detailed topographic maps of each of the candidate sites are shown in Figures A4 through A8. The site boundaries are shown in heavy black lines.

The other four areas were eliminated for the following reasons:

Danby Lake: This site was considered unsuitable for a distributed system requiring an area of 25 square miles because the terrain

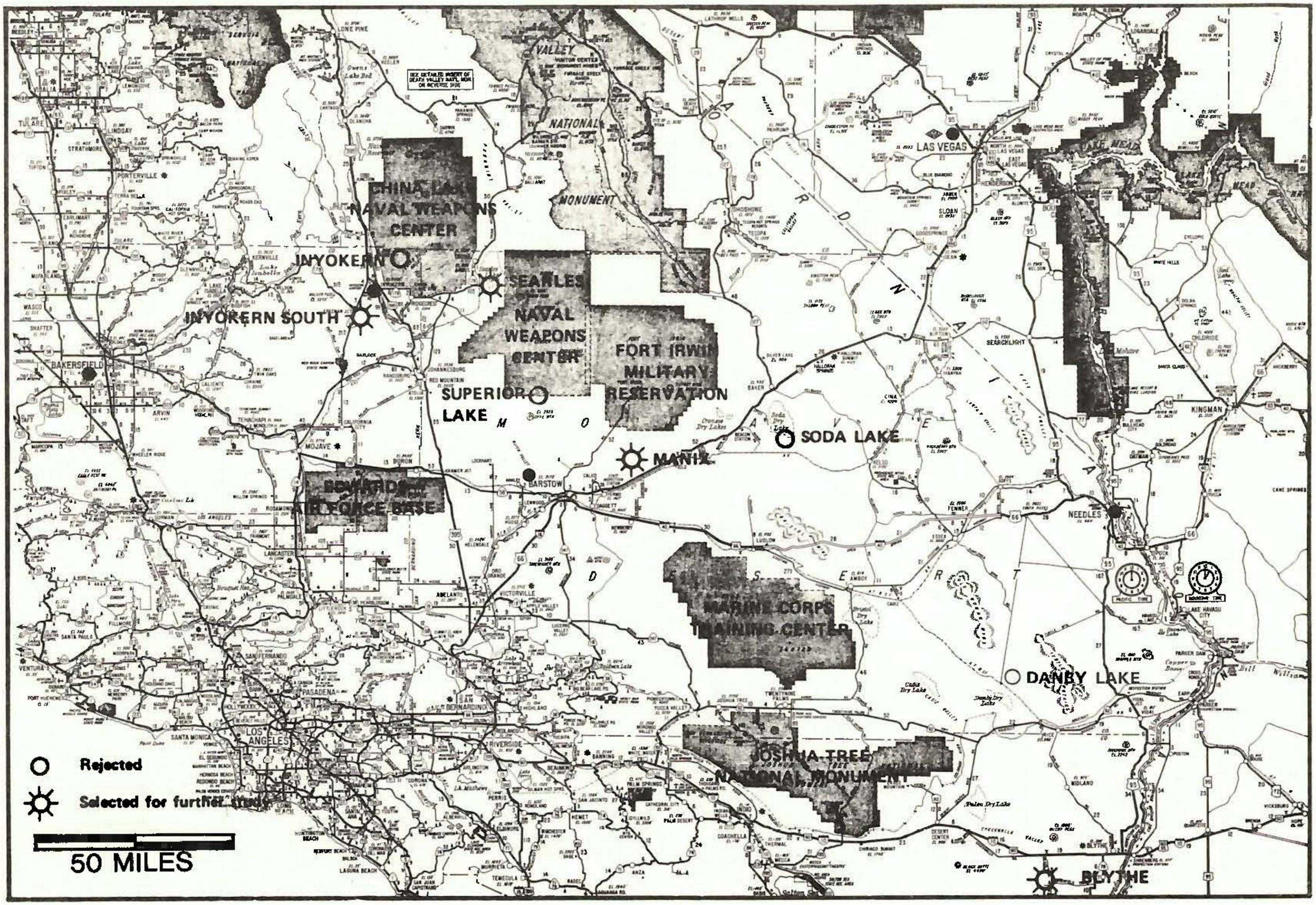

Figure A-3. Primary siting area

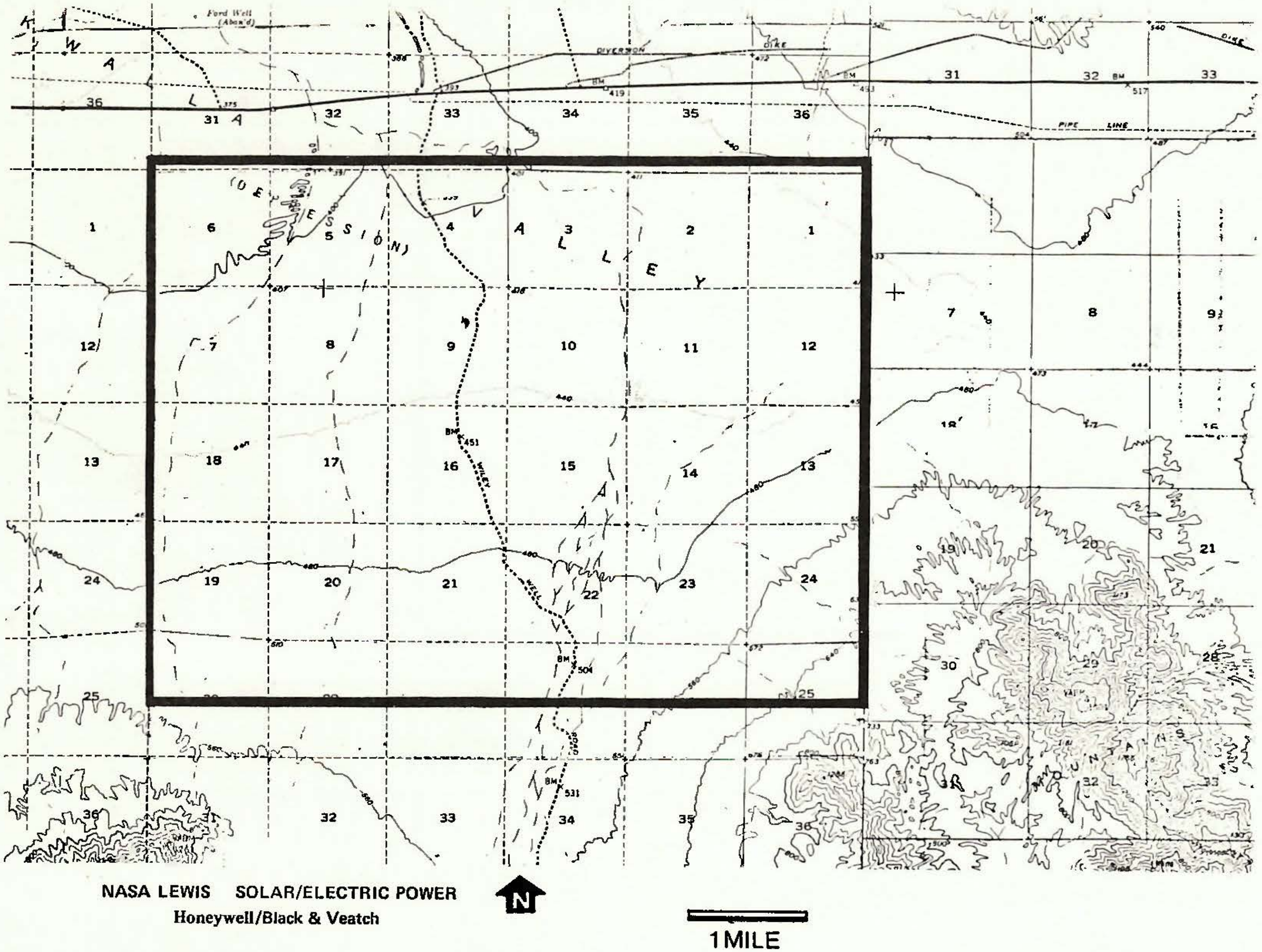

Figure A-4. Blythe South site

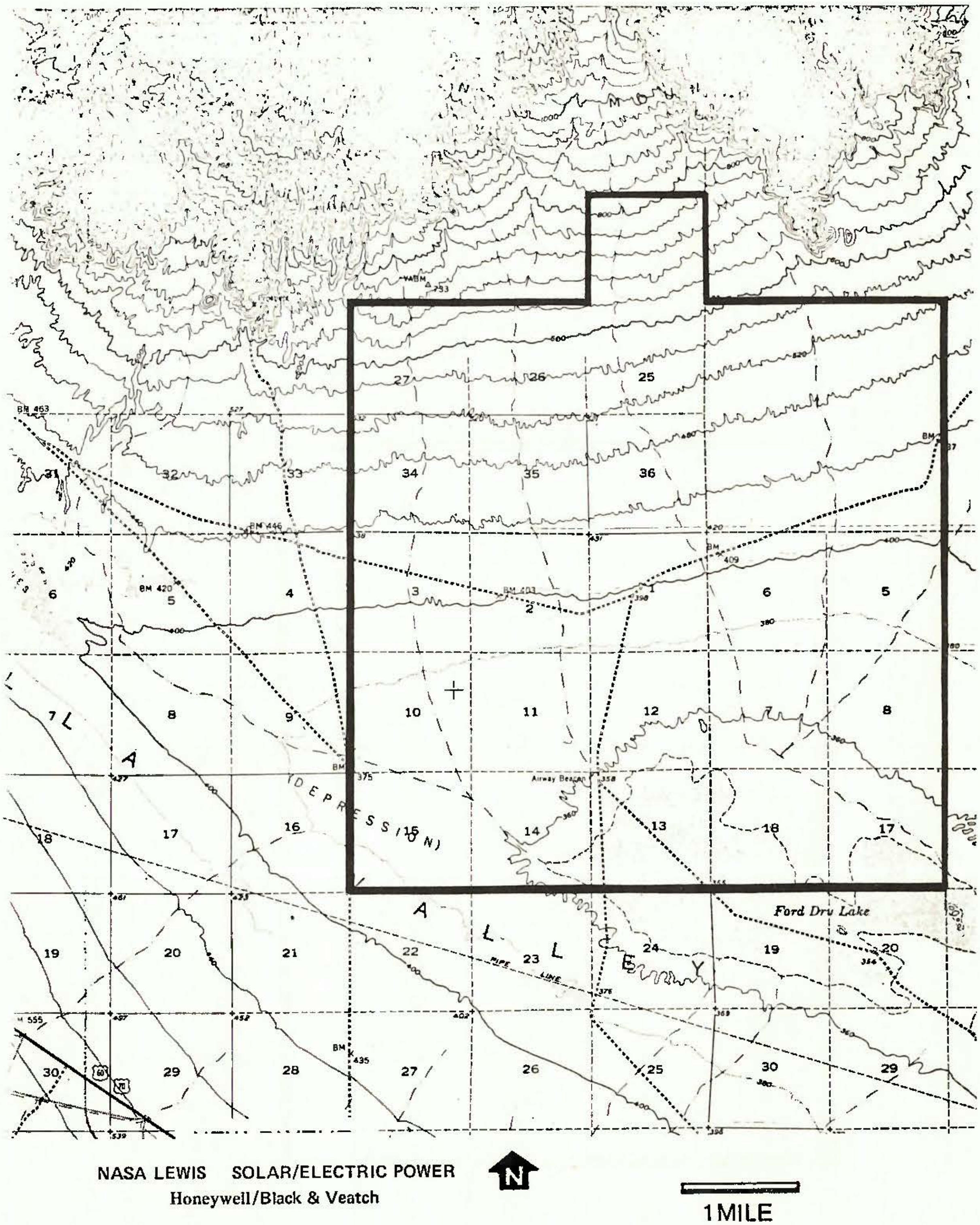

Figure A-5. Blythe North site

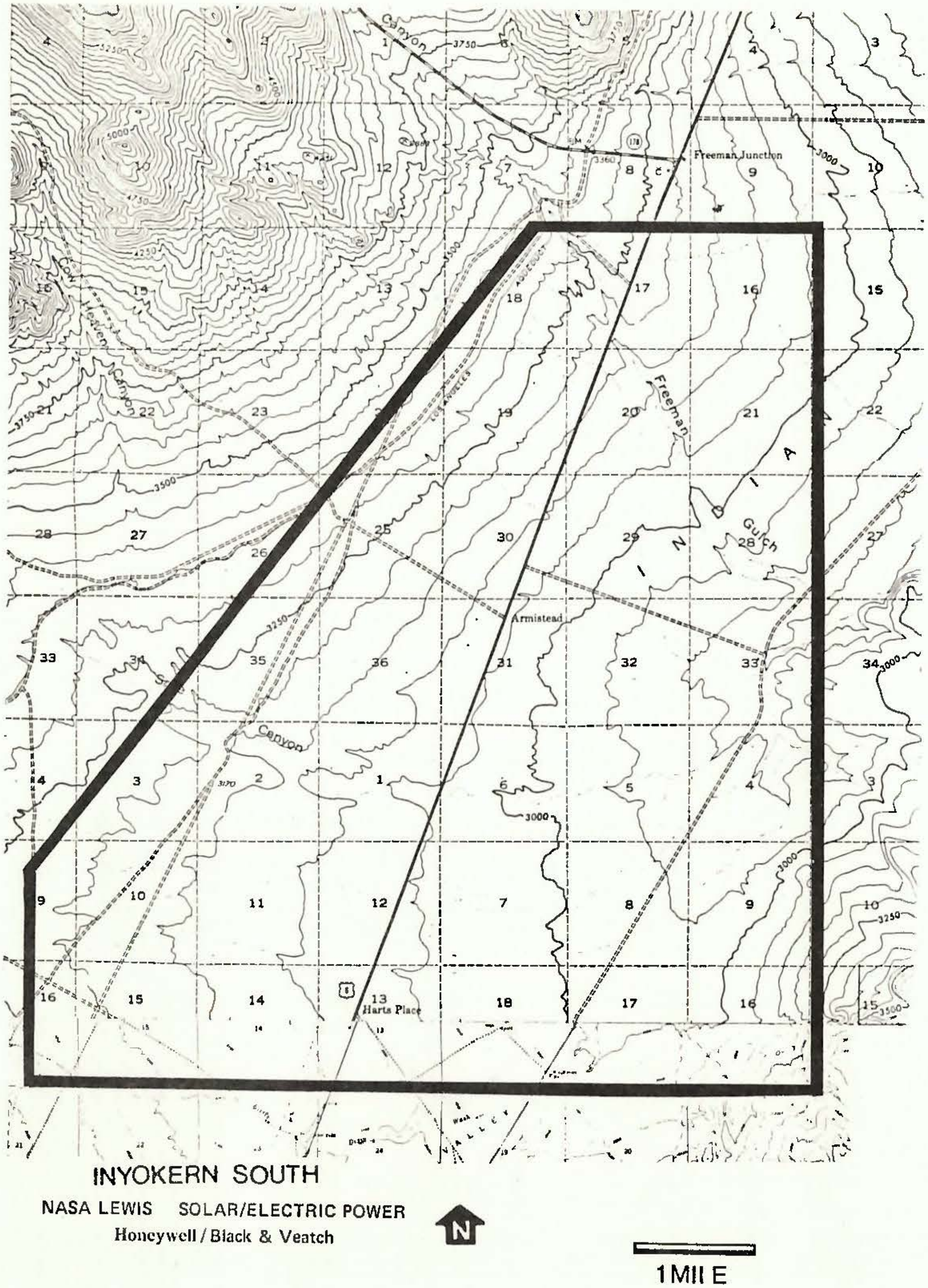

Figure A-6. Inyokern South site

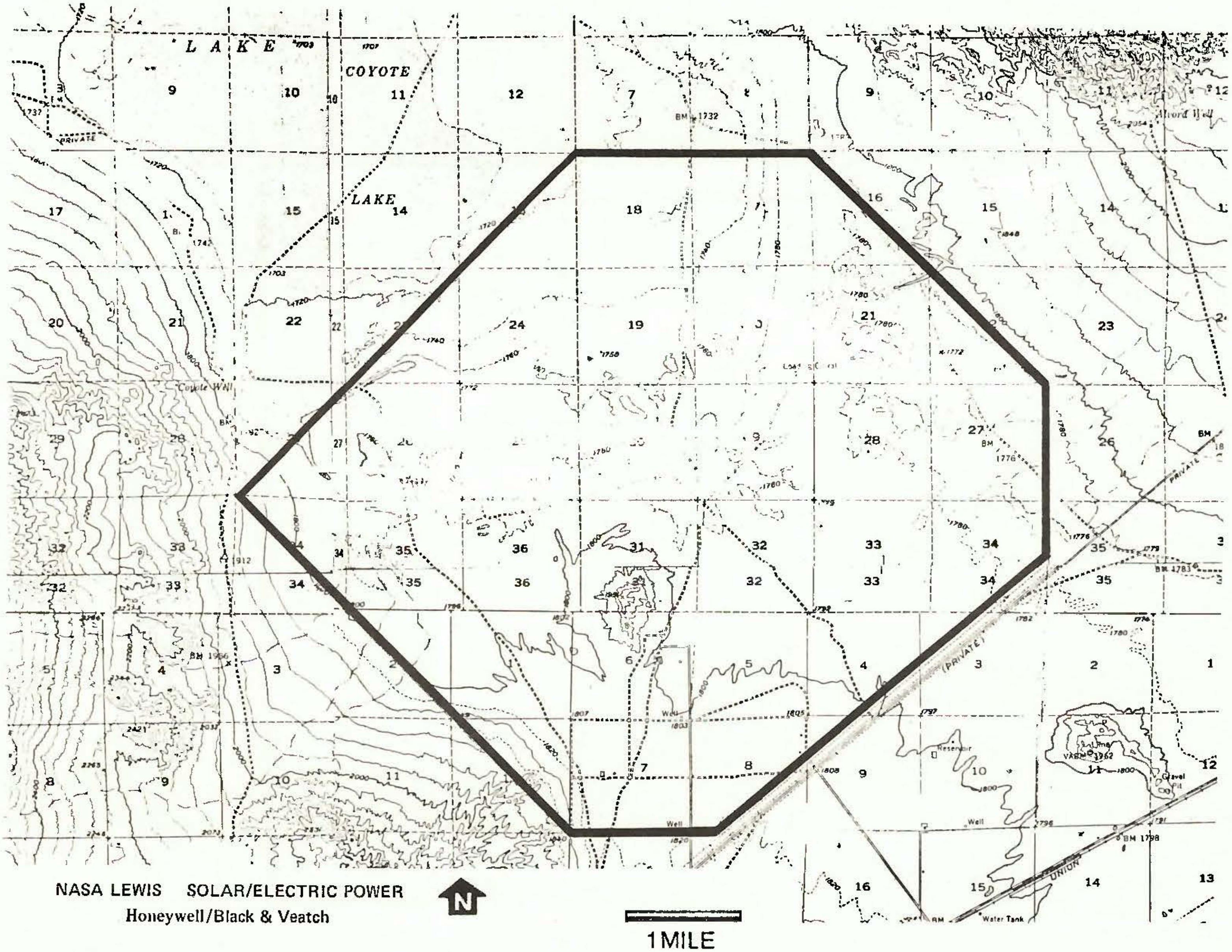

Figure A-7. Manix site

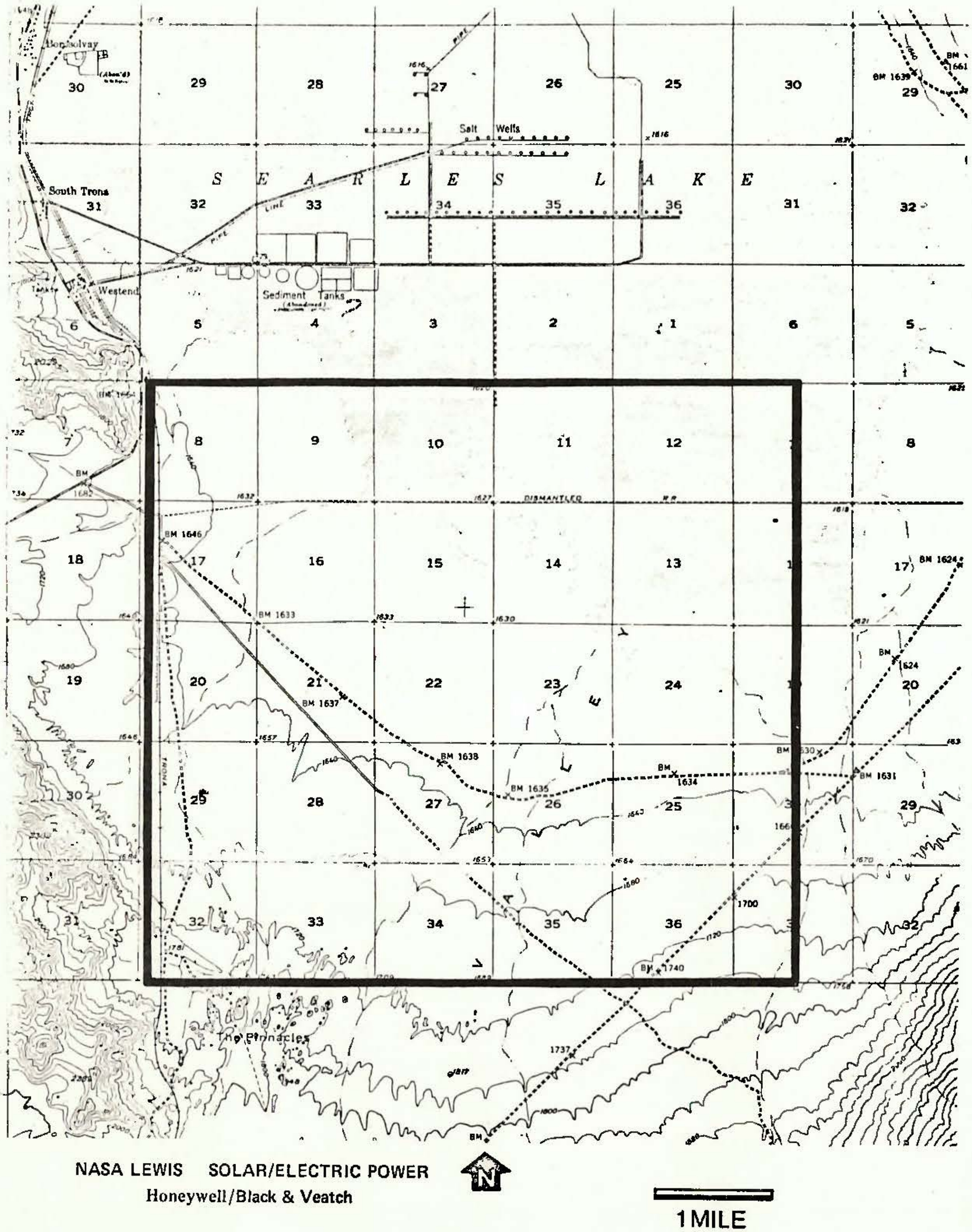

Figure A-8. Searles site

would require considerable site development for collector mounting and pipe routing. However, the site is quite suitable for a central receiver system, especially since it is located in a seismic zone 1. Water sources and railroad access are good.

Inyokern: The site is directly north of Armitage Air Field at China Lake Naval Weapons Center. It is anticipated that there would be interference by heavy air traffic.

Soda Lake: Water sources are very unfavorable.

Superior Lake: There is little possibility of ground water or of any water sources. It is farther from transmission lines than any of the five candidate sites.

EVALUATION AND COMPARISON OF CANDIDATE SITES

To evaluate and compare the candidate sites against the evaluation criteria listed in Subsection 5.3, available data were compiled and a description of each site written. Because make-up water sources is important in the arid regions of eastern California, an intensive effort was made to identify these sources for each candidate site. A detailed description of water sources is given below.

Following this description, the engineering, environmental, and economic evaluation of each site is summarized.

Water Sources

Ground water sources in the general siting region are totally inadequate to meet the plant's water requirements. Therefore, attention was directed to primary surface water sources. The locations of the candidate sites with respect to these sources are shown in Figure A9. The Searles and Inyokern South sites would require a diversion of water from the Los Angeles Aqueduct. The Manix site would require water from the Mojave River, and the Blythe site would take water from the lower Colorado River. Detailed analyses of the water sources for each candidate site are given in Tables A1 through A4.

To supplement these analyses and prove feasibility of the proposed water sources, direct contacts were made with State and Regional offices of the California Department of Water Resources to determine availability, allocation procedures, and future plans for water for use by thermal power plants. This information is summarized in the following paragraphs:

Table A1. Source of Water: Inyokern South

1. Cooling Water Make-Up:	Displacement from Los Angeles Aqueduct contingent on replacement from the California State Water Plan (California Aqueduct) near Buttes Reservoir or Fairmont Reservoir, if feasible.
2. Peaking Requirements:	Los Angeles Aqueduct ground-water supplement.
3. Plant Service Water:	Ground-water
4. Current Aqueduct Usage:	Transport to metropolitan water district in Los Angeles.
5. Current Ground-Water Usage:	China Lake Naval Weapons Center, agricultural and small industrial export.
6. Projected Usage:	Same as current usage.
7. Future Stability of Water Supply:	
Surface Water:	Stable for a large displacement from the Los Angeles Aqueduct if an allocation is obtainable.
Ground-Water:	Stable for small pumpage for service water.

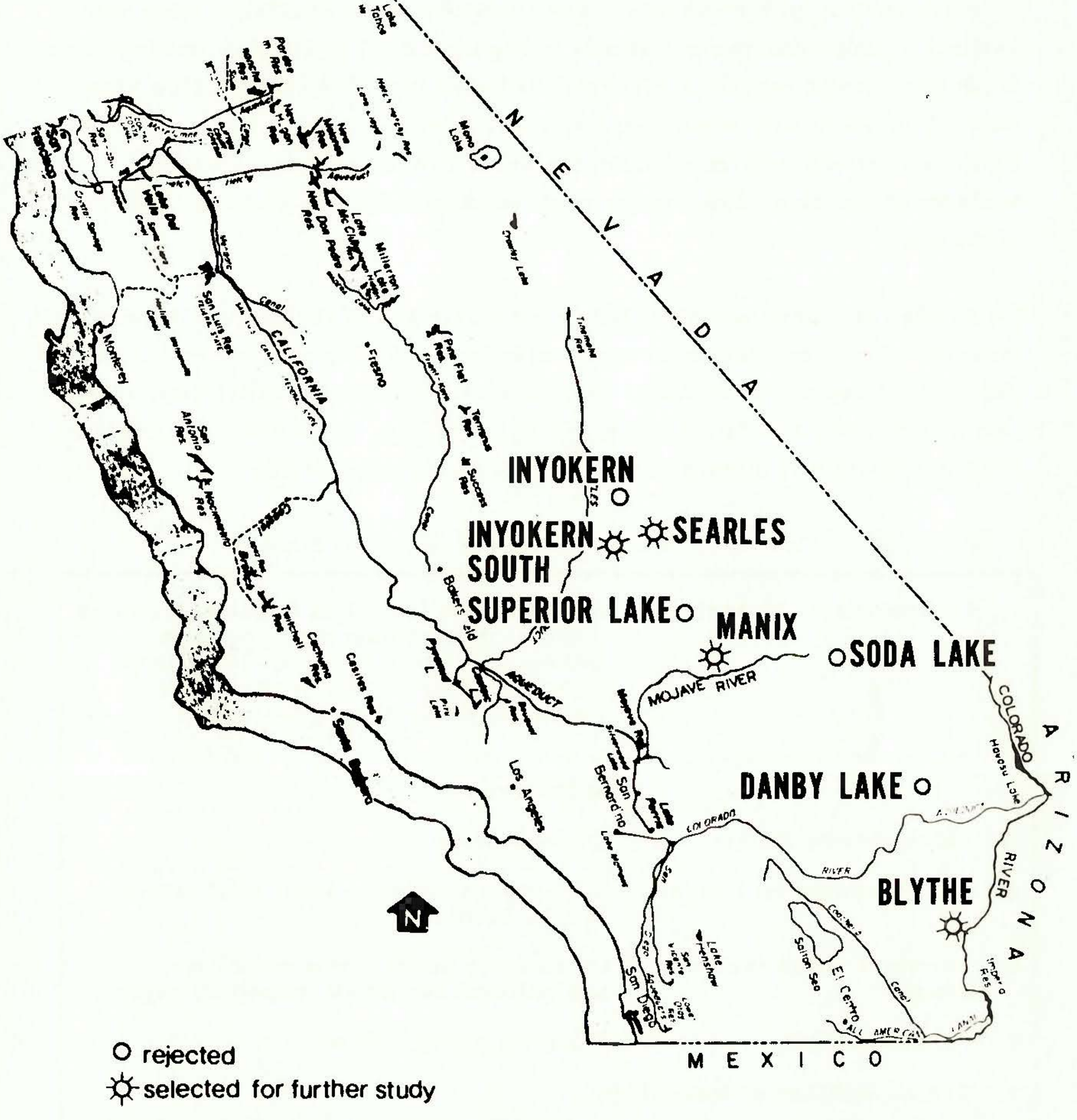

Figure A-9. Surface Water Resources
Southern California

Table A2. Source of Water: Searles

1.	Cooling Water Make-Up:	Displacement from Los Angeles Aqueduct contingent on replacement from the California State Water Plan (California Aqueduct) near Buttes Reservoir or Fairmont Reservoir, if feasible.
2.	Peaking Requirements:	Los Angeles Aqueduct ground-water supplement.
3.	Plant Service Water:	Ground-water.
4.	Current Aqueduct Usage:	Transport to metropolitan water district in Los Angeles.
5.	Current Ground-Water Usage:	Potash mining. Residential.
6.	Projected Usage:	Same as current usage.
7.	Future Stability of Water Supply:	
	Surface Water:	Stable for a large displacement from the Los Angeles Aqueduct if an allocation is obtainable.
	Ground Water:	Stable for small pumpage for service water.

Table A3. Source of Water: Manix

1.	Cooling Water Make-Up:	Inadequate surface and/or ground-water for wet tower operation. Adequate ground-water for dry tower operation.
2.	Plant Service Water:	Ground-water.
3.	Current Usage:	Small-scale urban; small-scale agriculture.
4.	Projected Usage:	Small-scale urban; agriculture and industry.
5.	Future Stability of Water Supply:	
	Surface Water:	Inadequate for large diversion for wet tower operation.
	Ground-Water:	Stable for dry tower operation.

Table A4. Source of Water: Blythe (Both Sites)

1. Cooling Water Make-Up:	Colorado River Diversion
2. Peaking Requirements:	Colorado River Diversion
3. Plant Service Water:	Colorado River Diversion
4. Current Usage:	Agriculture and urban
5. Projected Usage:	Agriculture, urban, and power plant supply.
6. Future Stability of Water Supply:	
Surface Water:	Colorado River is stable for a large diversion if obtained.
Ground-Water:	No current data on ground-water pumpage.

Feasibility of Proposed Water Diversions -- Diversion of water from the Los Angeles Aqueduct at Inyokern with subsequent replacement from the California Aqueduct near Fairmont Reservoir, Antelope Valley, is feasible provided all parties agree on a suitable contract. The City of Los Angeles, Department of Water and Power (owner of the Los Angeles Aqueduct), and the California Department of Water Resources (owner of the California Aqueduct) have discussed an interconnection near Fairmont Reservoir to exchange water in an emergency. However, there are no plans for such a connection at this time. California aqueduct water is similar in quality to that in the Los Angeles Aqueduct (200-300 ppm, total dissolved solids), so water quality presents no barrier to such an exchange. Exchange contracts of the type we propose do exist along the Colorato River Aqueduct, so legal precedent exists.

The procedure to achieve an exchange contract would be as follows:

(1) First contact should be made with the Chief Engineer, Los Angeles Water and Power.

(2) Subsequent contacts would then be made through the Chief Engineer with the Metropolitan Water District of Los Angeles and with the Metropolitan Water District of Southern California, of which the Metropolitan Water District of Los Angeles is one of twelve members.

(3) The State Department of Water Resources would review any proposal of exchange between the owner of a solar/electric power plant and these sub-agencies with regard to its impact on scheduling the California water systems.

The Metropolitan Water District of Southern California and the City of Los Angeles have proposed that 100,000 acre-feet of water per year be allocated from the Colorado River Aqueduct for use by four thermal power plants to be located in the Eastern California Desert. This proposal was made at the request of Southern California Edison and San Diego Gas and Electric. This proposal is subject to approval by the U.S. Department of the Interior.

Palo Verde irrigation waste water is a potential source of cooling water near Blythe. The water has a high salinity content: 3000-6000ppm.

Water Resources Planning in California -- Priorities in allocating water in California have not yet been addressed. Allocations are on a case-by-case basis. An excellent source of information on water resources planning for power plants and on siting in general is the report, "Energy Dilemma, California's 20 year Power Plant Siting Plan," issued by the State Resources Agency in June, 1973. The following points are relevant to this study:

- The 20-year plan projects the installation of 73,000 MW of new capacity from 1973 to 1991. Of this amount, about 55,000 MW will require cooling water in the amount of 1,100,000 acre-feet annually for wet cooling towers.

Adding this to the water requirements of municipalities, industries, and agriculture, the projected annual deficiency for 1990 is 2,170,000 acre-feet.

Therefore, development of additional water projects for conservation and transportation of surface water will be required.

- Because of serious ground water overdraft in many areas of the state, the report concludes that the use of ground water to meet future power plant cooling needs will create secondary environmental concerns equal to those of power plant siting, itself.

- A major shift to inland sites will intensify the need for additional fresh water. Because of the anticipated environmental and economic impact, the development of dry and wet/dry cooling systems is expected to accelerate.

Conclusions -- For the near term, cooling water for large thermal power plants located in the desert regions will be obtained by negotiated diversions from existing aqueducts, as proposed.* Irrigation waste water may be useful for smaller plants, provided water treatment is available to reduce the high salinity.

For the long term, dry or dry/wet cooling tower technology must be developed to mitigate anticipated cooling water demands. Alternatively, plant designs which do not require cooling towers should be developed, e.g., open-cycle gas turbines.

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*A 1000 MW solar/electric plant would require about 11,000 acre-feet of water per year.

California has implemented long-range plans for siting power plants and for allocating scarce water resources. If a solar power plant is to be built in the next decade, steps should be taken immediately to include it in the planning.

Engineering and Environmental Evaluation

A summary of the data gathered for evaluation and comparison of the candidate sites is given in Table A5. The amount of data and the degree of detail shown in Table A5 was limited by the scope and the time allotted to this particular exercise in site selection. A full-scale site selection study would address all of the evaluation criteria listed in Subsection 5.3.

Current land usage at each site was left blank in Table A5, but was determined by later on-site inspection (see page A23).

Table A5 shows that the Inyokern South site ranks the highest.

Economic Evaluation

Economic evaluations and comparisons of the candidate sites were made on a differential cost basis. The costs of land and site preparation were assumed equal for all sites. Cost estimates for constructing plant access roads and railroad spurs were made on the basis of \$74,000 per mile for roads and \$200,000 per mile for railroad.

The cost of transporting water was based on piping and pump costs of \$264,000 per mile.

Table A5. Engineering and Environmental Comparison of Sites

	Inyokern South	Searles	Manix	Blythe North/Blythe South (BN/BS)
1. Peak Total Insolation (Direct + Diffuse) Langleys	819	819	750	700
2. Mean Sky Cover	0.35	0.35	0.35	0.20
3. Topography (ft/mile - Direction of Rise)	150 -NW -SE	15-S	9-S	27-S (BS) 105-N (BN)
4. Transmission Distance to Nearest Major Load Center (Miles)	100	120	150	150 (BN) 160 (BS)
5. Water Supply (For Cooling Tower				
A. Ground Water	Inadequate	Inadequate	Inadequate	Inadequate
B. Surface Water	Potentially Adequate	Potentially Adequate	Inadequate	Potentially Adequate
C. Distance to Surface Water (Miles)	5	45	72	25 (BN) 15 (BS)
6. Plant Access				
A. Distance to Nearest Railroad (Miles)	4	0	6	20
B. Distance to Paved Road (Miles)	0	0	3	5 (BN) 1 (BS)
7. Land Use*	--	--	--	--
8. Land Ownership	BLM+	BLM	BLM	BLM
9. Population				
0-5 Miles	0	0	0	0
5-10 Miles	0	10,000	50	12,000
10-50 Miles	35,000	30,000	55,000	27,000

* Current land usage is presently undetermined for specific site areas.

+ BLM = Bureau of land management. Specific site areas may contain some private land.

The cost of constructing additional transmission lines for various sized plants was based on the figures given in Subsection 5. 3. 3. 5. A substation which would be required at Searles, was estimated to cost $380, 000.

The economic comparison of the five candidate sites is given in Table A6. Inyokern South is the most economic site.

FINAL SITE SELECTION

Selection of Top Candidates

In the particular exercise under discussion, the top three candidate sites were selected by a rating scheme which gave the heaviest weight to insolation, sky cover, and water supply. All other factors were given equal weight. The ratings of each site for each of nine different criteria are shown in Table A7, as determined from the previous engineering, environmental, and economic evaluation. Inyokern South is the top-rated site.

On-Site Inspection

A special trip was made to inspect, by air and ground, the Inyokern South and the Blythe sites. An aerial reconnaissance was also made of Searles Lake, the Fremont Valley (south of Inyokern South) and of the Manix site. Numerous photographs were taken from the air and on the ground to record such site-specific data as land topography, drainage patterns, soil conditions, atmospheric conditions, and typical flora.*

*A detailed, illustrated account of this inspection trip is given in the report, "On-site Survey of Candidate Solar/Electric Power Plant Sites," dated June 1974. Prepared by Honeywell, Inc. and Black & Veatch under Contract NAS3-18014, Report No. NASA CR-13468.

Table A6. Economic Comparison of Sites

Differential Costs	Inyokern South	Searles	Manix	Blythe
1. Transmission				
250 MW(e)	Base	$ 2,225,000	$ 3,415,000	$ 1,470,000
500 MW(e)	Base	Base	$ 9,300,000	$ 9,300,000
1000 MW(e)	Base	Base	$14,400,000	$14,400,000
2. Water Supply (1000 MW(e)	Base	$10,500,000	$17,700,000	$ 5,300,000
3. Plant Access	$148,000	Base	$ 1,400,000	$ 296,000
4. Cooling Cost	Base	Base	Base	Base
5. Site Preparation	Base	Base	Base	Base

Table A7. Rating of Candidate Sites

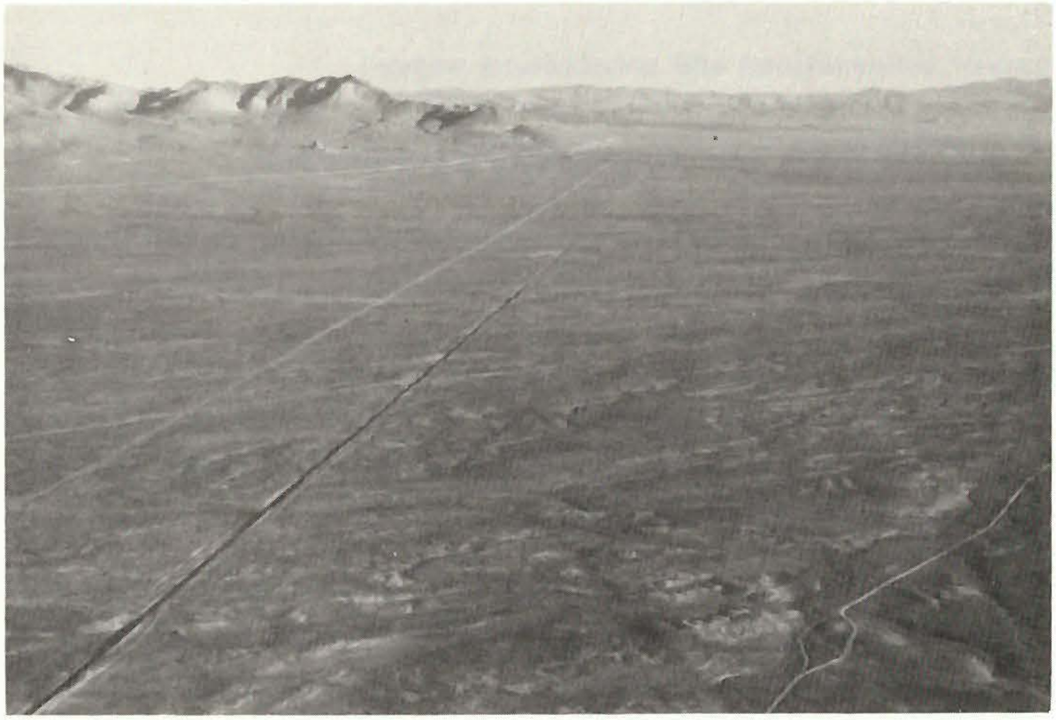
Item	Inyokern South	Searles	Manix	Blythe	Weight Factor
1. Insolation	1	1	2	3	0.25
2. Sky Cover	2	2	2	1	0.25
3. Topography	4	3	1	2	0.05
4. Transmission	1	2	4	3	0.05
5. Water Supply	1	3	4	2	0.25
6. Plant Access	2	1	4	3	0.05
7. Land Use	3	2	1	4	0.05
8. Land Ownership	--	--	--	--	--
9. Population Density	1	3	2	4	0.05
Weighted Average	1.55	2.05	2.60	2.30	
Rating	1	2	4	3	

The primary observations and conclusions were:

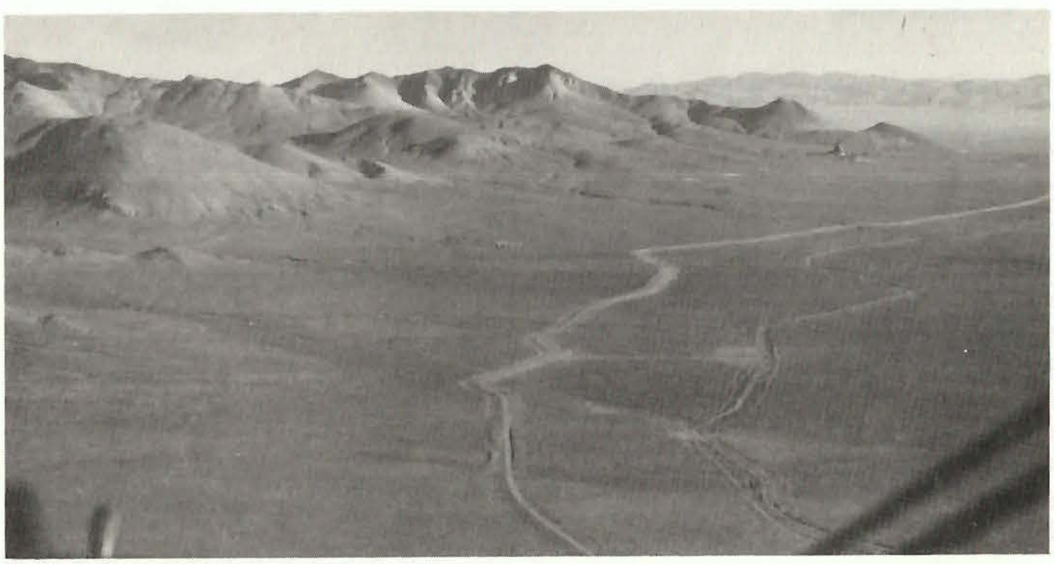
- Inyokern South was confirmed as the prime site.
- Searles Lake was rejected because of industrial development, stack plumes, inversion layers, and blowing alkali dust.
- The Blythe North site was rejected because of loose, unconsolidated fine sand, which occurs in a portion of the area, and severe drainage washes on the slope which comprises the northern half of the site.
- The Blythe South site was judged adequate. It would require less site development than Inyokern South, but soil conditions were not as good. Blowing sand could be a potential problem.
- The Manix site was judged adequate from aerial reconnaissance. However, water supply is inadequate for wet cooling towers at this site.
- The Fremont Valley which lies south of the Inyokern South site has areas suitable for siting, but agricultural development in the region would be a competing factor. Moreover, this valley lies outside of the 350 Langley contour and receives an estimated 250-300 Langleys per day of insolation averaged over the year.

Selection of Prime Site

Inyokern South is the prime site, based on office engineering analysis and on-site inspection. Figure A10 shows two aerial views of the site. Blythe South is the second-ranked site.



a) State Highway 14 cuts across site in above view



b) View shows two lines of Los Angeles Aqueduct

Figure A-10. Aerial Views of Inyokern South Site

The location of Inyokern South in a Seismic Zone III makes it somewhat less desirable for a central receiver configuration with its tall tower. Although reinforced concrete towers 700-800 feet tall can be built to withstand Zone III ground accelerations, the cost is about 10% greater than for a Zone I or II location. Therefore, the preferred site for a central receiver would be Blythe South. Danby Lake should also be considered a candidate site for the central receiver, and a choice between Danby Lake and Blythe South rests on an on-site inspection of Danby Lake.

APPENDIX B
SOURCES OF INFORMATION

APPENDIX B
SOURCES OF INFORMATION

Collection of site data can be a time-consuming task. To aid this task, a list of information sources is given below. It is not extensive, but may be used as a guide in the beginning stages of site data collection.

INSOLATION AND METEOROLOGICAL DATA

Climatic Atlas of the United States, U.S. Government Printing Office, Washington, D.C. 20402.

Local Climatological Data: Annual Summary with Comparative Data, (Various stations available), National Climatic Center, Federal Building, Asheville, N.C. 28801.

Solar Radiation Tabulations 610C and 610D (Various stations available), National Climatic Center, Federal Building, Asheville, N.C. 28801.

National Atlas of the United States, United States Geological Survey, Washington, D.C., 1970.

MAPS (GENERAL)

National Atlas of the United States, U.S. Geological Survey, Washington, D.C., 1970.

Topographic Quadrangle Maps and State Maps (as desired), U.S. Department of Interior, Denver Distribution Section, U.S. Geological Survey, Denver Federal Center, Building 41, Denver, Colorado 80225.

State Highway Maps, County Maps, available from the various states.

Principal Electric Facilities, Southwestern Region, (1971), Federal Power Commission, Bureau of Power (for sale by GPO, Washington, D.C. 20401).

WATER RESOURCES

Bulletin No. 132-73, The California State Water Project in 1973, Dept. of Water Resources, 1973.

Bulletin No. 160-70, Water For California, The California Water Plan Outlook in 1970, Dept. of Water Resources, 1970.

McGauhey, P.H., and Erlick, H., 1957, Economic Evaluation of Water, Part 1, A Search for Criteria, University of California, Water Resource Center, Contribution No. 13.

Publication No. 3, Water Quality Criteria, Addendum No. 1, State Water Pollution Control Board, 1954.

Bulletin No. 106-1, Ground Water Occurrence and Quality, Lahontan Region, Department of Water Resources, 1964.

Streamflow Data, U.S. Geological Survey

Ireland, B., 1971, Salinity of Surface Water in the Lower Colorado River - Salton Sea Area, U.S.G.S. Professional Paper 486-E, U.S. Printing Office.

Bulletin No. 91-9: Data on Water Wells in Indian Wells Valley Area, Inyo-Kern, and San Bernardino Counties, California. May 1963; 246 p.

Bulletin No. 91-10: Data on Wells and Springs in the Lower Mohave Valley Area, San Bernardino County, California. December 1963; 212 p.

Bulletin No. 91-13: Water Wells and Springs in Soda, Silver, and Cronise Valleys, San Bernardino County, California. August 1967; 80 p.

Bulletin No. 91-7: Data on Water Wells and Springs in the Chuckwalla Valley Area, Riverside County, California, 1968; 78 p. (Out of print and have not received yet.)

Boyd, R.M., and, Robson, S.G., 1971, Mathematical Ground-Water Model of Indian Wells Valley, California, Open-File Report, U.S.G.S., Water Resource Division. 36 p.

Bookman, M., 1973, Plans for Decreasing Salinity and Meeting Recreational, Municipal and Nuclear Power Plant Water Demands Along the Colorado River in California, Bookman-Edmonston Engineering, Inc., An Oral Report.

Kunkel, Fred and, Chase, G.H., 1969, Geology and Ground Water in Indian Wells Valley, California, January 23, 1969, U.S.G.S. Department of Interior, Water Resources Division, in cooperation with Naval Weapons Center at China Lake, California. Open-File Report.

Water Resources Investigations in California, 1969, (Index), U.S.G.S., Water Resources Division. 855 Oak Grove Avenue, Menlo Park, California.

Water Resources Investigations in Arizona, 1969, (Index), U.S.G.S., Water Resources Division. P.O. Box 4070, Tucson, Arizona 85717.

Comprehensive Framework Study - California Region, Appendix V, Water Resources, June, 1971, Pacific Southwest Interagency Committee, Water Resources Council, U.S. Bureau of Reclamation.

Comprehensive Framework Study - Lower Colorado Region, Appendix V, Water Resources, June 1971, Pacific Southwest Interagency Committee, Water Resources Council, U.S. Bureau of Reclamation.

LAND OWNERSHIP AND USAGE

Maps:

Cropland and Suitability Map of Arizona, 1971. United States Department of Agriculture.

Land Ownership and Administration of Arizona, 1965. United States Department of Agriculture.

Land Use Map, California. January 1972. Office of Planning and Research. Sacramento, California.

Land Use Map of Yuma County, Arizona. November 1971. United States Department of Agriculture.

Vegetal Cover Map, Arizona, 1971. United States Department of Agriculture.

Reports:

Environmental Goals and Policy, State of California. June 1973. Office of Planning and Research, Sacramento, California.

Lower Colorado Region Comprehensive Framework Study. June 1971. Lower Colorado Region State-Federal Interagency Group.

APPENDIX VI Land Resources and Use 1971

APPENDIX VII Watershed Management 1971

Comprehensive Framework Study, California Region. May 1972. California Region Framework Study Committee.

ENVIRONMENTAL

Environmental Goals and Policy, State of California. June 1973. Office of Planning and Research, Sacramento, California.

The Energy Dilemma: 20-Year Power Plant Siting Plan. State of California, Department of Conservation, Sacramento, California 95814.

Central Arizona Project, Environmental Statement-Final, September 26, 1972, Bureau of Reclamation, Department of Interior.

SOILS/GEOLOGY

Cole, Ralph C.; Storie, Earl R.; Weir, Walter W.; Soils of the Imperial East Mesa. Imperial County, California. June 1957. University of California, Berkeley, California. (2)

Kocher, A.E.; Youngs, F.O. Soil Survey of the Palo Verde Area, California, 1926. United States Department of Agriculture.

Porter, Kusler M. Southern Desert Area Report and General Soil Map. San Bernardino, California. June 1970. United States Department of Agriculture.

Storie, Earl R.; Weir, Walter W. Soils of the Palo Verde Mesa. Riverside, California. July 1946. University of California, Berkeley, California.

Torrance, S.W. General Soil Map of Maricopa County, Arizona. June 1969. United States Department of Agriculture.

List of Published Soil Surveys. Soil Conservation Service. January 1972. United States Department of Agriculture.

Western Riverside Area Soil Survey of California. November 1971. United States Department of Agriculture. (2)

APPENDIX C
ON-SITE SOLAR AND METEOROLOGICAL MEASUREMENTS

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Because many potential sites for solar/electric power stations are in remote desert areas, the required insolation and meteorological data for proper site evaluation and eventual design of the plant may not exist. This appendix provides some basic guidelines for setting up the required measurement program.

Data gathering over a long enough time to yield statistically significant results is generally expensive and requires careful planning. The instrumentation and measurement systems must be automatic, and the data recorded in a computer-compatible form to minimize the manpower requirements for data acquisition and analysis. Further, the measurement program must be carefully planned to yield the most useful and significant results. There are several designs for the instrumentation and data acquisition system. Rather than describe all of these alternatives, one simple system will be proposed which may be used to achieve the desired results.

In the proposed system, the radiation and meteorological sensors will provide analog voltages. These will be sampled and recorded at periodic intervals by a multi-channel, data acquisition system. The preferred recording medium is magnetic tape because of its high data storage capacity and reliability. A 9-track, write-only, incremental magnetic tape is better because it is cheaper than an analog magnetic tape or an incremental read-write magnetic tape. Depending on the number of sensors used and the frequency of sampling, a 10.5-inch diameter magnetic tape should provide sufficient storage space for data over a period of from several weeks to several months, and the system should be capable of unattended operation over the entire interval between tape changes. Table C-1 lists the proposed instrumentation and data acquisition systems.

The sensors recommended include a normal incidence pyrheliometer placed on an equatorial mount to measure the intensity of direct solar radiation, and two hemispherical pyranometers placed on a horizontal position to measure the total (direct + diffuse) radiation and the diffuse radiation. A temperature sensor will measure the ambient air temperature.

In addition to the minimal sensors for this particular application, additional sensors are recommended to obtain data useful for other applications. The meteorological package and dew point hygrometer, although not essential, will provide supportive meteorological data for the chosen site. These data would be useful both in the design of the plant and in planning the operational philosophy. The addition of an ultraviolet sensor would generate useful data to evaluate the response to sunlight of various plastics which might be employed in the plant design.

Table C-1. System Instrumentation and Data Acquisition Systems

	Est. Cost (1973)
Data Acquisition System: a 10-channel data acquisition system with a 9-track, write-only, incremental magnetic tape recorder and interface	$8,400
Sensors (minimal requirements): one normal incidence pyrheliometer, 2 hemispherical pyranometers, equatorial mount, shading ring, and temperature sensor	$5,000
Sensors (desirable): barometer, dew point hygrometer, meteorological package (wind speed and direction) and ultraviolet radiation sensor	$5,000
Total Estimated Cost	$18,400