SATELLITE POWER SYSTEM (SPS) RECTENNA SITING: AVAILABILITY AND DISTRIBUTION OF NOMINALLY ELIGIBLE SITES

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ABSTRACT

Siting of 60 ground receiving stations (rectennas) for the SPS may pose a problem due to the large area per rectenna (15,000 hectares, 38,000 acres) and numerous siting constraints. This study analyzes areas potentially "eligible" for rectenna sites by mapping, at a national scale, those conditions which would preclude rectenna construction. These exclusion variables which reflect restricted lands, topography, safety, national policy and electromagnetic (microwave) effects, have been computer encoded and tabulated.

Subsequent analysis of the nine electric power planning regions that make up the contiguous states indicate an apparently adequate number of "nominally eligible" sites in all regions in comparison to projected electrical generation. This conclusion is subject to several important qualifications. "Eligibility" in this context means only that areas were not excluded in this national level analysis; more detailed investigation may reveal purely local constraints or smaller scale exclusions. An extensive sample validation effort indicated that while all excluded areas were properly excluded, almost 24 percent of the "eligible" areas should also probably be excluded for reasons other than topography. An additional 47 percent of the areas posed potentially very costly topographic problems. A second major qualification relates to small isolated "eligible" areas. Eliminating individual "eligible" clusters with less than nine times the area of one rectenna eliminates much of the Eastern U.S.; a four-to-one adjacent "eligible" area test poses no such problem.

An independent study of the placement of 60 nominal sites in relation to projected load centers reveals that, even with modest transmission distances, the supply of eligible areas is not a key constraint, except perhaps in the Mid-Atlantic (Electric Reliability) Council Region.

Even when several less critical (potential) exclusions are considered, more than 19 percent of the U.S. is "eligible"; every region except Mid-Atlantic has at least 50 times as many "eligible" sites as are "required".

LIST OF ACRONYMS AND ABBREVIATIONS

Agencies

BEA	Bureau of Economic Analysis
BPA	Bonneville Power Authority
EEI	Edison Electric Institute
EIA	Energy Information Administration (of U.S. DOE)
ERA	Economic Regulatory Administration
FAA	Federal Aviation Administration
FCG	Florida Coordinating Group
FERC	Federal Energy Regulatory Commission
FPC	Federal Power Commission
ITS	Institute for Telecommunications Sciences
NERC	National Electric Reliability Council
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratories
U.S. DOE	U.S. Department of Energy

National Electric Reliability Council (NERC) Regions

ECAR	East Central Area Reliability Coordination Agreement
ERCOT	Electric Reliability Council of Texas
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interpool Network
MARCA	Mid-Continent Area Reliability Coordination Agreement
NPCC	Northeast Power Coordinating Council
SERC	Southwestern Electric Reliabiltiy Council
SPP	Southwest Power Pool
WSCC	Western Systems Coordinating Council

Abbreviations of Terms and Legislation

EMC	Electromagnetic compatibility
FAR	Federal Administrative Region
FPA	Federal Power Act
GRS	Ground receiving station
GW	Gigawatt (1,000,000 kilowatts)
LEAP	Long-term Energy Assessment Program
MEFS	Mid-term Energy Forecasting System
PIFUA	Power Industry Fuel Utilization Act
PURPA	Public Utilities Regulatory Policies Act
SPS	Solar Power Satellite
CONUS	Continental United States

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EXECUTIVE SUMMARY

The Solar Power Satellite (SPS) concept envisions a massive platform of photovoltaic cells in geosynchronous orbit which would convert solar energy to electricity and beam it to earth via microwave transmission. The ground receiving station (rectenna) for each satellite will require more than 15,000 hectares (38,000 acres) of land to accommodate the vast expanse of microwave receiving panels and a suitable buffer zone. There are many limitations imposed on the location of rectennas and the task of siting the projected 60 rectennas may present major difficulties. The primary objective of this study is to examine systematically the impact of rectenna siting constraints on the potential availability of suitably located sites.

The present study represents an extension and refinement of two previous separate studies by the present authors: "Initial Identification of Eligible Areas For Rectenna Siting" (Blackburn, 1978) and a concurrent paper on SPS resource impacts, including land use (Kotin, 1978).

The current study expands on the prior research in many key respects:

- Higher resolution mapping
- Improved geographic data base for a larger number of variables
- Improved base map with precise latitude-longitude coordinates
- Extended energy projections
- Incorporation of selected utility integration considerations
- Specific consideration of clustered vs. "isolated" potential siting areas.

Classification of land areas as to suitability for rectenna siting was, in this study, subjected to systematic sample validation using more detailed maps.

The base map used in this study was divided into grid cells, using the Albers equal area projection. Each grid cell corresponds to a 7.5 minute quadrangle and measures approximately 13 kilometers square, a size which will just about accommodate one SPS ground receiving station (rectenna). Through the use of a special encoding device (graphics tablet), data plotted on this map could be directly encoded in a computer data base which could, in turn, be accessed and manipulated using the Rice University geographic information system.

MAPPED VARIABLES USED TO CLASSIFY POTENTIAL SITING AREAS

The primary analytic task was to identify mappable characteristics which, if present, could serve to exclude the area (grid cell) from consideration as a potential rectenna site. In this manner, the remaining cells could be considered, in some general sense, to be "eligible". A total of 37 different variables, some with several gradients, were mapped. These variables, which are listed by Exhibit 1, were grouped into four categories to reflect different degrees of sensitivity and certainty and to reduce the potentially unmanageable number of combinations.

Absolute exclusion variables represent those conditions which, when present in a grid cell, would absolutely bar the construction of a rectenna and which are not subject to any feasible mitigation, given the current reference concept design. The primary basis for classifying an exclusion variable as "absolute" is that it will interfere significantly with human activity and/or impair human health. This accounts for the exclusion of populated areas and of areas encompassing electromagnetically sensitive facilities whose operation would be impaired if an SPS rectenna site were located within a specified distance. A second major reason for absolute exclusion is public policy as reflected in the dedication of certain lands to military, recreational or transportation uses, or manifested in the stated protection of marshlands and endangered species habitats. Two of the fifteen absolute exclusion variables are critical design considerations, unacceptable topography (defined as major mountain ranges) and inland water.

There are nine variables in the category "Potential Exclusion-High Probability Of Impact". The definition of this category implies that some adverse impact is virtually certain if the rectenna were to be sited in these areas. This impact could probably be mitigated by the standards set forth above for absolute exclusion varibles. Three of these variables represent national policy in the form of land dedication (Indian Reservations, National Forests, Wild and Scenic Rivers). Another represents the combined economic and national policy variable (Agricultural Lands). In addition, there are four classes of potential electromagnetic incompatibility variables representing different exclusion distances.

Perhaps one of the most elusive categories of exclusion variables is the one entitled "Potential Exclusion-Impact Unknown". This category was created

EXHIBIT 1

CATEGORIES OF MAPPED VARIABLES

ABSOLUTE EXCLUSION VARIABLES

Inland Water
Military Reservations
Atomic Energy Commission Lands
National Recreation Areas
SMSA's
Adjusted Population Density
Marshland Vegetation
Perenially Flooded Areas
Endangered Species
Interstate Highways
Navigable Waterways
Topography Unacceptable
EMC-A150* (Electromagnetic Compatibility)
EMC-A100 (Electromagnetic Compatibility)
EMC-A50 (Electromagnetic Compatibility)

POTENTIAL EXCLUSION VARIABLES - HIGH PROBABILITY OF IMPACT

Indian Reservations
National Forests and Grasslands
Wild and Scenic Rivers
Agricultural Lands - Mostly Cropland
Agricultural Lands - Irrigated
EMC-P150 (Electromagnetic Compatibility)
EMC-P100 (Electromagnetic Compatibility)
EMC-P60 (Electromagnetic Compatibility)
EMC-P50 (Electromagnetic Compatibility)

POTENTIAL EXCLUSION VARIABLES - IMPACT UNKNOWN

Flyways of Migratory Waterfowl - Ducks
Flyways of Migratory Waterfowl - Geese

DESIGN/COST VARIABLES

Tornado Occurrence
Acid Rainfall
Snowfall
Freezing Rain
Sheet Rainfall
Wind
Lightning Density
Hail
Seismic Risk
Timbered Areas
Water Availability

*Numbers refer to minimum separation, in kilometers, from the nearest rectenna.

expressly to deal with the flyways of migratory water fowl. Too little is known about the impact of microwave illumination on birds to state with any certainty that there is an adverse impact. Nevertheless, some flyways are so broad in their coverage that their consideration, albeit in a separate category, is warranted.

A large number of variables fall into the "Design/Cost" category. For the most part these reflect climatic conditions, e.g. tornadoes, snowfall, different types of damaging rainfall, wind, etc. Seismic risk, timber coverage and water availability are also in this group. None of the mapped conditions for these variables would categorically preclude rectenna construction. In every case, however, the severest gradient condition would significantly exceed the nominal specifications of the reference concept rectenna.

These criteria differ materially from potential and absolute exclusion variables in the sense that they clearly represent cost trade-offs, rather than policy or legal obstacles. The same situation may exist with respect to "unacceptable topography" which was initially considered only as an absolute exclusion variable on a somewhat subjective basis. Subsequent investigation revealed, that topography is a highly sensitive variable. As a consequence, topography was reexamined as a Design/Cost variable with three gradient values.

COVERAGE OF ABSOLUTE EXCLUSION VARIABLES

The total area in which one or more of the fifteen absolute exclusion variables is present comprises 60 percent of the land area of the contiguous United States (CONUS). Of the 52,500 cells that make up the land area, 31,200 are excluded. The remaining 21,300 cells represent "nominally eligible" locations for an SPS rectenna and account for 40 percent of the land area. The term "nominally eligible" is used advisedly since there are numerous other constraints which, upon further investigation, could preclude the construction of a rectenna. In the narrow context of this analysis, "eligible" means only that the site is not excluded *a priori* by those constraints defined as absolute exclusion variables.

The results of this analysis are shown on the map in Exhibit 2, on which the excluded areas are shaded. A visual inspection of the map reveals that

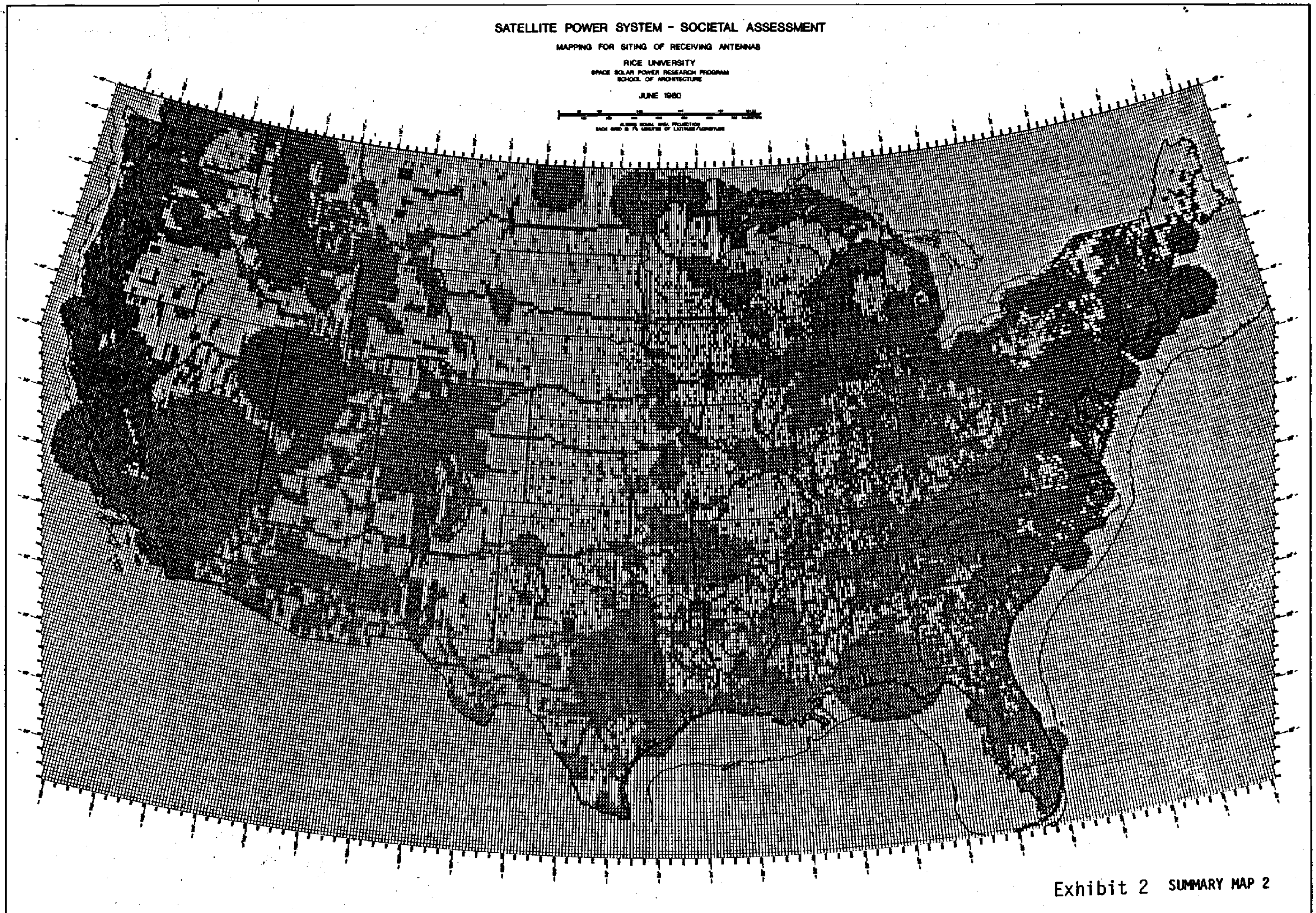


Exhibit 2 SUMMARY MAP 2

there are large areas of "eligible" cells in the great basin of the West and in the plains states. Perhaps even more significant is the fact that there are at least modest areas of eligible cells throughout the United States. Detailed analysis indicates only three states in which there were no eligible areas: Rhode Island, Connecticut, and New Jersey.

The total area that is "eligible" is less important than the distribution of that area. The generation, transmission, and distribution of electric power is accomplished on a local or regional scale. There is no national power generation or transmission system. Therefore, it is much more appropriate to examine the distribution of excluded and eligible areas in terms of regions. Although there are many different sets of regions, the regional framework most appropriate to this study consists of nine Electrical Reliability Council Regions (ERC's). The ERC regions correspond to major joint electrical planning regions for the utility companies and are the basic reporting unit for projected electrical generation expansion.

The region with the most eligible areas in absolute terms (7,300 cells) is the Western States Coordinating Council (WSCC) and the region with the smallest eligible area is the Mid-Atlantic Area Council (MAAC) with 83 grid cells. In percentage terms, the region with the largest proportion of eligible cells (66 percent) is the Mid-America Regional Coordinating Council (MARCA) which includes the Dakotas, Nebraska, Iowa and Minnesota and MAAC is the region with the smallest proportion (10 percent). These statistics and a complete tabulation of eligible and excluded areas by region are shown in Exhibit 3. This exhibit also shows the incidence of component variables. It should be noted that for CONUS or any region the sum of the incidence of the component variables will exceed the total excluded. This is due to the fact that the coverage of the exclusion variables overlaps and two or more exclusion variables may occur in the same grid cell.

A simplified map showing the regional boundaries is presented in Exhibit 4 along with bar charts showing the total eligible area by region and the ratio of eligible areas to allocated rectenna sites. (The number of and basis for the allocation of rectennas is summarized below in a later section.)

EXHIBIT 3

GRID SQUARE PROFILE OF SUMMARY MAP OF ABSOLUTE EXCLUSION AREAS
BY ELECTRICAL RELIABILITY COUNCIL REGION

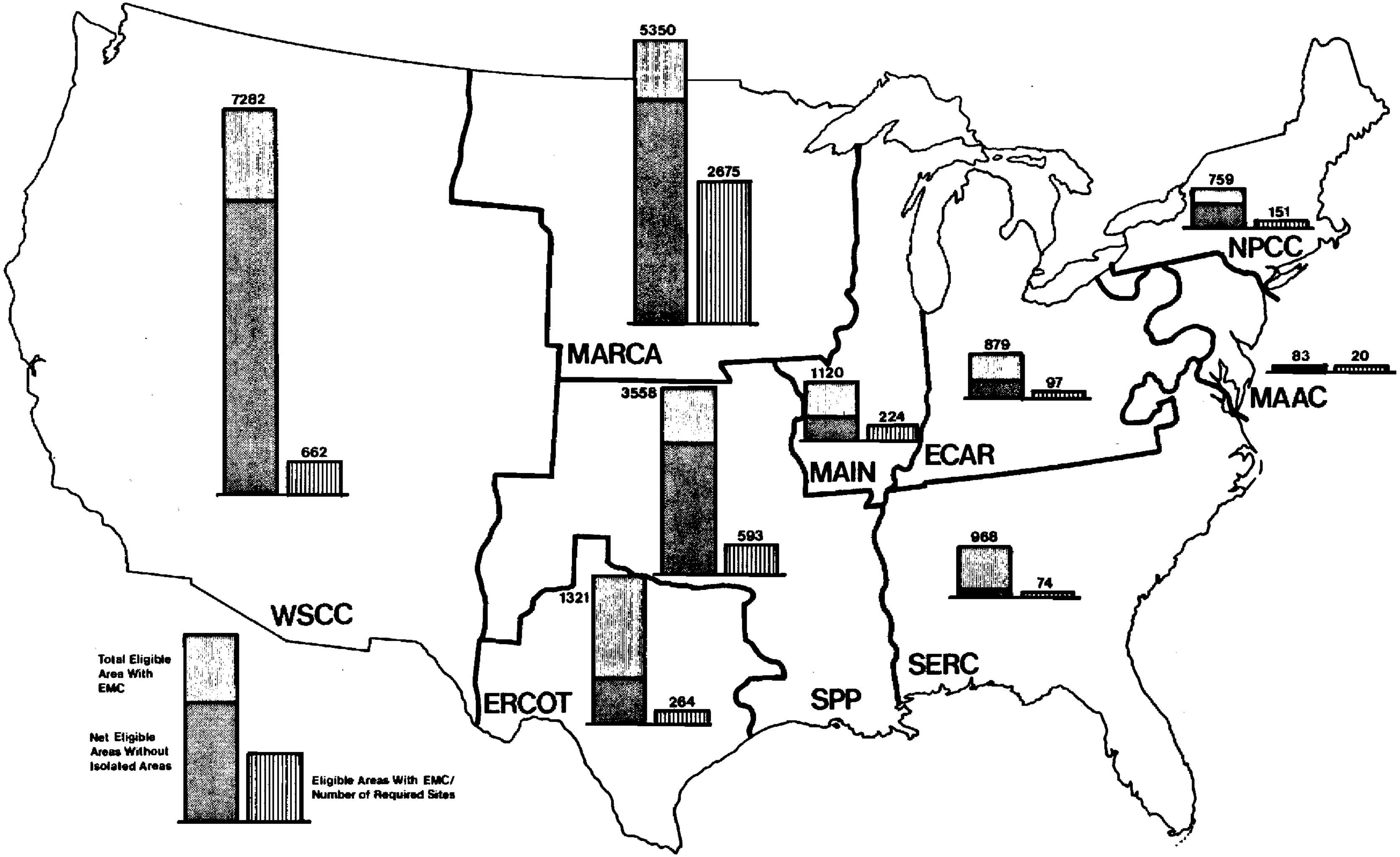
ELEC AREAS	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND PER STATE	TOTAL LAND EXCLUDED	POPULATION SMSA	POPULATION ADJUSTED
WSCC	7282	36	20135	12853	2235	767
MARCA	5350	66	8043	2693	656	679
SPD	3558	55	6421	2863	883	881
ERCOT	1321	41	3190	1869	710	293
SERC	968	17	5470	4502	1425	1513
MAIN	1120	46	2387	1267	450	501
ECAR	879	22	3918	3039	1208	1283
MAAC	83	10	782	699	378	240
NPCC	759	35	2133	1374	492	558
TOTALS	21320	40	52479	31159	8437	6715

ELEC AREAS	INTERSTATE HIGHWAYS	TOPOGRAPHY UNACCEPTABLE	MILITARY	AEC LAND	RECREATION AREAS	MARSH VEGETATION
WSCC	1232	8677	451	69	747	0
MARCA	477	41	3	5	49	0
SPD	499	415	21	0	22	136
ERCOT	269	270	8	0	26	68
SERC	722	524	69	14	82	157
MAIN	252	0	5	0	12	0
ECAR	582	444	13	0	11	0
MAAC	144	179	2	0	1	21
NPCC	274	236	6	0	5	6
TOTALS	4451	10786	578	88	955	388

ELEC AREAS	PERENNIALLY FLOODED	ENDANGERED SPECIES HABITATS	NAVIGABLE WATERWAYS	INLAND WATER	EMC 50	EMC 100	EMC 150
WSCC	13	14	102	64	1048	298	2781
MARCA	202	255	65	39	581	553	0
SPD	284	21	311	36	692	0	0
ERCOT	35	14	31	9	241	0	656
SERC	742	78	398	23	1739	0	483
MAIN	24	0	119	5	557	0	0
ECAR	7	14	155	1	994	0	0
MAAC	3	0	27	0	390	0	0
NPCC	0	0	103	12	612	65	0
TOTALS	1310	396	1311	189	6854	916	3920

EXHIBIT 4

Eligible Area by Region



INCREMENTAL IMPACT OF SELECTED VARIABLES

A simple tabulation of the incidence of each variable cannot show its net incremental impact, i.e. the number of additional cells excluded when it is combined with a series of previously excluded variables. A separate analysis of this issue shows that, of the absolute exclusion variables, the three with the largest incremental impact are topography, population, and the electromagnetic compatability (EMS) variables considered as a group. Without topography there would be 6,600 more eligible cells and the eligible proportion would increase from 40 to 53 percent. Note that the 6,600 added cells are many fewer than the total 10,800 cells in which this variable occurs. For population, the net incremental impact is 6,200 cells which would increase the eligible proportion from 40 to 52 percent. For the EMC variables, which collectively represent 11,700 cells, the net incremental effect is only 3,600 cells or approximately 7 percent of the total land area.

The incremental effect of these variables is distributed very unevenly among the nine ERC regions. For example, the majority of the impact of topography is felt in the West (WSCC), while the areas most severely affected by population are the Southeast (SERC) and the Southwest (SPP). For the EMC variables, the particularly sensitive regions are the West (WSCC), Mid-America (MAAC), and the Southeast (SERC).

In addition to the summary map showing the location of all cells excluded by the absolute exclusion variables, four more summary maps were generated showing the impact of successive additions of selected potential exclusion variables. An examination of the incremental impacts associated with these additional summary maps indicates the magnitude and distribution of the problems that may be encountered in siting rectennas within the nominally eligible areas defined by the absolute exclusion variables. A summary tabulation of these impacts is provided in Exhibit 5. One major conclusion to be drawn from this analysis is that Federal dedicated and protected lands (National Forests and Grasslands, Wild and Scenic Rivers) modestly erode the percentage eligible, reducing the available land to 35 from 40 percent. Potential EMC exclusions have only a trivial effect, while the exclusion of private agricultural lands dramatically reduces the proportion of available land to 25 percent.

EXHIBIT 5

INCREMENTAL IMPACT OF POTENTIAL EXCLUSION VARIABLES

	Summary Map	Added Variables	Eligible Area Cells	Eligible Area %	Net Incremental Impact Cells	Net Incremental Impact %
2	All Absolute Exclusions	--[1]	21,320	40%	--[1]	--[1]
3	Absolute Plus Dedicated and Protected Federal Lands	Indian Reservations National Forests National Grasslands Wild & Scenic Rivers	18,492	35%	-2,828	-5%
4	Absolute Plus All High Probability Potential (except agricultural)	Potential EMC (P150, P100, P60 and P50)	17,918	34%	- 574	-1%
5	Absolute Plus All High Probability Potentials	Agricultural Lands[2]	13,323	25%	-4,495	-9%
6	Absolute, High Probability Potentials, and Selected Flyways	Selected Duck and Geese Flyways[3]	9,786	19%	-3,537	-6%

[1] Base for comparison. Details shown in Exhibit 3.
[2] Irrigated agricultural land and cropland.
[3] Duck Flyways with more than 50,000 birds and Geese Flyways with more than 26,000 birds.

Even with all potential exclusion variables, including flyways, considered, fully 19 percent of the land area remains nominally eligible and in all but two ERC regions more than 10 percent of the land area is "available" for rectenna siting. The two exceptions are the Mid-Atlantic (MAAC) and East Central (ECAR) Regions with 5 percent and 9 percent, respectively.

To analyze the impact of design/cost variables on those eligible cells more likely to be selected for rectenna sites, another site sample developed by Environmental Resources Group in a parallel study of SPS utility integration (ERG, 1980) was used. This sample consisted of the 240 nominal sites which they selected in four alternative 60-site scenarios in accordance with generally rigid constraints to serve U.S. load centers. The frequency with which the various design cost variables were encountered among these 240 sites was tabulated. The results were expressed as the number of sites in a 60-site set for which the particular variable would pose a problem. The results of the tabulation are presented in Exhibit 6. Among the design cost variables with the highest frequency of incidence in this sample are: low-to-medium acid rain (39 of 60); medium and high snow loading (32); sheet rain (28 of 60); high and low frequency of freezing rain (57); and topography of intermediate difficulty (29 out of 60).

Consideration of Isolated Areas

One pattern which emerges clearly from an inspection of the map in Exhibit 2 is that many of the eligible areas are relatively isolated, occurring singly, in pairs, or in small "finger-like" projections into otherwise excluded areas. The likelihood of actually siting a rectenna in one of these isolated areas is considerably lower than in an area with a large number of adjacent "eligible" grid cells. Many critical exclusion variables are not covered in the mapping exercise. These include: purely local variables involving local land uses; other phenomena not susceptible to national mapping; and absolute exclusions too small to register on national maps. Furthermore, there is the problem of actual site assemblage which requires certain flexibility to overcome the many problems of public or private acquisition.

EXHIBIT 6

FREQUENCY OF OCCURANCE OF DESIGN/COST VARIABLES

Design/Cost Variable	Frequency (out of 60)*
Tornado	
10-200 occurances (1955-1967)	47
200 or more occurances (1955-1967)	1
Acid Rain	
Low-medium (pH between 4.0 and 5.0)	39
High (pH less than 4.0)	1
Hail (4 or more days per year)	2
Seismic	
Major damage	4
Moderate damage	26
Snow Loading	
Low (Less than 10 lb./ft.^{2})	22
Medium-high (over 10 lb./ft.^{2})	32
Sheet Rain	28
Freezing Rain	
Low (1-8 days per year)	30
High (8 or more days per year)	21
Wind (50 year maximum)	
70 to 80 miles per hour	37
90 miles per hour	1
Lightning	
10-20 strikes per km.^{2}	22
20+ strikes per km.^{2}	3
Flatland	
Flat	18
Mostly flat	13
Intermediate	29

*Predicated on frequency of incidence in 4 alternative nominal siting scenarios developed as part of the utility integration study (ERG, 1980)

To provide a more sensitive analysis of land availability, a separate analysis of isolated cells was undertaken. Two classifications of isolation were established. In the first category were cells which did not fall within a two-by-two grid pattern of eligible cells. This is to say that there were not at least four adjacent eligible cells within which to acquire one specific site. A second and much more restrictive category included all eligible cells which did not fall within a three-by-three pattern containing nine adjacent eligible cells.

Imposition of the three-by-three constraint on eligible areas almost eliminates eligible areas in the Mid-Atlantic (MAAC) region, where the number of eligible cells is reduced to 21 or only 2.7 percent of the total. In the Southeast (SERC) the residual proportion eligible is almost as bad at 3.0 percent, but there are still 165 eligible cells. In the East Central (ECAR) region, the number of remaining eligible cells is 315 and the proportion eligible is 8.0 percent. In all other regions, there are at least 450 eligible cells and the proportion eligible ranges from 19 to 64 percent.

The imposition of only a two-by-two constraint does not appear to have nearly as drastic an effect in the east and still leaves all other regions with substantial numbers of eligible cells. This is shown clearly by the shaded portions of the eligible area "bars" in the bar chart-map in Exhibit 4.

The limited negative impact of excluding all eligible cells which do not fall in at least 4-square (two-by-two) pattern of adjacent eligible cells is further confirmed by research into utility integration patterns performed by the Environmental Resources Group. In that study, the exercise of designating 60 sites to rationally serve U.S. load centers did not prove to be any more difficult after excluding these two-by-two isolated areas than before.

One of the most significant aspects of this research is in the joint analysis of the eligible areas by the Kotin/Rice study team and Environmental Resources Group. Their effort was to site 60 nominal rectennas within the United States, using a set of generally rigid constraints which reflect only the present state of the art. An important result of this joint analysis was to reveal that the number of eligible areas is for the most part not a constraint in the actual siting exercise.

VALIDATION

The validation effort associated with mapping was actually a process involving three major elements: (1) The use of a more refined and latitude/longitude consistent base map which could readily be checked against a wide variety of other sources; (2) Extensive pre-validation in which mapping on a national scale was selectively checked against regional mapping and other variables to assure that the exclusion variables were properly plotted; and (3) Post-validation in which a random sample of 360 cells (180 eligible and 180 excluded) was drawn for further detailed verification of the excluded/eligible classifications.

The first phase of the post validation effort involved examination of 180 randomly selected excluded cells. For each grid cell in the sample the corresponding USGS 7.5 minute quadrangle map (or other most detailed map available) was inspected to verify the presence of at least one absolute exclusion variable. This analysis revealed no instances in which an area designated as excluded should have been reclassified as eligible. This result is due in large part to the small size of the grid square in relation to the rectenna size which causes the presence of an exclusion variable in even a small portion of the cell to be fully disqualifying.

The second element in the post-validation effort was the validation of eligible areas. Technically speaking this was not validation at all, since there is no representation that "eligible" areas will actually accommodate rectenna sites. Instead, the entire effort is negatively defined and eligible areas are simply those which were not excluded based on nationally mapped criteria. The focus is therefore on the extent of reclassification required when selected cells are examined in much more detail. Of the 180 cells examined on a regionally weighted basis, 71 percent had to be reclassified. Stated alternatively, only 29 percent of the cells initially classified as eligible remained eligible. Much of the reclassification was due to topographic considerations. Without considering topography, the reclassification rate drops to 24 percent. Primary factors in reclassification other than topography were marshlands (8%), inland water (11%), and state and local recreational areas (9%).

The table in Exhibit 7 summarizes the reclassification by region and shows the results also for a nominal 50-cell sample selected randomly for the entire country. In the national sample, the reclassification rate was somewhat lower at 64 percent, including topography as an exclusion, and 16 percent excluding topography from consideration.

SPECIAL ANALYSIS OF TOPOGRAPHY

The concept of topography as an exclusion variable was initially poorly defined. Published specifications by NASA and its contractors created two conflicting impressions: (1) all visual depictions indicated a "flat site"; and (2) General Electric, in a recent study for NASA, reported that the SPS rectenna could be built anywhere that could be reached by a bulldozer. Based on this 'specification', the initial unacceptable topography exclusion variable was restricted only to the major and visible mountain ranges in the United States, e.g. the Sierras, Rockies, Appalachians, etc. In the course of the validation exercise it became apparent that a better operational definition of unacceptable topography was required.

In any event, the concept of "unacceptable topography" as an absolute exclusion variable is rather elusive. Technically speaking, topography is a design/cost variable insofar as the expenditure of substantial additional funds can probably overcome any topographic constraint. Nevertheless, the reference concept for the SPS does have certain tentative cost parameters. Presumably, a design variable which would increase these by more than 10 percent would give serious pause to construction. To develop formal guidelines, a special team consisting of a geographer, an environmental analyst involved in the initial prototype environmental assessment for the SPS rectenna, and an experienced earthworks civil engineer was assembled to jointly review the problem. Specifications of the SPS were reviewed in detail, and a variety of highly detailed (7.5 minute USGS Quadrangle) maps were reviewed to develop emperically and theoretical tests for acceptable topography. The threshold used was the addition, in 1980 dollars, of more than $250 million in earthwork costs. The rules evolved were to reject any grid square with slopes in excess of 25% other than small drainage incisions. Cells with up to 90% area with slopes of 20% or less were acceptable provided that drainage incisions were not excessive.

EXHIBIT 7

SUMMARY FINDINGS OF ELIGIBLE AREA VALIDATION (WITH RECLASSIFICATION)

Area/Region Covered	Total Eligible Area	Percent Sampled	Number in Sample	Not Reclassified	Reclassified			Reclassified Without Considering Topography
					Total	Topography	Other	
NATIONAL SAMPLE	21,320	0.2%	50 (100.0%)	18 (36.0%)	32 (64.0%)	27 (54.0%)	5 (10.0%)	8 (16.0%)
NPCC	759	1.9%	15 (100.0%)	1 (6.7%)	14 (93.3%)	12 (80.0%)	2 (13.3%)	7 (60.0%)
MAAC	83	14.0%	12 (100.0%)	1 (8.3%)	11 (91.7%)	8 (66.7%)	3 (25.0%)	4 (33.3%)
SERC	968	3.9%	38 (100.0%)	12 (31.6%)	26 (68.4%)	17 (44.7%)	9 (23.7%)	12 (31.6%)
ECAR	879	3.0%	27 (100.0%)	3 (11.1%)	24 (88.9%)	15 (55.6%)	9 (33.3%)	7 (25.9%)
MAIN	1,120	1.2%	14 (100.0%)	5 (35.7%)	9 (64.3%)	7 (50.0%)	2 (14.3%)	3 (21.4%)
MARCA	5,350	0.2%	11 (100.0%)	6 (54.5%)	5 (45.5%)	4 (36.4%)	1 (9.1%)	1 (9.1%)
SPP	3,558	0.5%	18 (100.0%)	10 (55.6%)	8 (44.9%)	5 (27.3%)	3 (16.6%)	3 (16.6%)
ERCOT	1,321	0.9%	12 (100.0%)	7 (58.3%)	5 (41.7%)	3 (25.0%)	2 (16.6%)	2 (16.6%)
WSCC	7,282	0.4%	33 (100.0%)	7 (21.2%)	26 (78.8%)	26 (78.8%)	0	2 (6.1%)
TOTAL		0.8%	180 (100.0%)	52 (28.9%)	128 (71.1%)	97 (53.9%)	31 (17.2%)	43 (23.9%)

In order to treat topography much more selectively as a design/cost variable, two additional variables were added to the analysis. From a different USGS source, two classifications of land were added, one being "flat" and the other being "mostly (80 percent) flat". The use of these two classifications created as a residual a third classification of intermediate topography, which fell in neither the flat nor mostly flat area. Comparative validation checks on these categories clearly established a meaningful gradient. Flat and mostly flat areas are present in all ERC regions although they are somewhat underrepresented in the Northeast. The flat areas, when subject to detailed investigation, involve only a 4 percent reclassification rate based on a sample of 50. The mostly flat areas represent a reclassification rate of one-third based on a similar sample of 54. In the residual area, the reclassification rate, as expected, is quite high at 76 percent.

INCREASED SITING FLEXIBILITY WITH A SMALLER RECTENNA

The redesign of the SPS system to operate with a significantly smaller rectenna has been proposed as a method to increase effective site availability. As a by product of the validation exercise, two alternative smaller rectenna sizes were tested. For all 180 excluded cells examined in detail an attempt was made to position the smaller rectenna within an eligible portion of the cell. The first alternative smaller size rectenna tested was one which would occupy one-half the total area of the reference concept size. This would be an ellipse of 9.2 x 7.1 km without a buffer zone. For none of the 180 excluded sample cells did it appear that this size rectenna could be situated in the "eligible" portion of the cell. The second and smaller size tested was a one-half diameter (1/4 area) rectenna with dimensions of 6.5 x 5.0 km without buffer. Only in 5 of the 180 excluded cells (less than 3 percent) could even this smaller size be "eligibly" placed.

The 128 "eligible" cells which were reclassified provided another sample in which to test the impact of smaller size. Using the one-half area size reduced the number of cells reclassified from eligible to excluded by 31 percent to 88. Stated alternatively, the number of eligible cells that "stayed" eligible rose from 52 to 88. For the smaller one-quarter size rectenna, the results were even more dramatic as the number of cells that "stayed" eligible more than doubled from 52 out of 180 to 136 out of 180.

One conclusion to be drawn is that smaller site sizes are unlikely to make previous excluded cells "eligible". On the other hand, the use of a smaller rectenna would clearly increase the likelihood that "nominally eligible" cells would remain eligible upon closer examination.

ELECTRICAL GENERATION AND CAPACITY INCREASE BY REGION

The foregoing analysis dealt exclusively with an approximation of where rectennas can be located. In order to interpret these findings meaningfully, it is also necessary to establish where they should be located. The allocation of rectennas could be based on share of national electrical generation at a target future date, and/or electrical capacity increase by region over some future period. In both cases, reliable projections of electrical generation at a highly disaggregated geographic level are required at least through the initial operating date of the SPS (nominally the year 2000). A major part of the initial analysis was to establish such a set of projections and, to the extent necessary, disaggregate, adjust and reaggregate the projections so they correspond to ERC region boundaries used elsewhere in the analysis.

Based on an extensive literature review designed to identify electrical use projections that were simultaneously geographically disaggregated, susceptible to alternative energy scenario analysis, and prepared by a recognized and reliable source, the research team adopted the midterm and long term forecasts developed by the Energy Information Administration (EIA) of the Department of Energy. In their Annual Report to Congress (ARC) the EIA develops midterm projections under different energy scenarios and a single set of long term projections. The midterm projection scenario which serves as the "standard" projection, is the Series C, which assumes medium level demand and medium level supply. These projections were last published in early 1979 in the 1978 ARC. The midterm projections through the year 1995 were based on the Midterm Energy Forecasting System (MEFS) model while the longer term projections for the year 2000 and beyond were based on the Long-Term Energy Assessment Program (LEAP).

Using MEFS and LEAP, the projections of electrical consumption and capacity increases were developed for the nine ERC regions through the year 2000. These projections of consumption and generation proved to be remarkably stable with respect to the allocation of electrical consumption within various regions, as the allotment for all regions varied by no more than 0.6 percent in all projections. A parallel analysis of capacity increases proved relatively inconclusive insofar as the only published data dealt with gross capacity increases and therefore reflected many changes in mix and retirement of existing capacity rather than providing a meaningful measure of net growth or "need".

In addition to stability of allocation among regions even through the year 1995, the EIA projections also showed a high degree of stability in total electrical generation through the year 1995 over a wide range of scenarios. Among the scenarios considered were the 1978 mid-mid (Series C) forecast, the 1978 Series C high forecast which assumes a significantly higher increase in oil prices than the mid-mid forecast. Even these two forecasts, by virtue of their preparation in early 1979, understated probable oil price increases.

To reflect this, a more recent series of projections released in December 1979 was also evaluated in which significantly higher oil prices were projected, e.g. prices of $29 per barrel (1978 dollars) in 1985 rising to $39 per barrel (1978 dollars) in 1995. With only a 7 percent general inflation rate, this would imply an oil price of over $120 per barrel by 1995 in then current dollars.

In all cases total electrical generation varied only modestly and the total range of generation was from 4,355 trillion kilowatt hours to 4,438 trillion kilowatt hours.

The allocation of rectennas to each ERC region was based on each region's proportion of total generation in the year 1995 or 2000. For each of the 9 regions the allocation and the associated range of percentages of U.S. total are shown in Exhibit 9. The number of rectennas per region ranges from 2 in MARCA to 13 in the Southeast (SERC), as also shown in Exhibit 8.

This allocation of sites has some distinct limitations of which perhaps the most important is that an allocation based on generation in the year 2000 may not adequately reflect changes in generation or relative additions in capacity in the period 2000-2030, during which the SPS is to be deployed.

REGIONAL RANKING ACCORDING TO SELECTED VARIABLES

There are a variety of ways by which to relate the distribution of eligible areas to distribution of allocated rectennas by region. For each of the

EXHIBIT 8

REGIONAL ALLOCATION OF RECTENNAS

ERC Regions		Reference Scenario[1]		Alternate Scenarios[2]	
Acronym	Name	Generation ($KWH \times 10^9$)	Percent of U.S.	Percent of U.S. (Range)	Rectennas Allocated
ECAR	East Central Area Reliability Coordination Agreement	712	14.3	15.7 - 16.6	9
ERCOT	Electric Reliability Council of Texas	367	7.4	6.6 - 6.9	5
MAAC	Mid-Atlantic Area Council	345	6.9	6.6 - 7.0	4
MAIN	Mid-American Interpool Network	409	8.2	8.1 - 8.4	5
MARCA	Mid-Continent Area Reliability Coordination Agreement	204	4.1	4.2 - 4.4	2
NPCC	Northeast Power Coordinating Council	453	9.1	8.3 - 8.6	5
SERC	Southeastern Electric Reliability Council	1,044	21.0	20.4 - 21.0	13
SPP	Southwest Power Pool	521	10.5	9.8 - 10.1	6
WSCC	Western Systems Coordinating Council	918	18.4	18.3 - 18.9	11

[1] MEFS-LEAP regional reconciliation for the year 2000.

[2] Alternative Scenarios for the year 1995 are:

- MEFS Series C, Mid-Mid
- MEFS Series C, Nuclear Moratorium
- MEFS Series C, High Oil Prices
- MEFS Preliminary 1979, High Oil Prices with 35% Reserve Limit
- MEFS Preliminary 1979, High Oil Prices with No Limit on Reserve Expansion

EXHIBIT 9

RECTENNA SITING FEASIBILITY RANKING BY REGION

RANKING VARIABLE

NERC REGION

VALUE	ECAR	ERCOT	MAAC	MAIN	MARCA	NPCC	SERC	SPP	WSCC	TOTAL	MEAN
1) Total Eligible Areas Without EMC	1,069	1,746	103	1,278	6,005	851	1,537	3,770	8,602	24,961	2,773
2) Total Eligible Areas With EMC	879	1,321	83	1,120	5,350	759	968	3,558	7,282	21,320	2,369
3) Net Eligible Areas Without Isolated Areas	314	853	21	450	4,233	451	165	2,490	5,578	14,555	1,617
4) Eligible Areas Without EMC/ No. of Required Sites	118.8	349.2	25.8	255.6	3,002.5	170.2	118.2	628.3	782.0	416.0	--
5) Eligible Areas With EMC/ No. of Required Sites	97.7	264.2	20.8	224.0	2,675.0	151.8	74.5	593.0	662.0	355.3	--
6) Eligible Areas Without Isolated Areas/ No. of Required Sites	34.9	170.6	5.3	90.0	2,116.5	90.2	12.7	415.0	507.1	242.6	--
7) % of Potential Exclusion Variables in Eligible Areas											
8) Projected Capacity Increase - Series C Nuclear Moritorium	7,532	4,030	2,812	2,838	1,383	4,517	8,119	5,147	11,977	48,355	5,373
9) Projected Capacity Increase - Series C Mid-Mid	7,481	4,483	3,625	3,932	1,992	3,636	10,385	6,339	13,544	55,417	6,157
10) Incidence of Environmental Impact Variables											
11) Total Load Centers ≥ 5.0 Gigawatts (Rectenna Capacity)	2	2	1	1	0	1	4	1	3	15	1.7
12) Proportion of Load Centers ≥ 5.0 Gigawatt Capacity	0.08	0.17	0.14	0.08	0.00	0.09	0.12	0.06	0.10	--	--
13) Total Load Centers ≥ 1.0 Gigawatts (Capacity of 1000 Megawatt Line)	18	8	4	4	3	4	32	12	14	99	11
14) Proportion of Load Centers ≥ 1.0 Gigawatt Capacity	0.72	0.67	0.57	0.33	0.13	0.36	0.94	0.67	0.48	0.58	--
15) Siting Difficulty - Fully Constrained	--	--	--	--	--	--	--	--	--	--	--
16) Siting Difficulty - Partially Constrained	--	--	--	--	--	--	--	--	--	--	--
17) Siting Difficulty - Revised Absorption	--	--	--	--	--	--	--	--	--	--	--

RANKING (Ordinal Point Rating)

RANKING (Ordinal Point Rating)	ECAR	ERCOT	MAAC	MAIN	MARCA	NPCC	SERC	SPP	WSCC
1) Total Eligible Areas Without EMC	7	4	9	6	2	8	5	3	1
2) Total Eligible Areas With EMC	7	4	9	5	2	8	6	3	1
3) Net Eligible Areas Without Isolated Areas	7	4	9	6	2	5	8	3	1
4) Eligible Areas Without EMC/ No. of Required Sites	7	4	9	5	1	6	8	3	2
5) Eligible Areas With EMC/ No. of Required Sites	7	4	9	5	1	6	8	3	2
6) Eligible Areas Without Isolated Areas/ No. of Required Sites	7	4	9	6	1	5	8	3	2
7) % of Potential Exclusion Variables in Eligible Areas									
8) Projected Capacity Increase - Series C Nuclear Moritorium	3	6	8	7	9	5	2	4	1
9) Projected Capacity Increase - Series C Mid-Mid	3	5	8	6	9	7	2	4	1
10) Incidence of Environmental Impact Variables									
11) Total Load Centers ≥ 5.0 Gigawatts (Rectenna Capacity)	3.5	3.5	6.5	6.5	9	6.5	1	6.5	2
12) Proportion of Load Centers ≥ 5.0 Gigawatt Capacity	6.5	1	2	6.5	9	5	3	8	4
13) Total Load Centers ≥ 1.0 Gigawatts (Capacity of 1000 Megawatt Line)	2	5	7	7	9	7	1	4	3
14) Proportion of Load Centers ≥ 1.0 Gigawatt Capacity	2	3.5	5	8	9	7	1	6.5	6
15) Siting Difficulty - Fully Constrained	5	1.5	9	5	1.5	5	5	5	8
16) Siting Difficulty - Partially Constrained	3	3	8.5	6.5	3	3	3	6.5	7.5
17) Siting Difficulty - Revised Absorption	4	4	8	4	4	4	4	4	9

nine regions the number of eligible cells per allocated rectenna is shown in Exhibit 4.

There is a very wide range of cells per nominal number of sites. The highest ratio is in the MARCA Region (northern plains states) with 2,675 cells per nominal site.

The availability of cells in which a rectenna may nominally be located is only one of several measures. There are a total 17 such measures identified in this study. These variables also include measures of generation capacity increase, absorption capacity in terms of the size and distribution of load centers; the siting difficulty encountered in attempting to develop 60 nominal sites constrained by region; a variety of environmental variables; and the incidence of potential exclusion variables.

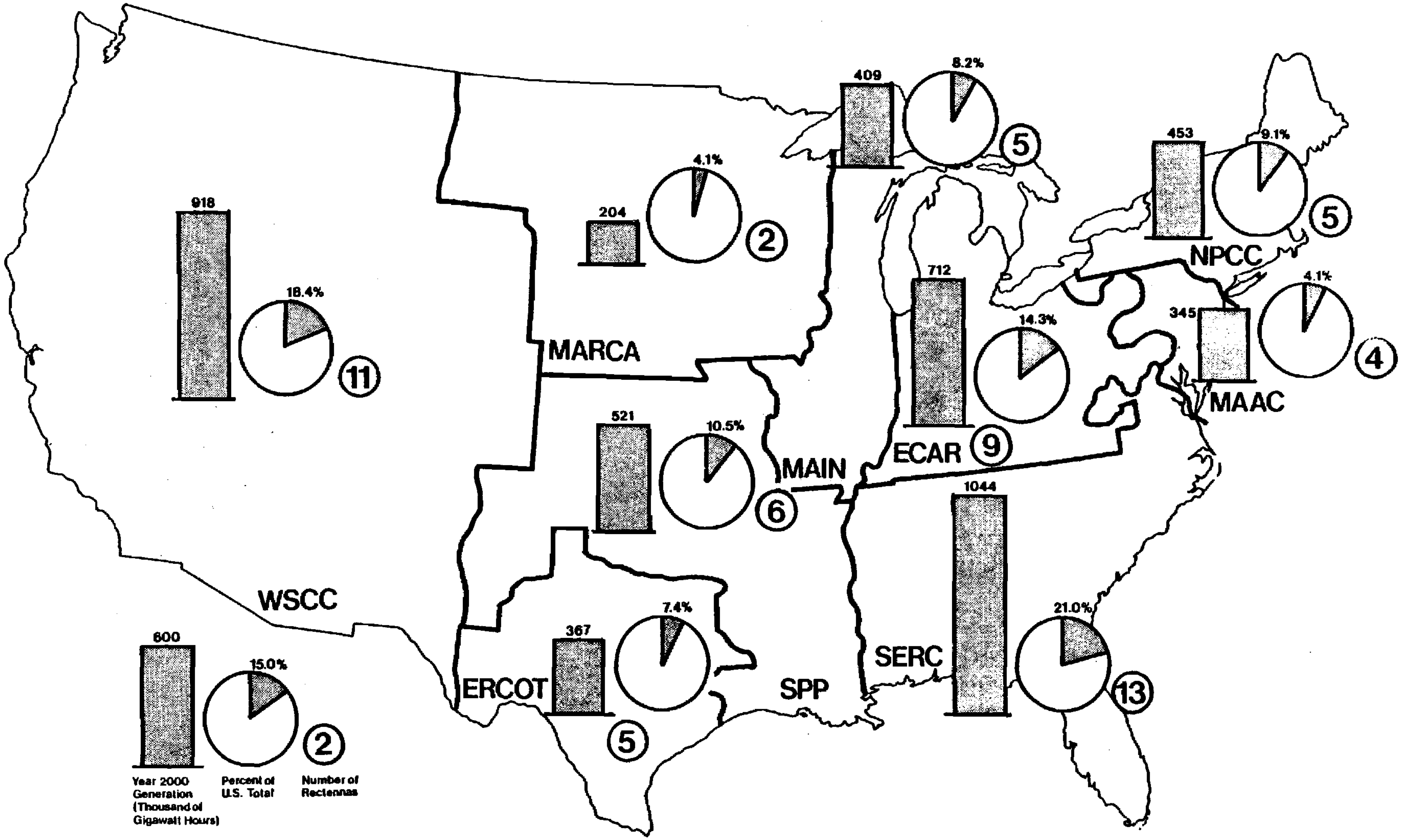
The 17 ranking variables are enumerated in Exhibit 9. The upper portion of the exhibit shows the absolute values for each region, while the lower portion displays the regions' ordinal rankings. The ranking values used range from 1 (most eligible) to 9 (least eligible).* The ordinal system was used to show more clearly, the relative siting feasibility of the nine regions. For example, MARCA (Mid-American Region) ranked either first or second for variables 1 through 6 which reflect site availability, but last for variables 7 through 14, which reflect capacity increase and absorptive capacity, e.g. presence of large load centers.

A review of these rankings indicates a general pattern of availability problems on the Atlantic seaboard offset except in MAAC by relatively easy siting at 60 nominal locations. The rankings also indicate siting problems in the west (WSCC) and the preponderance of smaller load centers in the midwest (MAAC, MAIN).

*Where two or more regions had equal values, e.g. total load centers with 5 GW or more capacity (variable 11), the regions were assigned equal rankings equal to the sum of the ordinal ranks divided by the number of tied variables, e.g. ranks 1 plus 2 equal 3, divided by 2 equals 1.5.

EXHIBIT 10

Regional Generation (2000) and Rectenna Allocations



I. INTRODUCTION

I.A. STUDY FRAMEWORK

A potential new source of energy is being investigated in detail by the Department of Energy and the National Aeronautics and Space Administration. This new potential energy source is the Satellite Power System (SPS). The SPS consists of a solar-collecting satellite in geosynchronous orbit that transmits microwave energy to an earth-based receiving antenna. The receiving antenna converts the microwave energy to electrical energy which is distributed to consumers through the utility grid system. The satellite and the receiving antenna are sized to deliver 5 gigawatts (5000 megawatts) of power.

Beginning in the year 2000, two 5 gigawatt systems are encisioned to be deployed each year for 30 years. As such, the SPS program will require the construction 60 satellite/receiving antenna pairs and will represent a potential source of 300 gigawatts (300,000 megawatts) of power.

This report is prepared as part of the DOE/NASA Concept Development and Evaluation Program. The objective of this program is to "achieve by the end of 1980 an initial understanding of the technical feasibility, economic practicability and social and environmental acceptability of the SPS so that recommendations concerning program continuation can be made". (DOE, 1978). This report was commissioned as part of the Societal Assessment, one of four major study areas identified in the DOE/NASA Concept Development and Evaluation Program.

The specific purpose of this project is to assess the availability of sites for receiving antennas. The overall availability of potential sites is addressed as well as the distribution of these sites with respect to regional demand for electrical power. The issue of site availability was approached by eliminating unsuitable sites instead of attempting to select sites per se. This approach resulted in "excluded" areas and residual lands termed "eligible" areas. These "eligible" areas are potentially available as receiving antenna sites.

I.B. SCOPE

The scope of this study is broad. In addition to determining site availability and the distribution of sites with respect to electrical demand, many specific research tasks were completed during this study. Specific issues addressed include:

* an investigation of the electromagnetic compatability issue implicit in rectenna siting

* an investigation of the impact of slope conditions upon rectenna siting

* an investigation of the relationship of bird migration corridors and rectenna siting

* an investigation of the criteria for siting an offshore receiving antenna

* an investigation of the electrical power projections for various regions of the United States

* the development of a geographically accurate, computerized data management system

* the compilation of data describing various natural and social constraints to siting

* a detailed investigation of the accuracy of the data used in the site-availability analysis

* an overview assessment of cumulative environmental impacts generated by siting 60 rectennas

* an overview assessment of design/cost implications of various environmental factors

As can be seen from the diversity of tasks, this study is intended to provide a comprehensive overview of many major issues raised by the siting of receiving antennas.

I.C. RELATION TO PRIOR STUDIES

This study is a follow-up to two previous studies completed for PRC Energy Analysis Company. An investigation of the land use aspects of rectenna siting was completed by Allan Kotin in the first phase of the SPS evaluation program (Kotin, 1978) and is referenced in portions of this report. Additionally, Blackburn and Bavinger completed a study on rectenna siting (Blackburn and Bavinger, 1978). During these independent early research efforts, substantial interaction occurred between Kotin and the Rice University team. This study represents the coalescing of a more rigid interaction.

In many respects, the current study represents an extension and a refinement of the two prior studies by the present authors. The scale of the effort and the extent of the refinement are, however, so significant as to change materially the character of the research. Among the more important changes and refinements are:

1. The use of a much more refined mapping system, incorporating higher resolution and substantially greater geographic accuracy.

2. The list of exclusion variables has been significantly modified and refined. Better data sources were used, and more extensive pre-validation of the data has been employed.

3. The analysis of regional supply and demand of electrical power through the initial operating date of the SPS has been significantly refined and expanded.

4. There has been a much more systematic treatment of regional variation including an attempt at regional ranking in terms of availability of sites and desirability/feasibility of SPS power.

5. An extensive post-mapping validation effort has been conducted based on a statistically sound sample subjected to rigorous detailed examination at a scale much smaller than that used in the original mapping.

I.D. RELATIONSHIP TO PARALLEL SPS STUDY EFFORTS

The rectenna siting research described in this paper was undertaken in close cooperation with several other ongoing SPS evaluation studies. Perhaps most important among these was a utility integration study conducted by Environmental Resources Group (ERG) with extensive technical support from Allen D. Kotin of Kotin & Regan, Inc. (ERG 1980). In this study, utility integration problems associated with the SPS were considered in a context of locating nominal rectenna sites within the "eligible" areas defined in this report. The analysis of the implications of this nominal siting effort was highly interactive with this rectenna siting study and contributed important insights about the relevance and significance of "eligible" areas.

Because this research deals extensively with environmental considerations and depends in part on a refined analysis of rectenna development constraints, it also drew heavily on a prototype environmental impact statement study also undertaken by Environmental Resources Group for a hypothetical site in California (Coso Hot Springs) (ERG, 1980).

As noted in the discussion of electromagnetic compatibility factors, the study also draws heavily on ongoing research being conducted by the Institute for Telecommunications Sciences (ITS) on behalf of Argonne National Laboratories for the Department of Energy (ITS, 1980).

I.E. THE STUDY TEAM

This study was conducted under two contracts with Planning Research Corporation (PRC) Energy Analysis Company. One contract was let to Rice University, Houston, Texas and the other contract was let to Kotin and Regan, Inc., Los Angeles, California. James Blackburn and Bill Bavinger were co-principal investigators of the Rice University study and Allan Kotin was principal investigator of the Kotin and Regan study. Although this study was conducted under two separate contracts, the results of these two research efforts are reported in this single document.

I.F. ACKNOWLEDGEMENTS

The Rice/Kotin & Regan study team has received extensive support from a wide range of sources involved in SPS research. In particular, the authors would like to extend their appreciation to Dr. John Hill and Mr. Jim Rabe of Environmental Resources Group, both for their cooperation and coordinating their utility integration study with the instant research and also for specific efforts in the validation study and the examination of the problems posed by topography. Dr. Patricia Caldwell of Caldwell & Associates, geographic consultants, was primarily responsible for the validation of eligible areas and the examination of isolated areas, which form an important part of the analysis. Mr. Ernest L. Morrison ot the Institute for Telecommunication Sciences was a primary and extremely helpful source of knowledge with respect to electramagnetic compability impact, a particularly significant and highly technical aspect of rectenna siting constraints.

Mr. Peter Rowe of Rice University and the Rice Center was particularly helpful in the design of the validation approach and providing ongoing technical commentary in review of much of the research conducted by Rice University.

Dr. John Freeman of Rice University was very helpful and cooperative in sharing his research findings with respect to the offshore rectenna. Dr. A. A. Few of Rice University was also quite helpful in sharing his research efforts concerning lightning effects on rectennas.

Special thanks are also extended to David Dyche who did most of the programming adaptations for the larger data structure and to Scott Callaway who did most of the coding work on the tektronix graphics tablet.

II. RECTENNA DESCRIPTION

Throughout this report, reference is made to receiving antenna siting (or rectenna siting). However, the receiving antenna is only one part (albeit large) of a sophisticated power production complex. This production complex includes the receiving antenna field and an electric power collection system as well as ancillary facilities such as a control center, roads, maintenance facilities and security facilities.

Additionally, a buffer zone is needed to insure that microwave power densities beyond the rectenna field fall within acceptable levels. The size of this buffer zone has been specified to be approximately 1 km wide along the perimeter of the rectenna field.

II.A. RECTENNA FIELD

The reference ground receiving antenna is a series of serrated panels perpendicular to the incoming microwave beam. These panels contain the dipoles and diodes which are underlain by a steel mesh ground plane with 75% - 80% optical transparency. "This mesh is mounted on a steel framing structure, supported by steel columns in concrete footings" (DOE, 1978).

The rectenna contains 2.5 million panels that are 3 meters high and 10 meters wide. The reference design shows two panels mounted one above the other on a single support structure. There are approximately 3000 dipole/diode elements on each panel. The dipoles are "T"-shaped with a height of a few inches.

As currently specified, the receiving antenna will be constructed in an elliptical form, with the vertical axis being approximately 13 km in diameter and the horizontal axis being approximately 9 km in diameter. This elliptical configuration is required to receive the circular microwave beam transmitted from geosynchronous orbit. The vertical dimension will increase as the site is moved further north and will decrease as the site is moved south from this reference latitude. In this study, the rectenna field dimensions used were those associated with a site at 35 degrees north latitude.

The rectenna field will be flat or terraced to allow horizontal connection of the panels in long, continuous rows. These rows would be spaced approximately 4 meters apart to eliminate shading effects. Vehicular access would be accommodated by a series of roads approximately 6 meters wide. The electrical power distribution system lies within the rectenna field. This system is composed of 125 converter stations, 25 collection/transmission stations and five step-up switching stations. The five step-up switching stations will connect with transmission lines for power delivery.

A number of permanent ancillary facilities are adjacent to the rectenna field. These include a control center, maintenance facilities, provisions for vehicle access and parking, security facilities and necessary wastewater treatment facilities (ERG, 1980). These facilities would be located within the buffer zone.

II.B. BUFFER ZONE

A buffer zone is proposed to reduce microwave power density to acceptable levels for human contact. Although the reference system did not specify the need for or the size of a buffer zone, subsequent NASA correspondence has specified the use of a buffer zone to reduce exterior microwave power densities to 0.1 mW/cm^2 or less. The power density profile associated with the receiving antenna is shown in Exhibit II.1.

Because the rectenna size varies with latitude, the following list identifies the rectenna dimensions (with buffer zone) for various latitudes (Schwenk memorandum, 1979).

Location	Rectenna Dimensions - KM	
Latitude-Degrees	East-West	North-South
Equator	12.0	12.0
25	12.0	13.8
30	12.0	14.6
35	12.0	15.8
40	12.0	17.4
45	12.0	19.4
50	12.0	22.2

II.C. SUMMARY DESCRIPTION OF THE RECTENNA SITE

In summary, the site required for a receiving antenna at 35^o N. latitude must accommodate a 12.0 km X 15.8 km rectenna field (with buffer zone). The total land area required by this pattern is 148.9 km^2 (36,800 acres). The geometric pattern of the rectenna site is shown in Exhibit II.2 and the arrangement of panels within the rectenna field is shown in Exhibit II.3.

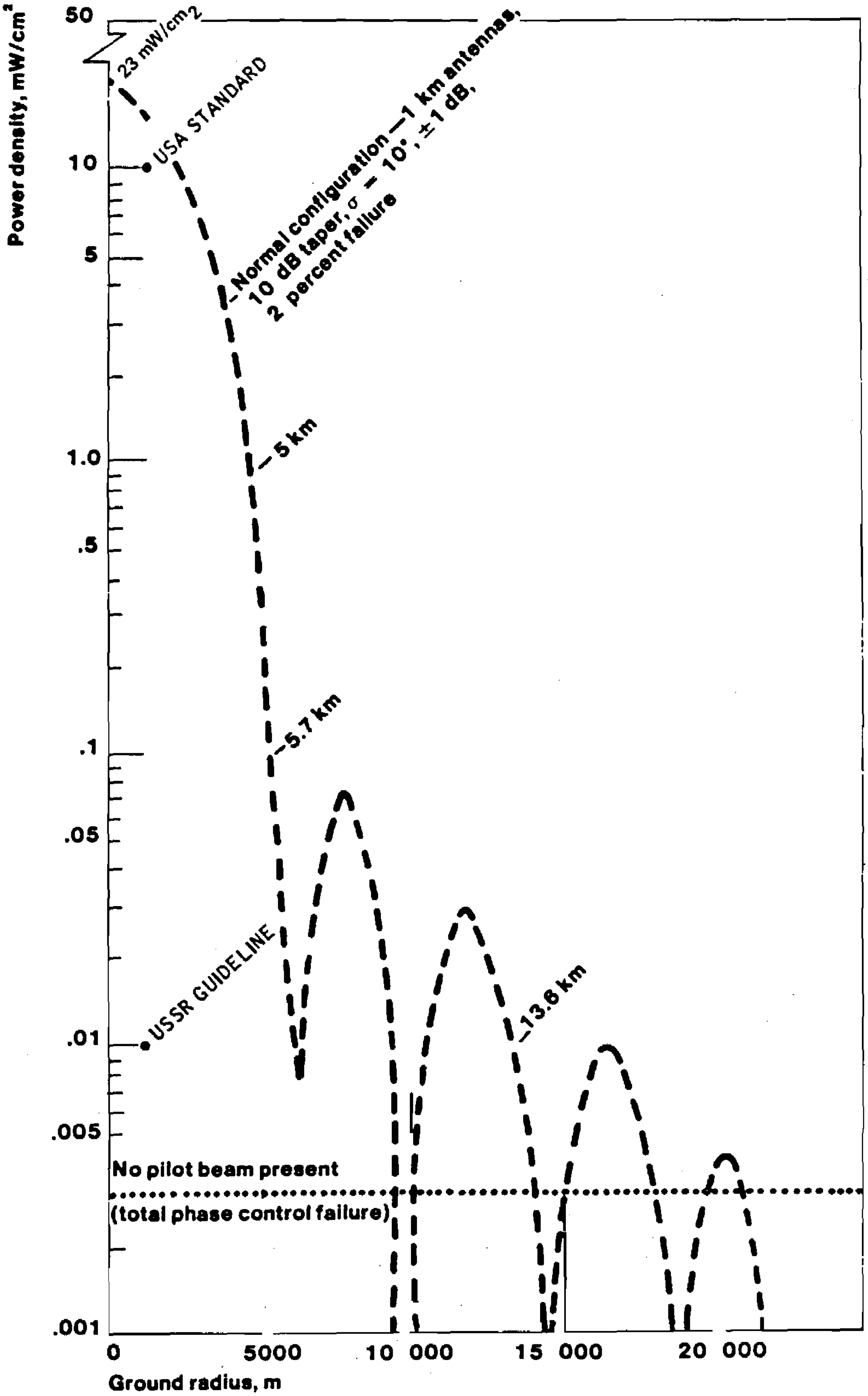


Exhibit II-1 Power Density Profile

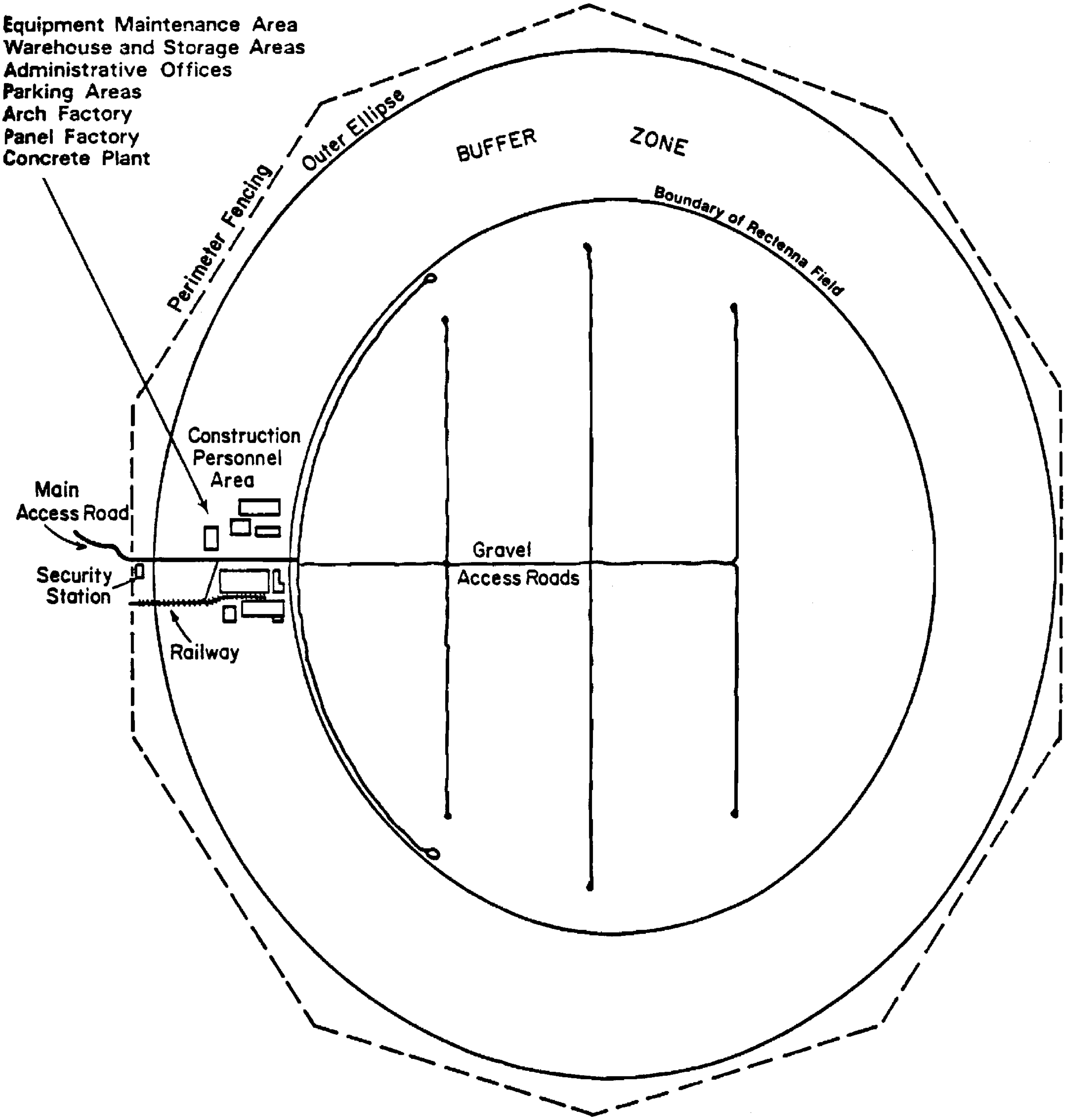


Exhibit II-2 Geometric Pattern of the Rectenna Site

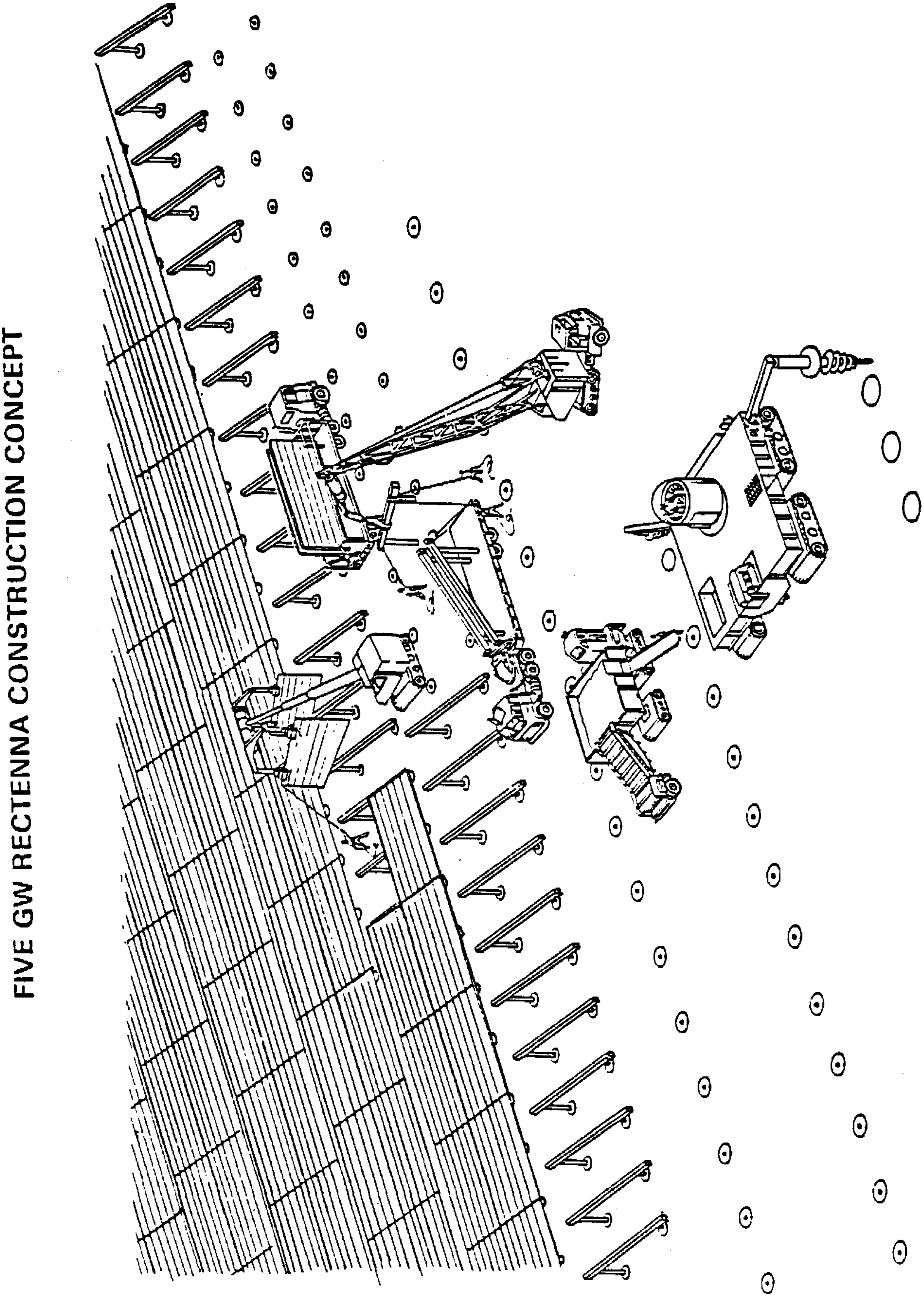


Exhibit II-3 Rectenna Panel Arrangement

III. RESEARCH APPROACH

The initial research efforts were divided into four elements:

1. development of a computerized data management system;
2. development of maps depicting constraints to rectenna siting;
3. development of data concerning electrical demand projections for various regions of the United States; and
4. completion of research on specific ancillary tasks.

Upon completion of these initial tasks, the mapped data was entered into the Rice University computer system and a series of maps were generated that indicated the spatial coverage of an overlaid set of constraints. These summary maps were then subjected to detailed examination to determine:

1. the incremental impact of selected variables, and
2. the relationship of residual or eligible areas to regional electric demand.

A large and systematically chosen sample of both excluded and "eligible" areas was then examined in much greater detail to validate the initial "national" classification as to actual eligibility. Finally, the environmental and design/cost implications of siting in "eligible" areas were examined.

III.A. GENERAL SITING METHODOLOGY

A primary purpose of this research was to assess the availability of receiving antenna sites within the continental United States. The reference system analyzed in this study specified the construction of 60 satellite/receiving antenna pairs (DOE, 1978). Therefore, all of the analyses in this report posit the development of 60 sites.

In accord with previous siting studies completed for the DOE/NASA evaluation program (Kotin, 1978; Rice, 1978), this study addressed siting by determining where rectennas could not be constructed. For this reason, the focus of the research effort was upon constraints to development, rather than upon requirements for development.

Constraints to land utilization arise in several ways. Land areas may be permanently dedicated to certain uses and are not available as sites. Land areas may not be permanently dedicated to certain uses, but extensive capital investments may be foregone or social disruption may result from the utilization of these land areas, thereby representing a siting constraint. Additionally, certain negative impacts may be generated by the receiving antenna's proximity to certain types of uses, thereby constraining sites close to the impacted use. Direct environmental impacts of the utilization of certain sites may also constrain availability and the presence of certain natural factors may preclude rectenna development under current design specifications.

To address the disparity in the severity of siting constraints, four classes of constraints were developed:

1. absolute constraints;

2. potential constraints with a high probability of impact;

3. potential constraints with an unknown probability of impact; and

4. design/cost constraints.

Absolute constraints preclude the use of a given site. The data developed to describe these absolute constraints were termed absolute exclusion variables. In general, constraints were considered to be absolute if the location of a rectenna in an excluded cell would:

1. endanger human health or safety;

2. violate national policy with respect to dedicated or protected land uses;

3. seriously disrupt human productive activity;

4. impair national security; or

5. require major design adaptations or such an increase in capital costs as to render the project infeasible.

Included in this classification were variables describing land areas protected under federal law, variables describing extensive capital investments and/or land areas which, if utilized, would lead to significant social disruption, land areas from which the rectenna must be excluded if certain highly sensitive facilities are to be free from disruption, and areas where rectenna construction was physically impossible. Those variables classified as absolute exclusion variables are:

1. Populated Areas
2. Marshlands and Perennially Flooded Areas
3. Areas With Unacceptable Topography
4. Navigable Waterways
5. National Recreation Areas
6. Military Reservations
7. Atomic Energy Commission Lands
8. Designated Habitats of Endangered Species
9. Inland Lakes
10. Interstate Highways
11. Areas exhibiting electromagnetic compatibility problems (endangering human safety or national security).

Potential exclusion variables with a high probability of impact represent those for which it appears highly likely that some adverse impacts will be encountered if a rectenna is located within a cell where these potential exclusion variables are found. The magnitude of the impact may vary, but the adverse impact cannot be said to absolutely preclude rectenna location if the site is otherwise uniquely desirable. This class of variables exemplify characteristics which have (or may be given) a unique legal status or that represent areas from which the rectenna should be removed if certain important (but not essential) sensitive uses are not to be impacted. Regardless of the basis of the potential constraint, all of the variables included in this category will be impacted if the land areas exhibiting the variables are selected as rectenna sites. The variables included in the potential exclusion, high impact category are:

1. Indian Reservations
2. National Forests and National Grasslands
3. Wild and Scenic Rivers
4. Prime Agricultural Lands
5. Areas Exhibiting Electromagnetic Compatibility Problems (other)

A third classification was developed for potential exclusion variables with an unknown probability of impact. In other words, these variables might preclude an area as a rectenna site if it were clear that negative impacts would ensue from the rectenna. However, due to the absence of definitive research, an assessment of the resulting impacts is impossible to make at the current time. The variables included in this classification are:

1. Duck Migration Corridors
2. Goose Migration Corridors

The fourth classification was developed for certain natural factors that would preclude construction of the rectenna as currently designed. However, if modifications were made to the reference rectenna design, the constraints represented by these natural factors would be addressed and the land areas exhibiting these characteristics could be utilized as sites. Implicit in design alterations to address these natural factors are cost increases for rectenna construction. Those variables classified as design/cost variables are:

1. Areas subject to high winds
2. Areas subject to sheet rainfall
3. Areas subject to hail
4. Areas with a high tornado incidence
5. Areas with acid rainfall
6. Areas with a high lightning density
7. Areas with high snowfall loading factors
8. Areas with high seismic risks
10. Timbered areas
11. Areas with groundwater overdraft
12. Areas with surface water supply problems
13. Areas with difficult topography

These four general classifications were utilized to indicate varying levels of siting difficulty. In all cases, data was developed to describe the land areas exhibiting these characteristics.

III.B. MAPPING APPROACH

III.B.1. The Base Map

An initial research task required the development of a base map for data display purposes. The projection system chosen for the base map was the Albers Equal Area Projection System (Ricardus and Adler, 1972). Two reasons were controlling in the decision to use this projection system. First, most of the information that has been mapped at the national scale was presented in the Albers Equal Area Projection System. Second, the Albers Equal Area Projection System produces a depiction of the United States that is visually contiguous (in contrast to the Mercator System, for example) (Land Use Analysis Laboratory, 1978).

The next step in the development of the base map required the selection of the grid square size. Grid squares are utilized for data depiction purposes in this study's mapping approach. In particular, it had been agreed at the outset that our maps would reflect the presence or absence of the variable of concern at the grid square level. This approach was utilized in the previous Rice University siting study (Blackburn and Bavinger, 1978), although the grid square size utilized in that study (26 km on a side) was over twice as large as an individual rectenna site. The 26 km square grid had been selected rather arbitrarily and a more relevant grid square size was needed for this second siting study.

This new grid square needed to be smaller in order to conform more exactly to the size of the rectenna, indicating a grid square in the 13 km range. Because the United States' Geological Survey's 7-1/2 minute quadrangle maps are approximately 13 km X 13 km, the decision was made to synchronize the grid squares with the USGS 7-1/2 minute quadrangle series. The base map shown in Figure 3.1 is overlain by a grid square pattern that is registered to the USGS quad map coverage of the United States. Each grid square may be cross-referenced to one of these USGS maps.

As shown in Exhibit III.1, the grid square coverage is complete for the Continental United States and extends well offshore. The continental United States is covered by 52,479 grid squares and the offshore areas are covered by 5,332 grid squares.

Due to the geometric properties of the Albers Equal Area Projection System, the grid squares are smaller in the northern portions of the United States and are larger in the southern portions of the map. The smallest grid square is 14 km X 9.2 km and the largest is 14 km x 12.2 km. Therefore, although the grid squares vary in size latitudally, the longitudinal dimensions remain constant and comparable to the geometry of the rectenna.

In Exhibit III.2 the relationship of the reference-system rectenna to the northern-most and southern-most grid squares is depicted. In this figure, it can be seen that the rectenna field fits within the grid squares, and the buffer zone extends slightly beyond the north and south boundaries of the grid square. However, it can be generally stated that a grid square represents a rectenna site.

III.B.2. Discussion of The Mapping Approach

All of the data shown in Appendix A was initially mapped upon 29" x 41" mat acetate base maps. The transfer of data to these mat acetates was accomplished in one of three ways:

1. Separate sheets of Albers Equal Area projection maps were photographically enlarged to the base map scale and the information was transferred to the base map.

2. Smaller scale maps of interpolated data were enlarged with an overhead projector and traced onto blackline prints of the base maps and then transferred to mat acetates.

3. Certain maps were developed through a series of cross-references to enlarged maps with identified landmarks and the development of maps at a smaller scale with subsequent translation to the base map scale.

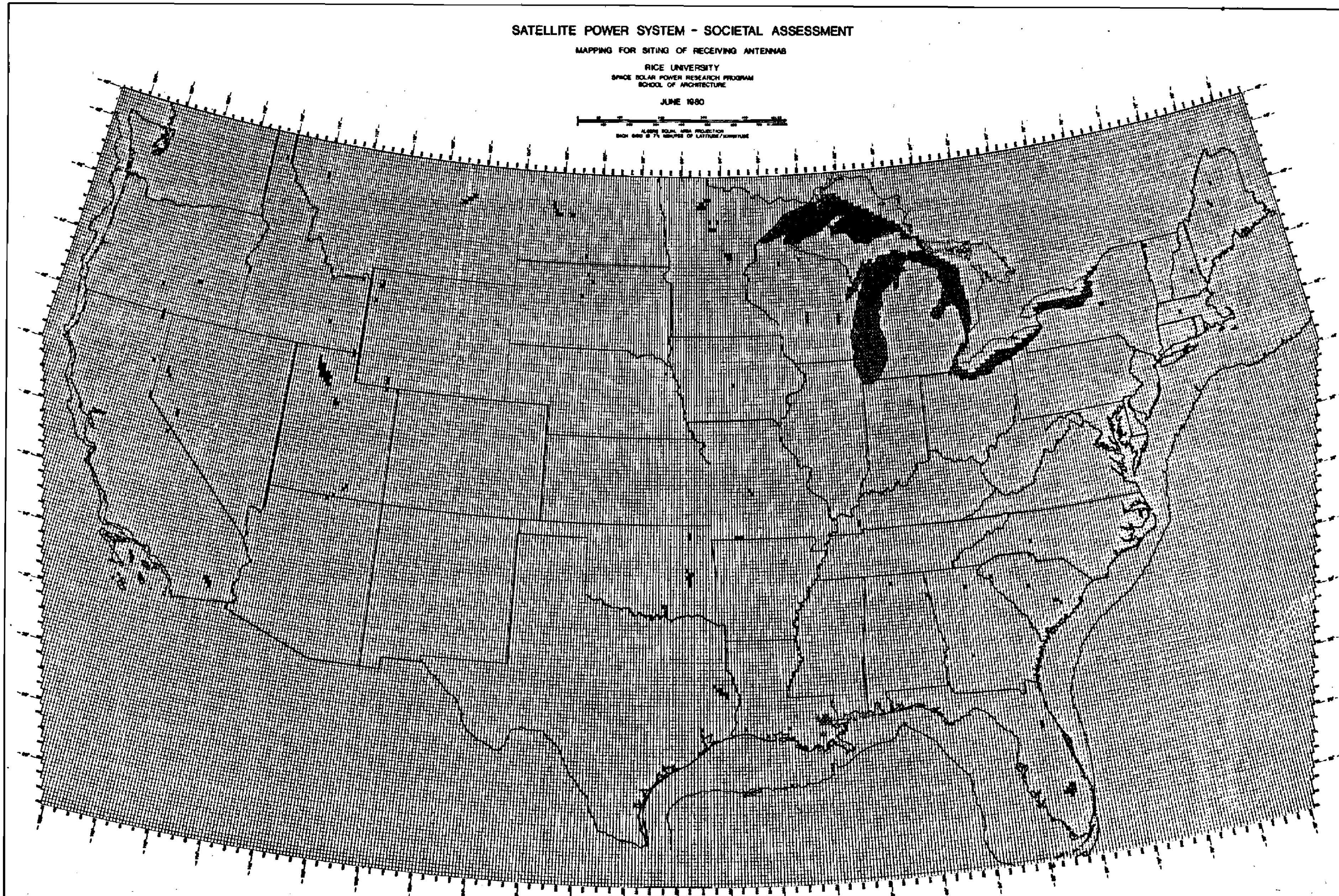
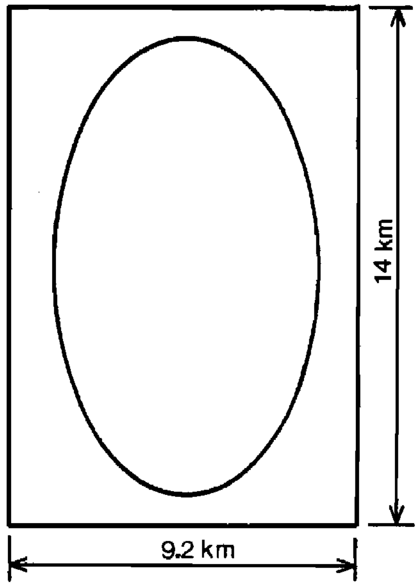


Exhibit III-1 The Base Map w INLAND WATERS

Northernmost Grid



Southernmost Grid

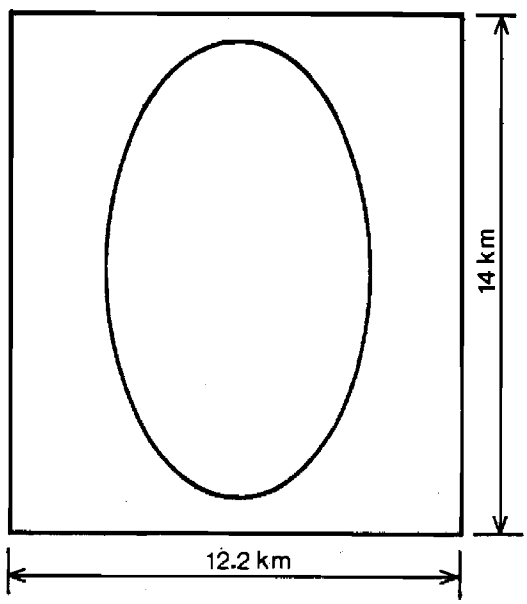


Exhibit III-2 Approximate Grid Square/Rectenna Fit (Without Buffer)

All of the maps produced in this study underwent a systematic accuracy check. An initial screening was used to select source maps. This screening generally involved reference to either the USGS 7-1/2 minute map series or other map sources (USGS 1/250,000 scale maps; other detailed map sources). A second accuracy check was utilized to determine that the mapped information was correctly transferred from the source map to the acetate base map. This accuracy check entailed a visual check by a Principal Investigator to determine that the specified mapping protocol was followed. In many cases, subjective determinations were required (such as along boundary lines) and these determinations were ultimately made by the Principal Investigators.

III.C. DATA PROCESSING

III.C.1. The Data Encoding Process

Once the data had been entered upon the acetate base maps, this information was transferred to the Rice University computer system. This transfer was accomplished through the use of a Tektronix graphics tablet. The graphic tablet is a flat surface underlain by a matrix of electronic sensors. These electronic sensors are activated by a signal which is received by a hand-held device called a "mouse". Through a series of buttons on the mouse, a single data point (grid square) can be coded (or deleted) or an entire line (or portions of a line) of data can be coded.

Once a data pattern was encoded, the accuracy of the encoding process was verified. Two methods were utilized in this checking process. One method involved the tabulation of all grid squares coded for the variable being checked. Each grid square has a unique x/y coordinate identification, and each identified grid square was manually cross-referenced to the acetate base map being coded. This process was supplanted by a computer-generated plot which was then overlaid with the acetate base map. Any coding errors were corrected and the process was repeated to insure the accuracy of the coding process.

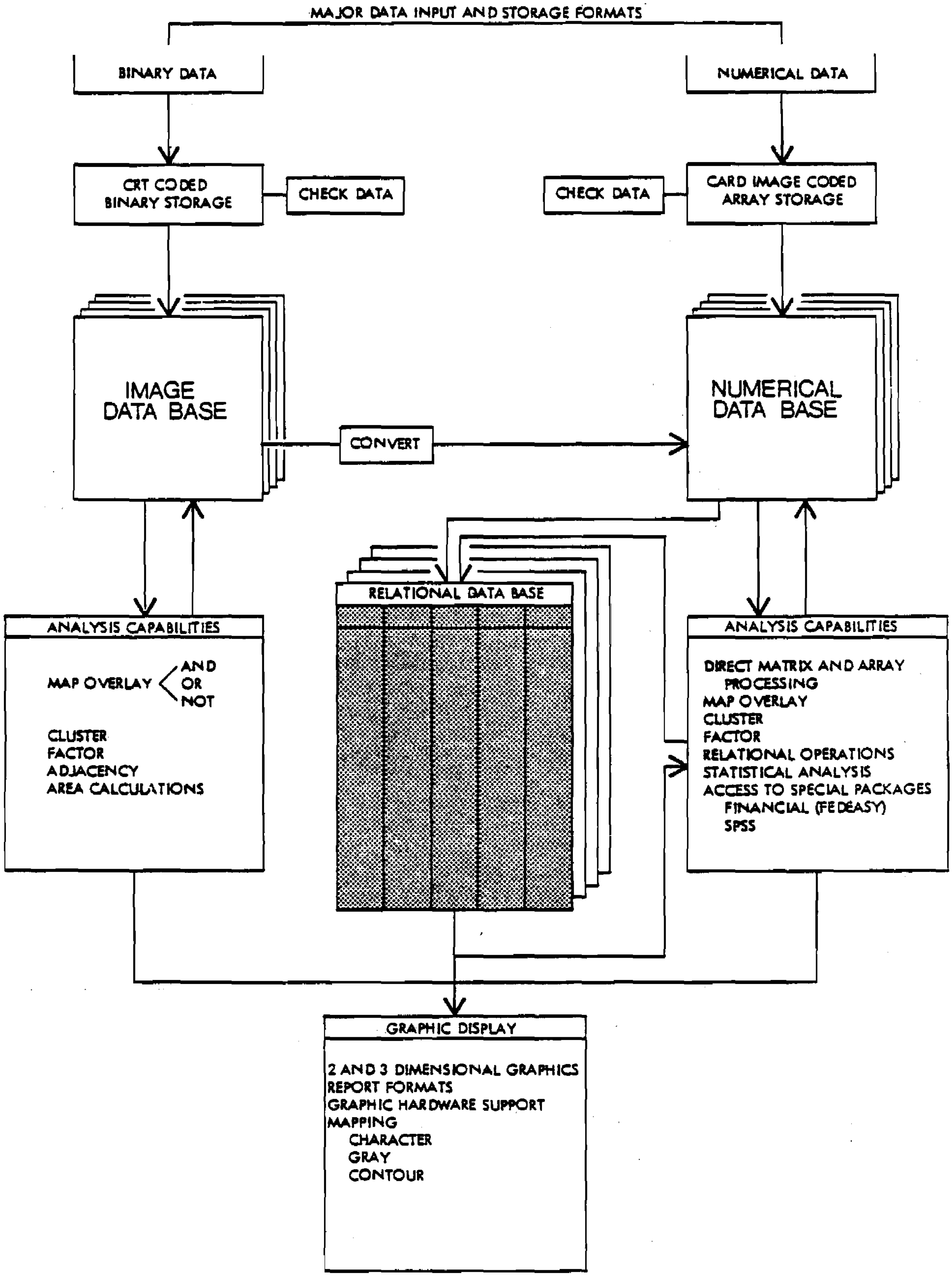
III.C.2. The Data Management Process

The data encoded as described above was entered into the Rice Architecture Geographic Information System (RAGIS). The basic elements of RAGIS are shown in Exhibit III.3. One of the central features of the information system is the use of a host language to support and control its operations. The computer language Speakeasy (developed at Argonne National Laboratory, Cohen and Pieper, 1977, and currently maintained by the Speakeasy Computing Corporation, 222 West Adams, Chicago, Illinois) was used since it stresses the use of English syntax, conversational input-output modes and on-line interactions. Speakeasy is an extensible language that comes with broad general operating capabilities but also allows users to include functions and operations peculiar to their classes of problems. These functions or

Exhibit III-3

RAGIS

SYSTEM DIAGRAM



operations may take the form of algorithms written and compiled in other system-supported languages, such as FORTRAN, and simply linked into Speakeasy's processor. These linked load modules are called "linkules". To the user, linkules are a vocabulary of English language key words that allow the associated programs to be called and executed by name. During the development of RAGIS, an extensive number of linkules specifically related to mapping and spatial analysis were established (Bavinger, 1976). In fact, RAGIS performs as a subsystem within Speakeasy consisting of more than 250 linkules and special operations for geographic information processing.

For purposes of this analysis, certain additional programs had to be developed to extend the size of the array that could be analyzed. Speakeasy is limited to operating with 32,767 grid squares and the analyses required in this project involved the utilization od data patterns involving some 92,512 grid squares. Therefore, several external programs were developed to accommodate these large data structures. Once the data was coded and compressed into byte arrays, the analytical core system of RAGIS as described above performed without modification. A full description of the data management system may be found in Appendix E.

III.C.3. Data Analysis

After encoding and accuracy verification, a series of analytical operations were employed through RAGIS. The basic approach to analysis of the data was two fold. First, each variable was cross-referenced by state and by Electrical Reliability Council (ERC) region. In this manner, the spatial dimensions of the variable could be seen for the United States and for smaller areas that corresponded with other analyses. Secondly, sets of variables were overlaid and maps were produced which indicated the areas covered by those variables. These summary maps were produced to designate areas unavailable as rectenna sites and residual "eligible" areas. The output from this analysis was both visual (maps) and tabular.

The basic analytical tool that led to the production of "Summary Maps" was overlay or sieve analysis. This technique required an ordering of data items in either decreasing or increasing importance. The ordering utilized in this study was one of decreasing importance of variable sets. In all, six variable sets were developed. These were:

1. Absolute exclusion variables except those related to EMC

2. Absolute exclusion variables related to EMC

3. Potential exclusion variables having a high probability of impact and a unique legal status (except EMC)

4. Potential exclusion variables having a high impact of probability related to EMC.

5. Potential exclusion variables having a high probability of impact but currently lacking nationwide protection.

6. Potential exclusion variables having an unknown probability of impact.

The number of variables within each set ranged from a low of two to a high of twelve.

Sieve analysis has been utilized to aid in land use decision-making (Lewis, 1962; Alexander and Manheim, 1962; McHarg, 1969). The approach utilized in this study differed from the referenced studies to the extent that those studies emphasized the number of variables intersecting whereas the presence of a single variable was of primary importance in this study. This study's approach also varied from more traditional uses of sieve analysis for land-use decision-making to the extent that a series of overlay maps were created which emphasized varying degrees of exclusion across sets of data. In this respect, the methodology utilized herein also varies from the methodology utilized in the original Rice University siting study (Blackburn and Bavinger, 1978). Regardless of the variable set utilized, this analytical approach produced a resultant map showing those grid squares eliminated by the overlaid variables. Conversely, the map indicated those grid squares which were free from the overlaid variables.

The second analytical tool utilized in this research was the relational data base management subsystem Rspeak (Schlicting, 1977). This tool was primarily utilized to display the characteristics of the "eligible" cells with respect to coded variables that were not included in the sieve analysis. These characteristics of the "eligible" cells were aggregated at the state level, the Electrical Reliability Council level and the national level. This descriptive information was used in analyses concerning environmental impact and design/cost implications.

A third analytical tool that was developed to aid this research was the capability to encode grid square coordinates and obtain a profile of the characteristics of the grid square. These grid square characteristics could be aggregated across several grid squares to indicate the cumulative presence (or impact) of each variable. This tool was utilized in the environmental impact and design/cost analyses.

A fourth analytical tool that was developed was a mapping program that indicated the density of certain variables on a grid square by grid square basis. The areas exhibiting the highest density of certain selected variables were assigned a unique symbol indicating the presence of a specified variable density. In this manner, profiles of variable density can be developed across the United States. This tool was used to aid in the analysis of design/cost variables.

A fifth analytical tool that was utilized in this research was a so-called "pairs analysis". Through this tool, the relationship of the variables could be exposed. In essence, each of the variables of concern were established in a matrix pattern and the number of times each variable appeared in the same grid square as another variable was displayed. In this manner, an understanding of the variable overlap and interaction could be gained.

III.D. PROJECTION OF REGIONAL AND NATIONAL POWER SUPPLY AND DEMAND

Though much of the analysis in this study was focused on derivation of eligible areas and the mapping of exclusion variables, a parallel element was to establish where rectennas would be needed. As a primary indicator of the need or "appropriate" distribution of rectennas, projections of regional power supply and demand were developed as part of this study.

III.D.1. Projection Selection Process

Independent forecasting of electrical power generation and consumption was outside the scope of this study. Consequently, this phase of the research focused on an extensive literature review of existing projections.

The primary emphasis was to develop and/or adapt a set of electrical power generation and consumption projections that simultaneously met the following criteria:

1. That they be geographically disaggregated at least to a regional level if not to a state level.
2. That they emanate from a reliable and recognized source.
3. That they be regularly updated, preferably on an annual basis.
4. That they extend at least through the initial operating date of the SPS program (2000).
5. That they be published in a form which would permit the examination of alternative energy future scenarios; e.g., continued high oil prices, nuclear moratoria, etc.

A systematic literature review was instituted, resulting in the selection of a series of interrelated projections developed by the mid-term and long-term forecasting groups within the Energy Information Administration (EIA) of the Department of Energy. This information was augmented by a state-level disaggregation analysis of these forecasts performed by Oakridge National Laboratories (ORNL).

III.D.2. Adaptation of Selected Projections

Since the regional disaggregation employed by the EIA was based on ten federal administrative regions which bear no relationship to power pools, utility company service areas or regional enterprise, a special computer program was developed to disaggregate and reaggregate this information into the nine Electrical Reliability Council (ERC) regions used for much electrical generation planning and management throughout the country. Further extrapolation techniques were developed to extend the mid-term forecasts, which are regionally disaggregated, from their terminal date of 1995 to the year 2000 based on a consistent national forecast also developed by the EIA for the periods 2000-2020.

III.E. COMPARISON OF POWER GENERATION AND ELIGIBLE AREA DISTRIBUTIONS

III.E.1. Regional Allocation of Rectennas

Based on the projections developed in this analysis, a series of tests were made to determine the sensitivity of the regional distribution of electrical generation to alternative energy scenarios. A "shift-share" approach was utilized to allocate the sixty rectennas according to power generation by region in the year 2000. Alternative modes of allocation were explored including allocation based on projected capacity increase as distinguished from total generation. For a variety of technical and data limitations, this approach was discarded.

III.E.2. Comparative Distribution Analysis

Once the rectennas had been allocated "appropriately" to the regions in proportion to their projected electrical generation, a series of measures were developed relating to the availability of eligible areas to the number of rectennas required. Most simply stated, these involved the computation of a variety of ratios of eligible cells to required rectennas. Refinements of the analysis included considerations of isolation and special tests were developed to categorize the eligible area according to whether it occured in isolated situations where there were only one or two eligible grids in an otherwise excluded area, or whether eligible grid squares occured in large groups with likelihood of being able to obtain a site in that vicinity was presumably much enhanced by the availability of numerous adjacent eligible grids.

III.E.3. Regional Ranking

The conclusion of this process was the development of a 17-variable approach to ranking each region. Ranking variables were developed in several different categories to reflect, among other things:

1. The availability of sites in an absolute sense.
2. The availability of sites in relation to required number of rectennas.
3. Difficulty in locating sites meeting the constraints of the utility integration study.
4. The likelihood of encountering less critical but still adverse exclusion characteristics.
5. Proxy measurements for environmental impact.
6. Measures of absorption capacity as reflected in the size and distribution of load centers within a region.

IV. DESCRIPTION OF MAPPED VARIABLES

For purposes of determining the availability of 60 sites across the United States, information relating to variables was collected and mapped. Because the methodology was to exclude areas as sites (rather than trying to locate sites), the data collected and mapped were directly related to constraints that will be encountered in siting a receiving antenna as described in the reference design.

As previously discussed, the methodology utilized was one of excluding areas from consideration as potential sites. To aid in this analysis, the variables were classified as either absolute exclusion variables or potential exclusion variables. Additionally, the potential exclusion variables were further classified as potential exclusion variables with a high impact probability, potential exclusion variables with unknown impact probability and design/cost variables. Therefore, four specific groups of variables emerged from the analysis.

IV.A. ABSOLUTE EXCLUSION VARIABLES

Absolute exclusion variables preclude the location of the receiving antenna in these areas. The decision to classify variables as absolute exclusion was based upon current laws, avoidance of severe impacts and qualitative judgments regarding future growth and development. In the sections which follow, each absolute exclusion variable is discussed with respect to the reason for its classification, the shortcomings in the data utilized and the geographic coverage of the variables. Detailed discussion and maps showing the coverage of the variable are included in Appendix A.

IV.A.1. Inland Water Areas

Inland water areas were mapped and considered as absolute exclusion variables for two reasons. First, these areas are likely to be major recreational areas and their conversion would generate a substantial controversy. Secondly, the onshore rectenna is not designed to be constructed over water areas and would not be able to be constructed in these inland areas without significant design changes. Those water areas mapped are only those occupying 50% or more of the grid cell (20,000 acres +). Therefore many smaller water bodies are not represented by this mapped variable. The inland water variable covers 189 grid squares.

IV.A.2. Military Reservations

The major military facilities of the United States were mapped and considered as absolute exclusion variables. These lands are dedicated for military purposes and the conversion of these lands to domestic energy production purposes was considered to be contrary to dedicated purposes of these lands. A grid square was coded as being a military reservation if a reservation were present in the square (20% + of the square was indicated as a military reservation). Military lands cover 578 grid squares, and all of the major military installations are represented. Many of the smaller military bases are not included within the data base because they did not appear upon the base map used for coding purposes.

IV.A.3. Atomic Energy Commission Lands

Prior to the dissolution of the Atomic Energy Commission, certain land areas were dedicated to atomic energy research and testing. These AEC lands are still devoted to such purposes and were considered to be absolute exclusion variables because the siting of a rectenna within these areas would conflict with the dedicated purposes. This variable covers 88 grid squares, and all of the major AEC lands are included in the data base.

IV.A.4. National Recreation Area

Through various acts of Congress and the Executive Branch, certain areas of the United States have been set aside for recreational purposes. These lands include National Parks, National Monuments, National Recreation Areas, National Seashores and National Wildlife Refuges. The location of a receiving antenna within these dedicated areas would preclude their use for their stated purposes and the conversion of these lands was considered to be prohibited by current laws. Together, these five categories of "National Recreation Areas" cover 955 grid squares. The coverage of the mapped data is comprehensive for the larger recreational areas, although many smaller areas were not included in the base data from which the map was compiled.

IV.A.5. Standard Metropolitan Statistical Areas (SMSA's)

Standard Metropolitan Statistical Areas are the major urbanized areas of the United States. These areas were considered as absolute exclusion variables for two reasons. First, areas currently dedicated to urban land uses are precluded as sites for receiving antennas because large numbers of persons would have to be relocated in order to site the rectenna. Second, much of the future growth of the United States will occur within designated SMSA's. Therefore, this variable is also a proxy for future growth and development. In mapping these data, certain SMSA's in the western United States were restricted in their geographic coverage because western counties cover very large land areas. In these cases, the counties were trimmed to better represent areas within which future growth might occur. The total coverage of the SMSA variable was 8437 grid squares. The SMSA's area shown in Exhibit IV-1.

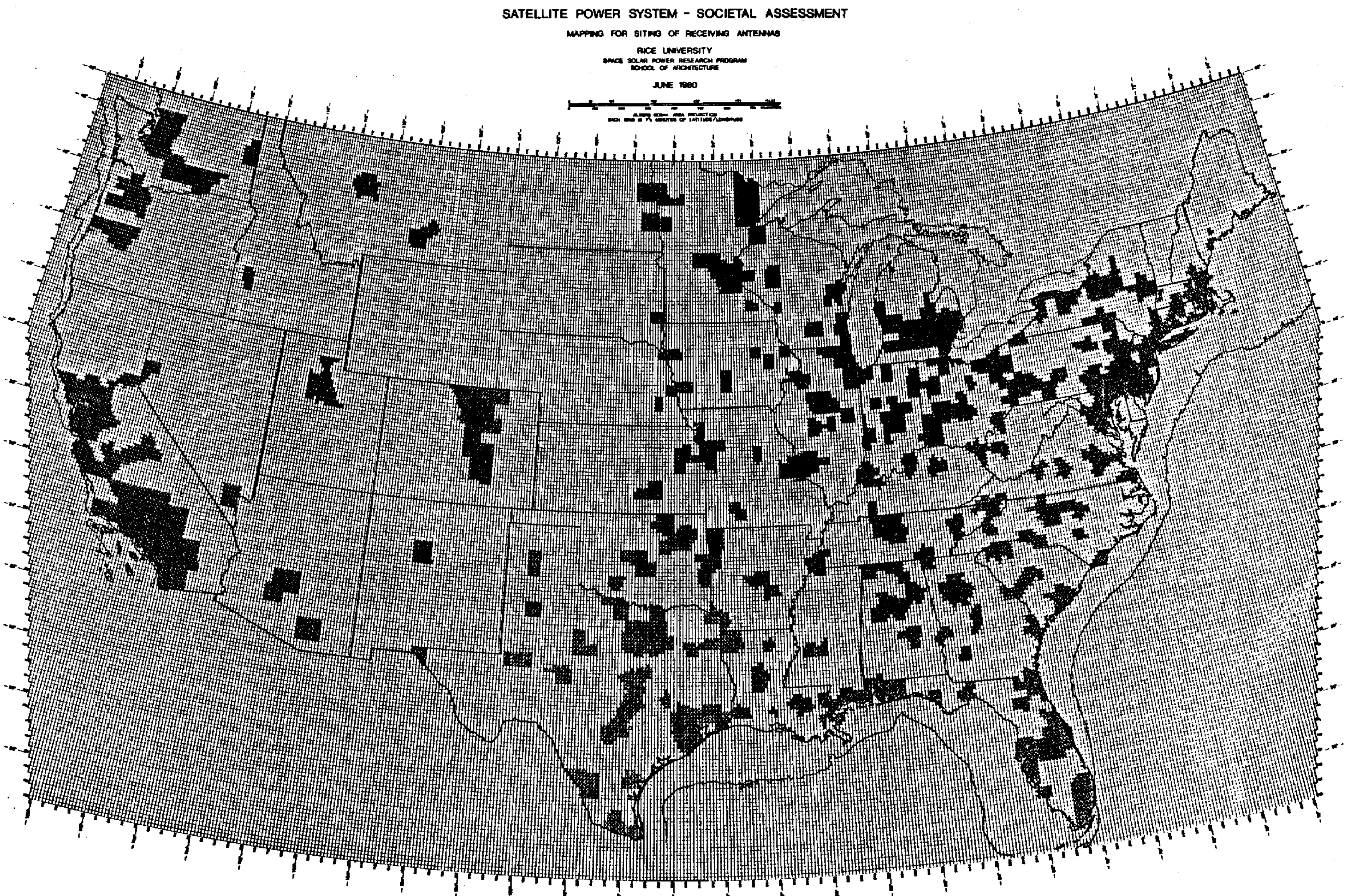


Exhibit IV-1 STANDARD METROPOLITAN STATISTICAL AREAS

IV.A.6. Adjusted Population Density

Although SMSA's represent urbanized areas, they do not include all populated areas. Therefore, a second population variable was developed. This "adjusted population density" variable represents areas with a population of over 1500 persons per grid square. This variable is an important adjunct to the SMSA variable and covers an additional 6715 grid squares. While the data protrayed is considered to be accurate, population changes occurring since 1970 are not included in this information.

IV.A.7. Marshland Vegetation

Marshland areas are important biologically and the conversion of these lands to other lands is discouraged, if not prohibited, under current federal laws. The construction of a rectenna in marshlands would destroy the functional and structural integrity of the marshes. Therefore, these areas were mapped and considered as absolute exclusion variables. The geographic coverage of these marshlands represented 388 grid cells, but many smaller marshland areas are not represented in this map.

IV.A.8. Perennially Flooded Lands

Like marshlands, perennially flooded lands are important biologically and recent court cases indicate that flooded bottom-land hardwoods and other perennially flooded lands are to be included within the Section 404 permit program of the Corps of Engineers and the U. S. Environmental Protection Agency. Additionally, the construction of the rectenna in these areas would be very difficult if not impossible. For these reasons, perennially flooded lands were considered as an absolute exclusion variable. The perennially flooded lands covered 1310 grid cells, although the actual coverage of the variable is probably more extensive than the mapped information.

IV.A.9. Endangered Species

Designated habitats of endangered species are protected under the federal Endangered Species Act. Although mechanisms exist whereby the habitat may be destroyed, it is very difficult to convert these lands to uses that are incompatible with the preservation of the species of concern. Therefore, designated habitats of endangered species were considered as an absolute exclusion variable. These designated habitats cover 396 grid squares. It is important to note that this map covers only those habitats that have been designated for the protection of certain species. Many endangered species have not had habitats designated for their protection and these species could occur almost anywhere within the United States.

IV.A.10. Interstate Highways

Interstate Highways represent sizeable capital investments. For purposes of our analysis, it was concluded that rerouting these major highways was not possible and that the land areas dedicated to these highways should be absolutely excluded from consideration as sites. Although the land areas set aside (a grid cell) for the Interstate Highway is much larger than the highway, it was considered that these highways represent a proxy variable for future population growth because the land areas proximate to Interstate Highways would be more susceptible to urbanization than would other land areas of the United States. Therefore, the grid cells within which Interstate Highways were found were mapped and considered as absolutely excluded for rectenna siting purposes. This variable covered 4451 grid cells.

IV.A.11. Navigable Waterways

Navigable waterways are major arteries of commerce within the United States and represent sizeable capital investments that cannot be relocated. Therefore, those grid cells containing navigable waterways were considered unavailable for rectenna sites. 1311 grid cells were mapped as navigable waterways.

IV.A.12. Topography Unacceptable

Although the most recent rectenna design profile states that rectennas may be constructed "anywhere bulldozers can go", certain areas simply contain too much relief to be available as rectenna sites. Because the design profile is drawn so loosely, slope characteristics could not be utilized at the national mapping scale to determine the limits of unacceptable topography. Therefore, a subjective judgment of "unacceptable topography" was utilized in determining the geographic coverage of this absolute exclusion variable. Those areas mapped as containing unacceptable topography are the major mountain ranges and those areas exhibiting substantial relief. For this reason, the mapped variable is a conservative estimate of the areas precluded as rectenna sites on the basis of topography. In all, 10786 grid cells were mapped as containing unacceptable topography.

IV.A.13. Electromagnetic Compatability (EMC) Variables (No. 13-15)

Wide spread low-density microwave illumination (i.e., broadcast microwave energy) can cause potentially serious problems to a wide variety of facilities that are engaged either in communication (radio and microwave) or in electromagnetic sensing and monitoring. Many of these adverse effects can be mitigated, particularly over the time frame available between now and the installation of the first SPS. In some instances, however, mitigation is difficult or the risks associated with adverse effects are so severe as to make anything short of complete mitigation unacceptable. The Institute for Telecommunications Sciences (ITS) is currently engaged in extensive study of EMC effects of the SPS. Based on information provided by them and discussed in much greater detail in Appendix B, a categorization of EMC exclusion variables was developed based on two dimensions (ITS, 1980).

Adverse EMC effects on different facilities were first categorized as to whether they were appropriately considered as "absolute" or "potential" exclusion variables. In general, there were two tests for absolute exclusion. The first was that mitigation of the adverse effects of SPS microwave illumination could not be completely effected. The second test was that a major risk to human health and safety or national security would be associated with impaired operation of the affected facility.

The second dimension of categorization had to do with distance. Unlike all other exclusion variables, the boundary of the affected facility or the grid square within which it is actually located did not represent the EMC exclusion area. Instead, there is some minimum separation that must exist between the nearest rectenna site and the affected facility. This minimum separation has, for purposes of this analysis, been established in four intervals of 50, 60, 100 and 150 kilometers. Hence, for each facility, there is the boundary of the facility augmented by a radius circle of the specified exclusion distance (e.g., 50 kilometers).

Examples of absolute exclusion variables include military operational testing and evaluation facilities involving extensive use of electromagnetic sensors and electromagnetic communication, particularly in electronic countermeasures. In this instance, any attempts at mitigation would run the risk of impairing the effectiveness of the operational testing. Another example of an absolute exclusion variable is nuclear power plants which, over a relatively small radius (50 kilometers), can be adversely affected in that they employ a variety of electromagnetic sensing and control mechanisms designed to detect and measure extremely weak signals. These sensing and control mechanisms could be impaired by protracted microwave radiation. While opportunities for mitigation exist, the imposition of any additional hazard to nuclear power plant operation, no matter how small, was deemed by ITS to be unacceptable.

There are three absolute exclusion EMC variables reflecting exclusion distances of 150, 100, and 50 kilometers. These variables are labeled as EMC-A150, EMC-A100 and EMC-A50. A map depicting the variable EMC-A150 may be found in Exhibit IV-2. A much more extended discussion, including a detailed breakdown of the location and the basis for classification may be found Appendix B.

The area coverage of the three absolute exclusion variables, including the exclusion areas around the boundaries of the affected facilities were as follows:

EMC-A150: 3920 grid cells

EMC-A100: 916 grid cells

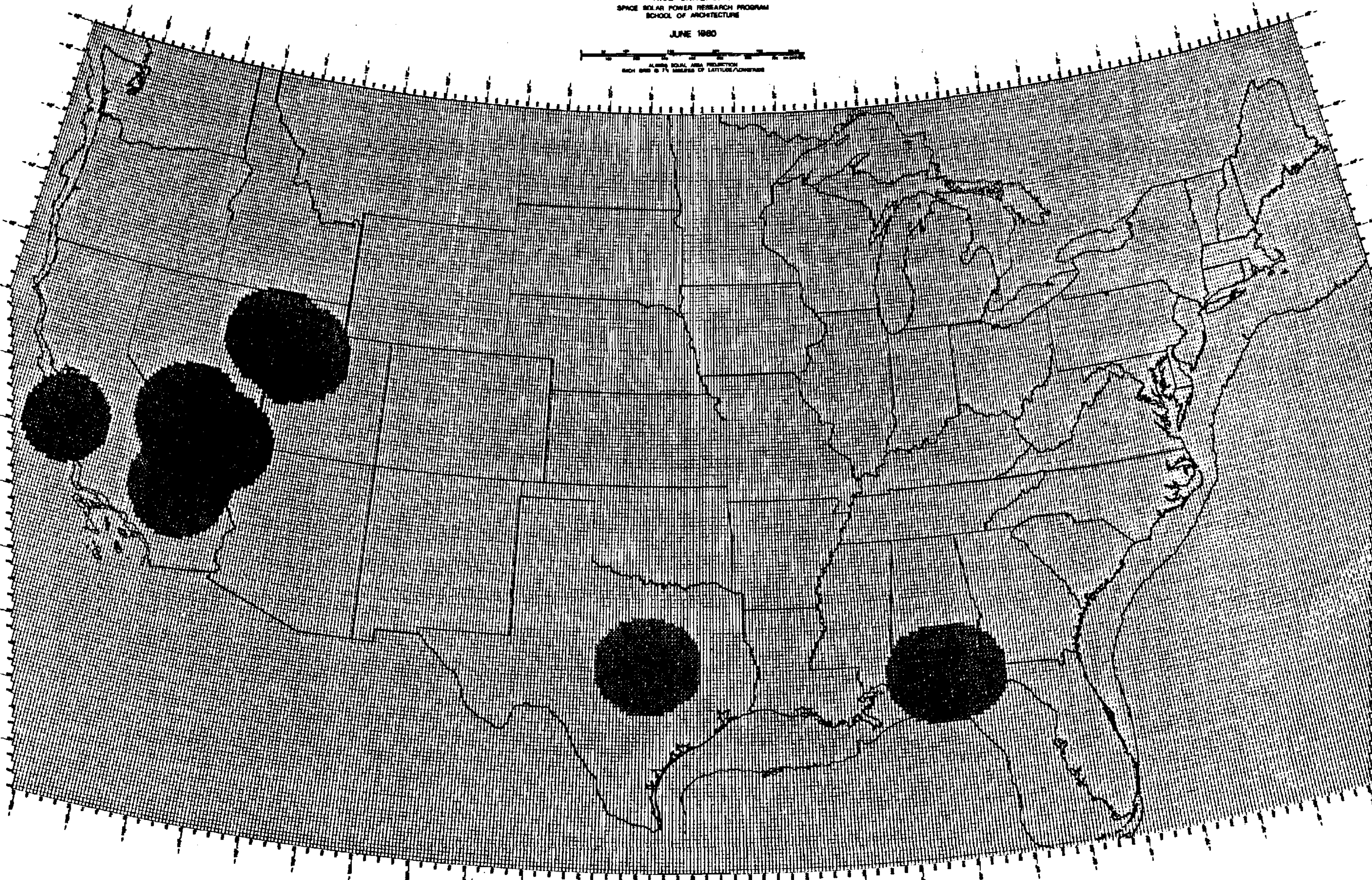
EMC-A50: 6854 grid cells

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

MAPPING FOR SITING OF RECEIVING ANTENNAS

RICE UNIVERSITY
SPACE SOLAR POWER RESEARCH PROGRAM
SCHOOL OF ARCHITECTURE

JUNE 1980



ELECTROMAGNETIC COMPATIBILITY A150

IV.B. POTENTIAL EXCLUSION - HIGH PROBABILITY OF IMPACT

A second major classification of mapped variables are those considered as potential exclusion variables with a high probability of impact. These are variables that may preclude the rectenna from certain areas, although it cannot be stated that the variable will absolutely preclude the use of a site. From the standpoint of classification, these potential exclusion variables are segregated from certain other exclusion variables because it can be stated with surety that these land areas will be impacted by the location of a receiving antenna within their geographic confines. With the other potential exclusion variables, there is a question concerning the impact of the rectenna upon the issue of concern. In the following discussion, the potential exclusion variables with a high probability of impact are discussed.

IV.B.1. Indian Reservations

Indian Reservations are federal lands that are administered by both the tribes and the Bureau of Indian Affairs. With concurrence of the Indian Tribe and the Bureau of Indian Affairs, a receiving antenna could be located upon an Indian Reservation. However, if the tribe or BIA strenuously objected to the location of a rectenna upon these lands, it is doubtful that the site would be available. Because the use of Indian Reservations is not absolutely prohibited, these areas are considered as potential exclusion variables. However, if a rectenna is sited upon an Indian Reservation, there is no doubt that the Indian Reservation would be impacted by that action. 1982 grid cells are mapped as Indian Reservations.

IV.B.2. National Forests and National Grasslands

National Forests and National Grasslands are federal lands that are mapped according to the Multiple Use Sustained Yield Act. Therefore, they are not precluded as sites for rectennas per se. However, substantial opposition to the use of these areas as sites would ensue from the Department of Agriculture as well as other interested groups and the overall availability of these lands is questionable. Because the use of these areas is not precluded per se, these federal lands are considered as potential exclusion variables, although there is no doubt that they would be impacted if a rectenna were located therein. National Forests were mapped as covering 5630 grid cells and National Grasslands were mapped as covering 299 grid cells.

IV.B.3. Wild and Scenic Rivers

Wild and Scenic Rivers are designated for protection under federal and state laws. Although protection under the federal law is comprehensive for designated wild and scenic rivers, the protection is not comprehensive for nominated wild and scenic rivers and for state-designated wild and scenic rivers. Because the mapping of wild and scenic rivers did not differentiate between state and federal designations or between designated and nominated rivers, the variable is considered as a potential exclusion variable. However, it is doubtful that a site containing a wild and scenic river of any type could be utilized for the receiving antenna. Wild and scenic Rivers were present in 1084 grid cells.

IV.B.4. Agricultural Lands

Although "prime" agricultural lands are not currently protected under federal law, there is substantial concern about the conversion of agricultural lands to other uses. The potential exists that farming operations could occur beneath a rectenna, but the current reference system does not include consideration of multiple use. For this reason, agricultural lands were mapped and considered as potential exclusion variables. It is important to note that two proxy variables were utilized for "prime" agricultural lands. These were irrigated cropland and areas that were mostly cropland. Although there is a good probability that these areas will be classified as "prime" agricultural lands, substantially more land area will be designated as "prime" lands than is shown in the mapped information. Therefore, the spatial coverage of this variable is less than the coverage of prime agricultural lands across the United States. 8490 grid cells were indicated as being mostly cropland and 962 grid cells were indicated as being irrigated cropland.

IV.B.5. EMC-P150, EMC-P100, EMC-P60 and EMC-P50

Four variables relating to electromagnetic compatibility were also considered as potential exclusion variables. This classification is based upon the fact that the sites will be impacted but neither national security nor human health complications arise from the EMC impacts. A complete discussion of the potential EMC variables is presented in Appendix B. As was the case with the absolute EMC variables, the rectenna must be located a specified number of kilometers away from certain land uses if interference is to be avoided. EMC-P150 covers 1978 grid cells, EMC-P100 covers 474 grid cells, EMC-P60 covers 1637 grid cells and EMC-P50 covers 798 grid cells.

These five classes of variables represent the suite of potential exclusion variables with a high probability of impact.

IV.C. POTENTIAL EXCLUSION - UNKNOWN PROBABILITY OF IMPACT

The second class of potential exclusion variables has been created to identify variables that may eliminate a site if subsequent research indicates that a rectenna would impact the variable. Specifically, certain corridors are used by migratory birds. If subsequent research indicates that the receiving antenna or the microwave beam has a significant impact upon migratory bird species, then the rectenna should be located in areas of low migratory bird activity. Further, subsequent research may indicate that impacts are related to the size of the bird being exposed to the microwave beam. As discussed in Appendix C on migratory birds, detailed migration corridors have been delineated only for ducks and geese. A substantial amount of research is needed to determine if these corridors of high usage by ducks and geese are accurate descriptions of migratory patterns for all species. Absent definitive patterns for all migratory birds, only the migratory corridors for ducks and geese were mapped as part of this study.

IV.C.1. Flyways of Migratory Waterfowl - Ducks

This map identifies corridors used by ducks during migration. Six density categories were included in the mapped information. These were areas used by 5,250,000 to 9,000,000 ducks, corridors used by 3,010,000 to 5,250,000 ducks, corridors used by 1,510,000 to 3,000,000 ducks, corridors used by 751,000 to 1,500,000 ducks, corridors used by 256,000 to 750,000 ducks and corridors used by 50,000 to 225,000 ducks. These were respectively labeled flyways D1 - D6. 6415 grid cells fall within flyway D1, with D2, D3, D4, D5 and D6 respectively containing 6147, 3280, 4253, 7771 and 9280 grid cells.

IV.C.2. Flyways of Migratory Waterfowl - Geese

This map identifies corridors used by geese during migration. Five density categories were included in this mapped information. These were corridors used by 301,000 to 500,000 geese, corridors used by 151,000 to 300,000 geese, corridors used by 76,000 to 150,000 geese, corridors used by 26,000 to 75,000 geese and corridors used by 5,000 to 25,000 geese. These were respectively labeled flyways G1 - G5. 3815 grid cells fall within flyway G-1, with G2, G3, G4 and G5 respectively containing 6263, 7961 3986, and 3273 grid cells.

These two variables were the only two which were considered as potential exclusion-impact unknown.

IV.D. DESIGN/COST VARIABLES

The fourth variable classification is one related to environmental conditions that may preclude the reference system. However, these conditions may be addressed through a change in the design of the rectenna. These variables have been further subdivided into climatic variables and other variables. In both cases, the impediment represented by the variables may be overcome through design modifications, but these modifications will undoubtedly add to the cost of the receiving antenna. If the cost penalty is considered too great, then these design variables may be elevated to absolute exclusion variables.

IV.D.1. Climatic Variables

IV.D.1.a. Tornado Occurrence - 1955-1967

According to a recent design specification set forth for NASA-Johnson Space Center, the receiving antenna is not designed to withstand tornadoes. Instead, the receiving antenna will be constructed in a manner to allow easy rebuilding. Therefore, a certain risk will be encountered in areas having a high incidence of tornadoes. The mapped information shows areas of the United States that had 300+ tornadoes from 1955-1967, 200-300 tornadoes, 100-200 tornadoes, 50-100 tornadoes, and 10-50 tornadoes. Respectively, these five tornado occurrence variables cover 160, 1411, 9211, 10618 and 11873 grid squares.

IV.D.1.b. Acid Rainfall

Areas having rainfall with high acidity represent a design constraint because of an increased risk of corrosion. As the pH of rainfall decreases, the risk of corrosion becomes greater. Acid rainfall was divided into three categories for mapping purposes. These were areas having an average pH of rainfall of less than 4.0, areas with a pH between 4.0 and 5.0 and areas having a pH of from 5.0 - 5.5. Respectively, these three acid rainfall variables cover 495, 6021 and 11873.

IV.D.1.c. Snowfall

Snowfall loading factors have been computed for most of the United States. According to recent NASA-Johnson Space Center design information, the rectenna is designed to accommodate a snowfall loading factor of 10#/ft.^{2}. For this reason, snowfall loading factors greater than 10#/ft.^{2} have been mapped. Specifically, three classifications have been mapped. These are areas with a snowfall loading factor of from 10-30#/ft.^{2}, areas with a snowfall loading factor over 30#/ft.^{2} and areas where the snowfall loading factor must be computed using site specific data. Respectively, these three variables cover 17,642, 4,088 and 15,145 grid squares.

IV.D.1.d. Freezing Rain

Freezing rainfall also represents a design constraint. In particular, Bill Wilson of Rice University has determined that an ice build-up of 5 mm on the diode will lead to the reflection of 50% of the beam energy. This problem may be overcome by specifically insulating the diode, but this represents an additional design consideration not addressed in the reference system. For this reason, areas having freezing rainfall were mapped. Here, two variables were isolated - those areas having over 8 days of freezing rainfall per year and those areas having from 1-8 days of freezing rainfall. These two variables respectively covered 14853 and 31005 grid cells.

IV.D.1.e. Sheet Rainfall

Rainfall sheeting on the rectenna face will also cover the diode, leading to significant reflection. Although the rain may not remain on the diode as long as ice, sheeting rainfall recurs more frequently than severe icing. For this reason, areas having sheeting rainfall conditions, defined as over 700 gallons of rainfall per square mile per year, were mapped and considered a design variable. The sheeting rainfall variable covers14147 grid cells.

IV.D.1.f. Wind

Two different wind designs have been offered for the rectenna. One design allows for winds of 70 mph while the second, and more recent, design allows for winds up to 115 mph. For this reason, the profile of maximum expected winds, 50 year recurrence interval, were mapped and considered as a design variables. Three maximum wind speeds were mapped. These were winds of from 70-80 mph, winds of from 80-90 mph and winds in excess of 90 mph. Only the latter category would pose problems for the most recent design. Respectively, these wind speed categories cover 23428, 14344 and 1518 grid cells.

IV.D.1.g. Lightning Density

The rectenna must be protected from lightning, and the degree of protection needed is related to the anticipated number of flashes per year per square kilometer. Accordingly, areas having from 10-20 flashes per year per square kilometer and areas having more than 20 flashes per year per square kilometer were mapped. These variables cover, respectively,17358 and 1624 grid cells.

IV.D.1.h. Hail

The receiving antenna could be damaged by hail and a rectenna constructed in an area having a high incidence of hail will have to be designed to address this climatic variable. For this reason, areas having more than 4 days of hail per year were mapped and cover 6483 grid cells.

IV.D.2. Other Design Variables

Four other design-related variables were mapped and are discussed below.

IV.D.2.a. Seismic Risk

Depending upon the design utilized for the rectenna, earthquakes could be a design consideration. For this reason, areas with a major seismic risk and areas with a moderate seismic risk were mapped and considered as design variables. The areas shown as major seismic risk cover 5564 grid cells and the areas mapped as having a moderate seismic risk cover25724 grid cells.

IV.D.2.b. Timbered Areas

In order to prepare a 25,000 acre site for construction, all stumps from trees will have to be removed from the site. This stump removal is very costly and may represent a design constraint. For this reason, areas that are covered with forests were mapped and considered a design variable. Timbered areas covered 11862 grid cells.

IV.D.2.c. Water Availability

In the design evaluated by ERG in the impact analysis study, significant amounts of high quality water were needed for rectenna construction. Although definitive statements about water availability are difficult to make, areas with water availability problems can be indicated. For this reason, areas with groundwater overdrafts were mapped and areas having surface water problems during both average and dry years were mapped. 9296 grid cells were indicated as having groundwater overdraft problems. 9982 grid cells were indicated as being 70% depleted of surface water during an average year and 4923 grid cells were indicated as being 70% depleted of surface water supplies during a dry year.

IV.D.2.d. Topography

As discussed in more detail in Section VII.C.3, particular problems were encountered in the treatment of topography. In particular, while the mapped absolute exclusion variable for topography accurately described unacceptable areas, it was too restrictive. In other words, many land areas outside the absolute exclusion areas were also unacceptable. Because detailed mapping of these additional areas was not possible at the national scale, three land form classifications were developed which describe three differing degrees of difficulty in finding suitable sites. In essence, these land form classes describe flat lands, mostly flat lands and a zone of transition between mostly flat lands and unacceptable topography. Approximately 96% of the flat lands could be used as sites, whereas only 67% of the mostly flat lands could be used as sites. Only 24% of the "transition" zone is eligible. If these ineligible grid squares must be utilized, then substantial coats will be incurred for earth-moving and other site work. Flat lands were present in 15552 grid cells and mostly flat lands were present in 9665 grid cells. The "transitional" zone covered 16755 grid cells.

V. COMBINED IMPACT OF EXCLUSIONS: SUMMARY MAPS

V.A. THE SUMMARY MAPPING PROCESS

As discussed in the section on methodology, overlay or sieve analysis was utilized to determine the areas from which rectennas were excluded. The absolute and potential exclusion variables were encoded into the Rice Computer system and a series of maps were generated which indicated the areas covered by the variables. The presence of a single specified variable would lead to the grid cell being marked as ineligible. No distinction was made when more than a single variable excluded the site.

The procedure utilized in this mapping effort produced a map depicting the aerial coverage of the specified variables and tables depicting the occurrence of the individual variables employed in the analysis. The occurrence of the variables is shown for each state as well as for each electrical reliability council area. Additionally, each of the tables indicate the occurrence of "eligible" areas which are those areas not excluded by the overlay analysis.

The sequence of overlay mapping shown in the following sections is from the most restrictive constraints through the potential constraints. Each successive summary map represents an additive process. In other words, each summary map builds upon previous summary mapping efforts.

In all, six summary maps were produced. The six sets of variables successively overlaid are as follows:

1. Absolute Exclusion Variables (Except EMC)
2. Absolute Exclusion Variables (with EMC)
3. Absolute Exclusion Variables Plus Dedicated/Restricted Land Uses
4. Absolute Exclusion Variables Plus Dedicated/Restricted Land Use Plus EMC
5. Absolute Exclusion Variables Plus Dedicated/Restricted Land Uses Plus EMC Plus Other Potential Exclusion Variables With a High Probability of Impact
6. All of the above plus selected flyways.

V.B. SUMMARY MAP ANALYSIS

V.B.1. Absolute Exclusions (Without EMC)

The initial summary map (Exhibit V-1) is composed of twelve absolute exclusion variables. These twelve exclusion variables are:

1. Standard Metropolitan Statistical Areas
2. Adjusted Population Density

3. Unacceptable Topography
4. Marshlands
5. Perennially Flooded Lands
6. Interstate Highways
7. Navigable Waterways
8. Inland Waters
9. Designated Habitats of Endangered Species
10. National Recreation Areas
11. Military Reservations
12. Atomic Energy Commission Lands

As can be seen from Exhibit V-2, the overlaying of these variables caused 27,518 grid cells to be excluded as potential sites. The distribution of the individual variables as well as the distribution of "eligible" areas can also be seen in Exhibit V-2. The total shown at the bottom of this table is the total for either the states or the Electrical Reliability Council Areas.

V.B.2. Absolute Exclusions with EMC

Summary Map 2 is shown in Exhibit V-3. This map was produced by overlaying the Electromagnetic Compatibility variables EMC-A150, EMC-A100 and EMC-A50 with Summary Map 1. In all, fifteen variables were combined in this map. The distribution of the individual variables and the distribution of the "eligible" areas are shown in Exhibit V-4. After the combination of variables in Summary Map 2, 31,159 grid cells were excluded.

V.B.3. Absolute Exclusion Variables Plus Dedicated/Restricted Land Uses

The third summary map was produced by overlaying the fifteen variables represented in Summary Map 2 with the potential exclusion variables exhibiting a unique legal status. There were four variables in the "dedicated/restricted land uses" set. These were:

1. Indian Reservations
2. National Forests
3. National Grasslands
4. Wild and Scenic Rivers

The results of this overlay analysis are depicted in Exhibit V-5. Exhibit V-6 indicates that 33,987 grid cells were eliminated by the nineteen variables overlaid in Summary Map 3.

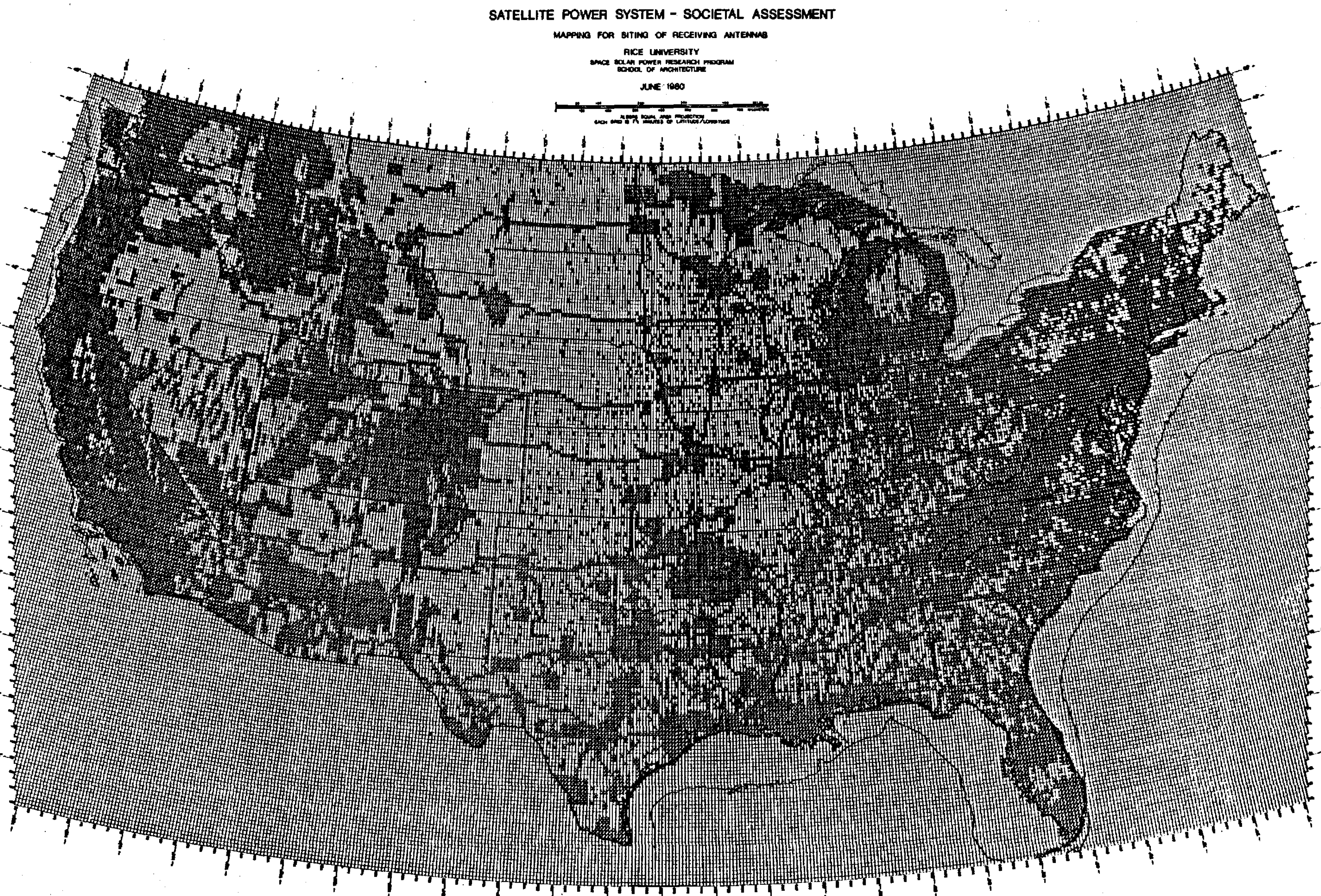


Exhibit V-1 SUMMARY MAP 1

GRID SQUARE PROFILE OF SUMMARY MAP 1															
STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	STANDARD METROPOLITAN STATISTICAL AREA	ADJUSTED POPULATION DISTRIBUTION	INTERSTATE HIGHWAYS	TOPOGRAPHY UNACCEPTABLE	MILITARY RESERVATIONS	ATOMIC ENERGY COMMISSION LAND	NATIONAL RECREATION AREAS	MARSH VEGETATION	PERENNIALLY FLOODED LANDS	ENDANGERED SPECIES HABITAT	NAVIGABLE WATERWAYS	INLAND WATER
Alabama	322	39	490	241	156	91	51	9	0	0	0	55	2	75	2
Arizona	861	46	997	124	63	141	699	76	0	145	0	0	0	0	1
Arkansas	361	40	524	136	154	60	247	4	0	5	0	7	2	72	0
California	418	15	2249	950	164	205	1615	123	0	150	0	0	8	32	11
Colorado	591	33	1169	304	71	114	875	7	0	23	0	0	3	0	0
Connecticut	2	2	83	54	29	10	0	0	0	0	0	0	0	6	0
Delaware	5	13	31	8	20	2	0	0	0	0	0	1	0	3	0
Florida	193	22	684	384	99	142	0	20	0	28	139	149	44	99	12
Georgia	344	36	595	170	249	118	63	15	1	13	0	130	0	62	2
Idaho	638	40	936	21	72	73	787	4	19	4	0	0	2	0	3
Illinois	385	38	607	281	257	166	0	0	0	1	0	0	0	62	0
Indiana	158	25	458	235	203	96	0	7	0	0	0	0	0	14	0
Iowa	633	63	371	109	213	85	0	0	0	0	0	3	0	34	1
Kansas	1102	77	318	92	154	160	0	7	0	2	0	0	5	4	0
Kentucky	241	35	435	96	276	76	12	8	0	8	0	2	0	71	2
Louisiana	169	22	585	185	153	84	0	4	0	8	126	188	0	163	19
Maine	490	77	141	10	89	33	18	0	0	1	0	0	0	6	4
Maryland	30	15	165	74	67	19	30	0	0	0	8	2	0	15	0
Massachusetts	22	13	142	87	48	35	7	0	0	4	0	0	0	2	1
Michigan	571	51	534	301	174	109	0	0	0	7	0	29	0	14	0
Minnesota	793	48	843	344	161	108	0	0	0	7	0	188	246	20	19
Mississippi	390	50	379	74	186	76	0	0	0	4	1	114	5	21	0
Missouri	773	63	435	150	194	117	0	5	0	2	0	0	0	83	5
Montana	1752	61	1081	111	70	149	809	0	3	72	0	0	0	0	8
Nebraska	1193	85	208	30	111	74	2	0	2	9	0	0	9	7	0
Nevada	1192	61	734	60	16	64	511	72	30	90	0	6	0	0	5
New Hampshire	59	35	107	13	55	23	39	0	0	0	0	0	0	0	1
New Jersey	0	0	141	105	34	34	15	2	0	1	13	0	0	10	0
New Mexico	1165	58	811	37	82	114	601	88	4	18	0	0	1	0	0
New York	234	26	656	315	270	127	93	6	0	0	6	0	0	83	2
North Carolina	105	12	735	175	370	88	165	8	0	9	3	162	3	50	1
North Dakota	1213	83	233	68	57	83	31	0	0	15	0	0	0	3	9
Ohio	126	17	810	332	263	143	0	0	0	0	0	0	0	19	0
Oklahoma	659	57	490	216	144	91	116	6	0	4	0	0	14	13	13
Oregon	846	46	970	197	90	73	822	4	0	35	0	0	0	42	4
Pennsylvania	144	18	643	326	260	159	191	0	0	0	0	0	0	14	0
Rhode Island	1	5	16	13	3	7	0	0	0	0	0	0	0	0	0
South Carolina	94	18	414	129	206	77	11	2	8	11	11	135	0	19	5
South Dakota	1218	85	199	15	56	87	61	0	0	8	0	0	0	0	3
Tennessee	177	25	516	186	215	104	156	4	5	12	0	33	24	58	0
Texas	2391	57	1796	856	380	343	342	8	0	29	78	81	14	42	9
Utah	543	37	921	99	41	102	691	61	0	70	0	7	0	0	29
Vermont	43	23	137	0	64	31	79	0	0	0	0	0	0	6	4
Virginia	96	14	555	150	235	101	307	9	0	8	3	7	14	28	0
Washington	431	32	897	316	80	86	606	16	16	64	0	0	0	28	0
West Virginia	102	24	307	55	137	50	146	0	0	0	0	0	0	29	0
Wisconsin	639	60	424	199	187	57	0	3	0	4	0	11	0	5	8
Wyoming	1046	58	746	0	35	117	588	0	0	84	0	0	0	0	6
NERC REGIONS															
WSCC	8602	42	11533	2235	767	1232	6677	451	65	747	0	13	14	102	64
MARCA	6005	74	2038	656	679	477	41	3	5	49	0	202	255	65	39
SPP	3770	58	2651	883	881	499	415	21	0	22	136	284	21	311	36
ERCOT	1746	54	1444	710	293	269	270	8	0	26	68	35	14	31	9
SERC	1537	28	3933	1425	1513	722	524	69	14	82	157	742	78	398	23
MAIN	1278	53	1109	450	501	252	0	5	0	12	0	24	0	119	5
ECAR	1069	27	2849	1208	1283	582	444	13	0	11	0	7	14	155	1
MAAC	103	13	679	378	240	144	179	2	0	1	21	3	0	27	0
NPCC	851	39	1282	492	558	274	236	6	0	5	6	0	0	103	12
TOTALS*	24961	47	27518	8437	6715	4451	10786	578	88	955	388	1310	396	1311	189

Exhibit V-2 Summary Table 1

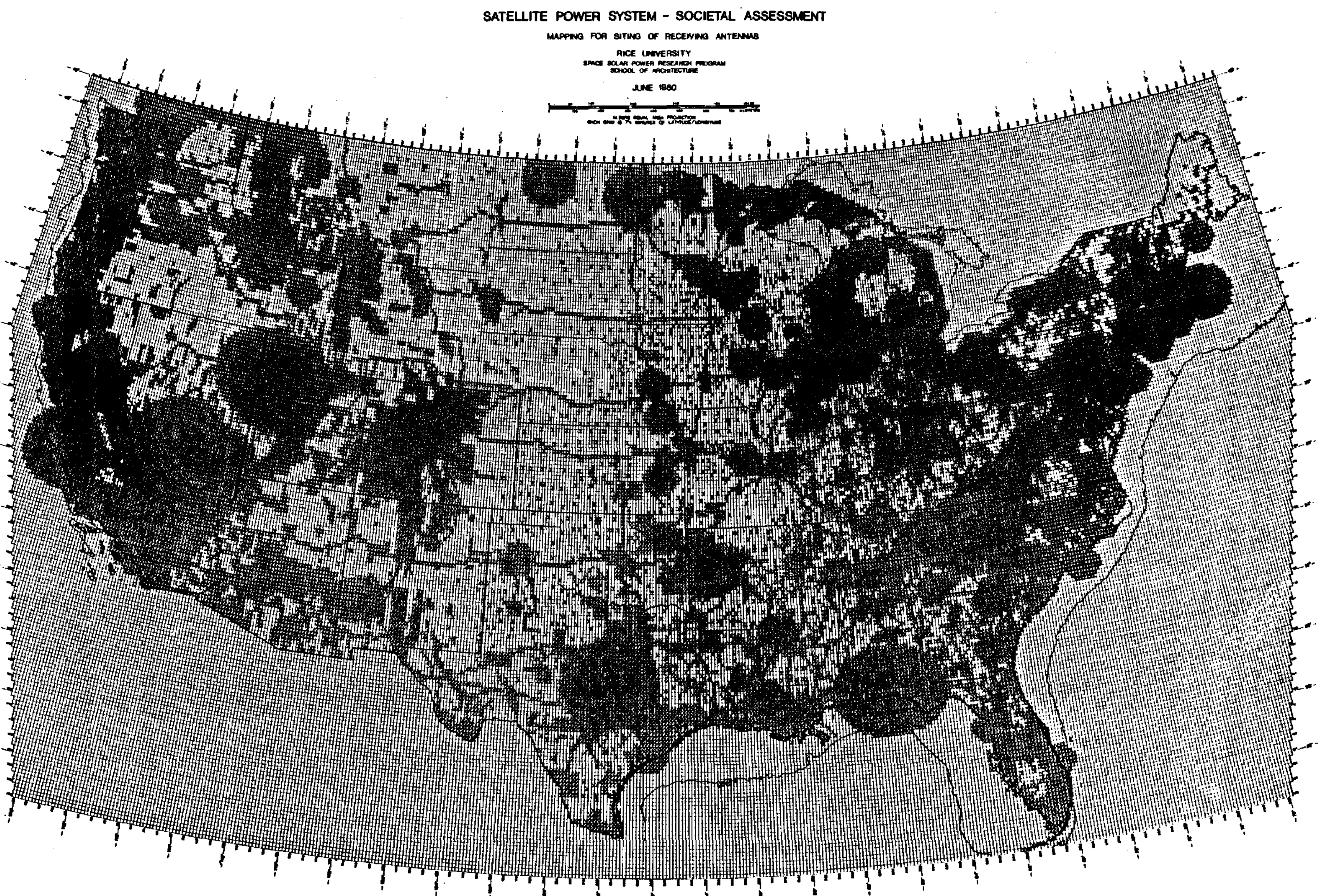


Exhibit V-3 SUMMARY MAP 2

GRID SQUARE PROFILE OF SUMMARY MAP 2							
STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	EXCLUDED GRIDS SUMMARY MAP 1	EMC A50	EMC A100	EMC A150
Alabama	166	20	646	490	198	0	248
Arizona	785	42	1073	997	93	0	73
Arkansas	353	39	532	524	107	0	0
California	235	8	2432	2249	288	298	987
Colorado	589	33	1171	1169	93	0	0
Connecticut	0	0	85	83	77	0	0
Delaware	3	8	33	31	17	0	0
Florida	109	12	768	684	127	0	167
Georgia	238	25	701	595	229	0	45
Idaho	575	36	999	936	93	0	14
Illinois	299	30	693	607	360	0	0
Indiana	140	22	476	458	105	0	0
Iowa	531	52	473	371	208	0	0
Kansas	1027	72	393	318	108	0	0
Kentucky	197	29	479	435	144	0	0
Louisiana	152	20	602	585	187	0	0
Maine	468	74	163	141	56	0	0
Maryland	15	7	180	165	95	0	0
Massachusetts	2	1	162	142	156	64	0
Michigan	494	44	611	534	300	0	0
Minnesota	665	41	951	843	156	133	0
Mississippi	327	42	442	379	110	0	23
Missouri	711	58	497	435	120	0	0
Montana	1752	61	1081	1081	0	0	0
Nebraska	1136	81	265	208	92	0	0
Nevada	599	31	1327	734	0	0	1066
New Hampshire	41	24	125	107	59	0	0
New Jersey	0	0	141	141	90	0	0
New Mexico	1165	58	811	811	0	0	0
New York	213	23	677	656	216	0	0
North Carolina	72	8	768	735	335	0	0
North Dakota	888	61	558	233	0	420	0
Ohio	87	11	649	610	243	0	0
Oklahoma	641	55	508	490	93	0	0
Oregon	764	42	1052	970	141	0	0
Pennsylvania	131	16	656	643	349	0	0
Rhode Island	0	0	17	16	17	1	0
South Carolina	25	4	483	414	314	0	0
South Dakota	1218	85	199	199	0	0	0
Tennessee	119	17	574	516	339	0	0
Texas	1924	45	2263	1796	334	0	656
Utah	305	20	1159	921	0	0	640
Vermont	35	19	145	137	31	0	0
Virginia	60	9	591	555	191	0	0
Washington	348	26	980	897	340	0	0
West Virginia	102	24	307	307	5	0	0
Wisconsin	548	51	515	424	238	0	0
Wyoming	1046	58	746	746	0	0	1
NERC REGIONS							
WSCC	7282	36	12853	11533	1048	298	2781
MARCA	5350	66	2693	2038	581	553	0
SPP	3558	55	2863	2651	692	0	0
ERCOT	1321	41	1869	1444	241	0	656
SERC	968	17	4502	3933	1739	0	483
MAIN	1120	46	1267	1109	557	0	0
ECAR	879	22	3039	2849	994	0	0
MAAC	83	10	699	679	390	0	0
NPCC	759	35	1374	1282	612	65	0
TOTALS*	21320	40	31159	27518	6854	916	3920

Exhibit V-4 Summary Table 2

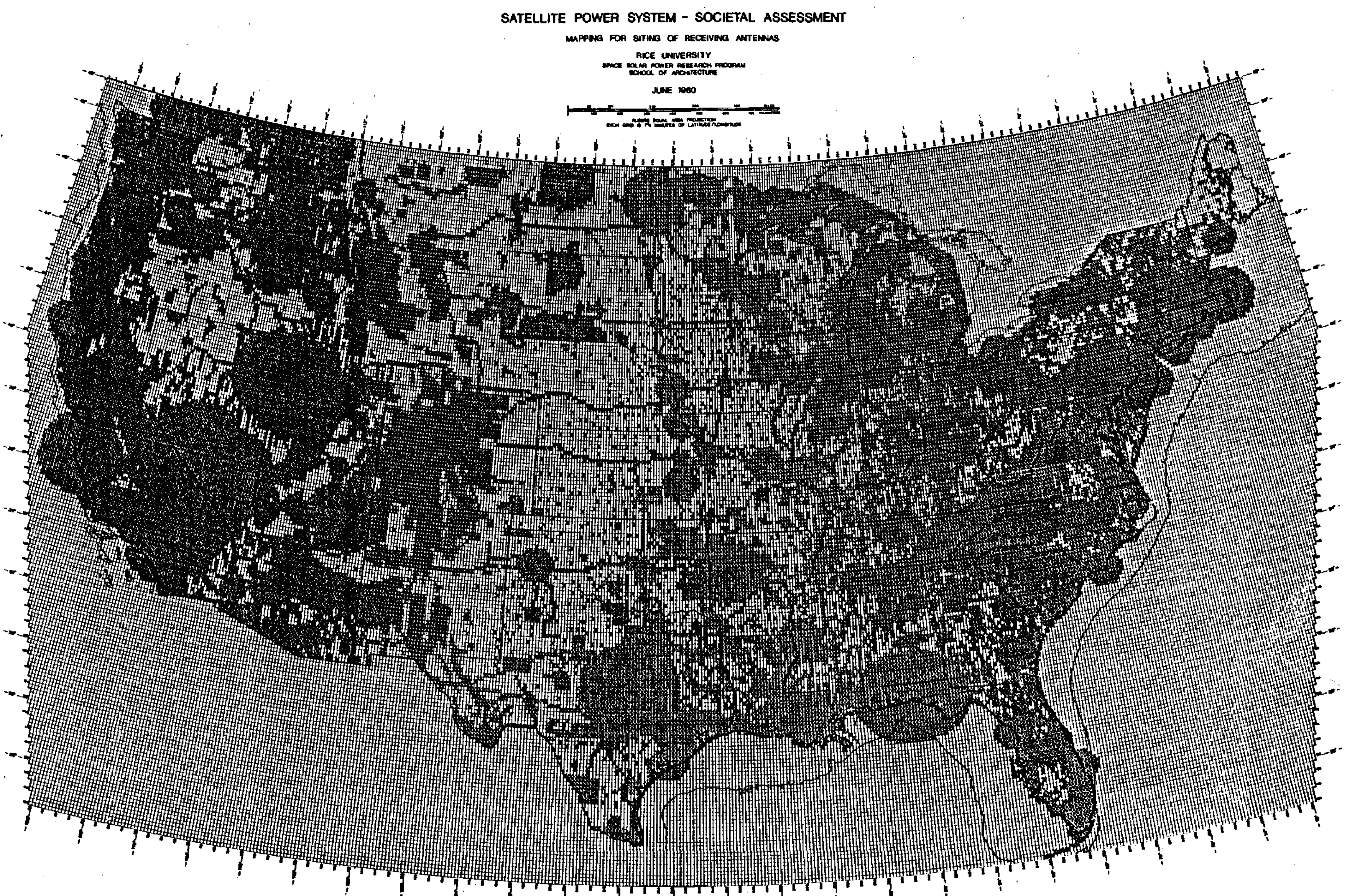


Exhibit V-5 SUMMARY MAP 3

GRID SQUARE PROFILE OF SUMMARY MAP 3 STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	EXCLUDED GRIDS SUMMARY MAP 2	INDIAN RESERVATIONS	NATIONAL FORESTS	NATIONAL GRASSLANDS	WILD AND SCENIC RIVERS
Alabama	154	18	658	646	0	35	0	10
Arizona	357	19	1501	1073	501	323	0	0
Arkansas	339	38	546	532	0	92	0	9
California	188	7	2479	2432	18	664	0	104
Colorado	548	31	1212	1171	29	409	60	49
Connecticut	0	0	85	85	0	0	0	7
Delaware	3	8	33	33	0	0	0	0
Florida	100	11	777	768	3	31	0	18
Georgia	233	24	706	701	0	43	0	8
Idaho	455	28	1119	999	60	646	5	99
Illinois	286	28	706	693	0	18	0	0
Indiana	124	20	492	476	0	21	0	5
Iowa	527	52	477	473	0	0	0	11
Kansas	1017	71	403	393	3	0	8	0
Kentucky	175	25	501	479	0	41	0	11
Louisiana	115	15	639	602	0	30	0	93
Maine	427	67	204	163	0	2	0	44
Maryland	13	6	182	180	0	0	0	25
Massachusetts	2	1	162	162	0	0	0	0
Michigan	346	31	759	611	0	148	0	43
Minnesota	636	38	1000	951	80	138	0	92
Mississippi	288	37	481	442	0	63	0	0
Missouri	634	52	574	497	0	76	0	19
Montana	1460	51	1373	1081	276	526	0	40
Nebraska	1101	78	300	265	14	14	12	0
Nevada	551	28	1375	1327	33	157	0	0
New Hampshire	39	23	127	125	0	26	0	0
New Jersey	0	0	141	141	0	0	0	0
New Mexico	1004	50	972	811	188	279	13	5
New York	172	19	718	677	0	0	0	73
North Carolina	69	8	771	768	1	76	0	7
North Dakota	793	54	653	558	65	0	71	20
Ohio	75	10	661	649	0	41	0	33
Oklahoma	629	54	520	508	41	13	5	10
Oregon	599	32	1217	1052	30	505	0	72
Pennsylvania	111	14	676	656	0	21	0	8
Rhode Island	0	0	17	17	0	0	0	0
South Carolina	21	4	487	483	0	33	0	4
South Dakota	821	57	596	199	365	41	53	0
Tennessee	112	16	581	574	0	38	0	48
Texas	1879	44	2306	2263	0	39	18	14
Utah	249	17	1215	1159	82	226	0	5
Vermont	35	19	145	145	0	18	0	0
Virginia	60	9	591	591	0	89	0	8
Washington	267	20	1061	980	104	319	0	17
West Virginia	99	24	310	307	0	50	0	18
Wisconsin	443	41	620	515	14	67	0	43
Wyoming	936	52	856	746	75	272	54	12
NERC REGIONS								
WSCC	5800	28	14335	12653	1324	4349	147	403
MARCA	4630	57	3413	2693	605	221	115	151
SPP	3437	53	2984	2863	44	175	33	112
ERCOT	1298	40	1892	1869	0	29	4	14
SERC	900	16	4570	4502	4	346	0	99
MAIN	946	39	1441	1267	5	168	0	34
ECAR	741	18	3177	3039	0	278	0	131
MAAC	65	8	717	699	0	18	0	16
NPCC	675	31	1456	1374	0	46	0	124
TOTALS*	18492	35	33987	31159	1962	5630	299	1084

Exhibit V-6 Summary Table 3

V.B.4. Absolute Exclusion Variables Plus Dedicated/Restricted Land Uses Plus Potential EMC Variables

The fourth summary map was produced by overlaying the nineteen variables from summary map 3 with the four potential exclusion variables related to electromagnetic compatibility. The four potential exclusion EMC variables are:

1. EMC - P150
2. EMC - P100
3. EMC - P60
4. EMC - P50

The results of this overlay analysis are presented in Exhibit V-7. The twenty-three variables overlaid in this analysis excluded 35,321 grid cells. The tabular presentation of the variables is shown in Exhibit V-8.

V.B.5. Absolute Exclusion Variables Plus All Potential Exclusion Variables With A High Probability of Impact

The fifth summary map was produced by overlaying the twenty-three variables from Summary Map 4 with the two remaining potential exclusion variables with a high probability of impact. These were irrigated croplands and mostly cropland potential exclusion variables. The resulting summary map is shown in Exhibit V-9. As shown in Exhibit V-10, 39,745 grid cells were eliminated by these twenty-five variables.

V.B.6. Absolute Exclusion Variables Plus Potential Exclusion Variables With a High Probability of Impact Plus Selected Flyways

The twenty-five variables from Summary Map 5 were overlaid with three selected flyways to produce Summary Map 6 which is Exhibit V-11. The flyways utilized in this summary map were the highest density flyways for ducks (5,000,000 to 9,000,000) and the two highest density flyways for geese (300,000 - 500,000 and 150,000 - 300,000).

From the table presented in Exhibit V-12, it can be seen that these twenty-eight variables eliminated 43,140 grid cells from consideration as sites.

V.C. INCREMENTAL IMPACT OF SELECTED VARIABLES

The six summary maps and tables provide extensive information on the incidence of the component variables, i.e., how frequently they occur by region and state. It also provides useful information on the net excluded area, after allowing for the overlap among exclusion variables. The relationship between specific variables is also of considerable interest for future site planning and possible redesign efforts relating to the SPS. This information requires a different type of analysis.

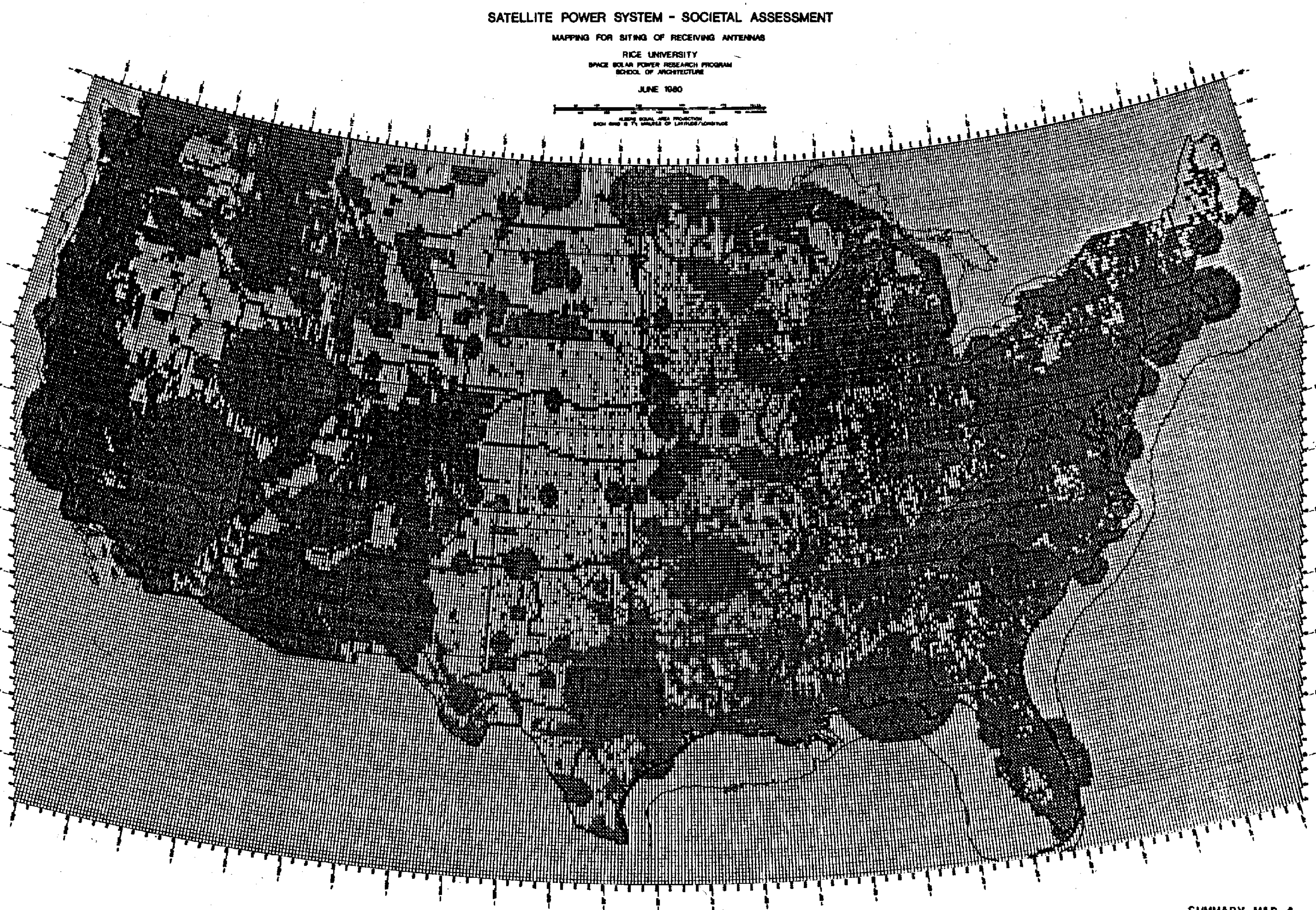


Exhibit V-7 SUMMARY MAP 4

GRID SQUARE PROFILE OF SUMMARY MAP 4								
STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	EXCLUDED GRIDS SUMMARY MAP 3	EMC P150	EMC P100	EMC P60	EMC P50
Alabama	139	17	673	658	0	0	187	0
Arizona	212	11	1646	1501	518	0	517	181
Arkansas	325	36	560	546	0	0	72	0
California	166	6	2501	2479	307	237	553	181
Colorado	501	28	1259	1212	0	0	140	96
Connecticut	0	0	85	85	0	0	7	10
Delaware	2	5	34	33	0	6	12	0
Florida	87	9	790	777	0	0	283	0
Georgia	206	21	733	706	0	0	127	0
Idaho	438	27	1136	1119	0	0	69	0
Illinois	286	28	706	706	0	0	37	67
Indiana	117	18	499	492	0	0	66	0
Iowa	503	50	501	477	0	0	92	0
Kansas	950	66	470	403	0	0	110	0
Kentucky	172	25	504	501	0	0	16	0
Louisiana	113	14	641	639	0	0	62	0
Maine	410	64	221	204	0	0	21	0
Maryland	3	1	192	182	20	130	147	0
Massachusetts	0	0	164	162	0	0	56	48
Michigan	338	30	767	759	0	0	54	0
Minnesota	606	37	1030	1000	0	0	144	0
Mississippi	250	32	519	481	0	0	97	0
Missouri	598	49	610	574	0	0	96	0
Montana	1439	50	1394	1373	0	0	102	0
Nebraska	1071	76	330	300	0	0	59	0
Nevada	505	26	1421	1375	0	0	111	0
New Hampshire	39	23	127	127	0	0	14	0
New Jersey	0	0	141	141	0	0	22	0
New Mexico	725	36	1251	972	545	0	506	84
New York	166	18	724	718	0	0	126	23
North Carolina	68	8	772	771	0	0	72	0
North Dakota	779	53	667	653	0	0	37	0
Ohio	55	7	681	661	100	0	63	0
Oklahoma	623	54	526	520	0	0	37	0
Oregon	584	32	1232	1217	0	0	130	0
Pennsylvania	85	10	702	676	188	23	152	0
Rhode Island	0	0	17	17	0	0	0	0
South Carolina	20	3	486	487	0	0	64	0
South Dakota	791	55	626	596	0	0	37	0
Tennessee	109	15	584	581	0	0	77	0
Texas	1768	42	2419	2308	0	0	332	69
Utah	243	16	1221	1215	0	0	105	0
Vermont	30	16	150	145	0	0	34	0
Virginia	49	7	602	591	59	71	96	0
Washington	263	19	1065	1061	0	0	63	0
West Virginia	24	5	385	310	241	7	3	0
Wisconsin	427	40	636	620	0	0	37	39
Wyoming	873	48	919	856	0	0	101	0
NERC REGIONS								
WSCC	5140	25	14995	14335	1370	237	2401	544
MARCA	4502	55	3541	3413	0	0	369	0
SPP	3313	51	3108	2984	0	0	423	0
ERCOT	1198	37	1992	1892	0	0	258	67
SERC	806	14	4664	4570	25	38	908	0
MAIN	902	37	1485	1441	0	0	139	106
ECAR	607	15	3311	3177	551	110	360	0
MAAC	45	5	737	717	32	89	229	0
NPCC	645	30	1488	1458	0	0	258	81
TOTALS*	17158	32	35321	33987	1978	474	5345	798

Exhibit V-8 Summary Table 4

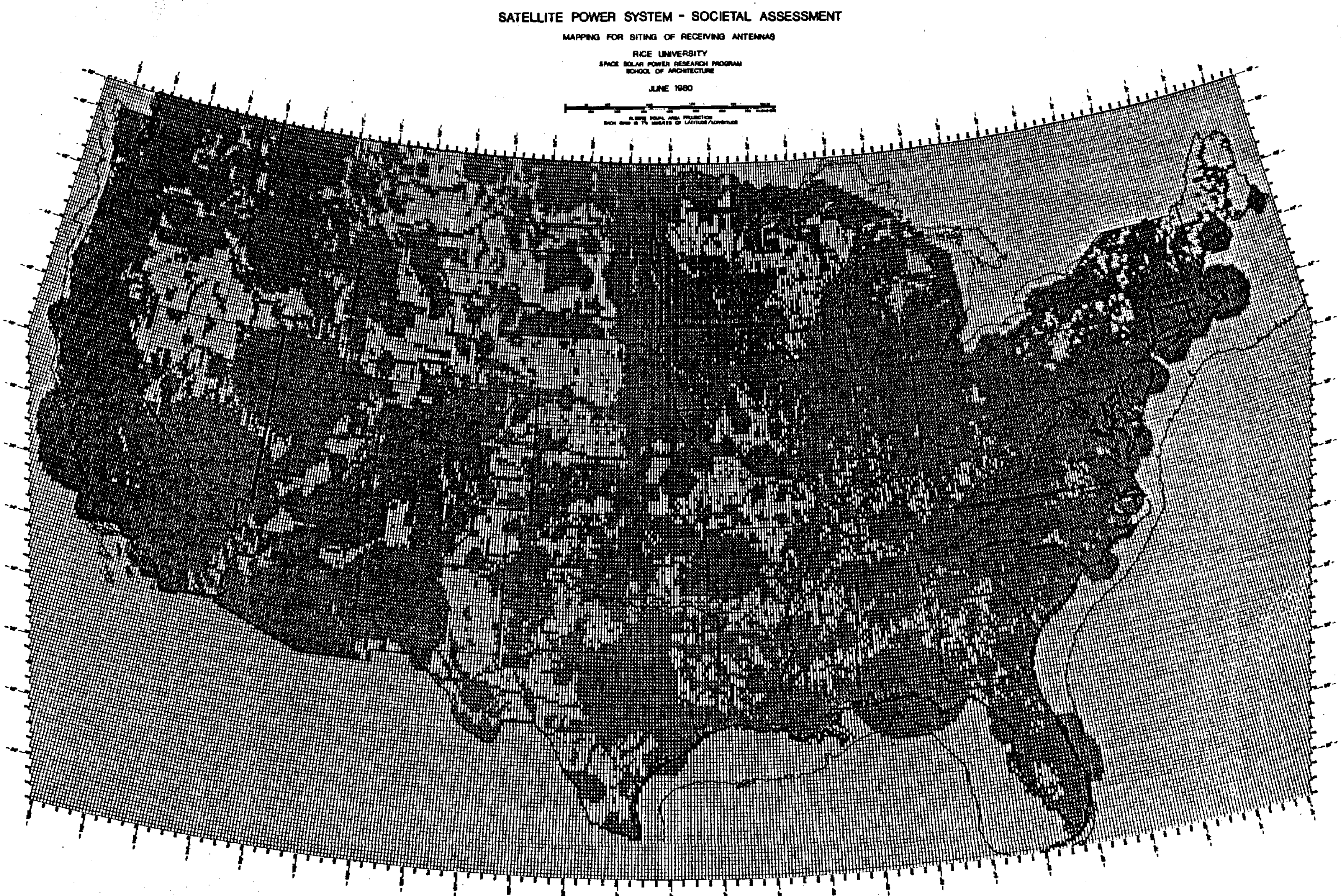


Exhibit V-9 SUMMARY MAP 5

GRID SQUARE PROFILE OF SUMMARY MAP 5						
STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	EXCLUDED GRIDS SUMMARY MAP 4	IRRIGATED AGRICULTURAL LANDS	CROPLANDS
Alabama	139	17	673	673	0	0
Arizona	212	11	1646	1646	17	0
Arkansas	266	30	619	560	0	121
California	150	5	2517	2501	239	0
Colorado	342	19	1418	1259	102	225
Connecticut	0	0	85	85	0	0
Delaware	2	5	34	34	0	0
Florida	86	9	791	790	0	17
Georgia	206	21	733	733	0	0
Idaho	404	25	1170	1136	80	42
Illinois	90	9	902	706	0	724
Indiana	40	6	576	499	0	392
Iowa	67	6	937	501	0	842
Kansas	454	31	966	470	10	674
Kentucky	169	25	507	504	0	19
Louisiana	112	14	642	641	3	0
Maine	410	64	221	221	0	0
Maryland	3	1	192	192	0	0
Massachusetts	0	0	164	164	0	0
Michigan	323	29	782	767	0	162
Minnesota	316	19	1320	1030	0	541
Mississippi	250	32	519	519	0	0
Missouri	515	42	693	610	0	198
Montana	1084	38	1749	1394	94	420
Nebraska	730	52	671	330	48	514
Nevada	503	26	1423	1421	10	0
New Hampshire	39	23	127	127	0	0
New Jersey	0	0	141	141	0	0
New Mexico	683	34	1293	1251	26	28
New York	166	18	724	724	0	0
North Carolina	68	8	772	772	0	0
North Dakota	333	23	1113	667	4	877
Ohio	28	3	708	681	0	317
Oklahoma	255	22	894	526	1	544
Oregon	557	30	1259	1232	39	96
Pennsylvania	85	10	702	702	0	0
Rhode Island	0	0	17	17	0	0
South Carolina	20	3	488	488	0	0
South Dakota	448	31	969	626	8	434
Tennessee	108	15	585	584	0	16
Texas	1387	33	2800	2419	167	820
Utah	241	16	1223	1221	29	0
Vermont	30	16	150	150	0	0
Virginia	49	7	602	602	0	2
Washington	119	8	1209	1065	38	219
West Virginia	24	5	385	385	0	0
Wisconsin	416	39	647	636	0	191
Wyoming	805	44	987	919	47	55
NERC REGIONS						
WSCC	4464	22	15671	14995	698	887
MARCA	2514	31	5529	3541	62	3384
SPP	2063	32	4358	3108	159	1711
ERCOT	1051	32	2139	1992	43	581
SERC	803	14	4667	4664	0	40
MAIN	663	27	1724	1485	0	1002
ECAR	486	12	3432	3311	0	885
MAAC	45	5	737	737	0	0
NPCC	645	30	1488	1488	0	0
TOTALS*	12734	24	39745	35321	962	8490

Exhibit V-10 Summary Table 5

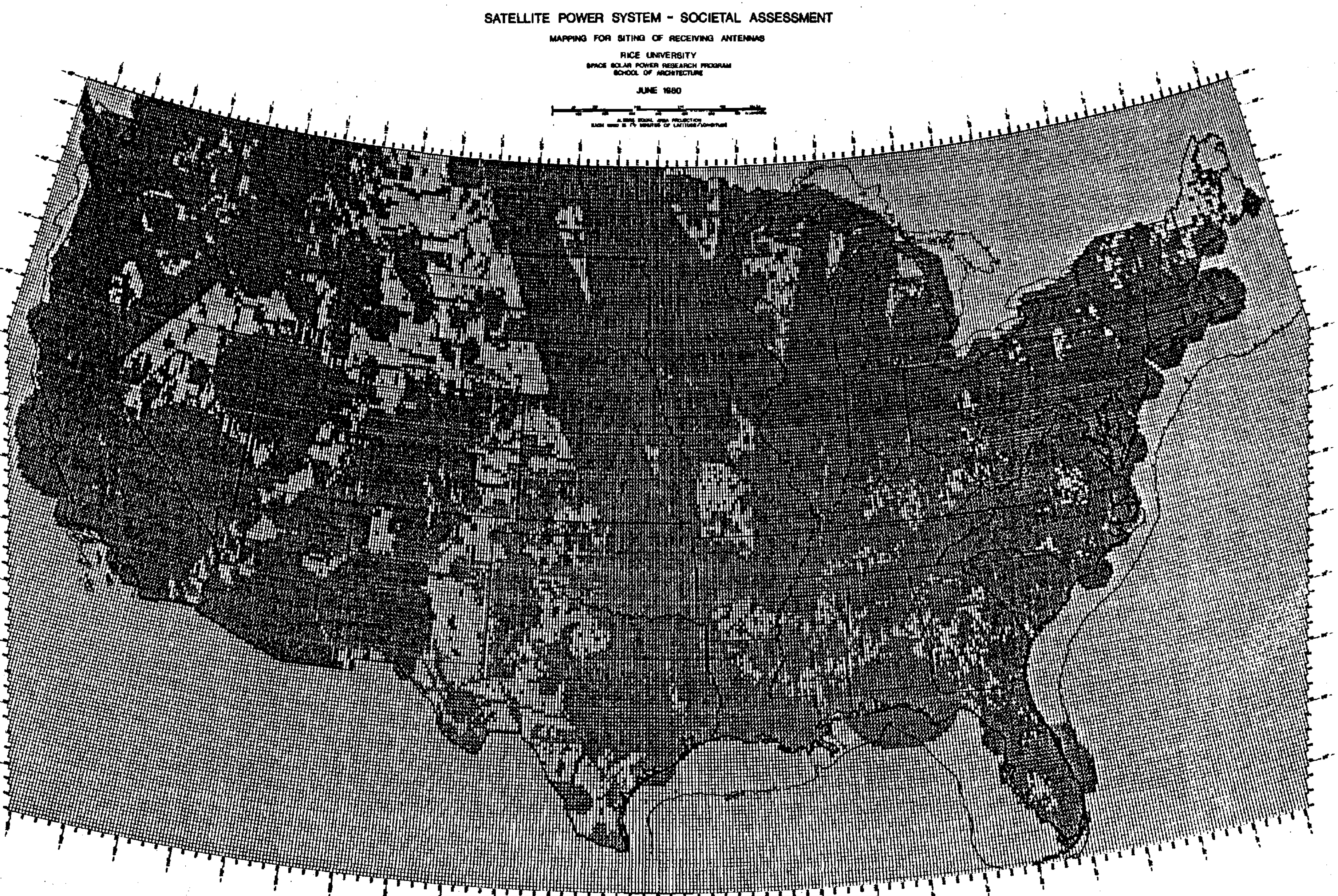


Exhibit V-11 SUMMARY MAP 6

GRID SQUARE PROFILE OF SUMMARY MAP 6							
STATES	'ELIGIBLE' LAND	PERCENT OF TOTAL LAND	TOTAL LAND EXCLUDED	EXCLUDED GRIDS SUMMARY MAP 6	5,250,000-9,000,000 DUCKS	301,000-500,000 GEESE	151,000-300,000 GEESE
Alabama	139	17	673	673	0	0	0
Arizona	212	11	1646	1646	0	0	0
Arkansas	162	18	723	619	349	94	0
California	92	3	2575	2517	0	415	132
Colorado	342	19	1418	1418	0	0	0
Connecticut	0	0	85	85	0	0	4
Delaware	0	0	36	34	0	33	0
Florida	86	9	791	791	0	0	0
Georgia	206	21	733	733	0	0	0
Idaho	382	24	1192	1170	0	0	279
Illinois	16	1	976	902	443	337	198
Indiana	16	2	600	576	0	0	283
Iowa	17	1	987	937	462	82	295
Kansas	199	14	1221	966	613	179	330
Kentucky	142	21	534	507	1	0	110
Louisiana	46	6	708	642	349	33	0
Maine	410	64	221	221	0	0	0
Maryland	0	0	195	192	0	81	52
Massachusetts	0	0	164	164	0	0	0
Michigan	195	17	910	782	0	97	286
Minnesota	129	7	1507	1320	770	91	417
Mississippi	234	26	565	519	100	0	0
Missouri	288	23	920	693	416	211	86
Montana	1019	35	1814	1749	36	0	338
Nebraska	311	22	1090	671	637	194	248
Nevada	446	23	1480	1423	0	0	78
New Hampshire	39	23	127	127	0	0	0
New Jersey	0	0	141	141	0	0	131
New Mexico	683	34	1293	1293	0	0	0
New York	69	7	821	724	0	69	378
North Carolina	60	7	780	772	0	0	49
North Dakota	78	5	1368	1113	761	320	262
Ohio	28	3	708	708	0	0	0
Oklahoma	82	7	1067	894	528	162	379
Oregon	204	11	1612	1259	0	353	503
Pennsylvania	44	5	743	702	0	114	157
Rhode Island	0	0	17	17	0	0	0
South Carolina	20	3	488	488	0	0	0
South Dakota	182	12	1235	969	566	284	237
Tennessee	66	9	627	585	44	0	97
Texas	1204	28	2983	2800	340	283	634
Utah	241	16	1223	1223	0	0	0
Vermont	30	16	150	150	0	0	0
Virginia	43	6	608	602	0	0	134
Washington	107	8	1221	1209	0	85	12
West Virginia	24	5	385	385	0	0	24
Wisconsin	271	25	792	647	0	298	90
Wyoming	805	44	987	987	0	0	0
NERC REGIONS							
WSCC	3909	19	16226	15671	0	853	1342
MARCA	1294	16	6749	5529	3232	975	1549
SPP	1306	20	5115	4358	2070	824	778
ERCOT	922	28	2268	2139	187	89	634
SERC	737	13	4733	4667	66	0	251
MAIN	238	9	2149	1724	859	777	242
ECAR	354	9	3564	3432	1	0	835
MAAC	31	3	751	737	0	228	250
NPCC	548	25	1585	1488	0	69	382
TOTALS*	9339	17	43140	39745			

Exhibit V-12 Summary Table 6

There are two basic techniques available for analysis of the net incremental impact and overlap associated with specific variables:

1. Pairs analysis, in which the overlap between individual pairs of variables is examined to determine the extent to which each exclusion variable coincides with another.

2. Incremental impact analysis, in which the excluded areas under one set of exclusion variables are compared to the excluded areas under another set; the net difference is attributable to the added exclusion variables.

V.C.1. Pairs Analysis: The Overlap Between Variables

The degree of overlap between different individual exclusion variables is of some interest insofar as it may affect the need for changes in policy and/or design. For example, if the majority of interstate highway exclusion areas overlap with population exclusion areas, then considerations of policy that might indicate an ability to construct rectennas in grid cells with interstate highways, i.e., absorbing the cost of such relocation, would clearly be fruitless since most of those same areas are characterized by high population densities. Similarly, variables which have very little overlap to other variables but which, in and of themselves, exclude a large geographic area, may be of considerable interest.

In this analysis, two subsets of exclusion variables have been subjected to pairs analysis to determine the degree of overlap that exists between specific pairs of variables. The first such subset are the variables that make up the absolute exclusion set. The second subset of variables subjected to pairs analysis are those potential exclusion variables with the high probability of impact combined with selected duck and geese flyway variables. This latter category (flyways) represents exclusion variables with an uncertain impact.

The process by which the overlap between variables was examined consisted of three steps:

1. The number of variables initially mapped were grouped together to represent conceptually related elements, e.g., marshlands and perennially flooded areas were grouped together as "wetlands".

2. Those variables contributing trivially to the analysis and therefore of less interest in any overlap investigation were discarded, e.g., endangered species habitats, which account for 0.8 percent of the total mapped area.

3. The development of a simple pairs matrix for the remaining conceptual variables.

An example of such a pairs matrix is provided in Exhibit V-13. This exhibit examines the relationships between six conceptual variables, all of which were originally classified as absolute exclusion variables. These six variable groups are drawn from the 15 variables described in Exhibit V-4 which summarizes Summary Map 2 (all exclusion variables). The six variables are:

1. Population (SMSA, adjusted population density).
2. Interstate highways.
3. Unacceptable topography.
4. Wetlands (marshlands and perenially flooded areas).
5. Navigable waterways.
6. Electromagnetic compatibility (EMC) absolute exclusion variables (EMC A-150, A-100 and A-150).

The total number of cells in which the absolute exclusion variable occurs are shown both in the left most column and the top as total excluded area. The cells of the matrix show both in numerical terms and in percentage terms the degree of overlap. For example, of the 4463 cells excluded by interstate highways, 2,655 or 59.4 percent are also excluded by population. This suggests a very high degree of overlap between interstate highways and population. Proceeding down the interstate highways column, it also becomes apparent that there is a substantial overlap between interstate highways and EMC exclusion variables with over 1400 of the 4400 cells excluded for interstate highways also being excluded for EMC variables. A similar analysis of unacceptable topography shows only a limited overlap with other absolute exclusions. On the other hand, the elimination of interstate highways, wetlands or navigable waterways would appear to have relatively little effect in reducing the total exclusion areas since they have generally high degrees of overlaps to other excluded variables.

The second analysis of overlap between pairs of variables is summarized in Exhibit V-14. This applies to selected potential exclusion variables and covers all potential exclusion variables with a high probability of impact and selected flyways data. In this instance, there has been a limited amount of grouping of the specific variables described in Summary Map 5 and 6. Specifically, national forests and national grasslands have been grouped together as "national agricultural lands" and irrigated farmland and mostly cropland have been grouped together as "private agricultural lands". In addition, all four potential EMC exclusion categories have been presented as a single category (EMC P-150, P-100, P-60, and P-50).

The total excluded area designated by absolute exclusions is also shown in Exhibit V-14 as a single exclusion variable. By treating this as a single variable, it is possible to see the extent to which the potential exclusion variables overlap the absolute exclusion variables. This is highly significant in that potential variables with a high degree of overlap to the absolute exclusion variables tend to be of less interest. For example, 79.1 percent of the national agricultural lands are located in cells already excluded by the absolute exclusions. A somewhat similar conclusion may be drawn with respect to potential EMC variables in which 76 percent of the cells excluded by EMC are already in absolute exclusion areas.

EXHIBIT V-13

OVERLAP BETWEEN SELECTED ABSOLUTE EXCLUSION VARIABLES[1]

	Total Excluded Area		Intersection (overlap) with Other Variables											
			Population		Interstate Highways		Unacceptable Topography		Wet Lands		Navigable Water		EMC (Abs)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Total Excluded Area	15,221	100.0	15,221	100.0	4,463	100.0	10,787	100.0	1,700	100.0	1,556	100.0	13,024	100.0
Population	12,014	100.0	--		2,655	59.5	2,225	8.6	629	2.3	749	2.6	5,466	12.9
Interstate Highways	4,463	100.0	2,655	17.4	--		614	2.4	134	0.5	241	0.8	1,422	3.4
Unacceptable Topography	10,787	100.0	2,225	14.6	614	13.8	--		0		42	0.1	2,209	5.2
Wetlands	1,700	100.0	629	4.1	134	3.0	0		--		275	0.9	428	1.0
Navigable Waterways	1,556	100.0	749	4.9	241	5.4	42	0.2	275	1.0	--		632	1.5
EMC Variables	13,024	100.0	5,466	35.9	1,422	31.9	2,209	8.5	428	1.5	632	2.2	--	
Total Overlap	N.A.[2]		11,724		5,066		5,090		1,466		1,939		10,157	

[1] Summary Map 2 - All absolute.
[2] Not applicable. Overlap exceeds 100%.

EXHIBIT V-14

OVERLAP BETWEEN SELECTED POTENTIAL EXCLUSION VARIABLES[1]

	Total Excluded Area	Absol. Excls.		Indian Reservations		National Ag. Lands[2]		Private Ag. Lands[3]		Wild and Scenic Rivers		Potential EMC[4]		Duck Flyways[5] High		Duck Flyways[5] Medium		Duck Flyways[5] Low		Geese Flyways[6] High		Geese Flyways[6] Medium	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Total Excluded Area		33,814	100.0	1,982	100.0	5,929	100.0	9,455	100.0	1,087	100.0	8,107	100.0	6,425	100.0	9,803	100.0	23,899	100.0	10,679	100.0	16,378	100.0
Absolute Exclusions	33,814	--		659	33.2	4,691	79.1	4,669	49.4	754	69.4	6,163	76.0	2,764	42.7	5,587	57.0	13,866	58.0	6,592	61.7	8,319	50.8
Indian Reservations	1,982	659	1.9	--		53	0.9	147	1.6	21	1.9	290	3.6	389	6.1	377	3.8	370	1.5	218	2.0	578	3.5
National Ag. Lands[2]	5,929	4,691	13.9	53	2.7	--		75	0.8	307	28.2	781	9.6	202	3.1	1,376	14.0	1,895	7.9	899	8.4	1,337	8.2
Private Ag. Lands[3]	9,455	4,669	13.8	147	7.4	75	1.3	--		50	4.6	884	10.9	2,364	36.0	1,998	20.4	3,807	15.9	3,550	33.2	3,160	19.3
Wild & Scenic Rivers	1,087	754	2.2	21	1.1	307	5.2	50	0.5	--		112	1.4	83	1.3	287	2.9	357	1.5	201	1.9	235	1.4
Potential EMC[4]	8,107	6,163	18.2	290	14.6	781	13.2	884	9.3	112	10.3	--		418	6.5	1,256	12.8	3,042	12.7	1,273	11.9	1,909	11.7
Duck Flyways[5]																							
High	6,425	2,764	8.2	389	19.6	202	3.4	2,364	25.0	83	7.6	418	5.2	--	--	0	0	0	0	2,165	20.3	2,507	15.3
Medium	9,803	5,587	16.5	377	19.0	1,376	23.2	1,998	21.1	287	26.4	1,256	15.5	0	0	--	--	0	0	3,346	31.3	2,963	18.1
Low	23,899	13,866	41.0	370	18.7	1,895	32.0	3,807	40.3	357	32.8	3,042	37.5	0	0	0	0	--	--	3,331	31.2	6,895	42.1
Geese Flyways[6]																							
High	10,679	6,592	19.5	218	11.0	899	15.2	3,550	37.5	201	18.5	1,273	15.7	2,165	33.7	3,346	34.1	331	1.4	0	0	0	0
Medium	16,378	8,319	24.6	578	29.2	1,337	22.6	3,160	33.4	235	21.6	1,909	23.5	2,507	39.0	2,963	30.2	6,895	28.9	--	--	0	0

EXHIBIT V-14 (continued)

1 All high probability potential exclusions, per Summary Map 4, plus selected flyway data.

2 National forests and national grasslands.

3 Irrigated farmland and "mostly cropland".

4 Potential EMC includes P-150, P-100, P-60, and P-50 exclusions.

5 Duck flyways

High = 5,250,000 - 9,000,000 ducks
Medium = 3,010,000 - 5,250,000 ducks
Low = 1,510,000 - 3,000,000 ducks

6 Geese flyways

High = 301,000 - 500,000 geese
Medium = 151,000 - 300,000 geese

7 Not meaningful.

Among the other more interesting findings in the table are the relatively lower degrees of overlap between Indian reservations and the other variables. It may be that Indian reservations, particularly some of the more remotely located ones, are attractive potential sites notwithstanding the potential political problems they may present.

The duck and geese flyways are of particular interest insofar as the impact of this is quite uncertain. There is perhaps a limited comfort to be drawn from the fact that there is a high degree of overlap between duck flyways and absolute exclusion. The degree of overlap, i.e. the percentage of the flyways already excluded by the absolute variables, ranges from 43 percent for the high density flyways to 58 percent to the low density flyways. For geese the percentages are even higher at 62 percent (high density) and 51 percent (low density). This suggests that although the coverage of the duck and goose flyways is quite extensive that it also overlaps powerfully other variables which were also excluded. Another interesting phenomena is the degree to which duck flyways show some tendency to have a high or at least moderate overlap with private agricultural lands.

V.C.2. Incremental Impact Summaries by Region

The use of pairs analysis to identify the degree of overlap between individual variables is limited in its ability to depict the net incremental impact of a variable. The only way to show such an incremental impact is to generate two summary maps, one with the test variable and one without. In this manner, the total of excluded areas under the two conditions can be compared and the difference represents the net impact, after allowing for all duplication effects, of adding the one exclusion variable.

This exercise has been undertaken for the six summary maps. Unlike the previous analysis, these comparisons also show the incremental impact by region.

V.C.2.a. Incremental Impact of Absolute EMC Variables

A tabulation of excluded areas with and without absolute EMC variables is shown in Exhibit V-15. The first part of this table shows, as in the presentation of Summary Map 1, that there are just under 25,000 eligible cells after applying all absolute exclusion variables except the absolute EMC variables. The residual proportion of eligible areas in 47 percent. On a national basis, the introduction of absolute exclusion variables for EMC reduces the number of eligible cells from 24,961 to 21,320. In percentage terms, the proportion of eligible cells declines from 47 to 40 percent. There are, however, major differences between regions. The national reduction in the percent eligible was only 15 percent (14.6). Reductions in individual regions range from very modest reduction of less than 6 percent in SPP (Southwest) to a high of 37 percent in SERC (Southeast). Of particular interest in this table is also the fact that no region has less than 10 percent eligible cells even after the imposition of the EMC variable.

Also shown in Exhibit V-15 are tabulations of net and gross excluded areas. The net area is simply the total amount of excluded area as defined by the

EXHIBIT V-15

REGIONAL SUMMARY AND INCREMENTAL IMPACT ANALYSIS FOR ABSOLUTE EMC VARIABLES

	SUMMARY MAP NO. 1 ABSOLUTE EXCLUSION VARIABLES W/O EMC					SUMMARY MAP NO. 2 ABSOLUTE EXCLUSION VARIABLES W/EMC					INCREMENTAL IMPACT OF EMC CELLS LOST		
			Excluded Area					Excluded Area					
REGIONS	Eligible Cells	Area %	Net	Gross	Net/Gross	Eligible Cells	Area %	Net	Gross	Net/Gross	No.	Percent	Change in % Eligible
ECAR	1,069	27	2,849	3,718	76.6	879	22	3,039	4,712	64.5	190	17.8	5
ERCOT	1,746	54	1,441	1,733	83.2	1,321	41	1,869	2,630	71.1	425	24.3	13
MAAC	103	13	679	995	68.2	83	10	699	1,385	50.5	20	19.4	3
MAIN	1,278	53	1,109	1,368	81.1	1,120	46	1,267	1,925	65.8	158	12.4	7
MARCA	6,005	74	2,038	2,471	82.5	5,350	66	2,693	3,605	74.7	655	10.9	8
NPCC	851	39	1,282	1,692	75.8	759	35	1,374	2,369	58.0	92	10.8	4
SERC	1,537	28	3,933	5,747	68.4	968	17	4,502	7,969	56.5	569	37.0	11
SPP	3,770	58	2,651	3,509	75.5	3,558	55	2,863	4,201	68.2	212	5.6	3
WSCC	8,602	42	11,533	14,371	80.3	7,282	36	12,853	18,498	69.5	1,320	15.3	6
Total U.S.*	24,961	47	27,518	35,604	77.3	21,320	40	31,159	47,294	65.9	3,641	14.6	7

* Excluding Alaska and Hawaii.

EXHIBIT V-16

REGIONAL SUMMARY AND INCREMENTAL IMPACT ANALYSIS FOR DEDICATED LANDS POTENTIAL EXCLUSIONS

REGIONS	SUMMARY MAP NO. 2 ABSOLUTE EXCLUSION VARIABLES INCLUDING EMC					SUMMARY MAP NO. 3 ABSOLUTE EXCLUSION & DEDICATED LANDS POTENTIAL EXCLUSIONS					INCREMENTAL IMPACT OF DEDICATED LANDS CELLS LOST		
	Eligible Cells	Area %	Excluded Area Net	Excluded Area Gross	Excluded Area Net/Gross	Eligible Cells	Area %	Excluded Area Net	Excluded Area Gross	Excluded Area Net/Gross	No.	Percent	Change in % Eligible
ECAR	879	22	3,039	4,712	64.5	741	19	3,177	5,121	62.0	138	15.7	3
ERCOT	1,321	41	1,869	2,630	71.1	1,298	41	1,892	2,677	70.7	23	1.7	0 ±
MAAC	83	10	699	1,385	50.5	65	8	717	1,419	50.5	18	21.7	2
MAIN	1,120	46	1,267	1,925	65.8	946	40	1,441	2,132	67.6	174	15.5	6
MARCA	5,350	66	2,693	3,605	74.7	4,630	58	3,413	4,697	72.7	720	13.5	8
NPCC	759	35	1,374	2,369	58.0	675	32	1,458	2,539	57.4	84	11.1	3
SERC	968	17	4,502	7,969	56.5	900	16	4,570	8,418	54.3	68	7.0	1
SPP	3,558	55	2,863	4,201	68.2	3,437	54	2,984	4,565	65.4	121	3.4	1
WSCC	7,282	36	12,853	18,498	69.5	5,800	29	14,335	24,721	58.0	1,482	20.4	7
Total U.S.*	21,320	40	31,159	47,294	65.9	18,492	35	33,987	56,289	60.4	2,828	13.3	5

* Excluding Alaska and Hawaii.
± Less than 1/2 of 1 percent.

incidence of "one or more" excluded variables present in the cell. The gross area is the sum of the incidence if each exclusion variable without a reduction for overlap. The comparison between net and gross provides a useful general indicator of the extent to which the absolute exclusion variables considered as a group have a high degree or low degree of overlap in the particular region. For example, the ratio of net to gross area in Summary Map 2 as shown ranges from a low of 50.5 percent in the Mid-Atlantic (MAAC) region to a high of 74.7 percent in the MARCA (Dakotas, Nebraska, etc.) region. What this suggests is that absolute exclusion variables tend to be relatively highly clustered in MARCA but relatively unclustered in MAAC.

V.C.2.b. Incremental Impact of "Dedicated/Restricted" Potential Exclusion Variables

Three of the potential exclusion variables with a high probability of impact may be loosely grouped as dedicated or protected federal lands. These include national forests, national grasslands and wild and scenic rivers. They have collectively a relatively modest impact on the number of eligible areas.

The eligible areas after applying all absolute exclusion variables (Summary Map 2) numbers slightly more than 21,300 cells. This total drops for the nation to 18,500 cells, as shown in Exhibit V-16. The incremental impacts of these national dedicated or protected lands is fairly trivial in the southeast and southwest (SERC and SPP). It is, however, somewhat more significant in both Mid-Atlantic (MAAC) and Western (WSCC) regions. Overall the reduction in proportion of the U.S. is from 40 percent eligible to 45 percent eligible.

V.C.2.c. Incremental Impacts of Potential EMC Exclusion Variables

The only difference between Summary Map 3 and Summary Map 4 is the addition of potential EMC exclusion variables. Here perhaps more clearly than in any of the other examples, the importance of overlap is manifest. Despite the fact that potential exclusion variables represent more than 5,000 excluded cells, they add less than 600 to the total number of excluded cells when considered on a net incremental basis. The change in the percentage eligible is only one percent, representing a reduction from 35 to 34 percent. The impacts of this comparison by region is shown in Exhibit V-17. In four of the nine regions the percent change was virtually unmeasurable and only in the East Central (ECAR) and the Mid-Atlantic (MAAC) was the loss of eligible cells more than 10 percent.

V.C.2.d. Incremental Impact of Private Agricultural Lands

The only high probability potential exclusion variables not yet considered are the agricultural lands, specifically the private agricultural lands represented by the mapped variables "irrigated farmland" and "mostly cropland". The net incremental impact of these agricultural lands is shown in Exhibit V-18. This is clearly a nontrivial variable. The proportion of

EXHIBIT V-17

REGIONAL SUMMARY AND INCREMENTAL IMPACT ANALYSIS FOR POTENTIAL EMC EXCLUSIONS

	SUMMARY MAP NO. 3 ABSOLUTE EXCLUSIONS & DEDICATED LANDS POTENTIAL EXCLUSIONS					SUMMARY MAP NO. 4 ABSOLUTE EXCLUSION & ALL HIGH PROBABILITY POTENTIAL EXCL. EXCEPT AGRICULTURAL LANDS					INCREMENTAL IMPACTS OF POTENTIAL EXCLUSION CELLS LOST		
			Excluded Area					Excluded Area					
REGIONS	Eligible Cells	Area %	Net	Gross	Net/Gross	Eligible Cells	Area %	Net	Gross	Net/Gross	No.	Percent	Change in % Eligible
ECAR	741	19	3,177	5,121	62.0	637	16	3,281	5,809	56.5	103	13.9	3
ERCOT	1,298	41	1,892	2,677	70.7	1,263	40	1,927	2,744	70.2	35	2.7	1
MAAC	65	8	717	1,419	50.5	54	7	728	1,680	43.3	11	16.9	1
MAIN	946	40	1,441	2,132	67.6	942	39	1,445	2,238	64.6	4	0.4	1
MARCA	4,630	58	3,413	4,697	72.7	4,630	58	3,413	4,697	72.7	0	0	0
NPCC	675	32	1,458	2,539	57.4	675	32	1,458	2,620	55.6	0	0	0
SERC	900	16	4,570	8,418	54.3	887	16	4,583	8,725	52.5	3	0±	0±
SPP	3,437	54	2,984	4,565	65.4	3,437	54	2,984	4,565	65.4	0	0	0
WSCC	5,800	29	14,335	24,721	58.0	5,393	27	14,742	28,098	52.5	407	7.0	2
Total U.S.*	18,492	35	33,987	56,289	60.4	17,918	34	34,561	61,176	56.5	574	3.1	1

* Excluding Alaska and Hawaii.
± Less than 1/2 of 1 percent.

EXHIBIT V-18

REGIONAL SUMMARY AND INCREMENTAL IMPACT ANALYSIS FOR AGRICULTURAL LANDS

	SUMMARY MAP NO. 4 ABSOLUTE EXCLUSIONS & ALL HIGH PROBABILITY POTENTIAL EXCL. EXCEPT AGRICULTURAL LANDS					SUMMARY MAP NO. 5 ABSOLUTE EXCLUSION & ALL HIGH PROBABILITY POTENTIAL EXCLUSIONS					INCREMENTAL IMPACTS OF AGRICULTURAL LANDS CELLS LOST		
			Excluded Area					Excluded Area					
REGIONS	Eligible Cells	Area %	Net	Gross	Net/Gross	Eligible Cells	Area %	Net	Gross	Net/Gross	No.	Percent	Change in % Eligible
ECAR	637	16	3,281	5,809	56.5	505	13	3,413	6,694	51.0	132	20.7	3
ERCOT	1,263	40	1,927	2,744	70.2	1,102	35	2,088	3,325	62.8	161	12.7	5
MAAC	54	7	728	1,680	43.3	54	7	728	1,680	43.3	0	0	0
MAIN	942	39	1,445	2,238	64.6	688	29	1,699	3,240	52.4	254	27.0	10
MARCA	4,630	58	3,413	4,697	72.7	2,585	32	5,458	8,143	67.0	2,045	44.2	26
NPCC	675	32	1,458	2,620	55.6	675	32	1,458	2,620	55.6	0	0	0
SERC	887	16	4,583	8,725	52.5	883	16	4,587	8,765	52.3	4	0±	0±
SPP	3,437	54	2,984	4,565	65.4	2,133	33	4,288	6,435	66.6	1,304	37.9	21
WSCC	5,393	27	14,742	28,098	52.5	4,698	23	15,437	29,683	52.0	695	12.9	4
Total U.S.*	17,918	34	34,561	61,176	56.5	13,323	25	39,156	70,628	55.4	4,595	25.6	9

* Excluding Alaska and Hawaii.
± Less than 1/2 of 1 percent.

EXHIBIT V-19

REGIONAL SUMMARY AND INCREMENTAL IMPACT ANALYSIS FOR FLYWAYS

REGIONS	SUMMARY MAP NO. 5 ABSOLUTE EXCLUSIONS & ALL HIGH PROBABILITY POTENTIAL EXCLUSIONS					SUMMARY MAP NO. 6 ABSOLUTE, HIGH PROBABILITY POTENTIAL EXCLUSIONS, & SELECTED FLYWAYS					INCREMENTAL IMPACTS OF FLYWAYS CELLS LOST		
	Eligible Cells	Area %	Excluded Area Net	Excluded Area Gross	Excluded Area Net/Gross	Eligible Cells	Area %	Excluded Area Net	Excluded Area Gross	Excluded Area Net/Gross	No.	Per-cent	Change in % Eligible
ECAR	505	13	3,413	6,694	51.0	359	9	3,559	7,530	47.3	146	28.9	4
ERCOT	1,102	35	2,088	3,325	62.8	971	30	2,219	4,154	53.4	131	11.9	5
MAAC	54	7	728	1,680	43.3	35	5	747	2,158	34.6	19	35.2	2
MAIN	688	29	1,699	3,240	52.4	250	11	2,137	5,118	41.8	438	63.7	18
MARCA	2,585	32	5,458	8,143	67.0	1,317	16	6,726	13,899	48.4	1,268	49.1	16
NPCC	675	32	1,458	2,620	55.6	576	27	1,557	3,071	50.7	99	14.7	5
SERC	883	16	4,587	8,765	52.3	816	15	4,654	9,082	51.2	67	7.6	1
SPP	2,133	33	4,288	6,435	66.6	1,361	21	5,070	10,107	50.2	782	36.7	12
WSCC	4,698	23	15,437	29,683	52.0	4,111	20	16,024	31,878	50.3	587	12.5	3
Total U.S.*	13,323	25	39,156	70,628	55.4	9,786	19	42,693	87,121	49.0	3,537	26.5	6

* Excluding Alaska and Hawaii.

eligible cells on a national basis is reduced from 34 percent (17,900) to 25 percent (13,300). The impact is, however, regionally selected. The most powerful regional impacts are in the northern midwest plain states of North and South Dakota, Nebraska, etc. (MARCA) where fully 44 percent of the previously eligible land is eliminated by this criteria and the proportion of eligible land declines from 58 to 32 percent. It is significant, however, that even with this reduction, this region (MARCA) still has relatively high proportion of eligible lands. The same may be said for the Southwest region (SPP) with 38 percent of the eligible cells lost due to this variable.

In summary, croplands may appear to remove a significant amount of lands from consideration, but this loss tends to occur only in areas that are already relatively generously endowed with eligible cells. Hence this variable may have little significance in terms of rectenna siting even though it covers a large area.

V.C.2.e. Incremental Impact of Flyways

As noted above, very little is known about the impact of SPS microwave radiation on birds. Hence the classification of this as a potential exclusion variable with unknown impact. When all other absolute and potential exclusion variables have been eliminated, there is still 25 percent of the land area in the U.S. nominally eligible, or 13,300 good cells. No region has no less than 16 percent eligible cells except for Mid-Atlantic. When flyways are introduced, however, the situation does change significantly. The total proportion of eligible areas decline from 25 percent to 19 percent with less than 9800 "eligible" cells available. Several regions sustained substantial reductions in availability of eligible cells. These include the East Central (ECAR), the Mid-Atlantic (MAAC), the two Midwestern regions (MAIN and MARCA), and the Southwest region (SPP). Even with this additional variable, however, only two regions have less than 10 percent of their land area nominally eligible for rectenna siting. These are the East Central region (ECAR) with 9 percent and Mid-Atlantic region (MAAC) with 5 percent. Most of the other regions have 20 percent or more of their area available. Two regions characterized by intermediate availability even with this most rigid set of potential and absolute exclusion variables are the two Mid-West regions (MAIN and MARCA). It should be noted that both these regions still have a large absolute number of eligible cells with over 2,000 in MAIN and almost 7,000 in MARCA.

In summary, this incremental analysis suggests that, within the severe limitations of the data, the imposition of all absolute potential exclusion variables still leaves a substantial volume of nominally "eligible" sites in most regions. Two potential exceptions to this are the East Central region (ECAR) and the Mid-Atlantic (MAAC) region. Only in the Mid-Atlantic region (MAAC) is there an absolute scarcity of cells as distinguished from a low proportion.

VI. DEVELOPMENT OF REGIONAL ENERGY PROJECTIONS

VI.A. INTRODUCTION

The primary purpose for the development of regional energy projections was to determine in general, where the SPS rectennas should be located. Rectennas could be allocated to regions or areas of the continental United States based on any one of several criteria. One of the most appropriate would seem to be the future level of electricity generation in various regions of the U.S. This allocation mechanism is preferable to other possible allocation mechanisms because allocation of rectennas based on future electricity generation would allocate rectennas to regions based on some sense of "need" for electricity. The regions chosen for this analysis are the nine Electric Reliability Council regions (ERC) since these regions correspond to the extended service areas of utilities and power pools.

It is not the purpose of this report to develop new or independent projections of electricity production since other SPS study efforts are developing energy projections, though not at the disaggregated level. Although used only for allocation, the projections used in this report must be considered credible by both the government and professional energy forecasting community. A systematic literature search was undertaken to identify appropriate and reasonable energy projections.

VI.B. PROJECTION SELECTION CRITERIA

VI.B.1. Selection Criteria

In order to choose an appropriate set of energy projections, selection criteria had to be established. Given the projected timeframe of SPS development and deployment and the regional nature of the siting study, the chosen energy projections should:

- Provide projections to 2000 or, preferably beyond
- Be highly disaggregated or amenable to disaggregation to the state level
- Be regularly updated
- Provide for consideration of alternative scenarios

Provide Projections Beyond 2000: The requirement that the adopted projections extend to the year 2000 or preferably beyond is compatible with the development scenario in the SPS Reference System.

In that scenario, the first 5-GW SPS satellite would begin operation in the year 2000, with 60 satellites in operation in 2030. Projections that do not extend to the year 2000 would be inappropriate since they do not cover the SPS timeframe. This would be a less severe constraint if the projections did not have to be disaggregated, since extending a single projection (e.g. national) is less difficult than extending projections for many regions since regional growth rates are not consistent.

Highly Disaggregated: The energy projections need to be highly disaggregated due to the nature of the siting study. The siting study is structured to study the subnational availability of potential siting areas. The energy projections therefore need to be disaggregated to the state or regional level. State-level disaggregation would be preferable, but regional disaggregation is acceptable if there is a sound method for further disaggregation.

Electrical generation projections should also be disaggregated by fuel source. This level of disaggregation was necessary in order to ensure comparability to the parallel utility integration study undertaken by Environmental Resources Group.

Regularly Updated: The world energy situation is changing so rapidly that energy projections are quite often obsolete by the time they are released. The prime example of this is that any projections published in 1979 which did not include "very high" oil prices was already outdated. Regular updating is also important because it provides for a consistent energy input for future studies.

Consideration of Alternative Scenarios: The projections chosen should examine alternative energy scenarios which might result in different rectenna allocations to regions and/or might affect the viability of SPS. The primary reason for evaluating several alternatives in this report is to examine the change in the regional allocation of SPS rectennas. Alternative energy scenarios which result in alternative fuel mixes might change the regional allocation of rectennas by concentrating the location of generation facilities in one or more regions rather than spreading them across the U.S.

VI.B.2. Projections Reviewed

There are a number of different energy projections that were evaluated in the course of this study. There were three general classifications of models that were examined: balancing types, demand forecasts, and supply forecasts.

Another problem that helped to dictate the choice of a model was the proprietary nature of non federally funded models. The proprietary nature of the Gulf-SRI and DRI models made them considerably less attractive than they would have been otherwise. Table 2 provides a listing of the forecasting models that were seriously considered as well as several models which were reviewed and rejected.

The forecasting models that were rejected at the first cut were eliminated for proprietary reasons (Gulf-SRI), or for not satisfying the selection criteria. The RFF/SEAS model is a sensitivity model that is more a "what if" rather than a time forecasting model. The remaining models were either not sufficiently disaggregated or did not extend to the proper time frame.

VI.B.3. Selection of EIA/ORNL Projections

Of the forecasts listed in Exhibit VI-1, the EIA projections (MEFS and LEAP) in conjunction with the ORNL projections were chosen as the set of energy projections to be used in this study. While the choice of this set of models is not the perfect choice, it is the best choice given the alternatives.

The two models maintained by EIA, namely MEFS and LEAP, refer to the midterm (through 1995) and long term (1995-2020) respectively. The two models differ in one important respect. The MEFS model is disaggregated into the ten federal administrative regions and hence permits some disaggregation at a regional level. The LEAP model is not so disaggregated.

Another particular advantage of the MEFS model is that it is adaptable to a range of scenarios with respect to supply conditions, demand conditions and world oil prices. Considerable effort has been expended by EIA in assuring a high degree of compatibility between MEFS and LEAP and hence the disaggregated elements in MEFS could be projected through the year 2000 by blending in the LEAP model without too much arbitrary allocation.

The combination of MEFS and ORNL provides for regional disaggregation, subregional disaggregation, reaggregation to different regional boundaries and disaggregation by fuel type. Finally MEFS is regularly updated and has been exercised for several alternative scenarios.

EXHIBIT VI-1

CANDIDATE FORECASTS CONSIDERED

- MEFS: Midterm Energy Forecasting System; prepared and maintained in the Department of Energy, Energy Information Administration (EIA); A National forecast, regionally disaggregated to 1995

- Energy Availabilities for State and Local Development; prepared by Oak Ridge National Laboratories. Consists of state and substate disaggregations of the MEFS inputs (PIES Model), based on demographic and economic inputs from the Department of Commerce, Bureau of Economic Analysis. Projections to 1990.

- Preliminary Forecast of Likely U.S. Energy Consumption/Production Balances for 1985 and 2000 by States; prepared by the Department of Commerce, Office of Ocean Resource and Scientific Policy Coordination; projections to years 1985 and 2000. (Single scenario only)

- LEAP: Long Term Energy Analysis Program; prepared in the Department of Energy, EIA; Constitutes an extension of the Series C (Mid-Mid) MEFS projection to the year 2020, on a national basis only.

- FOSSIL 2: Prepared by the Department of Energy, Office of Policy and Evaluation, to integrate near, mid-term and long-term projections into an aggregated but self-consistent framework. Essentially consistent with MEFS & LEAP; provides baseline and data inputs for the National Energy Plan (NEP) II. National forecast only.

- Other Forecasts Reviewed and Rejected

  - Gulf-SRI Energy Model
  - BESOM: Brookhaven Energy System Optimization Model (BNL)
  - PILOT: Stanford University Energy - Economic Model
  - ETA-MACRO: Energy-Economy Interactions
  - RFF/SEAS Model: Economic, Energy and Environmental Consequences of Alternative Energy Regimes

VI.C. DESCRIPTION OF SELECTED PROJECTIONS

The primary advantage of using these models is that they are interrelated and consistent. Both the ORNL and LEAP projections begin with, or are an extension of, the MEFS projections.

VI.C.1 MEFS Projection

The MEFS projections are the backbone of this part of the study. Exhibit VI-2 lists the major features of the MEFS forecasts. The primary features of the MEFS forecasts are the large number of alternative scenarios, the disaggregation to ten regions, and a detailed analysis of fuel types for electricity generation. MEFS is also updated yearly, and preliminary versions of the 1979 model are incorporating the significant oil price increases that occurred in 1979.

The primary feature of the MEFS model is that it is a truly regional model. The electrical generation and consumption projections are calculated at the regional level, summed to a national total, and then reconciled to a separately calculated national total. This framework is advantageous in that each region's growth characteristics are captured and differing regional supply conditions and growth rates are more easily incorporated.

MEFS also incorporates a regional treatment of the changes in generating capacity by fuel type. This analysis includes, as an integral part of the model, the effects of the Powerplant and Industrial Fuels Act of 1978 (PIFUA) and the National Gas Policy Act of 1978 (NGPA). Together these parts of the National Energy Act lead to a decreasing reliance on oil and gas for the generation of electricity and a switch toward coal. Exhibit VI-2 is a reproduction of a regional table from the 1978 Annual Report to Congress which shows the detail of the MEFS projections at the regional level.

This analysis of generation capacity is further strengthened by an iterative financial evaluation. This evaluation examines the cost of fuel and the useful life of the generating unit to determine if a generating unit should be prematurely retired.

The MEFS model also presents energy supply and demand balances for each region for 1985, 1990, and 1995. These supply and demand balances are also presented for each scenario rather than just the reference C mid-mid scenario. Since the MEFS model is updated annually for EIA's Annual Report to Congress (ARC), these regional tables allow for regional comparisons between both alternative scenarios and projections made in different years. This trait of the MEFS model was utilized in the analyis of alternative scenarios. The alternative scenarios were two Series C scenarios from the 1978 ARC and two preliminary scenarios for the 1979 ARC. These preliminary scenarios may not appear in the 1979 ARC, but preliminary comments indicate that they are between the mid and high projections of the upcoming report.

EXHIBIT VI- 2

REGIONAL GENERATION PROJECTIONS, SOUTH ATLANTIC 1995

RESOURCE	----BASE---- EX	NEW	-INTERMEDIATE- EX	NEW	CAPACITY IN GIGAWATTS -DAILY PEAK- EX	NEW	SEASONAL PEAK EX	NEW	----------TOTAL---------- EX	*AV EX	NEW	*AV NEW	TOTAL GENERATION (MMMKWH/YR) EX	NEW
NUCLEAR	12.84	47.79							12.84	12.84	47.79	47.79	70.51	262.50
RESIDUAL (OIL-STEAM)						1.71				13.83	1.71	1.71		4.05
BIT HI-S W/SCRUB	1.26	4.93							1.26	1.26	4.93	4.93	6.93	27.09
BIT MED-S W/SCRUB	2.32	1.34							2.32	2.32	1.34	1.34	12.73	7.36
SUB-BIT LO-S W/SCRUB		22.83									22.83	22.83		125.37
LIGNITE MED-S W/SCRUB		.07				.09					.07	.07		.36
BIT HI-S NO SCRUB	17.95	.87							17.95	17.95	.87	.87	98.61	4.78
BIT MED-S NO SCRUB	25.78	.72							25.78	25.78	.72	.72	141.58	3.95
BIT LO-S NO SCRUB	10.93	8.48							10.93	10.93	8.48	8.48	60.02	46.55
DISTILLATE TURBINES								.55		7.33	.55	.55		.31
COMBINED CYCLE-DIST					.13				.13	.13			.31	
COMBINED CYCLE-GAS	.14	.47							.14	.14	.47	.47	.75	2.57
GAS TURBINES	1.62						1.54		3.16	3.16			9.74	
GAS STEAM	2.79								2.79	2.79			15.33	
HYDRO	1.96		.52		4.74	1.04	2.91		10.13	10.13	1.04	1.04	53.25	2.97
PUMPED STORAGE					.71		.41	5.47	1.13	1.13	5.47	5.47	1.13	4.17
LOW/MED BTU GAS-CC		3.92									3.92	3.92		22.32
CENTRAL ELECTRIC AFB		1.67									1.67	1.67		9.53
WIND SYSTEMS		.00									.00	.00		.00
BIOMASS-ELECTRIC		.00									.00			.00
OCEAN THERMAL		1.55									1.55	1.55		9.50
TOTAL	77.57	94.63	.52		5.59	2.76	4.87	6.02	88.55	109.71	103.41	103.41	450.87	533.39
													984.26	

NOTE: SYSTEM CAPACITY FACTOR = .527 LOAD FACTOR = .717 NUCLEAR BUILD LIMITS ARE 47.79 RESERVE MARGIN=25 %

THE FOLLOWING CONVERSIONS OF EXISTING PLANT CAPACITY (IN GIGAWATTS) OCCURRED:

CONVERT OIL TO BIT/HI SUL/N SCR	1.21
CONVERT GAS TO BIT/HI SUL/N SCR	.02
CONVERT OIL TO GAS STEAM	.40
CONVERT DISTILLATE TO GAS TURB.	.53
CONVERT N DIST TO GAS COMB CYCL	.47
CONVERT E DIST TO GAS COMB CYCL	.14

EX=EXISTING CAPACITY WHICH INCLUDES THAT PORTION OF 1/1/78 CAPACITY AFTER RETIREMENTS WHICH WAS OPERATED IN THE MODEL RUN.
*AV INDICATES AVAILABLE CAPACITY AFTER SCHEDULED RETIREMENTS AND AFTER CONVERSIONS WHICH EITHER OPERATES OR CONTRIBUTES TO RESERVE BITUMINOUS HI SULFUR IS AN EXCEPTION IN THAT THE CAPACITY IS INCLUDED IN BITUMINOUS LO SULFUR.

OIL IMPORT PRICE: 39.10

VI.C.2. LEAP Projection

The LEAP forecasts are in essence an extension of the MEFS forecasts to a longer horizon. The disadvantage of the LEAP forecast is that LEAP is only a national projection and is not disaggregated to the regional level. However, the LEAP format and methodology are consistent with MEFS so that the MEFS regional projections can be reliably extended to the year 2000. Extension of these regional projections beyond the year 2000 is much less reliable since it must assume that each region either maintains the same percentage of national generation or that each region's growth rate is adjusted by the same percentage in order to match the LEAP forecast.

VI.C.3. ORNL

The ORNL projections provide a disaggregation of the MEFS forecasts to Bureau of Economic Analysis (BEA) areas, states and census regions. Exhibit VI-3 provides a list of ORNL's disaggregation approach. Since the ORNL data is disaggregated down to the BEA level, the use of the ORNL model for reaggregation to ERC regions had the additional advantage of being useful in the parallel Environmental Resources Group study which delivered SPS power to those same BEA load centers.

The state level ORNL projections served as the basis for the transformation of the MEFS projections from Federal Administrative Regional (FAR) to ERC regions.

In its 1979 Annual Report to Congress (EIA, 1979), EIA has already prepared an evaluation of several other projections which is excerpted below. This is a comparison of similar projections, there are other projections which are significantly higher or lower.

VI.C.4. Comparison to Other Projections

"In addition to the EIA, other organizations engage in midterm energy forecasting. The forecasts presented in this section are a sample of those available. Included are energy forecasts by Data Resources, Inc. (DRI); the DOE Office of Policy and Evaluation; and the PACE Company. Each of these forecasts incorporates the major features of the NEA."

"(Exhibit VI-4) provides a comparative overview of the non-EIA and EIA energy projections for 1990. Although they are products of different modeling approaches, the forecasts project similar pictures of domestic energy demand. All three non-EIA forecasts for total energy consumption lie within the range projected by EIA. In fact, the DRI and FOSSIL2 forecasts differ from the Series C projection by less than 1.5 percent; the PACE forecast is approximately 3 percent higher. The general consensus follows largely from the similar macroeconomic forecasts that underlie the demand projections. In each case, the DRI model of the U.S. economy is used to generate the economic forecasts. That each forecast assumes world oil prices rise in real terms, and that domestic energy prices become less regulated over time, also contributes to the similarity of the demand forecasts." (EIA, 1979)

EXHIBIT VI-3

ORNL DISAGGREGATION APPROACH

- From DOE National and Regional projections, with consistent totals.
- First attempt (1978) disaggregated 1980 and 1985 to individual states and U.S. DOC Census Regions.
- Based on U.S. DOC, Bureau of Economic Analysis (BEA) population projections and other regional characteristics such as demographics and economies.
- Intention is to provide a set of energy supply and demand balances for census regions, individual states and 173 BEA regions in a consistent format which can be used for historical analysis and future projections.
- Consistent with overall BEA regional grid, which follows labor market boundaries and is approximately consistent with energy demand centers.
- Format permits further disaggregation by county groups, which may be reaggregated to state and multi-state levels.
- DOE scenario used is the Mid-Mid (supply and demand).
- Presentation format of supply deals separately with fossil fuel transformation to electric energy and electricity direct production, and imports.
- Demand format shows sectoral levels (i.e., residential-commercial, industrial, transportation and miscellaneous) with separate consideration for total electricity and major fossil fuel categories.

EXHIBIT VI-4

COMPARISON WITH OTHER PROJECTIONS

	History	1978 Annual Report Projections			Other Recent Projections		
	1977	1990 Minimum	1990 Series C	1990 Maximum	1990 DRI	1990 Pace	1990 Fossil
Energy Consumption, Excluding Coal Exports (quadrillion Btu per year)							
Total Consumption	76.6	94.4	101.5	110.2	101.8	104.8	100.0
Coal	14.1	26.5	29.2	30.8	24.9	23.8	25.0
Petroleum	37.2	37.9	40.0	46.6	44.1	45.1	40.3
Natural Gas	19.9	17.2	19.4	19.7	19.5	20.3	20.6
Nuclear	2.7	9.1	9.4	10.0	8.8	11.0	9.4
Other	2.6	3.5	3.5	3.6	4.4	4.5	4.7
Electricity	6.6	10.7	11.5	12.3	11.5	11.4	11.1
Total Imports[a]	20.1	14.5	19.0	19.7	27.5	26.6	21.0
Crude Oil	14.0	8.5	14.1	15.0	18.7	17.8	18.7
Products	4.7	2.7	2.8	5.9	6.0	6.3	A
Natural Gas	1.0	1.1	1.2	1.3	2.0	1.4	2.3
LNG	A	0.6	0.8	1.2	0.8	0.9	A
Energy Prices (1978 dollars per standard physical unit)							
Imported Oil	15.14	15.00	18.50	23.50	20.56	19.65	21.00
Average Refiner's Acquisition Cost	12.85	14.78	18.15	23.19	20.13	19.53	21.00
Average Wellhead Natural gas[a]	0.83	1.86	2.15	2.71	2.93	3.92	2.80

EXHIBIT VI- 4 (continued)

		1978 Annual Report Projections			Other Recent Projections		
	History 1977	1990 Minimum	1990 Series C	1990 Maximum	1990 DRI	1990 Pace	1990 Fossil
Economic Factors (Annual rates of change, 1977-1990)							
Real GNP	N.A.	2.99	3.46	3.86	3.28	3.45	3.37
GNP Deflator	N.A.	5.52	5.65	5.81	6.47	5.33	5.65
Population	N.A.	0.89	0.89	0.89	0.89	N.A.	0.89

[a] Total imports include coal, coke, and electricity imports.

[b] Natural gas prices are stated per million Btu.

A = Included in the value reported immediately above.

N.A.= Not available.

Note: The columns headed "1990 Minimum" and "1990 Maximum" report the lowest and highest values, including totals, projected in Series A through E for 1990.

Source: Energy Information Administration, 1978 Annual Report to Congress.

"In broad terms, the non-EIA and EIA forecasts also project similar trends for the fuel composition of domestic energy consumption. Oil and gas are projected to decline as a percent of the total consumption, whereas, coal and nuclear fuel are projected to increase. Series C projects the greatest decline in the share of consumption satisfied by petroleum. In this case, petroleum drops to approximately 39 percent of total consumption in 1990, from almost 49 percent in 1977. In the DRI and PACE forecasts, petroleum still accounts for 43 percent of total energy consumption in 1990. All of the forecasts indicate that natural gas consumption will decline, from 26 percent of total consumption in 1977, to about 19 percent by 1990.

While the forecasts basically agree that nuclear fuel would provide 9-10 percent of total consumption by 1990, less agreement exists concerning the future utilization of coal. Series C projects the most optimistic rate of coal utilization, increasing from less than 19 percent of total consumption in 1977, to almost 29 percent in 1990.

"In the non-EIA projections, coal accounts for 23 to 25 percent of total 1990 energy consumption. The eventual resolution of potentially serious conflicts between the goals of the Clean Air Act of 1977 and the PIFUA coal conversion programs could have a major effect on the future outlook for coal-use. In addition, the EIA forecasts the retirement of oil-refined electric powerplants earlier than in the other forecasts. The uncertainty, reflected in the broad range of projected coal consumption indirectly affects the petroleum consumption forecasts and the outlook for energy imports." (EIA 1979)

The Committee on Nuclear and Alternative Energy Systems (as reported by Amory Lovins) is one of the lowest alternative forecasts, projecting U.S. energy consumption at only 63-77 Quads in the year 2000! Preliminary DOE reports indicate that energy consumption in the year 2000 might be 100 Quads, approximately equal to the MEFS 1990 projections. As noted earlier any projections published in early 1979 were outdated when they were published.

VI.D. REGIONAL DISAGGREGATION

VI.D.1. Reconciliation of ERC and DOE Regions

The published electrical generation projections by EIA were available only for the United States as a whole and for the ten Federal Administrative Regions (FAR) through the period 1995. For a variety of reasons, this analysis is based on the Electrical Reliability Council regions (ERC). Two types of mathematical reconciliation were required. The first was to convert FAR regional projections into ERC regional projections. The second reconciliation or extrapolation required was to project forward from 1995 to the year 2000 on a regional basis. This forward extrapolation was permitted by the fact that the long-term projections (1995-2020) prepared by EIA using their LEAP model did reconcile at 1995 to the last year of the mid-term (MEFS) projections by the same agency which were regionally disaggregated.

The four basic tasks in this disaggregation/extrapolation process were:

1. For the base year 1978 to create from ORNL data a corrected baseline projection of electrical generation by state and fuel type.

2. To develop a methodology by which state projections could be updated in five year intervals through 1995 corresponding to the regional projections (MEFS) through that date.

3. To reconstruct the ERC regions by allocating the state projections developed in the preceding steps to each ERC region for the period 1985-1995.

4. To project from 1995 state/regional projections the increase that would occur between 1995 and 2000 according to the LEAP forecast.

Oak Ridge National Laboratories (ORNL) disaggregated in a systematic fashion the 1977 published Series C Mid-Mid projections by EIA (EIA, 1978) to individual state projections and to projections of the 173 Bureau of Economic Analysis areas (BEA) (ORNL, 1979). Unfortunately, ORNL has not disaggregated and reconciled the 1978 projections by EIA contained in the 1978 Annual Report to Congress (EIA, 1979). The first step consisted of adjusting the 1977 ORNL disaggregations to the 1978 EIA regional projections. Adjustment factors were based on the change in electrical generation by fuel type for each region, comparing the 1977 and 1978 EIA projections for the year 1990. These factors were then applied to the ORNL state projections by fuel type (reflecting the 1977 EIA projection) to derive "test" regional totals which should correspond to the 1978 EIA regional projections. These totals were then corrected and adjusted back (typically with a one percent or smaller change) to correspond exactly to the published EIA 1990 totals as projected in 1978. This provided a baseline set of projections.

This process was replicated once again between the period 1995 and 1990 to get 1995 state level projections.

The equations used in this process reflected first an adjustment for an increase or decrease in generation by fuel type and then a correction factor to reconcile the independently generated sum of state totals to the published sum as indicated in the EIA and FAR regional projections.

For each state, the projected generation G in time t was developed as follows:

G

where f represents one 6 fuel types
factor represents the proportional increase in fuel in the region between time t-1 and time t.

RCF represents a regional correction factor equal to the actual projected regional total divided by the sum of the derived state generation totals.

The process of generating ERC regional projections then required a recombination of state level projections into ERC regions. For all but nine states in the union this simply consisted of allocating the state to the appropriate ERC region. There are, however, nine states which are split between different ERC regions. These are evident from the map shown in Exhibit VI-5, which shows both ERC and FAR regional boundaries.

The basis for allocation of these states to the different ERC regions was taken from recent publication by Martin Baughman at the University of Texas involving long-term liability planning. (Baughman, 1979) The allocations of states in their entirety to ERC regions are self-explanatory and are noted in future sections.

The fourth and final phase of the analysis which involved the extrapolation forward of 1995 projections to the year 2000 followed a process quite similar to that used for the intermediate projections by state. In this case, the rate of change in electrical generation (in percent) characterizing each of six major fuel types at the national level was applied to each of the ten FAR regions. The national total derived by summing the ten FAR regions was adjusted, by multiplying by a constant, to precisely match the LEAP projection's U.S. national total for the year 2000. The result of this was to provide a pseudo-regional projection through the year 2000. The process by which this result was disaggregated into states and subsequently reaggregated into ERC regions was identical to that used for the earlier years.

VI.D.2. Resulting Projections for Reference Scenario (C-mid-mid)

Exhibits VI-6 and VI-7 present the 1995 reference scenario projections of electricity generation by Federal Administrative Regions (FAR) and Electric Reliability Council (ERC) regions. The FAR regions (Exhibit VI-6) are the format used by the Energy Information Administration to present their results. The ERC regions were used for this report and the parallel Environmental Resources Group report because the ERC regions were more closely related to utility power pool and service areas.

As discussed in the previous section there was a significant process required to transform the FAR regions to ERC regions. The reason for the transformation is apparent upon examination of Exhibits VI-6 and VI-7. Several states (Texas, Missouri, Montana, Pennsylvania and Mississippi) are split between more than one ERC region.

The general pattern of the FAR regions is also significantly different. FAR region 2 (New York, New Jersey) is deleted in the ERC regions with

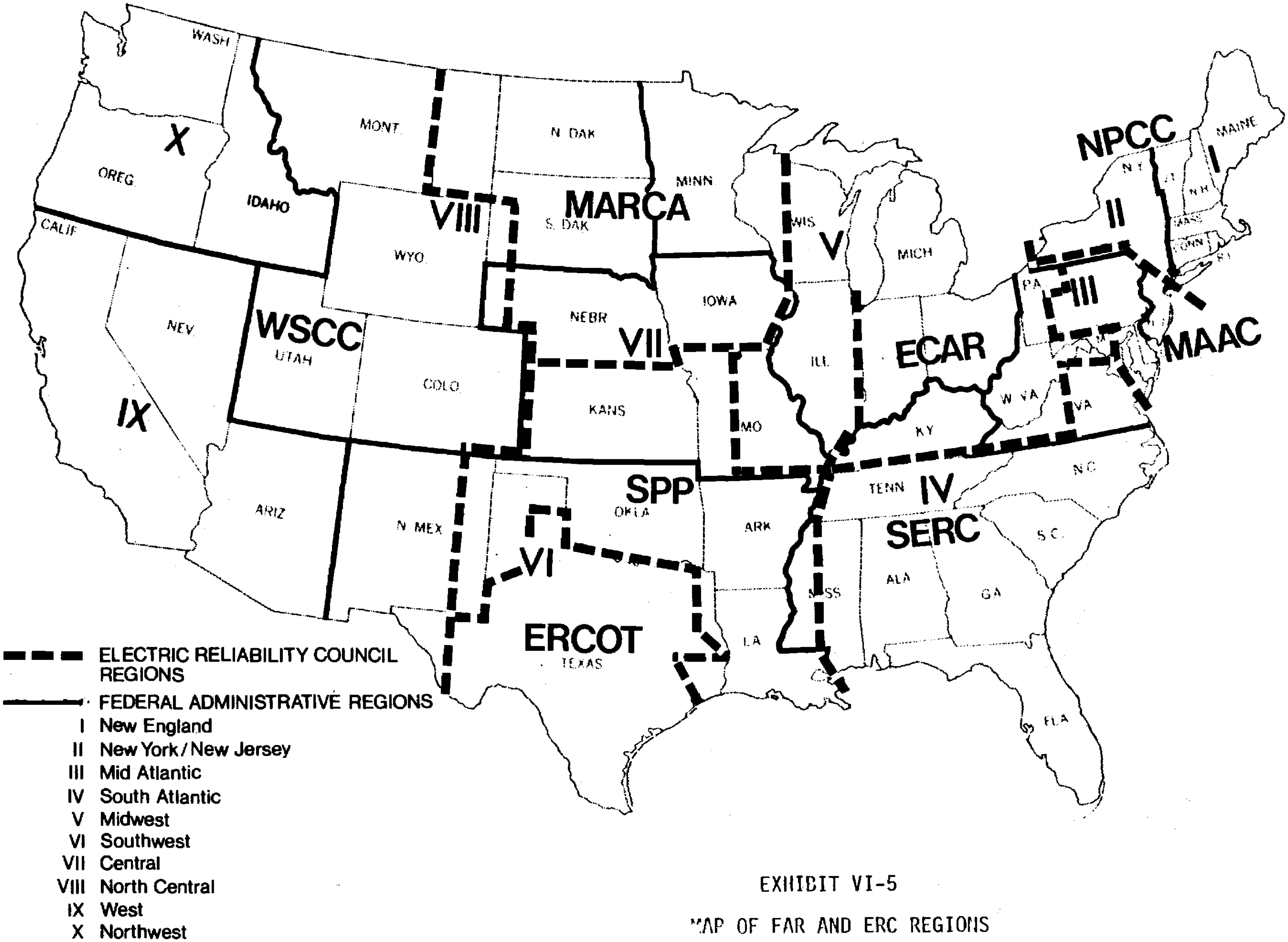


EXHIBIT VI-5

MAP OF FAR AND ERC REGIONS

EXHIBIT VI-6

MEFS SERIES C (MID-MID) PROJECTION PER ARC 1978: YEAR 1995
ANNUAL GENERATION IN THOUSANDS OF GIGAWATT HOURS

ST NO	STATE by FAR Region	TOTAL	PETRO-LEUM	NAT. GAS	COAL	NUCL. ENERGY	HYDRO-ELECT.	GEO-SOLAR
23	MAINE	16	1	0	9	5	1	0
33	NEW HAMPSHIRE	26	0	0	11	14	1	0
50	VERMONT	6	0	0	3	3	0	0
25	MASSACHEUSETTS	53	6	0	33	12	2	0
44	RHODE ISLAND	12	0	0	5	7	0	0
9	CONNECTICUT	46	4	0	20	22	0	0
**	TOTAL REGION 1	172	14	0	85	65	7	0
36	NEW YORK	213	6	0	118	64	25	0
34	NEW JERSEY	94	1	0	48	43	2	0
**	TOTAL REGION 2	312	7	0	167	108	28	0
42	PENNSYLVANIA	202	1	0	142	57	2	0
10	DELAWARE	5	0	0	5	0	0	0
24	MARYLAND	36	0	0	18	16	2	0
11	DIST OF COLUMBIA	0	0	0	0	0	0	0
51	VIRGINIA	57	0	0	20	30	7	0
54	WEST VIRGINIA	101	0	0	101	0	0	0
**	TOTAL REGION 3	414	3	0	290	107	13	0
37	NORTH CAROLINA	137	0	0	90	40	7	0
45	SOUTH CAROLINA	94	0	0	40	50	4	0
13	GEORGIA	122	0	0	85	30	7	0
12	FLORIDA	122	1	0	88	32	1	0
21	KENTUCKY	107	0	0	105	0	2	0
47	TENNESSEE	181	0	0	78	95	8	0
1	ALABAMA	134	0	0	78	47	9	0
28	MISSISSIPPI	67	0	0	35	32	0	0
**	TOTAL REGION 4	978	2	0	604	330	41	0
39	OHIO	235	1	0	194	40	0	0
18	INDIANA	135	0	0	118	17	0	0
17	ILLINOIS	226	1	0	137	88	0	0
26	MICHIGAN	135	0	0	95	37	3	0
55	WISCONSIN	82	0	0	56	26	0	0
27	MINNESOTA	55	0	0	46	9	0	0
**	TOTAL REGION 5	885	5	1	651	219	7	0
5	ARKANSAS	89	0	0	73	14	2	0
22	LOUISIANA	78	1	3	50	24	0	0
40	OKLAHOMA	83	0	1	63	18	1	0
48	TEXAS	363	3	9	308	42	1	0
35	NEW MEXICO	60	0	0	60	0	0	0
**	TOTAL REGION 6	689	6	16	556	101	6	1
19	IOWA	42	0	0	34	8	0	0
29	MISSOURI	90	0	0	78	10	2	0
31	NEBRASKA	31	0	0	19	11	1	0
20	KANSAS	37	0	0	32	5	0	0
**	TOTAL REGION 7	210	1	0	167	37	4	0
38	NORTH DAKOTA	12	0	0	11	0	1	0
46	SOUTH DAKOTA	6	0	0	1	0	5	0
30	MONTANA	19	0	0	10	0	9	0
56	WYOMING	28	0	0	28	0	0	0
8	COLORADO	34	0	0	31	0	3	0
49	UTAH	13	0	0	12	0	1	0
**	TOTAL REGION 8	122	0	0	96	2	23	0
4	ARIZONA	143	2	0	109	15	11	6
32	NEVADA	104	0	0	101	0	0	3
6	CALIFORNIA	163	18	0	0	50	37	58
**	TOTAL REGION 9	417	20	0	211	66	50	68
16	IDAHO	11	0	0	0	0	11	0
53	WASHINGTON	162	0	0	14	57	91	0
41	OREGON	59	0	0	5	15	39	0
**	TOTAL REGION 10	235	0	0	20	73	142	0
	TOTAL 48 & D.C.	4438	62	19	2851	1112	323	70

NOTE: ORNL1977 STATE ALLOCATIONS ADJUSTED BY GROWTH FACTORS
(TOTALS MAY NOT ADD DUE TO INDEPENDENT ROUNDING)
SOURCE: KOTIN & REGAN, INC.

EXHIBIT VI-7

MEFS SERIES C (MID-MID) PROJECTION PER ARC1978: YEAR 1995
ANNUAL GENERATION IN THOUSANDS OF GIGAWATT HOURS

ST NO	STATE by ERC Region	TOTAL	PETRO-LEUM	NAT. GAS	COAL	NUCL. ENERGY	HYDRO-ELECT.	GEO-SOLAR
42	PENNSYLVANIA	29	0	0	21	8	0	0
39	OHIO	235	1	0	194	40	0	0
18	INDIANA	135	0	0	118	17	0	0
26	MICHIGAN	95	0	0	67	26	2	0
24	MARYLAND	6	0	0	3	3	0	0
11	DIST OF COLUMBIA	0	0	0	0	0	0	0
51	VIRGINIA	8	0	0	3	4	1	0
54	WEST VIRGINIA	101	0	0	101	0	0	0
21	KENTUCKY	81	0	0	79	0	2	0
**	TOTAL REGION 1	704	3	0	591	100	7	0
48	TEXAS	293	3	8	247	34	1	0
**	TOTAL REGION 2	295	3	8	247	34	1	0
34	NEW JERSEY	94	1	0	48	43	2	0
42	PENNSYLVANIA	173	1	0	121	49	2	0
10	DELAWARE	5	0	0	5	0	0	0
24	MARYLAND	30	0	0	15	13	2	0
11	DIST OF COLUMBIA	0	0	0	0	0	0	0
**	TOTAL REGION 3	309	4	0	191	106	7	0
17	ILLINOIS	226	1	0	137	88	0	0
26	MICHIGAN	40	0	0	28	11	1	0
55	WISCONSIN	50	0	0	34	16	0	0
29	MISSOURI	45	0	0	39	5	1	0
**	TOTAL REGION 4	368	2	0	240	121	3	0
55	WISCONSIN	32	0	0	22	10	0	0
27	MINNESOTA	55	0	0	46	9	0	0
19	IOWA	42	0	0	34	8	0	0
38	NORTH DAKOTA	12	0	0	11	0	1	0
46	SOUTH DAKOTA	5	0	0	1	0	4	0
31	NEBRASKA	31	0	0	19	11	1	0
30	MONTANA	2	0	0	1	0	1	0
**	TOTAL REGION 5	192	1	0	139	40	11	0
23	MAINE	16	1	0	9	5	1	0
33	NEW HAMPSHIRE	26	0	0	11	14	1	0
50	VERMONT	6	0	0	3	3	0	0
25	MASSACHEUSETTS	53	6	0	33	12	2	0
44	RHODE ISLAND	12	0	0	5	7	0	0
9	CONNECTICUT	46	4	0	20	22	0	0
36	NEW YORK	213	6	0	118	64	25	0
**	TOTAL REGION 6	387	20	0	203	130	32	0
51	VIRGINIA	49	0	0	17	26	6	0
37	NORTH CAROLINA	137	0	0	90	40	7	0
45	SOUTH CAROLINA	94	0	0	40	50	4	0
13	GEORGIA	122	0	0	85	30	7	0
12	FLORIDA	122	1	0	88	32	1	0
21	KENTUCKY	26	0	0	26	0	0	0
47	TENNESSEE	181	0	0	78	95	8	0
1	ALABAMA	134	0	0	78	47	9	0
28	MISSISSIPPI	48	0	0	25	23	0	0
**	TOTAL REGION 7	927	2	0	531	347	45	0
29	MISSOURI	45	0	0	39	5	1	0
20	KANSAS	37	0	0	32	5	0	0
28	MISSISSIPPI	19	0	0	10	9	0	0
5	ARKANSAS	89	0	0	73	14	2	0
22	LOUISIANA	78	1	3	50	24	0	0
40	OKLAHOMA	83	0	1	63	18	1	0
48	TEXAS	53	0	1	46	6	0	0
35	NEW MEXICO	21	0	0	21	0	0	0
**	TOTAL REGION 8	442	3	7	338	85	6	0
46	SOUTH DAKOTA	1	0	0	0	0	1	0
48	TEXAS	17	0	0	15	2	0	0
30	MONTANA	17	0	0	9	0	8	0
16	IDAHO	11	0	0	0	0	11	0
56	WYOMING	28	0	0	28	0	0	0
8	COLORADO	34	0	0	31	0	3	0
35	NEW MEXICO	39	0	0	39	0	0	0
4	ARIZONA	143	2	0	109	15	11	6
49	UTAH	13	0	0	12	0	1	0
32	NEVADA	104	0	0	101	0	0	3
53	WASHINGTON	162	0	0	14	57	91	0
41	OREGON	59	0	0	5	15	39	0
6	CALIFORNIA	163	18	0	0	50	37	58
**	TOTAL REGION 9	810	20	0	367	144	207	68
	TOTAL 48 & D.C.	4438	62	19	2851	1112	323	70

NOTE: ORNL1977 STATE ALLOCATIONS ADJUSTED BY GROWTH FACTORS
(TOTALS MAY NOT ADD DUE TO INDEPENDENT ROUNDING)
SOURCE: KOTIN & REGAN, INC.

New York being a part of MPCC (region 6) and New Jersey being a part of MAAC (region 3). Another primary difference between the two projections is the size of WSCC (ERC region 9). WSCC covers all of FAR regions 9 and 10, a major portion of region 8 and part of region 6. There are other differences in state distributions between regions but these are the major ones.

VI.E. IMPACT OF ALTERNATIVE ENERGY SCENARIOS

An important reason for choosing the MEFS forecasts was the ability to examine a number of altnernative energy scenarios. The top half of Exhibit VI-8 presents the reference scenario and four other scenarios developed by EIA.

VI.E.1. Alternative Scenarios

The first three columns of Exhibit VI-8 are three of the scenarios published in EIA's 1978 Annual Report to Congress. Column 1 is the reference scenario (C mid-mid) while the others incorporate higher oil prices or a moratorium on nuclear construction. The last two columns are preliminary results for alternative scenarios prepared by EIA in late 1979. These last two scenarios reflect the substantial recent increase in oil prices. The Series C forecasts (columns 1, 2 and 3) had oil price projections, which at the time of preparation seemed reasonable, which included a modest real increase in the price of oil. The C high oil price scenario assumed a larger real increase in the price of oil to approximately $3/per barrel (1979 dollars). The nuclear moratorium scenario started with the C mid-mid assumptions but assumed that no additional nuclear plants beyond those already in the planning stages would be built.

The final two scenarios are perhaps the most interesting. These two scenarios begin to incorporate the significant price increases that occurred in 1979. The 1995 price of 39.50 when adjusted for inflation (assuming "only" 7% inflation) would be approximately $110 in 1995 dollars. The two scenarios differ only in their ability to retire or phase out oil and gas burning units prior to the end of their useful life. The 35 percent reserve limit prevents utilities from phasing out additional oil and gas fired units when those unts would increase the reserve margin above 35 percent. This limitation would prevent some utilities or regions from switching to coal even though it was economical to do so. The other scenario imposes no such restriction.

VI.E.2. Insensitivity of Total Power Generation

The most interesting thing about these projections is the apparent insensitivity of the generation of electricity to a change in the inputs for electrical generation. Even though, as shown in Exhibit VI-4, the overall demand for energy varied by 10 percent around the C mid-mid scenario, the lowest demand scenario was less than one percent lower than the reference scenario. This is due to the EIA methodology in which electricity generation is determined from a demand driven

EXHIBIT VI-8

COMPARATIVE SUMMARY OF ALTERNATIVE ELECTRICAL GENERATION SCENARIOS (WITH REGIONAL ALLOCATIONS)

Scenario Name	Series C (Mid-Mid)				EIA Per 1978 Annual Report to Congress (3/79): C with High Oil Prices			EIA Per 1978 Annual Report to Congress (3/79): C with Nuclear Moratorium			Update MEFS/EIA Forecast (12/79): High Oil - With 35% Reserve Limit			Update MEFS/EIA Forecast (12/79): High Oil - With No Limit on Reserve Expansion		
	1985	1990	1995	2000	1985	1990	1995	1985	1990	1995	1985	1990	1995	1985	1990	1995
Oil Price (1979s)	15.00	18.50	23.50		21.50	23.50	31.50	15.00	18.50	23.50	28.90	34.50	39.10	28.90	34.50	39.50
Generation KWH x 10^9	3,054	3,714	4,445	4,977	3,044	3,681	4,438	3,056		4,423	2,992	3,626	4,420	2,984	3,611	4,410
Pet Chge	--	3.4	3.7	2.3	--	3.9	3.4	--	4.2	3.0	--	3.9	4.0	--	3.9	4.1
Generation Mix by Fuel Type																
Oil	441	320	63	125	325	43	12	442	321	73	197	139	94	167	6	8
Natural Gas	199	47	19	178	208	54	17	199	46	19	335	316	282	320	120	77
Coal	1,518	2,175	2,851	2,623	1,610	2,407	2,893	1,519	2,286	130	1,559	1,991	2,506	1,598	2,308	2,808
Nuclear	572	824	1,115	1,584	572	829	1,119	572	749	778	572	824	1,120	572	830	1,120
Hydro	305	314	324	389	304	314	323	305	31	324	305	314	325	303	313	324
Geothermal	19	34	73	76	25	34	74	19	34	99	24	42	93	24	34	73

Regional Allocation (ERC)	Series C 1995 %	Sites	Series C 2000 %	Sites	C with High Oil Prices 1995 %	Sites	C with Nuclear Moratorium 1995 %	Sites	High Oil - 35% Reserve Limit 1995 %	Sites	High Oil - No Limit 1995 %	Sites
Region 1 ECAR (9)	15.9	9.5	14.3	8.6	15.9	9.5	16.6	9.9	15.9	9.5	15.7	9.4
2 ERCOT (5)	6.6	4.0	7.4	4.4	6.7	4.1	6.8	4.1	6.9	4.1	6.7	4.0
3 MAAC (4)	7.0	4.2	6.9	4.2	6.7	4.0	6.8	4.1	6.6	3.9	6.8	4.1
4 MAIN (5)	8.3	5.0	8.2	4.9	8.4	5.0	8.1	4.9	8.4	5.0	8.3	5.0
5 MARCA (2)	4.3	2.6	4.1	2.5	4.4	2.6	4.2	2.5	4.2	2.6	4.4	2.6
6 NPCC (5)	8.7	5.2	9.1	5.5	8.4	5.0	8.6	5.2	8.3	5.0	8.3	5.0
7 SERC (13)	20.9	12.5	21.0	12.6	20.8	12.5	20.4	12.2	20.9	12.5	21.0	12.6
8 SPP (6)	10.0	6.0	10.5	6.3	10.1	6.1	9.8	5.9	9.9	6.0	10.0	6.0
9 WSCC (11)	18.3	11.0	18.4	11.0	18.6	11.2	18.7	11.2	18.9	11.4	18.8	11.3
(60)		60.0		60.0	100.0	60.0	100.0	60.0	100.0	60.0	100.0	60.0

equation. The significant increase in input (fired) costs causes a significant change in the fuel mix but has a much smaller effect on the price of electricity and hence on the demand for electricity. The fuel input assumptions have their dramatic impact on the fuel used to generate electricity. All of the scenarios show a trend away from generating electricity by oil and gas toward coal and nuclear. One interesting occurrence is the slower phase out of natural gas in the newer high oil price scenarios.

VI.F. REGIONAL ALLOCATION

VI.F.1 Regional Generation Distribution

While it is important that the generation of electricity be relatively stable at the national level, this report is most concerned with the regional distribution and stability of electricity generation. The bottom half of Exhibit VI-8 presents the regional distribution of electricity generation across ERC regions.

In the reference scenario SERC, WSCC, and ECAR are the biggest users and generators of electricity. These three regions account for over 50 percent of national electricity generation in both 1995 and 2000. The differences in the regional distribution of generation between 1995 and 2000 are significant. The ECAR region's share of national generation declines by approximately 10 percent between 1995 and 2000 (from 15.9 to 14.3 percent) while ERCOT increases by more than 10 percent (from 6.6 to 7.4 percent). SPP and MPCC both increase by approximately five percent between 1995 to 2000. The remaining five regions remain relatively stable.

VI.F.1. Insensitivity of Alternative Scenarios

The advantage in using the MEFS model is that the alternative scenarios are also regionally disaggregable. Just as the national totals for each scenario were not significantly different among the scenarios, the regional percentages of generation are also stable across regions. In none of the alternative scenarios is there more than a 5 percent change in regional generation in comparison to the reference scenario. The scenario that exhibits the largest change from the reference case is the nuclear moratorium scenario. In this case the regions that are projected to have a greater reliance on nuclear power (SERC, MAAC, and MAIN) have reduced percentages in the nuclear moratorium case. The regions that are projected to have a greater dependence on fossil fuels, primarily coal, (ECAR and ERCOT) show increases in their proportion of total U.S. electrical generation.

In terms of the effect on regional generation, the five year period between 1995 and 2000 has a more significant effect than any of the scenarios. This occurs because the different scenarios affect the generation mix but not the overall demand for electricity.

In addition, the ERC regions are to a large extent autonomous. Electricity transfers between regions are a very small percentage of total generation, since utilities and pools plan their own generation capacity and they prefer to keep that capacity "nearby".

VI.F.3. Rectenna Allocation

All of the foregoing discussion was a prelude to the allocation of rectennas to regions. The allocation of rectennas to ERC regions based on electricity generation is an allocation mechanism based on "need." Regions that will generate and use more electricity have a greater "need" for SPS electricity. The choice and use of the EIA forecasts as opposed to other forecasts ensures comparability with other SPS studies and allows for consistency in future siting studies.

The rectennas were allocated to ERC regions based on each region's percentage of total U.S. electrical generation in the year 2000. Approximately 10 percent of U.S. electricity is projected to be generated in SPP, so SPP was allocated 6 rectennas (10 percent of 60). The rectennas were allocated to regions in the following amounts:

ECAR	(East Central)	9
ERCOT	(Texas)	5
MAAC	(Mid-Atlantic)	4
MAIN	(Mid-West)	5
MARCA	(Dakotas, Nebraska, etc.)	2
NPCC	(Northeast)	5
SERC	(Southeast)	13
SPP	(Southwest)	6
WSCC	(West)	11

In the allocation process one judgemental decision was made. Normal rounding to whole numbers distributed 59 of the rectennas. The last rectenna needed to be allocated to either ERCOT, NPCC or MARCA. Although Exhibit VI-9 shows NPCC and MARCA with a higher "partial" rectenna than ERCOT, when taken to two decimal places and rounded to whole numbers, all three rounded down (i.e. less than .50). The 60th rectenna was allocated to ERCOT based on ERCOT's larger growth between 1995 and 2000.

While it can be argued that the year 2000 is not the appropriate year for allocating rectennas to regions, the same can be said for any other year. The actual siting of rectennas (should SPS be developed) would be a dynamic process in which the regional allocation would be constantly reevaluated. A strong case might be made for the year 2015 since this would be the midpoint of the SPS deployment if the allocation was based on a single year. The year 2015 is not appropriate for this report, however, because there are no regional projections for this time frame.

VII. DATA VALIDATION

VII.A OVERALL APPROACH TO VALIDATION

One of the more important tasks undertaken in this research effort involved the validation of the data used in this analysis. Checks to insure the development of an accurate data base were established at the outset and validation may be seen as an ongoing, comprehensive process. However, a specific detailed inquiry was conducted in addition to the more general process of insuring data accuracy.

Validation as practiced in this report can be considered in four distinct phases. These were:

1. the initial map design,
2. pre-validation of selected data items,
3. data recording accuracy checks, and
4. post-validation using a random sample.

VII.A.1 Initial Map Design

As discussed in Section III.B, infra, substantial effort was devoted to developing an accurate base map. The Albers Equal Area projection system was utilized and a grid square overlay keyed to the United States Geological Survey's 7½ minute quadrangle series was developed. Further, in the mapping per se, only mapped sources utilizing the Alber's Equal Area projection system were utilized in the direct transfer of information from the source to the acetate overlays. The necessity for having map sources utilizing similar projection systems arises because maps appearing similar, but utilizing other projection systems, will be inaccurate. It is doubtful that over 50% of our mapped information would have been accurate (and traceable) had we not had a base map that utilized the Albers Equal Area Projection System.

VII.A.2 Pre-Validation of Selected Data Items

In many cases, more than one source existed that depicted the spatial coverage of certain exclusion variables. In these cases, several sources were cross-referenced to USGS 7½ minute quadrangle maps to determine which of two or more sources appeared to be more accurate. Additionally, there were certain mapped sources that needed to be checked to determine if they indeed portrayed the information accurately.

The process employed at this state of validation was relatively straightforward. The variable of concern was mapped on the base map and cross-referenced to the USGS quad sheets. If two sources existed, then two different maps would be developed and cross-referenced. The map source performing best was then selected. This process was utilized in determining the source to be utilized on the following variables:

1. Unacceptable Topography - Three potential sources existed for this variable. These were "Shaded Relief of the United States", "Classes of Land Surface Form" and the "AAA Roadmap of the United States". The AAA roadmap was not utilized because it used a different projection system. The final decision was made to utilize the "Shaded Relief of the United States" because it was possible to obtain a higher level of resolution than was apparent in the land surface form map, which tended to group large land areas by class, thereby incorporating less steep lands with very steep terrain. Post-validation of the resulting "eligible" areas led to the development of a second map which addresses topography as a design/cost variable. This second map utilized the land surface map for flatlands and a residual class resulted from computer analysis of the areas that were neither unacceptable nor flat.

2. Marshlands - The source utilized for marshlands was Kuchler's "Natural Potential Vegetation of the United States". This map was examined at the USGS 7½ minute quadrangle level and all areas indicated as being marshlands on Kuchler's map were validated using a sample of 10 USGS maps.

3. Perennially Flooded Lands - Two sources existed for perennially flooded lands. These were the USGS maps titled "Major Land Uses" and "Classes of Land Surface Form". Although both maps performed well in validation exercises, the "Major Land Uses" map was selected because no inaccuracies were found in the initial screening and the mapped data was easier to translate than the "Land Surface Form" map.

4. Adjusted Population Density - The adjusted population density was developed from the U.S. Bureau of the Census's "Dot Map of The Population of United States". Pre-validation was undertaken for this mapped source and the 10 USGS 7½ minute quad maps consulted indicated that the data was accurately portrayed. This source was considered to be preferable to another mapped source that indicated population density by county, thereby tending to obscure isolated populated areas in large counties and totally masking unpopulated areas surrounded by larger cities.

While other, less formal pre-validation was undertaken for all variables, those listed above were subjected to more formalized processes.

VII.A.3 Data Recordation Accuracy Checks

Although the original mapped source may be accurate, the information must be accurately transferred from the source to the acetate base maps and from the base maps to the machine if the data was to be worthwhile. For this reason, two checks were established to insure the accuracy of the data transfer process. First, all mapped data was visually inspected by a Principal Investigator prior to the encoding of data at the machine level. This visual check was particularly important in resolving boundary issues as well as in making sure that isolated occurrences of the variable of concern were not overlooked.

The second data transfer check occurred at the machine level. Each data pattern that was coded into the machine was cross-checked with the acetate base map to insure that the transfer had occurred accurately. In fact, each variable was checked three times in this manner. At this point, it is felt that the transfer from acetate base maps to the machine was 100% accurate.

VII.A.4 Post-Validation Using A Random Sample

In addition to the data checks described above, a formal validation effort was initiated after the development of the summary maps. In particular, the need existed to verify both the excluded areas (to see if they were accurately excluded) and the "eligible" areas (to determine if they were, in fact, eligible). For purposes of this post-validation effort, the decision was made to use the summary map that utilized all of the absolute exclusion variables, including the EMC variables. This summary map is displayed in Exhibit V-3.

To accomplish this procedure, a random sample of 180 excluded cells and 180 eligible cells was selected and the 360 grid cells were examined in detail. The results of these analyses are presented in Sections VII.B and VII.C, infra.

VII.A.5 Sample Design

Two interrelated samples were selected for post-mapping validation of the excluded and "eligible" areas. One was a small sample of 100 cells, divided 50 eligible and 50 excluded, randomly located throughout the United States. The random selection was accomplished through the generation of pairs of random numbers in a constrained computer program in which only those numbers representing eligible coordinates on the base map were used. A list of random numbers significantly larger than the required sample of 100 was generated and these were sequentially tested and assigned to excluded or eligible categories until there were 50 of each.

A national sample of 100, 50 each for eligible and excluded areas, was clearly inadequate to provide statistically valid differentiation between the regions. In addition, equal representation of the regions in any sample would probably be inappropriate, since the allocation of rectennas to the regions was dependent on a measure of need (e.g. power generation), and not based on area. Consequently, a weighted regional sample was developed consisting of 360 cells, 180 eligible and 180 excluded. This sample size was chosen because it represented a nominal multiplier of 6 times the number of sites and, more significantly, because it would produce regional samples with an average size of 40 sample points, 20 eligible and 20 excluded.

The same computer-generated random number pair selection procedure was used on a region-by-region basis. The random number generator in the computer was constrained to filter out all random number pairs which did not fit within the coordinates of a particular ERC region. Random number lists significantly larger than the required number of sample points were generated by the computer and then used sequentially until the appropriate quota of sample cells for each region was established.

It should be noted that the 50 cells or , more precisely, 43 of the 50 cells chosen for the national sample, were reused in the regional sample and augmented in the regional sampling procedure to bring each region up to its quota. As a general rule, regional quotas were set at 6 times the number of rectennas allocated to that region.

VII.B POST-VALIDATION OF EXCLUDED AREAS

VII.B.1 Procedure

The procedure employed in the validation of the excluded areas was quite straighforward. Initially, the 180 grid cells to be validated were encoded into the computer system and a print-out was produced which specified the variable or variables which caused the cell to be excluded. Then, the variable was examined to determine its presence in the grid square of concern.

In the case of exclusions by multiple variables, each variable was checked to determine its presence only to the extent that the cell had not already been validated by another exclusion variable. In other words, if the first of two exclusion variables was found to be present, the second exclusion variable was not examined for validation purposes. In this manner, we determined that the cell was validly excluded; we did not determine the accuracy of all variables indicated as excluding a cell.

Three general sources were utilized in the exclusion validation analysis. These were the U.S. Geological Survey 7.5 minute maps, the U.S. Geological Survey 1:250,000 scale maps and a county map of the United States. Due to the procedure undertaken in the validation of the excluded areas, it was not necessary to utilize other more detailed sources.

VII.B.2 Discussion of Results

The initial step in the post-validation of the excluded areas was to obtain the print-out of the excluded cells. The 180 grid cells to be examined in detail were as follows:

1. Number of Cells Excluded by Single Variable - 91
2. Cells Excluded by Two Variables - 65
3. Cells Excluded by Three Variables - 22
4. Cells Excluded by Four Variables - 2

The characteristics of the cells excluded by a single variable were as follows:

1. Standard Metropolitan Statistical Areas - 25
2. Adjusted Population Density - 18
3. National Recreation Areas - 1
4. Perennially Flooded Areas - 1
5. Interstate Highways - 5
6. Navigable Waterways - 1
7. Unacceptable Topography -23
8. Inland Water - 2
9. EMC A150 - 12
10. EMC A50 - 3

The characteristics of the cells excluded by two variables were as follows:

1. Standard Metropolitan Statistical Areas - 32
2. Adjusted Population Density - 20
3. National Recreation Areas - 2
4. Marshlands - 1
5. Perenially Flooded Lands - 3
6. Designated Habitats - 1
7. Interstate Highways - 13
8. Navigable Waterways - 13
9. Unacceptable Topography - 17
10. EMC 150 - 29
11. EMC A100 - 2
12. EMC A50 - 6

The characteristics of the cells excluded by three variables were as follows:

1. Standard Metropolitan Statistical Areas - 12
2. Adjusted Population Density - 6
3. Military Reservations - 1

4. National Recreation Areas - 1
5. Marshlands - 2
6. Perennially Flooded Lands - 4
7. Interstate Highways - 9
8. Navigable Waterways - 7
9. Unacceptable Topography - 8
10. EMC A150 - 15
11. EMC A50 - 1

None of these grid cells were reclassified upon detailed examination. Although we do not represent that the data base is 100% accurate, it does appear that the excluded areas are reasonably excluded. The major thrust of the validation effort, however, will come with the examination of the eligible areas to determine how many remain eligible.

There are several explanations for the absence of any reclassification of the exclusion areas. Initially, Standard Metropolitan Areas, areas with unacceptable topography (the very worst in the United States) and EMC variables represent easily verified (and mapped) variables. Together, these three variables accounted for 70% of the single variable exclusions, 92% of the two variable exclusions and 100% of the three and four variable exclusions. In other words, only 28 of the single exclusion grid squares, 5 of the double exclusion grid squares and none of the three and four variable grid squares were examined for variables other than unacceptable topography, standard metropolitan statistical areas and EMC.

Of the single exclusion variables other than topography, SMSA's and EMC, 64% of these were examined for the adjusted populations density variable and 10% were examined for the presence of interstate highways. Of the five double exclusion variables not containing unacceptable topography, SMSA's or EMC variables, all five grid cells showed the presence of adjusted population density variable. In three of the five pairings, the additional variable was interstate highways with the two additional pairings being with navigable waterways. These variables are logically related and were verified as present.

In summary, five variables were dominant in causing exclusion and in the high success rate of the exclusion validation effort. These five variables were:

1. Unacceptable Topography
2. Standard Metropolitan Statistical Areas
3. EMC (all three)
4. Adjusted Population Density
5. Interstate Highways

VII.C. ELIGIBLE AREA VALIDATION

Perhaps one of the most important aspects of the validation exercise involved the examination of the "eligible" areas. There are several reasons for attaching importance to this exercise.

First, all data was mapped from national sources. While it was felt that the accuracy of the information was excellent for the areas shown on the national-scale maps, it was also accepted that there were occurrences of many variables beyond the mapped data. This was expected to be true for marshlands, inland water areas, and perennially flooded areas (of the absolute exclusion variables).

Second, there are several important variables for which national-scale sources do not exist. Included in these variables are local and state parks, non-interstate divided highways and recent population growth. Although all of these variables could not be addressed in the validation of the "eligible" areas, a more realistic focus was afforded on these relatively site-specific issues.

Third, important insights about certain issues could be gained through this more-detailed analysis. In particular, the "eligible" area validation encountered a significant problem with respect to topography. Through this detailed analysis, a more rigorous specification had to be developed in order to evaluate the suitability of sites from a topographic standpoint. As a result of this detailed investigation, a much greater understanding of the importance of topography with respect to the rectenna now exists.

Fourth, and perhaps most importantly, the validation of the eligible areas allows more-definitive statements to be made about site availability. The stated purpose of this study has been to exclude areas as sites, not to find sites. However, without an understanding of the characteristics of the residual "eligible" areas, only vague and general statements about the availability of sites could be made. Although the results of this validation of "eligible" areas does not answer all questions concerning site availability, it does offer insights on the overall availability of sites.

VII.C.1. General Procedure

The eligibility validation procedure was designed to examine each of the sample eligible squares in detail in order to measure the incidence of absolute exclusion variables. It was established that the presence of eight of the variables could be determined by examining large-scale maps of each of the grid squares.

Since each grid square on the eligibility base map represents the equivalent of a 7.5 minute (1:24,000 scale) U.S. Geological Survey topographic quadrangle, the appropriate quadrangle was determined for each of the sample grid squares and subsequently examined for the presence of the variables. The 7.5 minute series was the preferred map source, but in 41 cases the grid squares had only been mapped in the 15 minute series (1:62,5000 scale), and for 7 sample grid squares only maps of a scale of 1:250,000 were available for examination. Although the printing dates of the sample maps varied, geomorphological and hydrographic characteristics of the earth are generally slow to change and major cultural changes would have normally mandated recent map revisions.

The exclusion variables that could be map verified were topography, marshland and perennially flooded areas, inland water, military reservations and AEC lands, recreation areas, interstate highways, and SMSA-adjusted population density. When necessary, additional map and text sources were used to verify questionable status of a variable.

The presence of two exclusion variables, endangered species habitats and sensitive electromagnetic systems, could not be determined from the conventional USGS quadrangle series. Habitats of federally designated endangered species were therefore cross-checked with the federal "Designated Critical Habitats" list and accompanying maps. Boundaries of excluded electromagnetic areas were checked for their proximity to eligible grid squares in the sample and the 150, 100, and 50 kilometer clearance radius remeasured.

The results of the detailed eligible area validation process were recorded individually for each sample grid square on a form that summarized the findings. These forms recorded information that identified each sample grid square (state, quadrangle name, grid coordinates, latitude, and longitude), the date of the quadrangle, whether the square was part of the national (1) or regional (2) sample, and information about the incidence of each of the examined variables. Once determined, the overall eligibility of the map area was indicated in the upper right portion of the form.

The actual determination of eligibility was made in the following manner. The first test for all of the physical variables (topography, marshland and perennially flooded areas, navigable waterway, and inland water) and for the military reservations/AEC lands was to determine whether these occurred within a 10 kilometer by 13.8 kilometer ellipse, centered within each quadrangle, that approximates the size and shape of the receiving antenna. If the variable was outside of the ellipse shape then the grid was not excluded for that variable. If the variable was present within the rectenna ellipse area, further criteria were used to measure its effect on the grid square's eligibility. The individual criteria are as follows:

1. Topography

The tests for the topographic variable are described in detail in the section on topography that follows.

2. Marshland and Perennially Flooded Areas

Up to 8 square miles of marshland or perennially flooded areas were considered acceptable within the rectenna site. Marshland is clearly designated by symbol on USGS quadrangles, and perennially flooded areas can be superficially descerned by indications of the characteristics of topography and hydrography.

3. Navigable Waterways

The presence of any navigable waterway changed the eligibility of the grid square. Waterways large enough to be navigable were easily distinguished.

4. Inland Water

Up to 4 square miles of inland water within the rectenna ellipse area were considered acceptable. This is the equivalent of about 10% of the rectenna site.

5. Military Reservation, Atomic Energy Commission Lands, Other Dedicated Land Use

This variable was also tested with the ellipse template. If any of these uses occurred within the rectenna ellipse, up to 4 square miles were acceptable without altering the status of the quadrangle.

6. Recreation Areas

National, state, or local recreation areas of over 1 square mile that appeared anywhere on the quadrangle rendered the grid square ineligible.

7. Interstate Highway

If two miles of four-lane (or more) divided highway or limited access road appeared anywhere on the map the quadrangle became excluded. No other form of highway altered the eligibility.

8. Endangered Species Habitat

Locations of critical plant and animal habitats were established by the federal "Designated Critical Habitats" List and maps. Presence of a critical habitat made the grid squares ineligible.

9. Standard Metropolitan Statistical Area (SMSA) and Adjusted Population Density

The initial screening for population density was done on the USGS quadrangles. Areas of possible exclusion were subsequently investigated in the County and City Data Book, 1977: A Statistical Abstract Supplement (U.S. Department of Commerce). The criteria used were that if an area had a population density of 25 people per square mile or more it might be excluded. If 500 or more dwelling units appeared on the map then the quadrangle was no longer eligible.

10. Electromagnetic (EMC) Compatibility

The distance from the edge of sensitive EMC facilities to nearby sample quadrangles was measured to establish eligibility.

VII.C.2. Results of Validation

The most striking finding was the high percentage of previously eligible grid squares that were reclassified as ineligible because of their topography. The effects of topography, therefore, are considered separately in Section VII.C.3. The significance of the topographic variable in the reclassification of "eligible" grid squares is underscored by the comparatively minor occurrence of the non-topographic variables. Generally, the eligibility validation process revealed that original sources, assumptions, and mapping standards adequately determined final eligibility for the 9 non-topographic variables.

The incidence of navigable waterways, military reservations, and Atomic Energy Commission lands or other dedicated land uses, interstate highways, population, endangered species designated habitats and electromagnetic variables was consistently less than 4% for the national sample and the regional samples. Neither the endangered species designated habitat nor the EMC variables caused the reclassification of any of the sample squares.

Three non-topographic variables accounted for greater than 3% reclassification either by themselves or in conjunction with some other variable. These were marshland and perennially flooded areas, inland water and recreation areas.

VII.C.2.a. Marshland and Perennially Flooded Areas

Although up to eight square miles of marshland or perennially flooded areas were considered acceptable, 14 quadrangles (7.8%) of the regional sample contained greater than this amount and were reclassified as excluded. For the most part, marshlands were the basis of the reclassification. The original exclusion mapping was known to be a conservative delineation of these areas so the appearance of these variables was not surprising. Over one-quarter of the regional sample for NPCC would have been reclassified by this variable alone. MARCA (18.2%) and MAIN (14.2%) were similarly affected. This variable was not noted in ECAR, ERCOT or WSCC. The presence of the wetlands variable was noted in 6% of the national sample.

VII.C.2.b. Inland Water

The inland water variable, alone or in conjunction with another variable, accounted for the reclassification of 19 grid squares of the 180 sampled (10.5%). The original inland water exclusion mapping was necessarily generalized and had not included smaller inland water bodies that might nonetheless preclude the construction of the rectenna. 6% of the national sample were reclassified by this variable. Regionally, NPCC contained the highest percentage (33.3%) of quadrangle reclassification by this variable. The incidence in ECAR (18.5%), MAAC (16.7%), ERCOT (16.7%) and SERC (13.2%) was less significant but noticeable. No grid squares in the sample were reclassified by the presence of inland water in MAIN, MARCA, SPP or WSCC.

VII.C.2.c. Recreation Lands

The 16 grid squares (8.9%) in the large number sample (4% of the national sample) that were reclassified as a result of the recreation lands variable reflect that while only the largest recreation areas were mapped initially, a large amount of relatively small (one square mile) recreational lands exist in the various regions. In NPCC, the most severely affected region, 4 of the sample quadrangles (26.7%) contained enough recreation land to mandate their reclassification. The percentage of reclassification diminished in MAAC (16.7%) and ECAR (11.1%) and was less than 10% in the other regions.

VII.C.2.d. Summary

It is important to note that the recitation of the incidence of the individual variables masks the fact that two or more variables may appear in the analysis of an "eligible" grid square. This situation is summarized as follows:

		National Sample	Regional Sample
1.	Marshland/Perennially Flooded		
	Quads excluded by this variable alone	3 (6%)	7(3.9%)
	Quads excluded by this variable and another	0	7(3.9%)
2.	Inland Water		
	Quads excluded by this variable alone	1 (2%)	4(2.2%)
	Quads excluded by this variable and another	2 (4%)	15(8.3%)
3.	Recreation Land		
	Quads excluded by this variable alone	0	4(2.2%)
	Quads excluded by this variable and another	2 (4%)	12(6.7%)

VII.C.3. Special Analysis of Topography

A particular problem was encountered in this research effort with respect to topography. Initially, topography was treated according to the most recent design information developed by General Electric for Johnson Space Flight Center (General Electric, 1979). In this document, it is stated that the receiving antenna can be constructed "anywhere a bulldozer can go". Using this broad definition, initial mapping of unacceptable topography as an absolute exclusion variable was limited to areas with the worst slope in the United States. These were areas represented by substantial relief on the United States Geological Survey map titled "Shaded Relief of the United States", accounting for approximately 20% of the land area of the United States.

Subsequent validation studies of "eligible" areas utilizing detailed map sources revealed the need for a more detailed understanding of the topographic constraint. Initial simplistic tests for acceptable topography caused 80% of the "eligible" areas to be reclassified as excluded.

Additional information upon which to base more accurate exclusion tests was developed by Stephan D. Hammitt, P.E., of the Ralph M. Parsons Company, Dr. John Hill of E.R.G. and Dr. Patricia Caldwell of Caldwell Associates. These consultants reviewed important aspects of the earth-moving involved in the construction of the receiving antenna and reexamined in detail most of the validation sample of eligible cells.

This review included the application of established procedures for estimating the volume and cost of required earthmoving. This analysis showed that many of the sites previously considered as "eligible", but only with substantial increase in the rectenna construction costs. For purposes of refining the "eligibility" analysis, the following criteria was specified for "eligibility" with respect to topography:

*The additional cost increment considered allowable with respect to topography was 10% of the rectenna cost, or $250,000,000.

*To stay within the $250,000,000 cost increment, a site must have 90% of its area with a slope of 20% or less provided that drainage incisions are not excessive.

*A site is unacceptable if it has slopes in excess of 25-30% in areas other than small drainage incisions.

Utilizing these refined criteria for topographic acceptability, the random sample of cells selected for validation were subjected to detailed analysis. Of the national sample of 50 grid squares, 54% of those cells selected failed to meet the more rigid eligibility requirements. Of the regional sample of 180 grid squares, 54% (97 grid squares) were also found to be ineligible. These high proportions of reclassification indicated the need for a more refined treatment of topography.

In response to this situation, a three-tiered topographic classification was developed from the United States Geological Survey's "Classification of Land Surface Form" (USGS, 1970). From the data presented in this map, lands that were flat and lands that were mostly flat were mapped as two classifications. Then, the area remaining that was not included in either of the two classifications nor in the initial absolute exclusion map was considered a third, or residual, topographic category. Therefore, three additional classifications were developed.

These three additional classifications were then subjected to additional validation. Of 50 flatland grid cells examined to determine their "eligibility" under the revised criteria, only 2 were found to be ineligible. Stated otherwise, 96% of the flatlands would be eligible. Of these 54 mostly flatlands grid cells, 18 were found to be ineligible; 67% of the mostly flatlands would be eligible as sites for rectennas. The 108 grid cells falling within the "residual" topographic category were also subjected to detailed validation and only 26 of these grid cells emerged as "eligible". In other words, only 24% of the grid squares falling within this third topographic category were found to be eligible.

Due to the broad scale of the mapping effort, it was impossible to refine the treatment of the topography variable beyond this level. Therefore, this information will be used in one of two ways. First, of the "eligible" cells in any given region, the utilization of the above validation factors will yield a realistic estimate of the number of cells that may actually be considered as "eligible". Second, topography will be treated as a design/ cost variable.

VIII. DESIGN/COST CONSIDERATIONS

VIII.A. DISCUSSION OF DESIGN/COST VARIABLES

As introduced in Section IV, many of the variables mapped were labeled "design/cost" variables. The basis for setting these variables aside was that the reference rectenna had been designed to certain specifications, generally representing environmental conditions encountered in the southern United States. Initially, it was thought that environmental conditions exceeding the design constraints would absolutely preclude the location of a site within areas exhibiting these characteristics. However, it is more realistic to consider these variables as design variables which may require a greater dollar expenditure if the environmental conditions are to be addressed. For this reason, these variables have been designated as design/cost variables.

These design/cost variables fall in three general categories. These are climate variables, topographic variables and other physical features variables. In the following discussion, the impact of design/cost variables is addressed through analysis of hypothetical sites and probabilistically. 240 hypothetical sites from the utility integration study were encoded in the Rice computer system and a print-out of the design/cost variables associated with these sites was prepared. Similarly, an analysis was undertaken that identified the probability of 60 rectennas encountering the design/cost variables. In this manner, an indication of the impact of the individual design/cost variables can be gained.

VIII.B. CLIMATIC DESIGN/COST VARIABLES

VIII.B.1. Tornado Occurrence

In the General Electric study for Johnson Space Center, it is stated that the rectenna is designed for quick repair in the case of tornados (General Electric, 1979). The mapping prepared for tornado occurrence specifies the number of tornados occurring over a 10 year period. In all, five intervals of tornado occurrence were mapped. These were areas with over 300 tornados in this time period, areas with from 200 to 300, areas with from 100 to 200, areas with from 50 to 100 tornados and areas with from 10 to 50 tornados. As such, this approach to tornado occurrence can be considered as an indication of the risk of repair that will be encountered in certain areas. Alternatively, this information may indicate the need for a stronger rectenna design in more severe areas or areas to be avoided.

In the table that follows, the incidence of sites within these five zones is shown for both the hypothetical siting exercise and for the probabilistic exercise.

Incidence of Tornados	Hypothetical Siting	Probabilistic Siting
300+	0	0
200 - 300	1	1
100 - 200	14	11
50 - 100	15	15
10 - 50	18	17

VIII.B.2. Snowfall Loading Factor

In the General Electric Study prepared for Johnson Space Center (General Electric, 1979), the rectenna is designed to meet the snowfall loading factor encountered in the southern Gulf Coast States. This factor is 10#/ ft^2 as specified by the Southern Standard Building Code. However, snowfall loading factors vary throughout the United States, and design modifications will be necessary to accommodate higher snowfall loading factors. In the mapped data, four ranges of snowfall loading factors are set forth. These are less than 10#/square foot, 10#/ft^2 to 30#/ft^2, over 30#/ft^2 and areas where site specific analysis is required due to the large variation in snowfall loading factors.

In the table which follows, the incidence of sites within these four zones is shown for both approaches to sample sites.

Snowfall Loading Factor	Hypothetical Siting	Probabilistic Siting
10#/ft^2 or less	22	20
10#/ft^2 - 30#/ft^2	26	23
30#/ft^2 or more	6	7
Site Specific Analysis Required	6	8

VIII.B.3. Freezing Rain

Freezing rainfall represents a design constraint. As discussed in Section IV, the build-up of 5 mm of ice on the diode will lead to a reflection of 50% of the beam energy. The problem of severe icing was addressed by mapping the number of days with freezing rainfall. Two levels of the incidence of freezing rainfall were specified: one to eight days of freezing rainfall and eight or more days of freezing rainfall. The number of rectennas subject to these conditions are shown below.

Days of Freezing Rainfall	Hypothetical Sites	Probabilistic Sites
1 - 8	30	32
8+	21	22

VIII.B.4. Sheet Rainfall

Rainfall sheeting on the rectenna face can cause a problem similar to that encountered with icing. Again, specific design adaptations will be required to avoid these effects. Sheet rainfall, as exemplified by 700+ gallons of water/square mile/year affected 28 rectennas in the hypothetical site selection and 17 rectennas in the probabilistic siting exercise.

VIII.B.5. Lightning Density

A unique design problem is represented by lightning. To address this issue, Marshall Sapce Flight Center contracted with Dr. A. A. Few of Rice University to perform an analysis of the incidence of lightning across the United States (FW, 1979). According to Dr. Few, the approach to lightning protection would be to design for an incidence of less than 10 flashes/square kilometer/year. For this reason, two densities of lightning occurrence were mapped from data provided by Dr. Few. These were 10-20 flashes/km^2/year and 20+ flashes/km^2/year. The incidence of rectennas within these zones are shown below.

Lightning Density	Hypothetical Sites	Probabilistic Sites
10-20 flashes/km^2/yr	23	22
20+ flashes/km^2/yr	2	3

VIII.B.6. Acid Rainfall

Although the presence of rectennas within areas subject to acid rainfall may be considered a beneficial impact in terms of preventing the worsening of acid rainfall, the presence of acidity in the rainfall may require unique design requirements to prevent corrosion. The incidence of acid rainfall with respect to potential allocations of rectennas is as follows.

Acidity of Rainfall	Hypothetical Sites	Probabilistic Sites
pH less than 4.0	1	0
pH 4.0 to 5.0	13	10
pH 5.0 to 5.5	26	21

VIII.B.7. Hail

The rectenna design specified by General Electric for Johnson Space Flight Center states that the rectenna is designed to withstand hail. However, the incidence of hail (and the severity) is greater in certain portions of the United States than in other portions. Those areas of the United States with an incidence of four or more days of hail per year were mapped. The relationship of rectenna allocation to these areas shows that 2 of the hypothetical sites and 5 of the probabilistic sites would be exposed to higher frequencies of hail.

VIII.B.8. Wind

Two different design wind speeds have been proposed for the rectenna. These were 70 mph winds and 115 mph winds. For this reason, the maximum expected winds, 50 year recurrence interval was mapped and considered with respect to the two approaches of site allocation.

Maximum Expected Winds	Hypothetical Sites	Probabilistic Sites
70 - 80 mph	23	23
80 - 90 mph	14	14
90+ mph	1	0

VIII.B.9. Summary

In summary, it appears that tornados, snowfall, icing and sheet rainfall are of primary importance from the standpoint of causing additional cost penalties. Acid rainfall and lightning density are also of particular concern. The impact of hail is restricted to a small number of sites and a rectenna designed to meet 115 mph wind speeds should be adequate throughout the United States.

VIII.C. TOPOGRAPHY

As discussed earlier in this report, a substantial problem was discovered with respect to the criteria specified for the topographic aspects of rectenna sites. Topographic constraints appear much more serious than previously anticipated. Further, it has been estimated that the cost of the rectenna could be doubled if sites with substantial topographic constraints are sculpted to the rectenna requirements. For this reason, a significant effort was made to group areas of the United States according to their topographic characteristics in addition to the mapping and elimination of those sites with clearly unacceptable topography.

As a result of this additional examination, three classes of topography were developed and classified as design/cost variables. These were labeled as flatlands, mostly flatlands, and residual lands. From the validation exercise, it was determined that 96% of the sites within the flatlands category were acceptable, 67% of the mostly flatlands category were acceptable as sites and 24% of the residual flatlands were acceptable as sites. However, the definition of acceptability included earth-moving costs not to exceed 10% of the cost of rectenna construction, or $250,000,000. The implication of this decision is that topographic difficulties may increase the cost of rectenna construction by 10% under "acceptable" conditions.

As was the case with the other design/cost variables, the hypothetical sites and the probabilistic sites were reviewed with respect to the topographic variable. The results are as follows:

Topographic Category	Hypothetical Sites	Probabilistic Sites
Flatlands	18	20
Mostly Flatlands	13	10
Residual Lands	29	30

From this analysis, it is clear that topographic considerations will have a substantial impact on the cost of the rectenna and/or upon the availability of sites.

VIII.D. OTHER PHYSICAL DESIGN/COST VARIABLES

VIII.D.1. Seismicity

The degree of constraint posed by seismic hazards is not clear at this time. In the General Electric study for Johnson Space Flight Center (General Electric, 1979), the statement is made that the rectenna is designed to withstand earthquakes. Nonetheless, the degree of seismic risk was mapped and is considered as a design/cost variable. Two levels of seismic risk were mapped - major and moderate. The results of the analysis of the two rectenna allocation procedures are as follows:

Degree of Seismic Risk	Hypothetical Sites	Probabilistic Sites
Major	4	3
Moderate	26	29

VIII.D.2. Timbered Areas

In the studies undertaken on site construction by ERG, it was determined that the presence of timbered areas would cause increases in site design costs due to the necessity for stump removal. Therefore, the timbered areas of the United States were mapped and considered as design/cost variables. In the case of both site allocation procedures, it was determined that timbered areas would be encountered in the siting of 22 rectennas.

VIII.D.3. Water Availability

The availability of water has importance beyond the consideration given this variable in the environmental impact discussion. Specifically, water may not be available and design modifications may be required to obviate the need for water. Secondly, water may be very expensive if it is available. The distribution of rectennas with respect to groundwater overdraft areas and surface water supply problem areas during average and dry years are also as follows:

Variable	Hypothetical Sites	Probabilistic Sites
Groundwater Overdraft	7	9
Surface Water Supply Problems in an Average Year	5	6
Surface Water Supply Problems in a Dry Year	2	6

IX. OTHER SITING CONSIDERATIONS

The foregoing analysis of exclusion variables and the entire mapping exercise deals only with the question of mappable constraints as they apply to the reference concept design for the SPS system. There are, consequently, several important limitations on this analysis including:

1. Local considerations - due to the national scale at which the variables were mapped, there is no consideration of purely local constraints which would preclude the location of a rectenna within a particular grid cell.

2. Land-based (onshore) locations - the mapping analysis summarized deals only with land-based locations for rectennas, although there has been considerable interest in offshore rectenna siting.

3. Acquisition problems and isolated cells - no attention has been paid at all to the practical problems in acquiring a site of sufficient size. Considerations of cost, eminent domain, and assemblage of a large number of ownerships may pose significant acquisition problems. These difficulties are likely to be exacerbated in situations where the only eligible square is an isolated square or one of two or three such squares, surrounded by excluded locations.

4. Fixed rectenna size - the entire analysis reflects the eligible areas only for the reference concept rectenna size which, at 35° latitude, is approximately 15.8 x 12 km, including buffer zone and 13 x 10 km without buffer zone. NASA has, however, raised the issue of greater land availability that might result from the use of smaller rectennas.

The first of the four limitations, purely local constraints, is dealt with to a limited degree in the data validation efforts described in Section VII. To the extent that such local constraints appear on the detailed USGS quad maps, they have been captured and incorporated into the reclassification estimates developed as part of the validation exercise.

The other three major limitations require some further discussion although, for a variety of reasons, they cannot be dealt with comprehensively within the scope of this report.

IX.A. IMPACT OF REDUCED SIZE ON SITE AVAILABILITY

IX.A.1. Procedure

A major consideration in developing the base map was that each grid cell represent approximately the area of one rectenna as defined in the reference concept. Consequently, any attempt to examine enhanced site availability as a function of reduced rectenna size required examination within individual grid squares using much more detailed maps than in the initial mapping exercise.

Fortunately, the validation effort provided a sample base of 360 locations within the United States which were to be examined in greater detail. Of this total, one half or 180 were excluded areas in which a test could be made as to whether or not the area would still be excluded with a smaller rectenna size. The other 180 were nominally eligible areas. More than half of these "eligible" cells were reclassified based on more refined investigation. This reclassified subset of "eligible" areas also provide a base for testing whether or not the areas would remain "eligible" if a smaller rectenna size were used.

The actual testing procedure was to superimpose on the larger scale maps two templates representing two alternative smaller rectenna sizes. The two sizes tested were:

1. Rectenna diameters reduced by one half, i.e. a 6.5 km x 5.0 km ellipse without buffer zone.

2. A rectenna representing one half the area coverage, i.e. a 9.2 x 7.1 km ellipse, without buffer zone.

These two sizes were selected somewhat arbitrarily based on independent analyses of "a one half size" rectenna. Since there are two different ways of measuring one half, i.e. reducing the diameters by half or reducing the total areas by half, both alternatives were examined. Exhibit X-1 shows both sizes in relation to the original scale.

IX.A.2. Excluded Area Analysis

A total of 180 cells was examined, randomly selected from the total number of excluded cells in Summary Map 2 which depicts all absolute exclusion variables. All of the 180 excluded areas were found to be appropriately excluded. The 180-cell sample was also subjected to template analysis to determine whether or not either of the two smaller sized rectennas could be located within the cell and still avoid the constraints which caused the exclusion. The results of this analysis were:

1. Only one of the 180 (0.6%) could be located using the one half-area rectenna (9.2 x 7.1 km ellipse).

2. For the one half-diameter rectenna, five cells or approximately 3 percent of the cells could be situated in these otherwise excluded areas with a rectenna of dimensions 6.5 km x 5.0 km.

IX.A.3. Reclassified Eligibility Areas

In the original analysis of 180 "eligible" cells, a total of 128 were reclassified for various reasons, most of them because of topographical difficulties. Stated alternatively, 52 or 29% of the cells were not reclassified using the original rectenna size. Using the one half-area testing size, increased the number of still "eligible" cells from 52 to 88, an increase of almost exactly 35%. For this test size, the largest numerical and percentage increases were in SERC, which increased from 12 to 20 available sites out of 38 samples, and in ECAR which increased from 3 to 13 available sites out of a sample of 27.

Using a still smaller rectenna test size (one half diameter), produced a more dramatic increase in the "eligible" cells that still remained "eligible". In this instance, the number of eligible cells increased from 52 out of 180 (29%) with the original rectenna size to 136 out of 180 (76%) with the one half-diameter size. All the regions shared in this increase with the most dramatic increases being in the Northeast (NPCC) in which the number of eligible cells increased from one out of fifteen to eleven out of fifteen. A similarly dramatic increase was found in MAAC (mid Atlantic) where the number of eligible cells increased from one out of twelve to eight out of twelve. A tabulation of these results by region and for the 50-cell national sample, is shown in Exhibit IX-1.

To summarize, the use of either smaller rectenna size has a negligible effect on initially excluded areas. Smaller rectenna sizes do, however, reduce the number of "eligible" areas that are reclassified upon closer examination. Whether or not this indirect "increase" in the number of effectively eligible areas is significant depends both on the region and the choice of which of two smaller rectenna sizes is used. In no case is there an increase anywhere near an order of magnitude. Furthermore, in the case of the one half-area rectenna, the increase is a matter of 60 or 70% and not even a multiple. Only in the instance of the one quarter-area or one half-diameter ellipse test size, is there an increase of as much as a factor of two in the number of apparently eligible cells.

These average increase factors do, however, mask some important regional variations. It seems clear that the use of a smaller rectenna size, particularly the one quarter-area (one half-diameter) test size, would significantly increase the number of cells in the crowded Northeastern regions (NPCC and MAAC). On the other hand, it should be noted that in no instance was there a total absence of initially classified "eligible" cells in the absolute exclusion mapping exercise. In fact, in all areas except MAAC, there were at least twelve times as many eligible cells as nominally allocated rectenna sites. Therefore, it would appear that the smaller rectenna size, while it would marginally enhance site availability would not make a substantial or material difference.

IX.B. OFFSHORE RECTENNAS

The distinct possibility exists that in certain portions of the United States (such as the Northeast) it will not be possible to find as many sites for receiving antennas as is desirable from a regional demand viewpoint. One major alternative that is available involves the

EXHIBIT IX-1

IMPACT OF SMALLER RECTENNA SIZES ON SITE AVAILABILITY: RECLASSIFIED INITIALLY "ELIGIBLE" AREAS

Region/Area	Total Number of Cells	ELIGIBLE CELL SAMPLE[1] Reclassified as Excluded (original size)[2] No.	%	Reclassified as Excluded (1/4 size)[3] No.	%
National Sample	50	36	64.0	12	24.0
NPCC (Northeast)	15	14	93.3	4	26.7
MAAC (Mid-Atlantic)	12	11	91.7	4	33.3
SERC (Southeast)	38	26	68.4	7	18.4
ECAR (East Central)	27	24	88.9	13	48.1
MAIN (IL, IA, MO)	14	9	64.3	5	35.7
MARCA (ND, SD, MN, NB)	11	5	45.5	2	18.2
SPP (Southwest)	18	10	44.4	-	-
ERCOT (TX)	12	5	41.7	1	8.3
WSCC (West)	33	26	78.8	8	24.2
Total	180 (100.0%)	128	71.1	44	24.4

1 Randomly selected cells based on Summary Map 2 (all excluded variables).
2 Reference concept 13 x 10 km (15.8 x 12.0 km with buffer) per NASA.
3 One-quarter rectenna area (1/2 diameter), nominally 6.5 x 5.0 km ellipse.

construction of receiving antennas offshore. The remainder of this section is concerned with an examination of issues involved in the siting of receiving antennas offshore.

IX.B.1. Status of Offshore Rectenna Design

The reference design prepared for the evaluation of the Satellite Power System does not consider the design of offshore receiving antennas. However, Marshall Space Flight Center has contracted with Rice University to study the concept of an offshore receiving antenna. This study is not complete, and no definitive designs have been discovered at this time.

In the Rice University proposal, a specific design was set forth as the conceptual alternative. This design involved the suspension of the receiver panels from guy wires which were suspended from towers rising from the ocean floor. This configuration is shown in Exhibit IX-2. Detailed analysis of this concept led to the discovery that the receiver panels had to be some eighty feet above mean sea level because of the potential wave heights which would be encountered in the area chosen for the prototypical design (south of Massachusetts). Therefore, the towers which were supporting the entire system would rise over 100 feet above sea level. The total height of these towers would, of course, be dependent upon the water depth at the site.

The evaluation of this concept by Rice University led to the determination that this rectenna design is very expensive. Estimates of the number of towers in the original design concept went as high as 25,000, and the preliminary estimates indicate that this offshore rectenna would be two or three times more expensive than the land-based rectenna. Recent design efforts revolve around substantially reducing the number of towers. In addition, alternative designs are currently being investigated. These alternatives include a design which minimizes the overall weight of the receiver panels, thereby requiring fewer towers to be utilized. Another alternative being investigated involves the use of a "floating" rectenna. In this alternative, an air bubble breakwater is posited as a mechanism for reducing the impact of wave action upon the receiving antenna. The major cost advantage of such a floating alternative is that the expense of the towers can be avoided. Instead of towers, the "floating" rectenna would require only anchoring. Because the rectenna would still cover approximately 25,000 acres, the anchoring system would be elaborate. It would not, however, entail the significant structural system required in the "tower" design.

The important point is that a preferred alternative has not been set forth at this time. Therefore, from the perspective of this siting study, no definitive design exists to evaluate from a detailed siting standpoint. For this reason, the decision was made to map and consider only those offshore variables that are clearly applicable regardless of the design undertaken. Further, extensive original data collection and mapping was not undertaken due to the premature nature of the design. Only in the case of navigation corridors and dedicated ocean areas was

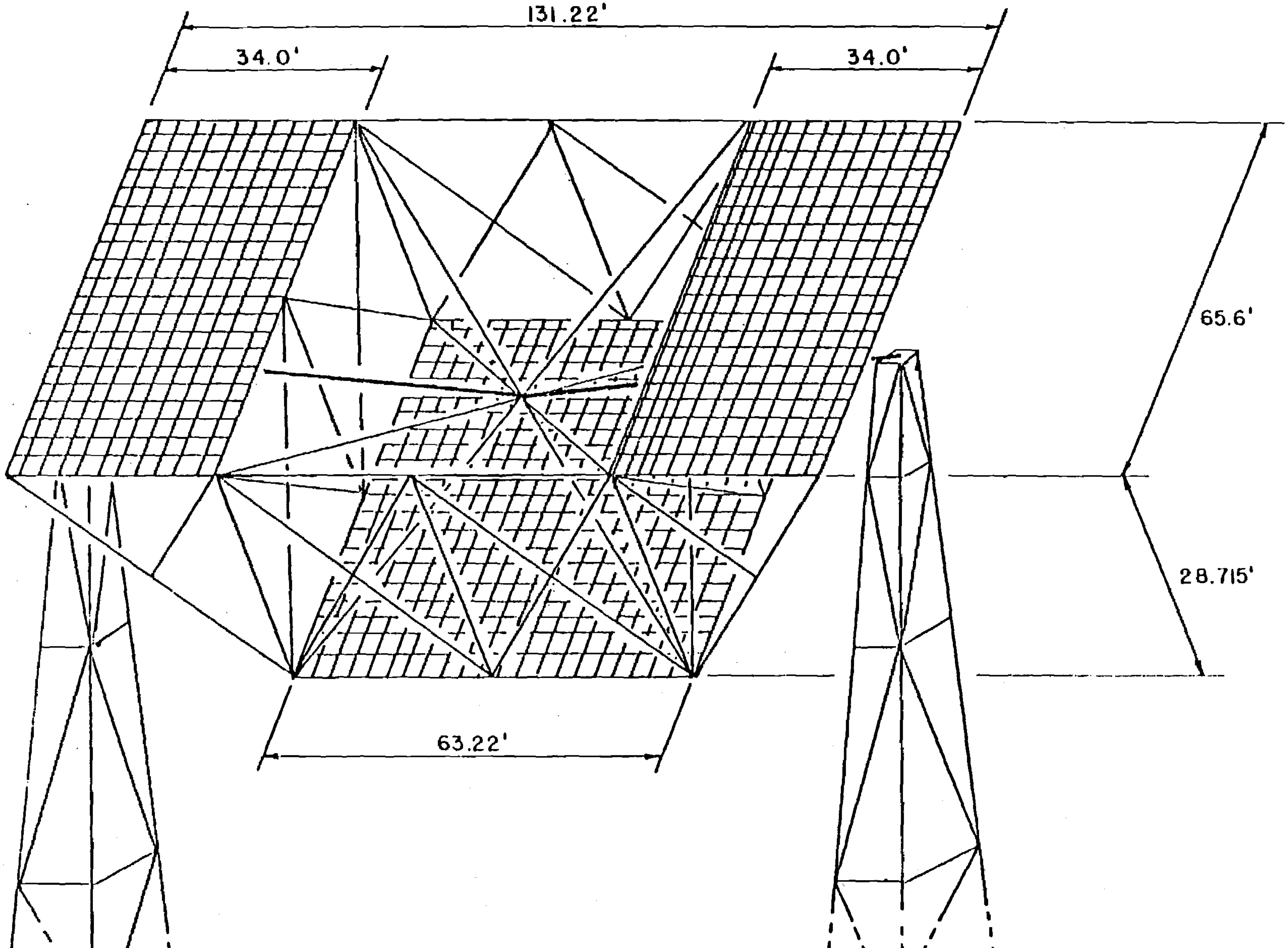


EXHIBIT IX-2
RECEIVER PANEL CONFIGURATION

such an original mapping effort undertaken. Those variables that appear to be important, but that were not mapped, are discussed in a qualitative fashion.

IX.B.2. Description of Variables

In certain respects, the analysis required for the offshore rectenna is very similar to that required for the onshore rectenna. Ocean areas that are dedicated to other uses would be considered as either absolute or potential exclusion variables. Electromagnetic compatibility problems would be very similar to these involved with the onshore rectenna. However, certain other variables will be more or less important depending upon the design configuration. For example, irregular bathymetry will be much less of a problem for "floating" alternatives requiring minimal botton contact, but irregular bathymetry would be of great importance for a rectenna design involving thousands of towers rising from the ocean floor. Similarly, water depth and bottom composition would be primary considerations for the tower system but would be less important for the floating design. In the discussion which follows, various aspects of the offshore environment will be discussed with respect to the relevance of the variables to the offshore rectenna. Additionally, data collection issues and problems will be discussed.

IX.B.2.a. Mapped Variables

Continental Shelf - The boundaries of the continental shelf are of primary importance because of the severe drop-off found in areas beyond the continental shelf. Although this aspect would be less important with a floating rectenna design, anchoring problems would be significant regardless of the design. Therefore, it seems reasonable to consider areas beyond the continental shelf as absolute exclusion areas. For this reason, the areas beyond the Continental Shelf were mapped and considered as absolute exclusion areas.

Navigation Lanes - Another constraint that will not vary with differing rectenna designs is the corridors of ingress and egress from major ports, as well as corridors established for coast-wise navigation. These navigation lanes are described on detailed navigation maps of the offshore areas and are considered as absolute exclusion areas. Although the navigation corridors could be changed, they do represent dedicated ocean areas and one would suspect that any variation in these lanes would lead to less than optimal navigation. Therefore, these areas should be eliminated as rectenna sites. These navigation lanes cover 351 grid cells.

Dedicated Ocean Areas - Certain of the areas offshore have been dedicated to disparate purposes. There are submarine corridors, missile test ranges, waste disposal sites and marine sanctuaries. All of these variables have been mapped and are considered absolute exclusion variables. In all, these dedicated ocean areas cover 458 grid cells.

Electromagnetic Compatibility - Many of the sites that have been identified for protection for reasons of electromagnetic compatibility have exclusion areas that extend offshore. These exclusion areas are also applicable to any rectenna design and will be considered absolute exclusion areas for the offshore analysis. 1121 grid cells fall within the absolute exclusion areas identified for EMC purposes.

A map showing these map exclusion variables is shown in Exhibit IX-3.

IX.B.2.b. Unmapped Variables

There are other variables of importance from the standpoint of the offshore rectenna that can only be treated in a qualitative manner in this study.

Bottom Conditions - Bottom conditions will be extremely important if the offshore rectenna requires extensive use of large towers. If a floating design is implemented, then the bottom conditions will be less important, although some anchoring will be necessary. Bottom conditions may be further segregated into two components:

1. Inherently unstable and hazardous conditions, e.g. included would be recent sedimentary deposits that are unconsolidated.

2. Bottom conditions with major design implications, e.g. sandy bottoms requiring towers designed to withstand scouring.

Irregular Bathymetry - The slope of the bottom may be a very important consideration if a tower design is utilized for the offshore rectenna. In particular, the towers will have to be laid out uniformly across the 25,000 acres required for the rectenna and extreme bathymetric variance would be undesirable. Therefore, the bathymetric conditions would affect site selection for the tower design. The presence of irregular bathymetry would be less important for an offshore rectenna requiring fewer towers or only anchoring.

Major Fishing Areas - Major fishing areas will be a variable of concern with respect ot any design chosen for the offshore rectenna. The problem with respect to fishing areas is determining what areas are of importance. At this time, it is impossible to point to any data source that identifies the "prime" fishing grounds. This information will need to be developed for any future offshore siting exercises. The interference of the offshore rectenna with fishing activities will be one of physical interference. The presence of either towers or other underwater structures should enhance fishery production and would not therefore be injurious to the fish resource. However, the rectenna would prevent, or at least impede, harvesting of fish resources. Therefore, the issue of fishing and its relationship to the offshore rectenna is one of restricting fishing activities in certain regions rather than one of impairing fish resources generally.

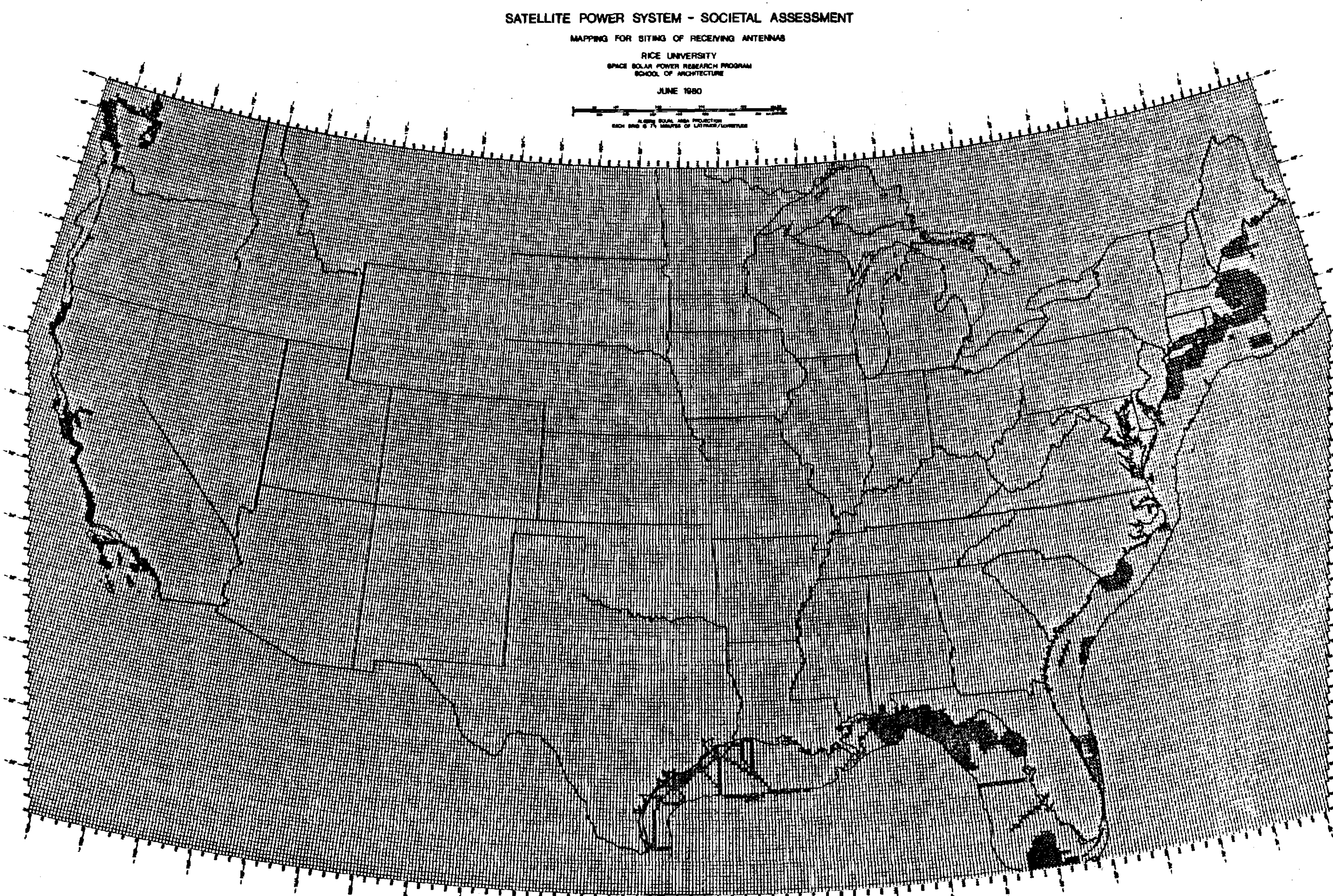


Exhibit IX-3 OFFSHORE SUMMARY MAP

Offshore Production Areas - Another issue of concern is the leasing of offshore areas for oil and gas production. At this time, it is impossible to speculate upon the degree of conflict that is presented by this variable. Current rules of the Interior Department require the removal of offshore production equipment when the field is abandoned. Due to the time inherent in the development of the SPS concept, the current plans contemplate the SPS to be deployed in the thirty year period from 2000 to 2030. By the time that an offshore rectenna will be ready for construction, it is possible that much of the offshore oil and gas resources will be exhausted and these production areas would no longer pose a siting problem. Therefore, production areas may or may not be a variable of concern.

Hurricane Corridors - The degree of problem posed by hurricane corridors will vary according to the design of the rectenna. The floating rectenna would seem to be much more susceptible to hurricane damage than would the tower rectenna. Neither rectenna should be located in areas that appear to be "corridors", but the tower design would appear to be more amenable to design modifications that would address the severe wind and wave problems posed by hurricanes.

Recreational Areas - Either rectenna would interfere with recreational uses of the waters underlying the rectenna as well as areas near the rectenna. The major problem in this respect is the identification of "recreational" areas. One approach to this issue would be to restrict the rectenna from areas near major population centers as well as requiring a minimum distance of the rectenna from beach areas. Much more detailed consideration must be given to this issue before a determination can be made regarding the severity of the constraint posed by recreational uses.

Height and Force of Tides - The height and force of tides will be of importance to both designs, but it appears that the height and force of tides would more severely impact a floating rectenna than a stationary one. The height and force of tides may be an exclusion variable for the "floating" rectenna whereas it would merely be a design variable for the "tower" rectenna.

Tsunami Risk - The risk of tsunamis, or tidal waves, would have to be considered with either offshore rectenna. Again, the constraint would vary according to the design.

Other Weather Variables - Just as with the onshore rectenna, many climate-related variables will affect the design of the rectenna. Severe icing conditions, sheet rainfall, hail, lightning density and other variables described in earlier sections will affect the design of the rectenna. These design constraints would apply regardless of whether the "tower" or "floating" design is utilized. However, the climatic data has not been compiled for the offshore areas in the same manner as it exists for the onshore areas. In other words, no comprehensive data maps exist for offshore areas even though these comprehensive data maps exist for the onshore areas. Both the National Atlas and the Climatic Atlas of the United States restrict their climate data to the onshore areas. Therefore, substantial effort will be required to create detailed weather maps for the offshore areas.

IX.C. PROBLEMS OF ACQUISITION: ANALYSIS OF ISOLATED AREAS

IX.C.1. Relation to Availability

As stated in both the introduction and the summary, this study is not designed to assist in the identification of actual specific sites. It is instead designed to reveal those areas within which it can be stated a priori that rectennas cannot be located and to examine the resulting distribution of residual nominally eligible areas. The use of this residual or exclusionary approach clearly fails to consider a whole host of problems involved in actually acquiring specific sites. Not only are purely local considerations of site availability ignored, but, even more important is the fact that there is no consideration given to the economic or negotiating problems that may be associated in assembling a site of adequate size.

One aspect of acquisition problem can be addressed in this analysis. In all the prior tabulations in this report, all "eligible" cells have been considered equal. An eligible cell surrounded by 10 or 20 or even 100 other eligible cells is counted the same as an eligible cell that is isolated and completely surrounded by excluded areas. Clearly the latter case, the isolated cell, will present much greater acquisition problems than eligible cells that are located in clusters of eligible areas. Where there is only a single eligible cell, opportunities for adjustment or compromise in the choice of a specific location are almost totally absent. This is due to the fact that a single grid square represents almost precisely the area of the rectenna and may, in the northern latitudes, be actually somewhat smaller.

In those situations where the eligible cells are clustered, the need for acquiring a specific piece of land withing very narrow tolerances is not present. If necessary, a rectenna can be sited in an adjacent cell or can overlap eligible cell boundaries.

To reflect this difference, a special tabulation of "isolated" areas was made. An attempt was made in this analysis to approximate the tolerance or freedom with which a site could actually be selected.

IX.C.2. Definition and Procedures

To approximate two conditions of availability or degrees of "isolatedness", two mapping tests were applied:

1. To consider as isolated all cells which did not occur within an area in which there were at least 4 contiguous eligible cells in a 2 x 2 square pattern.

2. To consider as isolated all cells which did not occur in a 9 square contiguous area of eligible cells consisting of a 3 x 3 square pattern.

The first of these two tests (2 x 2) represents a nominal 25% capture rate or a 4 to 1 tolerance in seeking to place a rectenna on a specific eligible cell. The second approach is much more stringent and represents an 11% recovery rate after allowing for various acquisition problems or, stated alternatively, a 9 to 1 tolerance in being able to locate a rectenna in or near a specifically chosen grid cell. Inevitably, proxy measurements of this type must be arbitrary and for this reason two different measures were used. Clearly the 9-to-1 tolerance (3 x 3 pattern) is a very rigid and conservative test since it permits a rejection of almost 90% of the cells due to acquisition or local consideration problems. In that regard it may be too conservative. The lesser 4-to-1 test in the 2 x 2 pattern seems to be a working minimum.

These two tests were applied to Summary Map 2 which shows all absolute exclusion variables but no potential exclusion variables. This is a good reference point insofar as it represents the best possible case with respect to the number and distribution of eligible cells. This summary map, in a large (3 x 5 foot) version was inspected manually and all points for which a 2 x 2 contiguous eligible area could not be established were recorded with one symbol and all points for which a 3 x 3 contiguous eligible area could not be established were recorded with another symbol. These two classes of isolated areas were then tabulated by state and region.

IX.C.3. Results

The results of this exercise are presented in two exhibits. Exhibit IX-4 is a map in which original exclusions, 2 x 2 isolated cells and 3 x 3 isolated cells are designated with different symbols. Exhibit IX-5 provides a parallel tabulation of the results.

The first and less stringent test was to consider as "isolated" only those cells for which it was impossible to find four adjacent cells in a square 2 x 2 cell pattern. An inspection of the two exhibits suggests the following general conclusions with respect to the impact of excluding this type of "isolated" cell:

1. The elimination of cells which do not fit in a 2 x 2 eligible cell area reduces total number of eligible cells by less than 15% or 3100 out of 21300 originally eligible cells.

2. The proportional reduction is generally minor in all the western ERC regions (WSCC, MARCA, SPP, and ERCOT).

3. The loss of eligible cells by this test is generally fairly significant in the Eastern regions since SERC, ECAR, and MAAC all lose at least 44% of their cells.

In summary, imposition of this boundary test would appear to have fairly drastic results in proportional terms in the East and fairly modest results in the West with intermediate conditions in the Midwest. It is

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

Summary Map With 'Isolated' Areas*

JUNE 1980

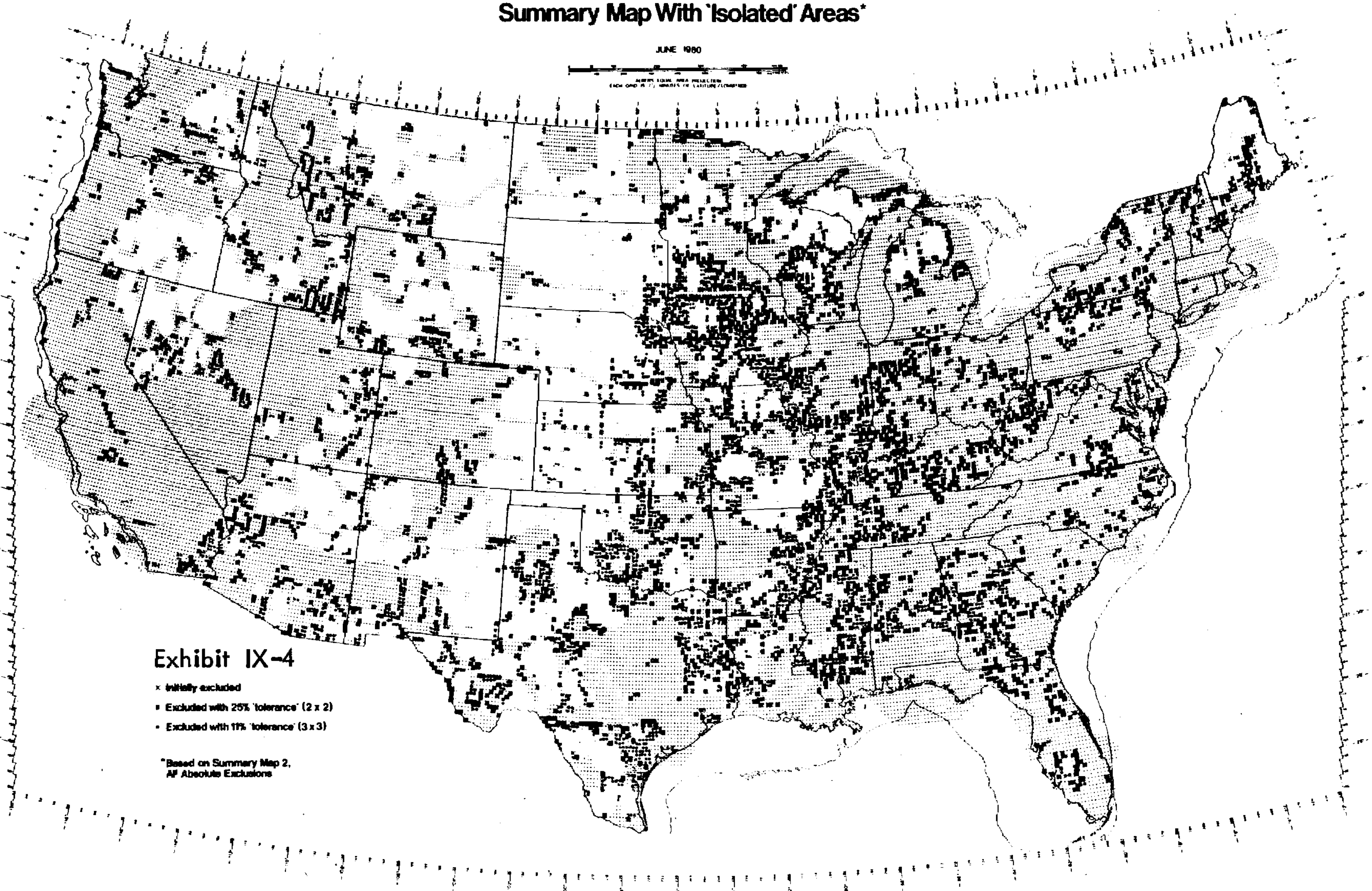


EXHIBIT IX-5

IMPACT OF CONSIDERING 'ISOLATED' ELIGIBLE AREAS BY REGION

Region	Total Cells	Total Eligible Cells[1]	Isolated Cell Count: Less than 4 (2x2)[2]	Isolated Cell Count: Between 4x9	Isolated Cell Count: Less than 9 (3x3)[3]	Residual 'Non-Isolated' Cells	Percent of Total Area as Eligible: Including Isolated	Percent of Total Area as Eligible: Excluding Isolated
WSCC	20,135	7,282 (100.0%)	753 (10.3%)	951 (13.1%)	1,704 (23.4%)	5,578 (76.6%)	36.2%	27.7%
MARCA	8,043	5,350 (100.0%)	399 (7.5%)	718 (13.4%)	1,117 (20.9%)	4,233 (79.1%)	66.5%	52.6%
SPP	6,421	3,558 (100.0%)	430 (12.1%)	638 (17.9%)	1,068 (30.0%)	2,490 (70.0%)	55.4%	64.2%
ERCOT	3,190	1,321 (100.0%)	184 (13.9%)	284 (21.5%)	468 (35.4%)	853 (64.6%)	41.4%	26.7%
SERC	5,470	968 (100.0%)	423 (43.7%)	380 (39.3%)	803 (83.0%)	165 (17.0%)	17.7%	3.0%
MAIN	2,307	1,120 (100.0%)	330 (29.5%)	340 (30.4%)	670 (59.8%)[4]	450 (40.2%)	48.6%	19.5%
ECAR	3,918	879 (100.0%)	389 (44.3%)	176 (20.0%)	565 (64.3%)	314 (35.7%)	22.4%	8.0%
MAAC	782	83 (100.0%)	42 (50.6%)	20 (24.1%)	62 (74.7%)	21 (25.3%)	10.6%	2.7%
NPCC	2,133	759 (100.0%)	157 (20.7%)	151 (19.9%)	308 (40.6%)	451 (59.4%)	35.6%	21.1%
Total	52,479	21,320 (100.0%)	3,107 (14.6%)	3,658 (17.2%)	6,765 (31.7%)[4]	14,555 (68.3%)	40.6%	27.7%

[1]Per Summary Map 2 (all absolute exclusions)

[2]All cells which would not fit into 2x2 pattern

[3]All Cells which would not fit into 3x3 pattern

[4]Discrepancy because of rounding

significant, however, that several hundred cells still remain after this elimination in all regions except the Mid-Atlantic which had less than 100 cells to begin with (83 eligible) and lost half of them with this definition of isolated areas to a residual total of 41.

When the much more stringent (3 x 3) test is applied results are much more drastic both nationally and for each region. Major aspects of the impact of this more stringent elimination of isolated areas include:

1. A reduction nationally of 31% of the previously eligible cells from a total of 21300 down to 14600.

2. A concomitant national reduction in the proportion of all cells that are eligible from 40.6% to 27.7%. In two regions, the Mid-Atlantic and Southeast, the impact of this more stringent isolation test is to eliminate 75% or more of the previously eligible cells.

3. Notwithstanding substantial proportional reductions, all of the regions except for the two mentioned above still have 300 cells or more.

Once again the conclusion is that the impact of this in proportional terms is very severe particularly in the East. On the other hand in absolute terms there are still several hundred eligible cells in each region except for the Mid-Atlantic region.

X REGIONAL COMPARISON AND RANKING

X.A. INTRODUCTION

The objective of this part of the study was to compare geographic regions of the United States to determine their relative general feasibility for accommodation of the siting of SPS rectenna facilities. This comparison was accomplished by a ranking of geographic portions of the country (Energy Reliability Council regions) through the use of ranking variables. These variables represent the key determinants of rectenna siting (such as availability of land, negative environmental impacts, and siting difficulties), as well as key economic and engineering efficiency requirements (such as base load capacities and the geographic distribution of load centers). The ranking variables were individually ranked to compare regions; and were also grouped by vectors, e.g. the several variables relating to availability, for comparison among regions by similar criteria. The following ranking vectors and individual ranking variables were used:

X.A.1. Availability Vector

1. Total Eligible Areas (cells) Without Electromagnetic Exclusion Criteria (EMC)

2. Total Eligible Areas With EMC

3. Net Eligible Areas Without Isolated Areas

4. Ratio of Eligible Area to Number of Required Sites (Without EMC)

5. Ratio of Eligible Area to Number of Required Sites (With EMC)

6. Ratio of Eligible Area Without Isolated Areas to Number of Required Sites

7. Proportion of Potential Exclusion Variables in Eligible Areas

X.A.2. Load Capacity Vector

8. Projected Capacity Increase - Series C (Assuming Nuclear Moritorium)

9. Projected Capacity Increase - Series C Mid-Mid

X.A.3. Environmental Vector

10. Incidence of Environmental Impact Exclusion Variables

X.A.4. Absorption Capacity Vector

11. Number of Load Centers with Capacity to Absorb One Full Rectenna

12. Proportion of Total Load Centers with Capacity to Absorb One Full Rectenna

13. Number of Load Centers with Capacity to Absorb One 1000 Megawatt Line

14. Proportion of Total Load Centers with Capacity to Absorb One 1000 Megawatt Line

X.A.5. Siting Difficulty Vector

15. Siting Difficulty - Fully Constrained

16. Siting Difficulty - Partially Constrained

17. Siting Difficulty - Revised Absorption

The ranking variables outlined above were grouped into vectors of similar types of variables to provide single measures for similar siting constraints or problems in a given ERC region.

The ranking analysis was performed by applying an ordinal system to quantified variables 1 through 14; and to a non-quantified measure, variables 15 through 17. This ordinal system assigns ranking status to the nine individual regions by applying the lowest numbers to the regions with the fewest constraints for rectenna siting per given variable (criteria) (e.g. a rank of 1 represents the ERC region most-feasible for siting, and 9 would represent the region least feasible. The allotment of equal rankings to two or more regions was conducted by assigning the mean of the ordinal values representing those regions affected to each of the affected regions. For example, if the regions requiring rankings between 2 and 6 (e.g. 3,4 and 5) deserved equivalent rankings, the ordinal ranking values 3, 4 and 5 were summed (12) and divided by the number of individual ranks covered (3). The resultant ranking value (4) was then assigned to the three regions requiring equivalent rankings.

X.B. ELIGIBLE AREA

X.B.1. Definition of Criteria

The eligible areas represent the amount of land area within each ERC region which has not yet been excluded from potential rectenna siting. The eligible areas are represented by grid cell counts with each grid cell representing approximately 169 square kilometers (a 13 by 13 kilometer square).

Total Eligible Areas Without EMC: The value this variable represents the total number of grid cells by region which have not been eliminated by the absolute exclusion variables, other than electromagnetic incompatibility (EMC).

Total Eligible Areas With EMC: The value of this variable represents the total number of grid cells which have not been eliminated from siting consideration due to the existence of one or more of the absolute exclusion variables, including absolute electromagnetic incompatibility variables.

Net Eligible Areas Without Isolated Areas: Isolated areas represent nonexcluded grid cells which are not part of a larger set of eligible grid cells (e.g. a square that is two grid cells on a side). The value of this variable is the number of eligible grid cells, after all absolute exclusions, which are in clusters of four or more grid cells.

X.B.2. Ranking Analysis

There was an extreme spread in the values of these three variables between the high and the low ranked regions. The small amount of eligible area in the lowest ranked region (MAAC) may present a major siting problem. The ranking of the above variables was based on the total number of nonexcluded or eligible areas within each region. The greater the number of eligible grid cells, the higher the ranking. The number of eligible grid cells without considering EMC varied by region from 103 in MAAC to 8,602 in WSCC (Exhibit X-1). When the EMC variable was included as an absolute exclusion variable, the number of eligible grid cells per region ranged from a low of 83 in MAAC to a high of 7,282 in WSCC. The elimination of isolated areas reduced the number of eligible grid cells by more than 20 percent in each region with the largest change occuring in SERC (over 80% reduction in the number of eligible cells).

For each of the variables, WSCC was ranked first followed by MARCA, SPP and ERCOT. The lowest ranked region in each case was MAAC. The largest changes in rank between the three variables were accomplished by NPCC and SERC, though in opposite directions. NPCC ranked eighth in the amount of eligible area available both with and without the EMC exclusion. However, other regions were more severely affected by the elimination of isolated areas (notably SERC), so that NPCC jumped to fifth after the elimination of isolated areas.

X.B.3. Relationship to Other Variables

The regional rankings for the above variables are in general agreement with the ranking of variables which measure eligible areas per rectenna. The potential exclusion and the environmental impact rankings were nearly the reverse of this ranking for total eligible areas. The potential and environmental variables include agricultural lands which are predominantly located in the midwestern regions. (MARCA, MAIN, and SPP).

EXHIBIT X-1

RANKING OF ELIGIBLE AREAS

Region	Eligible Areas without EMC Total	Eligible Areas without EMC Rank	Eligible Areas with EMC Total	Eligible Areas with EMC Rank	Eligible Areas Without Isolated Areas Total	Eligible Areas Without Isolated Areas Rank
ECAR	1,069	7	879	7	314	7
ERCOT	1,746	4	1,321	4	853	4
MAAC	103	9	83	9	21	9
MAIN	1,278	6	1,120	5	450	6
MARCA	6,005	2	5,350	2	4,233	2
NPCC	851	8	759	8	451	5
SERC	1,537	5	968	6	165	8
SPP	3,770	3	3,558	3	2,490	3
WSCC	8,602	1	7,282	1	5,578	1
Total	24,961		21,320		14,555	

X.C. ELIGIBLE AREAS PER RECTENNA SITE

X.C.1. Definition of Criteria

Since each region was not allocated the same number of rectennas, nor do they have the same amount of eligible area, a meaningful measure of regional site availability is the amount of eligible area in each region for rectenna. The allocation of rectennas per region ranged from 2 in MARCA to 13 in SERC.

Ratio of Eligible Areas Without EMC/to Required Sites: This variable is the amount of eligible area before EMC exclusions divided by the allocated number of rectennas.

Ratio of Eligible Areas With EMC/to Required Sites: This variable is the amount of eligible area, including EMC exclusions, divided by the allocated number of rectennas.

Ratio of Eligible Areas Without Isolated Areas/to Required Sites: This variable is the amount of eligible area, including EMC and isolated area exclusions, divided by the allocated number of rectennas.

X.C.2. Ranking Analysis

There was an extreme spread in the values of these three variables between the high and low rank regions. The small amounts of eligible area per rectenna in the lowest ranked region (MAAC) may present a major siting problem. For the eligible areas without the EMC exclusion, the highest ratio was found in MARCA (3,005 per rectenna) while the smallest ratio occured in MAAC (26 to 1). Exhibit X-2 shows that MARCA and MAAC were the highest and lowest ranked respectively for all three variables. WSCC and SPP have generally high ratios for each variable (only others above the national average), while ECAR, ERCOT, MAIN and NPCC form a middle group.

The rankings for these variables are remarkably consistent across all three variables with MAIN and NPCC having the only ranking change. The national average was 416 grid cells per rectenna in the without EMC case and fell to approximately 243 grid cells per rectenna for the without isolated areas variable.

X.C.3. Relationship to Other Variables

The ranking for these three variables is nearly the same as for the previous three variables. The relative changes are the reversal of WSCC and MARCA rankings between the two classes of availability variables and the "demotion" of SERC to eighth ranked. In both cases the ranking change was the result of the large number of rectennas allocated to SERC (13) and WSCC (11).

EXHIBIT X-2

RATIO OF ELIGIBLE AREAS TO ALLOCATED RECTENNAS

Region	Allocated Rectennas	Eligible Areas without EMC: Eligible Area / Rectennas	Rank	Eligible Areas with EMC: Eligible Area / Rectennas	Rank	Eligible Areas without Isolated Areas: Eligible Area / Rectennas	Rank
ECAR	9	118.8	7	97.7	7	34.9	7
ERCOT	5	349.2	4	264.2	4	170.6	4
MAAC	4	25.8	9	20.8	9	5.3	9
MAIN	5	255.6	5	224.0	5	90.0	6
MARCA	2	3,002.5	1	2,675.0	1	2,116.5	1
NPCC	5	170.2	6	151.8	6	90.2	5
SERC	13	118.2	8	74.5	8	12.7	8
SPP	6	628.3	3	593.0	3	415.0	3
WSCC	11	782.0	2	662.0	2	507.1	2
U.S.	60	416.0		355.3		242.6	
Mean							

X.D. PERCENT OF POTENTIAL EXCLUSION VARIABLES WITHIN ELIGIBLE AREAS

X.D.1. Definition of Criteria

Potential exclusion variables are variables which may, upon further examination, prevent the siting of a rectenna within a grid cell which has a potential exclusion variable. Potential exclusion variables include:

Indian Reservations

National Forests and Grasslands

Agricultural Lands

Areas of Potential Electromagnetic Incompatibility

These variables do not by themselves prevent the siting of a rectenna, however they might lead to additional expenditures (similar to design/cost variables), or potentially increase regulatory problems.

X.D.2. Ranking Analysis

There is a significant spread between the value of the highest ranked region and the lowest. The probability of finding a potential exclusion variable in the lowest ranked region (MARCA) might present a minimal future siting problem. Since these potential variables do not at this time eliminate a site, an appropriate ranking measure is the likelihood of finding one of these potential variables within an eligible area. The likelihood of finding potential variables in eligible areas of each ERC region is:

Region	Eligible Area Containing Potential Exclusion Variables	Eligible Area	% Potential Within Eligible Area	Rank
ECAR	374	879	42.6	7
ERCOT	219	1,321	16.6	3
MAAC	29	83	34.9	4
MAIN	432	1,120	38.6	6
MARCA	2,765	5,350	51.7	9
NPCC	84	759	11.1	2
SERC	85	968	8.8	1
SPP	1,425	3,558	40.1	8
WSCC	2,584	7,882	35.5	5
U.S.	7,997	21,320	37.5	

X.D.3. Relationship to Other Variables

The regional ranking of potential exclusion variables is a reversal of the previously discussed availability criteria. MARCA and SPP, which are highly related in terms of eligible areas, have a high probability of locating a potential variable within an eligible area. Conversely, SERC and NPCC have lower rank for eligible area but a high rank for this variable (low probability of finding a potential variable within an eligible area).

The potential variable might have a significant effect on the siting difficulty vector since the MARCA and ECAR which are highly rated in terms of siting, are low rated with regard to the potential variable. The ranking for the potential variable is similar to the ranking for environmental impact due primarily to the overlap of wild and scenic rivers and agricultural lands in the two variables.

X.E. CAPACITY INCREASE VARIABLES

X.E.1. Definition of Criteria

These variables are based on the U.S. Department of Energy 1978 Annual Report to Congress projections of 1977 to 1995 domestic electricity production system capacity increases assuming Series C mid level demand and mid level supply curves for energy and the projected increases in capacity are, to some degree, a measure of need for SPS rectennas.

Projected Capacity Increase - Series C Nuclear Moratorium: This scenario assumes a moratorium on construction of new nuclear power plants beginning in 1980. Those projects without significant work completed on the reactor building foundation by the end of 1979, will not be constructed, resulting in a maximum nuclear capacity of 137 GWe. This variable is the projected capacity increase associated with the series C-Nuclear Moratorium projections.

Projected Capacity Increase - Series C Mid-Mid: This variable is the projected capacity increases associated with the Series C Mid-Mid projections.

X.E.2. Ranking Analysis

For these variables the regions with the largest projected capacity increase were assigned the highest rank. The projected capacity increase for the United States under the nuclear moratorium scenario was approximately 48,000 megawatts while the capacity increase for the mid-mid scenario was approximately 55,000 megawatts. In both cases WSCC is projected to have the largest regional increase while MARCA has the smallest increase. The increase in MARCA should present a minimal siting problem. ECAR, SERC and SPP are also projected to have relatively large capacity increases. Three of these four top rated regions are the Sun Belt regions (excluding Texas) and are expected to grow faster than the national average.

X.E.3. Relationship to Other Criteria

The regional rankings for this variable vary significantly from those of the Availability Vector; as MARCA, SERC and ECAR differ to various degrees (see Exhibit X-3). MARCA, which was ranked either first or second with Availability Vector Variables, was ranked last with this variable; and SERC and ECAR, which generally ranked eighth and seventh with Availability Vector Variables, ranked second and third with this variable.

X.F. INCIDENCE OF ENVIRONMENTAL IMPACT VARIABLES

X.F.1. Definition of Criteria

The environmental impact variable measures the probability of encountering an environmental variable within an eligible area. The potential exclusion variables which are included in the environmental impact variable are:

Wild and Scenic Rivers

Agricultural Lands

Geese and Duck Flyways

Since this variable is not an exclusion variable but a potential cost or problem variable, an appropriate measure for this variable is the likelihood of finding an environmental impact variable within the eligible areas of a region.

X.F.2. Ranking Analysis

The likelihood of finding an environmental variable within an eligible area ranged from a low of 17.6 percent in SERC (highest rank) to a high of 64.8 percent in MAIN (lowest rank). The central U.S. regions (MARCA, SPP, MAIN) each had a greater than 60 percent chance of encountering an environmental variable within an eligible area (Exhibit X-4). The low rankings for these regions is due to their large proportion of agricultural lands and location under geese and duck flyways, and the low ranked regions may have moderate siting problems. For the United States as a whole the likelihood of finding an environmental variable within an eligible area is approximately 43 percent.

X.F.3. Relationship to Other Variables

The regional ranking for this variable is very similar to the regional ranking for the potential exclusion variable. The midwestern regions (MAIN, SPP, and MARCA) are low ranked while SERC, WSCC and ERCOT are more highly ranked. As was the case within the potential exclusion variable, the environmental impact variable might have a significant effect on siting and/or the amount of eligible area in MARCA because MARCA was highly ranked for each of these variables.

EXHIBIT X-3

PROJECTED CAPACITY INCREASE

Region	Nuclear Moratorium Capacity Increase (MW)	Nuclear Moratorium Rank	Mid-Mid Scenario Capacity Increase (MW)	Mid-Mid Scenario Rank
ECAR	7,532	3	7,481	3
ERCOT	4,030	6	4,483	5
MAAC	2,812	8	3,625	8
MAIN	2,838	7	3,932	6
MARCA	1,383	9	1,992	9
NCPP	4,517	5	3,636	7
SERC	8,117	2	10,385	2
SPP	5,147	4	6,339	4
WSCC	11,977	1	13,544	1
Total U.S.	48,355		55,417	

EXHIBIT X-4

INCIDENCE OF ENVIRONMENTAL IMPACT VARIABLES

Environmental Variables

ERC Region	Wild and Scenic Rivers	Agricul-tural Lands	Flyways	Total	Eligible Area	% Environmental in Eligible Areas	Rank
ECAR	131	132	146	409	879	46.5	6
ERCOT	14	161	131	306	1,321	23.2	3
MAAC	16	0	19	35	83	42.2	5
MAIN	34	254	438	726	1,120	64.8	9
MARCA	151	2,045	1,268	3,464	5,350	64.7	8
NPCC	124	0	99	223	759	29.4	4
SERC	99	4	67	170	968	17.6	1
SPP	112	1,304	782	2,198	3,558	61.8	7
WSCC	403	695	587	1,685	7,282	23.1	2
United States	1,084	4,595	3,537	9,216	21,320	43.2	

X.G. ABSORPTIVE CAPACITY VECTOR

X.G.1. Description of Criteria

The absorptive capacity variables measure the ability of load centers within a region to accept either five gigawatts or one gigawatt of SPS power. The four variables in this vector provide two different measures of the ability of regions to absorb SPS power. The two total measures (load centers greater than 5 gigawatts or 1000 megawatts) give the total number of load centers that are greater than a given threshold, while the proportion measures give an indication of the relative size of the regions load centers. (e.g. In SERC 94 percent of the load centers are larger than 1,000 megawatts.) The variables in this vector are ranked based on the number of load centers that could accept either five gigawatts or 1000 megawatts of SPS power or the proportion of load centers that could accept either five gigawatts or 1000 megawatts.

The load centers used for these variables are the 171 BEA areas used by ORNL in their disaggregation of the MEFS projections. The ORMC projections of load center electricity demands are for the year 1990. The parallel Environmental Resources Group (ERG, 1980) report required that SPS not exceed 25 percent of the baseload capacity at any load center. An order to stay under this 25 percent constraint the electricity demands at the load centers were extended to 2020 and converted to baseload capacities. The extension performed by ERG utilized baseload capacity factors calculated by EIA in their 1978 ARC and an extension and reconciliation of the MEFS Series C mid-mid scenario to LEAP projections for the year 2020.

<u>Load Centers With Capacity Greater Than or Equal to That Required For One Rectenna</u>: The value of this variable is equal to the total number of load centers within a region that can accept five or more gigawatts of SPS power.

<u>Proportion of Load Centers With Capacity Greater Than or Equal to One Rectenna</u>: The value of this variable is equal to the proportion of the load centers within a region that could accept five or more gigawatts of SPS power.

<u>Load Centers With Capacity Greater Than 1000 Megawatts</u>: The value of this variable is the number of load centers within a region that can accept 1000 or more megawatts of SPS power.

<u>Proportion of Load Centers With Capacity Greater Than or Equal to 1000 Megawatts</u>: The value of this variable is the proportion of load centers within a region that could accept 1000 or more megawatts of SPS power.

X.G.2. Ranking Analysis

The spread between regions is not significant for the two five gigawatt variables, but is significant for the 1000 megawatt variables. The absence of large load centers in MARCA (lowest ranked region) should cause only a minimal siting problem.

In the total measures of SPS absorptive capacity, SERC is the highest ranked with four load centers larger than five gigawatts and 32 load centers larger than 1000 megawatts. MARCA is the lowest ranked for both variables with no load centers larger than 5 gigawatts and only 3 larger than 1000 megawatts. Highly ranked regions for these two variables reflect the presence of either inexpensive electricity (TVA in SERC and the Pacific Northwest in WSCC) or high population density and industrial activity (ECAR).

For the proportion variables, ERCOT is most highly ranked for the above five gigawatts while SERC is the highest ranked in the above 1000 megawatt measure. MARCA is again the lowest rated for both measures. The proportion variables reflect the distribution of industrial activity and less expensive electricity to a greater degree than do the total measures. The highest ranked regions for the 1000 megawatts proportion measure (SERC, ECAR, ERCOT, SPP) are existing or growing industrial areas with access to cheaper electricity.

X.G.3. Relationship to Other Variables

The regional rankings of the absorptive capacity variables are generally the reverse of the site availability variables. This should be expected since the availability of sites reflects among other things the lack of population, while the absorptive capacity variables reflect the presence of population. The rankings for absorptive capacity are also similar to the potential and environmental impact variables.

X.H. SITING DIFFICULTY VECTOR (Variables 15-17)

X.H.1. Definition of Criteria

The regional ranking of the ease and difficulty of siting allocated rectennas is based on parallel research conducted as part of the SPS utility integration study (ERG, 1980). "Difficulty" rankings reflect several factors. The ratio of the regional power consumption to allocated rectennas is an example. If the regional load was greater than the power generated by the regional rectenna allocation, then siting was a relatively simple procedure. The ranking of SERC and ERCOT generally reflect this situation. If, as in WSCC, the regional load was less than the capacity of allocated rectennas, then siting difficulties occurred.[1]

[1] Regional power consumption and the regional allocation of rectenna capacity differ because rectennas were allocated based on electricity, generation in the year 2000 and load center electricity consumption extrapolated to the year 2020 as discussed in section XI.G.

EXHIBIT X-5

REGIONAL ABSORPTIVE CAPACITIES

Region	Total Load Centers	Load Center 5.0 Gigawatts: Number of Load Centers	Rank	Proportion of Load Centers	Rank	Load Center 1,000 Megawatts: Number of Load Centers	Rank	Proportion of Load Centers	Rank
ECAR	25	2	3.5	0.08	6.5	18	2	0.72	2
ERCOT	12	2	3.5	0.17	1	8	5	0.67	3.5
MAAC	7	1	6.5	0.14	2	4	7	0.57	5
MAIN	12	1	6.5	0.08	6.5	4	7	0.33	8
MARCA	23	0	9	0.00	9	3	9	0.13	9
NPCC	11	1	6.5	0.09	5	4	7	0.36	7
SERC	34	4	1	0.12	3	32	1	0.94	1
SPP	18	1	6.5	0.06	8	12	4	0.67	3.5
WSCC	29	3	2	0.10	4	14	3	0.48	6
Total U.S.	171	15				99		0.58	

The ratings also indicate the difficulties encountered in finding appropriate eligible squares within a set distance from a load center. Other rankings considered extensive transmission vector length, an occurrence in WSCC and occasionally MARCA.

<u>Siting Difficulty - Fully Constrained</u>: For this variable regions are ranked for the difficulty in siting rectennas under all constraints.

<u>Siting Difficulty - Partially Constrained</u>: For this variable regions are ranked based on the ease of siting rectennas when the colongitudinal constraint is relaxed.

<u>Siting Difficulty - Revised Absorption</u>: For this variable, regions are ranked based on their ease of siting rectennas when the absorptive capacity constraint has been revised and the colongitudinal constraint relaxed.

X.H.2. Ranking Analysis

For the fully constrained variable MAAC and WSCC were given the two lowest rankings because they both had low loads in relation to the numbers of allocated rectennas, and the half-degree colongitudinal siting separation severely limited the possible siting choices for MAAC. In addition, MAAC consistently had problems with a limited number of eligible squares within the region. The separation constraint also caused some difficulties for siting in MAIN, SPP, ECAR, SERC and NPCC giving them middle-range rankings. MARCA and ERCOT received the highest rankings, as they did not experience these siting difficulties (see Exhibit X-6).

MAAC and WSCC were also given the lowest rankings for the partially constrained variable because their low loads in comparison to their numbers of allocated rectennas. In addition, WSCC transmission vectors would exceed the 300 mile limit, and one rectenna would exceed the load of several load centers it would serve. MAIN and SPP also had low loads with respect to allocated rectennas. There was no difficulty in siting for ECAR, NPCC, MARCA, ERCOT and SERC (see Exhibit X-6).

In the revised capacity scenario, the revised absorptive capacity of WSCC was still inadequate for the allocated rectennas for this variable and is reflected in its ranking. MAAC needed a few split lines to be served to full capacity. All of the other regions presented few siting difficulties in this scenario, a quality that is reflected overall in the short transmission vectors and high number of unserved load centers.

X.H.3. Relationship to Other Variables

The ranking of the siting variables is generally different from all other ranking vectors. This is expected since these variables are in essence a combination of the availability variables and the absorptive capacity variables.

EXHIBIT X-6

RANKING OF DIFFICULTY IN NOMINAL SITING UNDER ALTERNATIVE SITING SCENARIOS

Region	Fully Constrained Scenario	Partially Contstrained Scenario	Revised Capacity Scenario
1. ECAR	5	3	4
2. ERCOT	1.5	3	4
3. MAAC	9	8.5	8
4. MAIN	5	6.5	4
5. MARCA	1.5	3	4
6. NPCC	5	3	4
7. SERC	5	3	4
8. SPP	5	6.5	4
9. WSCC	8	8.5	9

It is particularly significant that, except for MAAL, there is no consistent relationship between any of the site availability variables and the difficulty of locating nominal plant cites within the rather stringent constraints of the utility integration study. To the extent that "siting difficulty" is a partial proxy for an actual siting effort, this suggests that the availability of eligible areas is not a key limiting factor.

Of the two highest ranked siting regions (MARCA and ERCOT), MARCA has a high availability ranking while ERCOT has a high absorptive capacity ranking. WSCC which has a high availability ranking and a moderate absorptive ranking has the lowest siting ranking due to the dispersion of load centers and the relationship between absorptive capacity and the regional allocation of rectennas.

X.I. RANKING SUMMARY

The seventeen variables ranked in this analysis can be combined into five conceptual interrelated groups, or vectors:

1. Availability reflecting the total eligible cell count and ratio of eligible cells to allocated sites.

2. Capacity increase under two scenarios.

3. Absorptive capacity reflecting the number and proportion of large load centers.

4. Siting difficulty per three sets of constraints imposed the utility integration study.

These ranking vectors are so heterogenous as to preclude the development of any single total or other single figure of merit. On the other hand, the synthesis of rankings by vector and comparison of the five ranking vectors can provide some useful insights. Exhibit X-7 summarizes the combined rankings by vector, showing both the sum of the component ranking and the rank of the sums.

None of the regions has a truly consistent ranking across the five vectors. Only the mid-Atlantic region (MAAC) has no high rankings and it is, consequently, the one with the least favorable overall outlook. Three regions do appear to have only high or medium ratings across all five vectors. These are ERCOT (Texas), SERC (Southeast) and WSCC (West). All three rate well with respect to capacity increase, environment and absorption capacity. The remaining six regions present rather mixed pictures.

Initial siting of SPS facilities would appear to be least difficult and "most desirable" in the ERCOT, SERC and WSCC regions and most difficult in the MAAC region. Other midwestern and eastern regions present a generally mixed pattern with MAIN appearing least attractive.

EXHIBIT X-7

RANKING VARIABLE GROUPINGS

NERC REGION

SYNTHESIS OF RANKING VECTORS (Summation of Individual Ratings)	ECAR	ERCOT	MAAC	MAIN	MARCA	NPCC	SERC	SPP	WSCC
AVAILABILITY VECTOR (Variables 1-7)									
Sum of Individual Ratings	35	27	58	39	18	40	44	26	14
Synthesis Rating	5	4	9	6	2	7	8	3	1
CAPACITY INCREASE VECTOR (Variables 8 and 9)									
Sum of Individual Ratings	6	11	16	13	18	12	4	8	2
Synthesis Rating	3	5	8	7	9	6	2	4	1
ENVIRONMENTAL VECTOR (Variable 10)	6	3	5	9	8	4	1	7	2
ABSORPTION CAPACITY VECTOR (Variables 11-14)									
Sum of Individual Ratings	14	13	20.5	28	36	25.5	6	25	15
Synthesis Rating	3	2	5	8	9	7	1	6	4
SITING DIFFICULTY VECTOR (Variables 15-17)									
Sum of Individual Ratings	12	8.5	25.5	15.5	8.5	12	12	15.5	24.5
Synthesis Rating	4	1.5	8.5	6.5	1.5	4	4	6.5	8.5

APPENDIX A: DESCRIPTION OF INDIVIDUAL VARIABLES

In this appendix, information relating to the source of the individual variables and information relating to the accuracy of the individual data items will be presented. Additionally, maps showing the spatial coverage of the variables as mapped will be presented. It is not the intent of this Appendix to reproduce information concerning the rationale for the treatment of the variable and it is not the intent of this appendix to reiterate information presented in Section IV of this study.

A.1. INLAND WATER

Inland water was mapped off of the United States Geological Survey map titled "Shaded Relief of the United States", presented in the National Atlas of the United States of America. The scale of the original map was 1:7,500,000. The criteria for coding a cell as having inland water present was the presence of inland water in 50% or more of a cell. Because of this coding criteria as well as the scale of the map, many smaller water bodies were not coded. Undoubtedly, the mapped information underestimates the spatial coverage of this variable. Inland water was indicated as being present in 189 grid cells.

A.2. POPULATION

Two variables were developed to portray populated areas. Standard Metropolitan Statistical Areas and Adjusted Population Density were two separate variables which together indicated populated areas. Several difficulties were encountered with respect to mapped sources depicting population. First, the only national-scale information actually depicting population is based upon the 1970 Census. Therefore, much of the population data is ten years old. Secondly, the initial rectenna will not be operational until the year 2000 according to the reference system. For this reason, the population variable had to provide some indication of future growth. Undoubtedly, many areas will become populated prior to the initiation of the SPS program, but it is impossible to speculate where these population increases will take place. For this reason, Standard Metropolitan Statistical Areas were utilized as both an indication of currently populated area and as proxy variables for future development. The Adjusted Population Density variable compensates for more rural, but nonetheless populated areas.

A.2.a. Standard Metropolitan Statistical Areas

Standard Metropolitan Statistical Areas were coded from a map with the same title prepared by the U. S. Department of Commerce, Census Bureau, in 1978. The boundary cells were coded if 50% more of the cell was within the SMSA. As mapped, the SMSA variable covered 8437 grid cells, and is shown in Exhibit A-2.

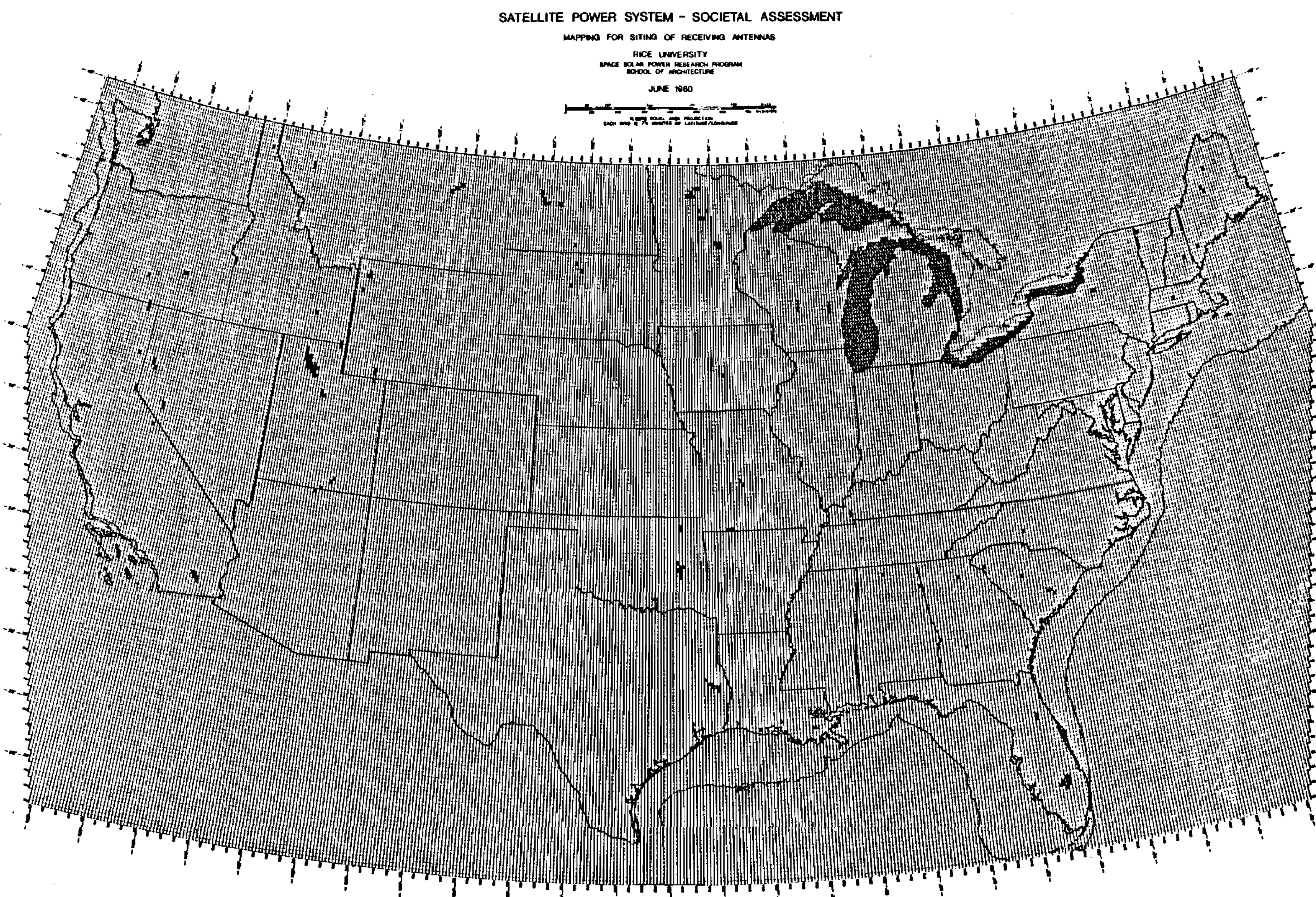


Exhibit A-1 INLAND WATERS

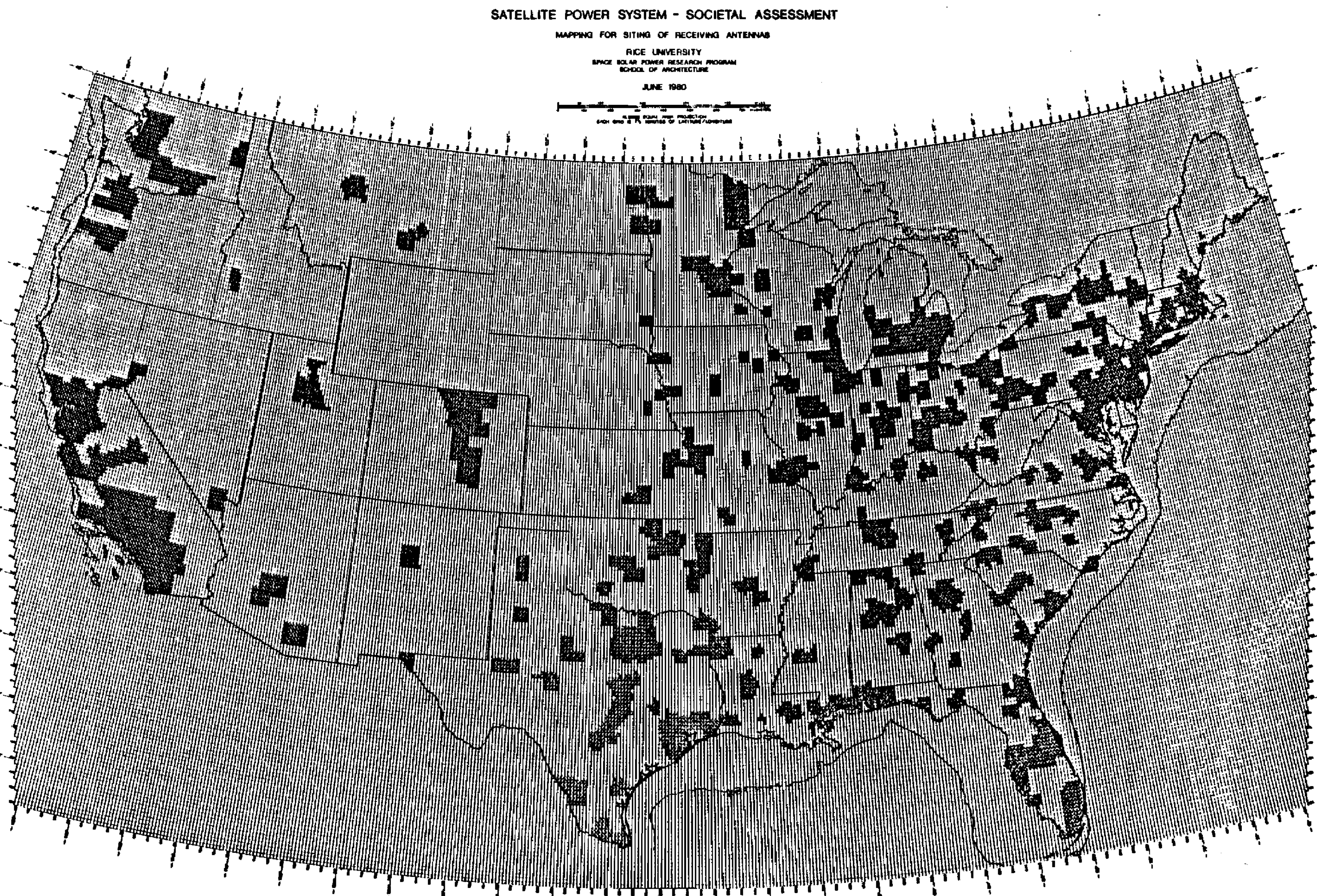


Exhibit A-2 STANDARD METROPOLITAN STATISTICAL AREAS

A.2.b. Adjusted Population Density

The adjusted population density was derived from the dot map of the population of the United States, prepared by the United States Department of the Census. This map is based upon the 1970 Census information. This map was selected over a map that displayed population density on a county basis. The major reason for this decision was that populated areas existing within large rural counties would be obscured by the county population density map and large counties with a single large populated area would have much land area available as sites but would have been eliminated by the overall county population density. The major concern with the dot map was the accuracy of the dots as spatial depictions of population and this concern was basically eliminated by pre-validation exercises. Another problem with this information was the coding process. A cell was coded if 1500 persons or more were indicated as present within the grid square. The major difficulty with this approach was in those cells with dots falling on the boundary line. If two or more dots were within the grid square and two or more were on the boundary, then the grid square was coded. While it is felt that this process was a good approximation of the occurrence of populated areas, this population variable is not as good as is desirable.

A.3. FEDERAL LANDS

Six of the absolute and potential exclusion variables are owned by the federal government. These variables are:

1. Military Reservations
2. Atomic Energy Commission Lands
3. National Recreation Areas (National Parks, National Wildlife Refuges, National Monuments, National Seashores and National Recreation Areas)
4. National Forests
5. Indian Reservations
6. National Grasslands

Each of these variables was mapped from the United States Geological Survey map titled Federal Lands from the National Atlas of the United States. This information is considered to be very accurate to the extent of its spatial coverage. However, the original from which this information was mapped was presented at the scale of 1:7,500,000. For this reason, smaller, isolated occurrences of certain of these variables were omitted from this source map. Additional maps were examined to determine if they would provide better information, but the rigor of the mapping process in these maps was less exacting than that exhibited on the federal lands map. For example, a map exists that depicts the national wildlife refuges. However, the smaller national wildlife refuges are indicated by an extremely large circle rather than by the presentation of the boundaries of the refuge. Because these large circles encompassed as many as four of our grid cells, the decision

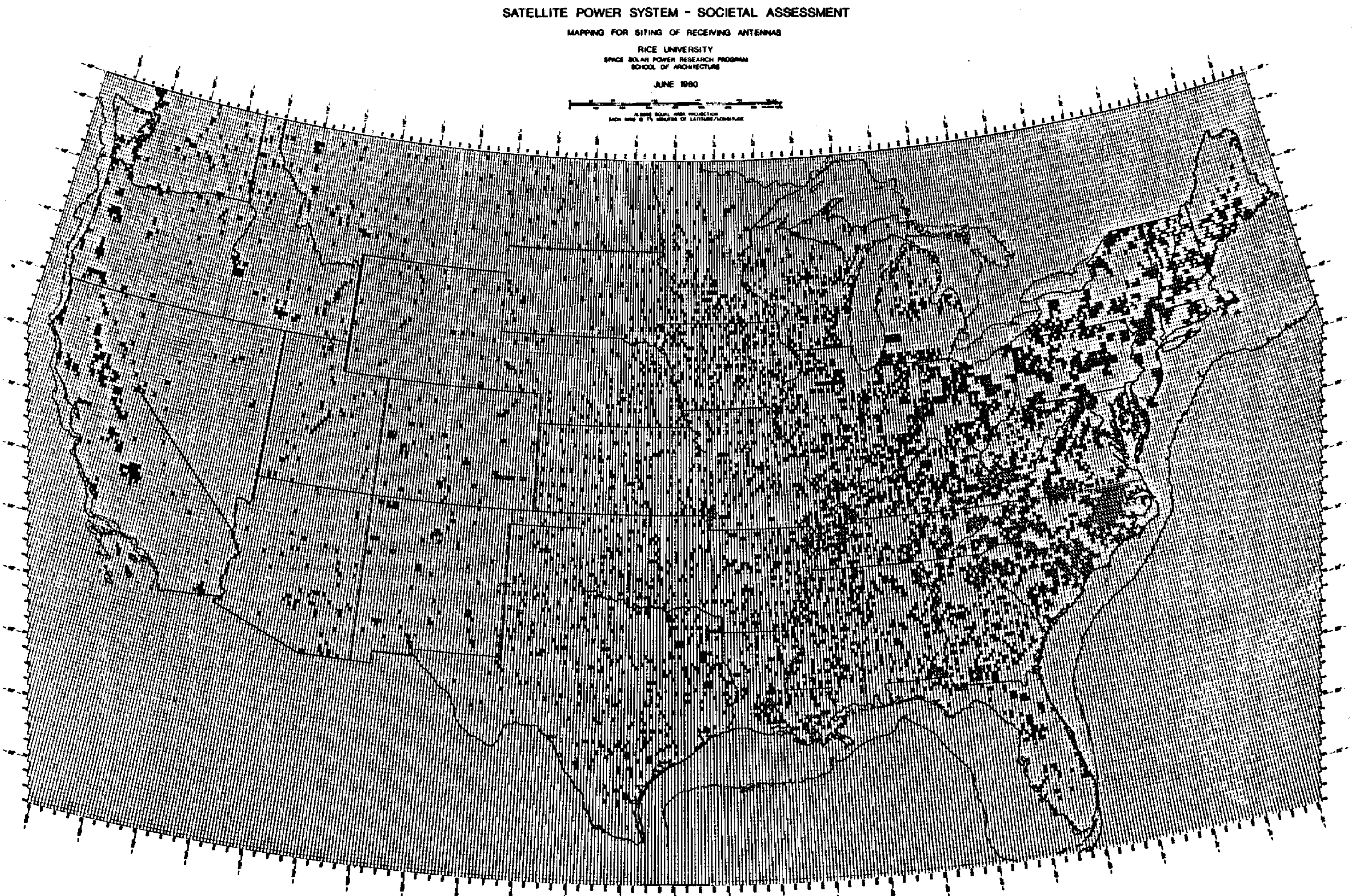


Exhibit A-3 ADJUSTED POPULATION DENSITY

was made to map off of the USGS Federal Lands map with the realization that the coverage of the variable as indicated was less than the actual coverage of the variable. Similar maps using symbols instead of boundaries were found for other variables included in this category. National Recreation Areas, Military Reservations and Atomic Energy Commission Lands were coded in a cell if they were present whereas Indian Reservations, National Forests and National Grassland were coded if they were present in 50% of a grid cell. The spatial coverage of the variables are as follows:

Military Reservations.	578 grid squares	(Exhibit A-4)
Atomic Energy Commission Lands .	88 grid squares	(Exhibit A-5)
National Recreation Areas. . . .	955 grid squares	(Exhibit A-6)
Indian Reservations.	1982 grid squares	(Exhibit A-7)
National Forests	5630 grid squares	(Exhibit A-8)
National Grasslands.	299 grid squares	(Exhibit A-9)

A.4. WETLANDS

Marshlands were mapped from A. W. Kuchler's map titled "Natural Potential Vegetation" from the U.S.G.S. National Atlas of the United States. As discussed in the section on pre-validation, this was considered to be the best of two sources. Unfortunately, detailed mapping of areas is only now being undertaken by the United States Department of Interior and was not available for this study's use. Although Kuchler's map is quite accurate, additional wetlands coverage was provided by the U.S.G.S. map titled "Major Land Uses" from the National Atlas of the United States. These areas were titled perennially flooded areas. However, many isolated wetlands areas were not included in either the Kuchler map or the U.S.G.S. land use map. Therefore, the coverage of the variables is less than the actual coverage of the variables. Marshlands and wetlands were coded as being present if they occurred in a grid cell. Marshlands covered 388 grid cells (Exhibit A-10) and perennially flooded areas covered 1310 grid cells (Exhibit A-11).

A.5. DESIGNATED HABITATS OF ENDANGERED SPECIES

The designated habitats of endangered species were mapped from data published in the Federal Register. This information was assembled in this study and a grid cell was coded as having a designated habitat if that habitat appeared in any portion of the grid square. The major shortcoming of this information is that it is based upon a legal status and not upon the distribution of endangered species generally. The only data concerning endangered species generally was a map indicating the density of endangered species that was very generalized. The decision was made that without site specific investigations, general statements about the density of endangered species were less desirable than information depicting designated habitats. However, many areas of the United States are inhabited by endangered species not shown in this study's mapped data. The spatial coverage of the designated habitats was 396 grid cells and is depicted in Exhibit A-12.

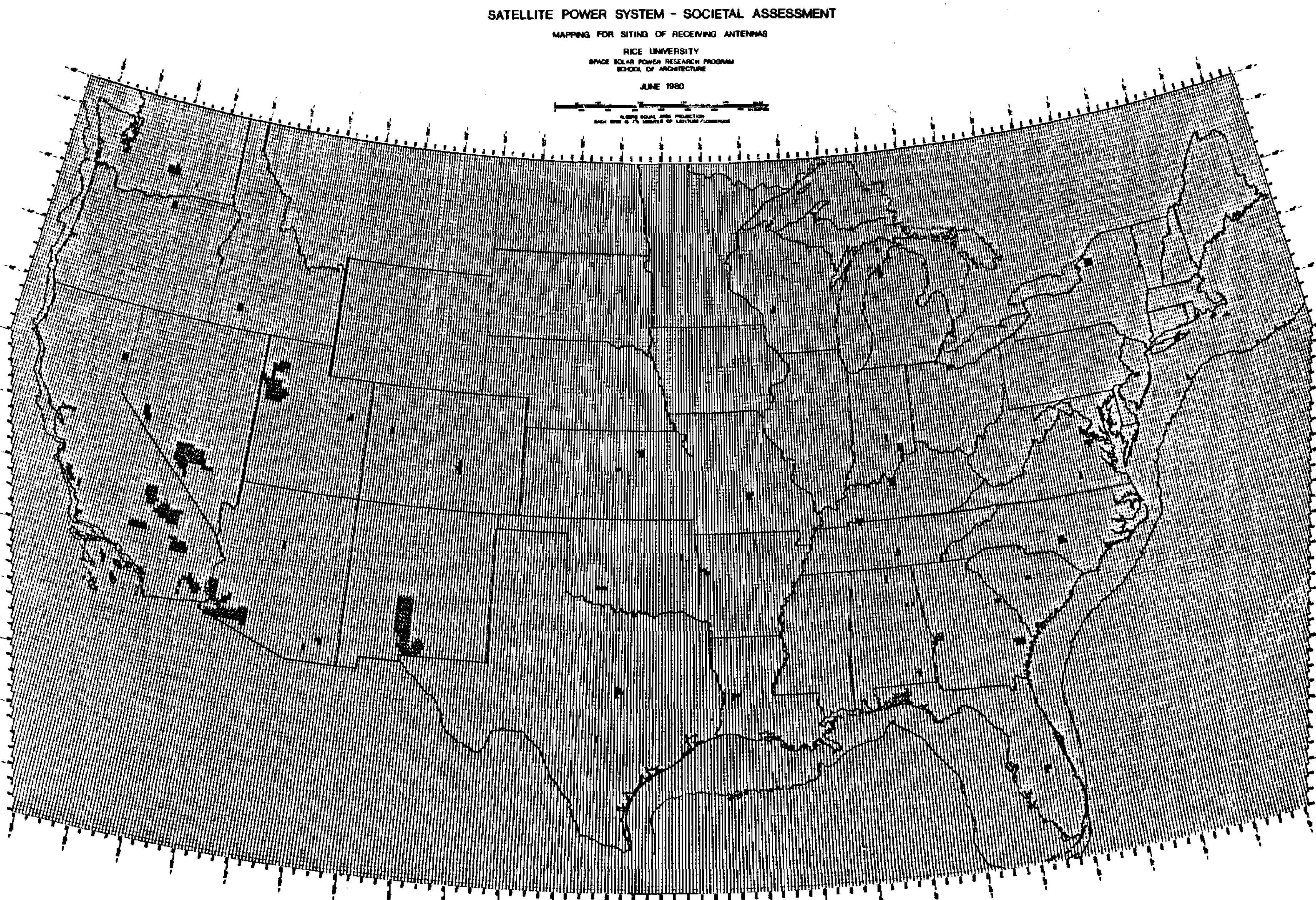


Exhibit A-4 MILITARY RESERVATIONS

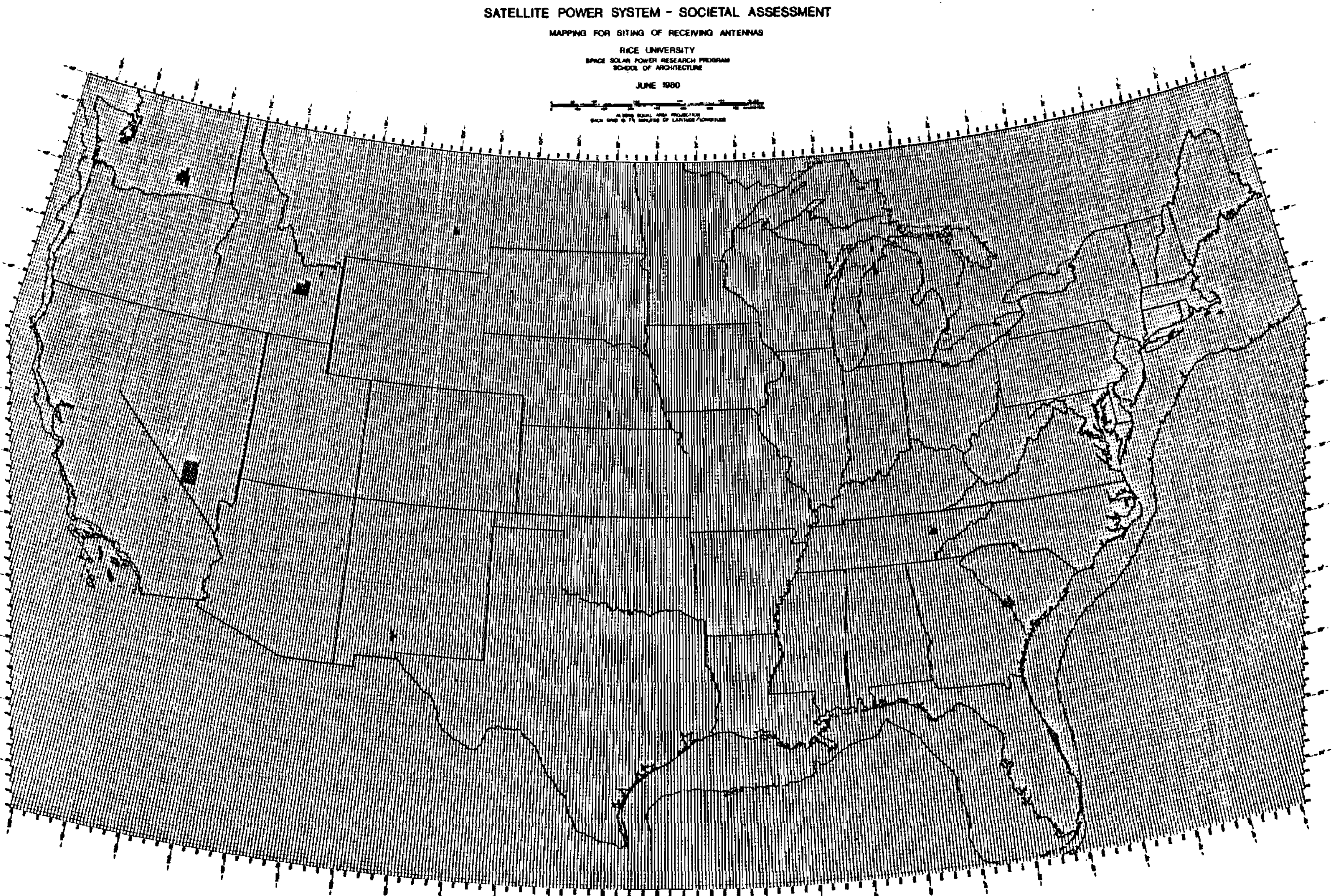


Exhibit A-5 ATOMIC ENERGY COMMISSION LANDS

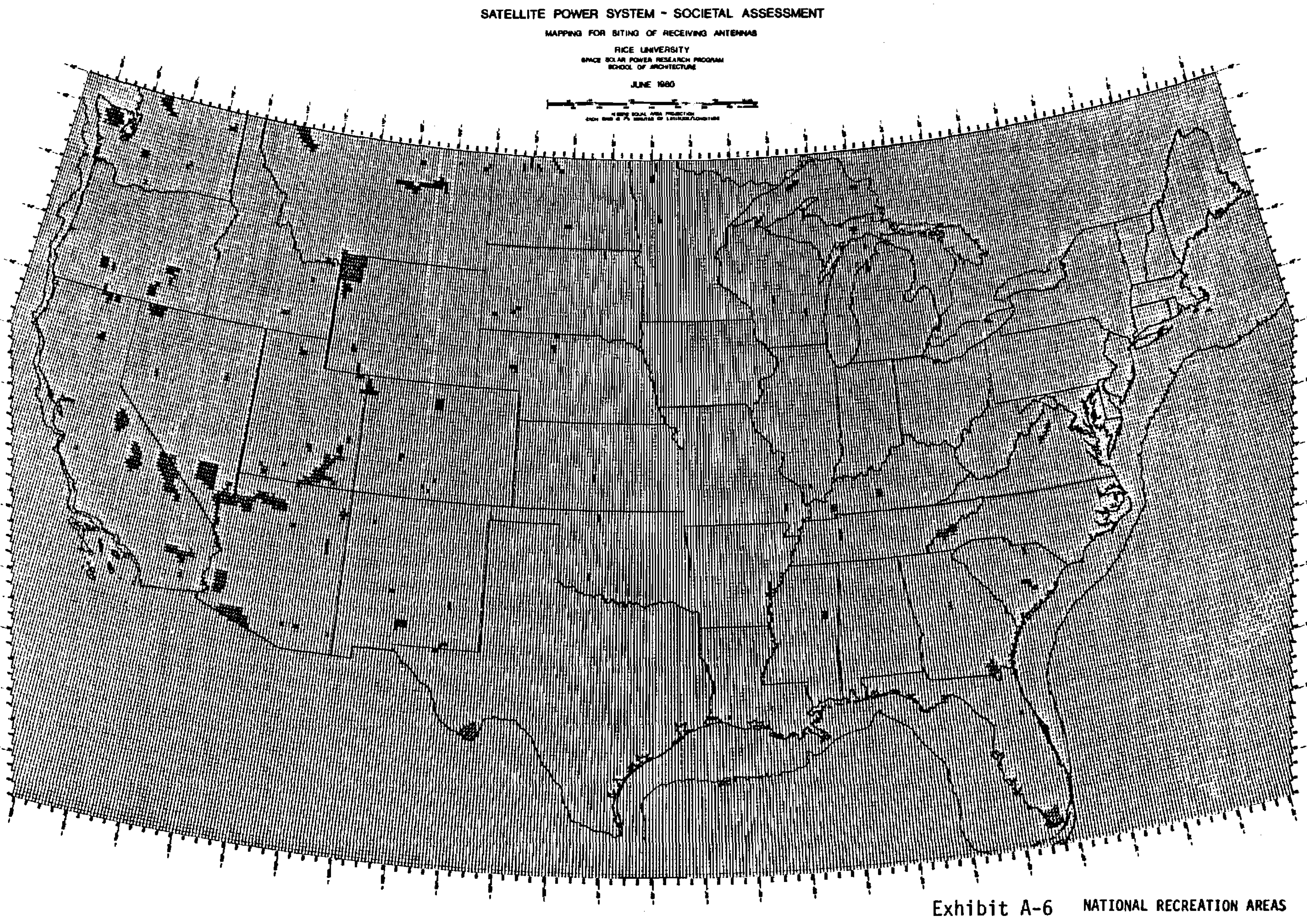


Exhibit A-6 NATIONAL RECREATION AREAS

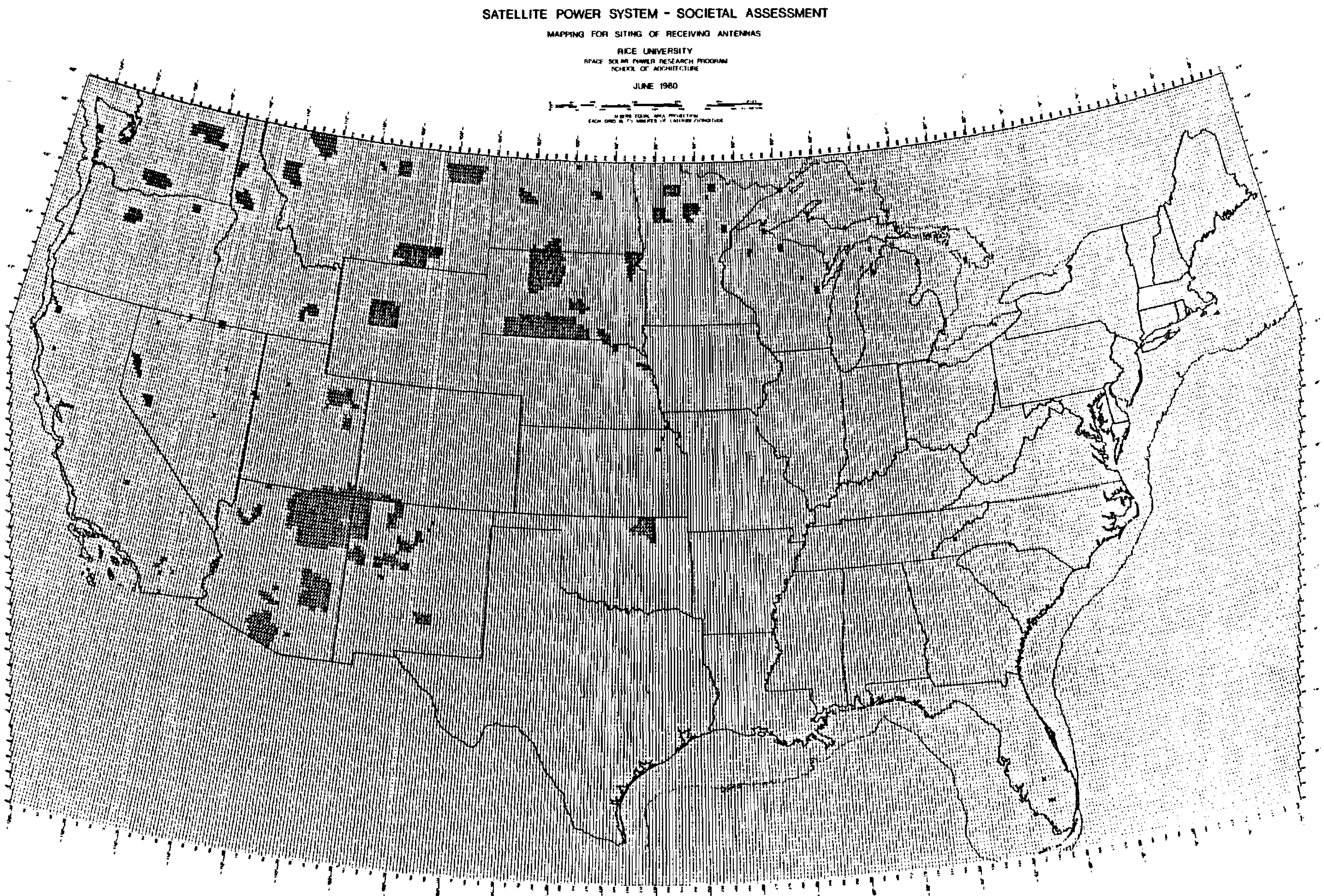


Exhibit A-7 INDIAN RESERVATIONS

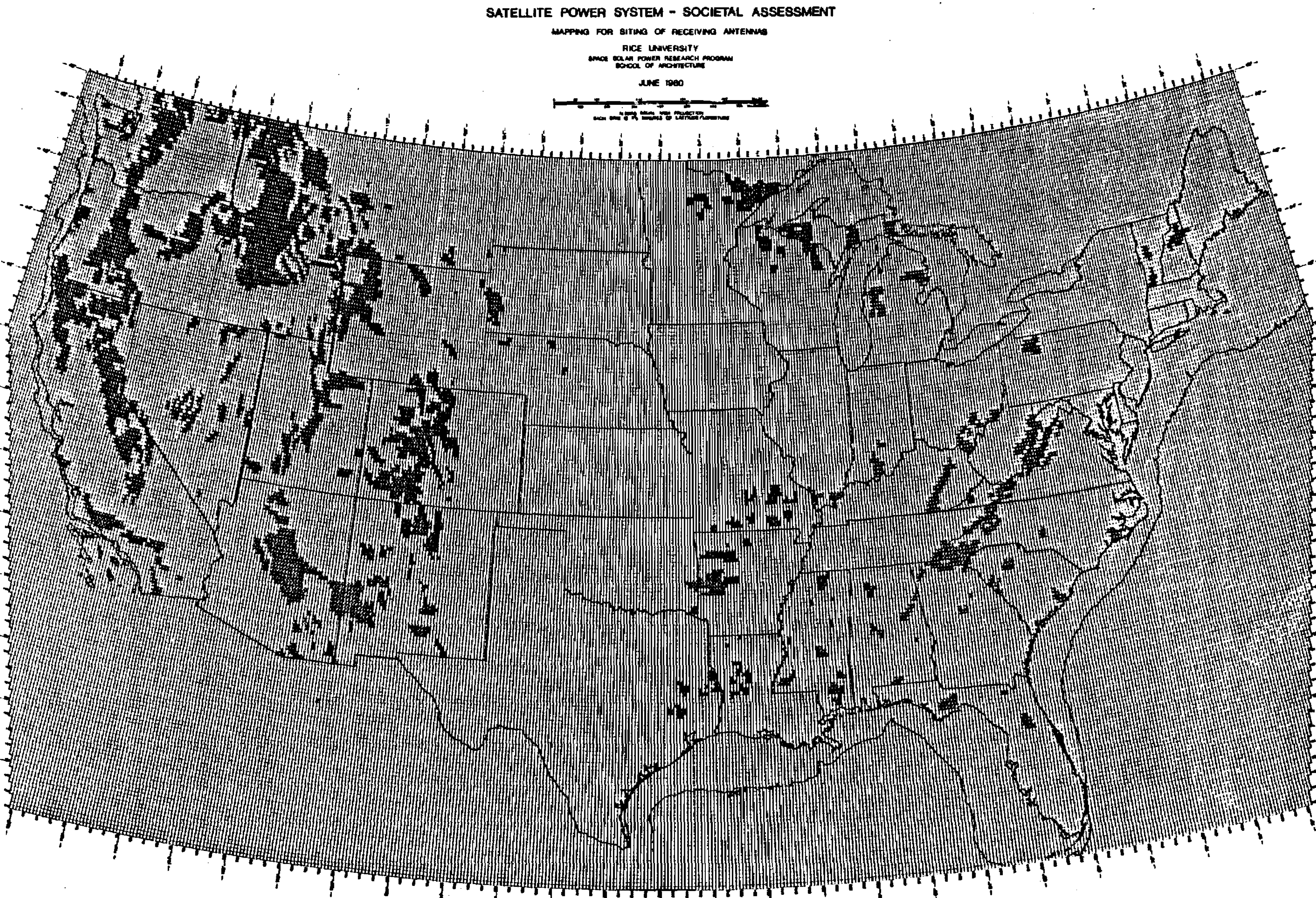


Exhibit A-8 NATIONAL FORESTS

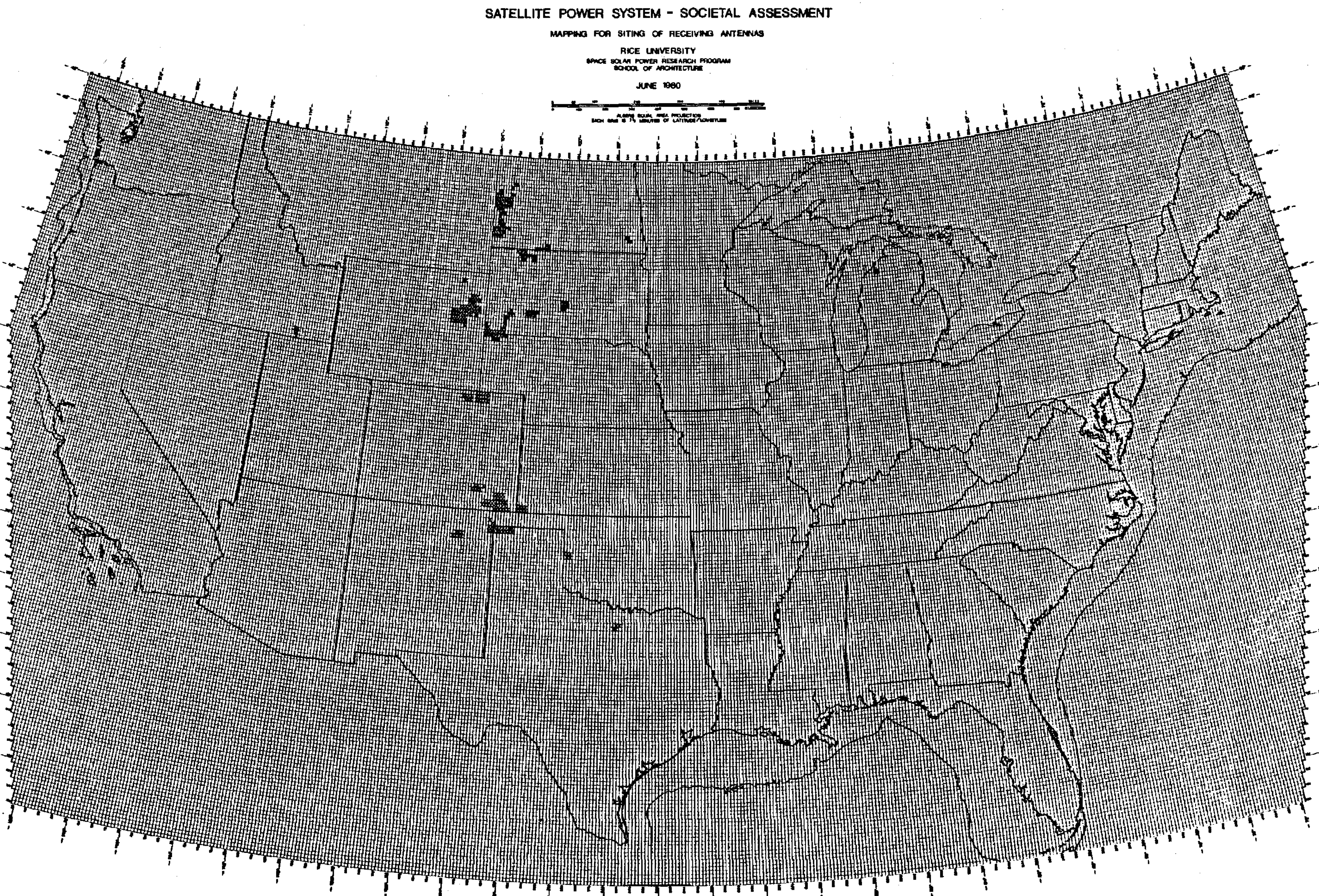


Exhibit A-9 NATIONAL GRASSLANDS

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

MAPPING FOR SITING OF RECEIVING ANTENNAS

RICE UNIVERSITY

SPACE SOLAR POWER RESEARCH PROGRAM

SCHOOL OF ARCHITECTURE

JUNE 1980

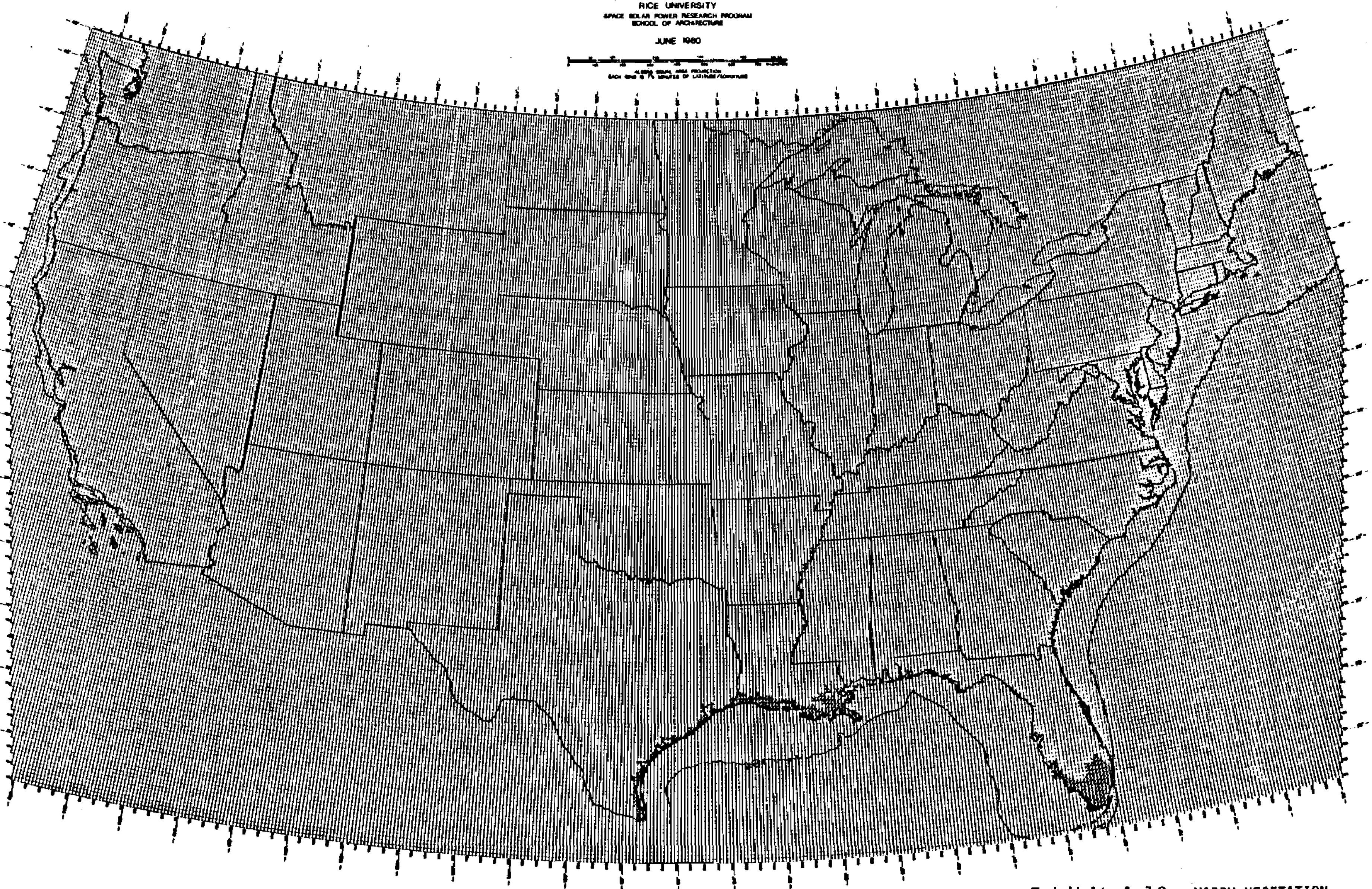


Exhibit A-10 MARSH VEGETATION

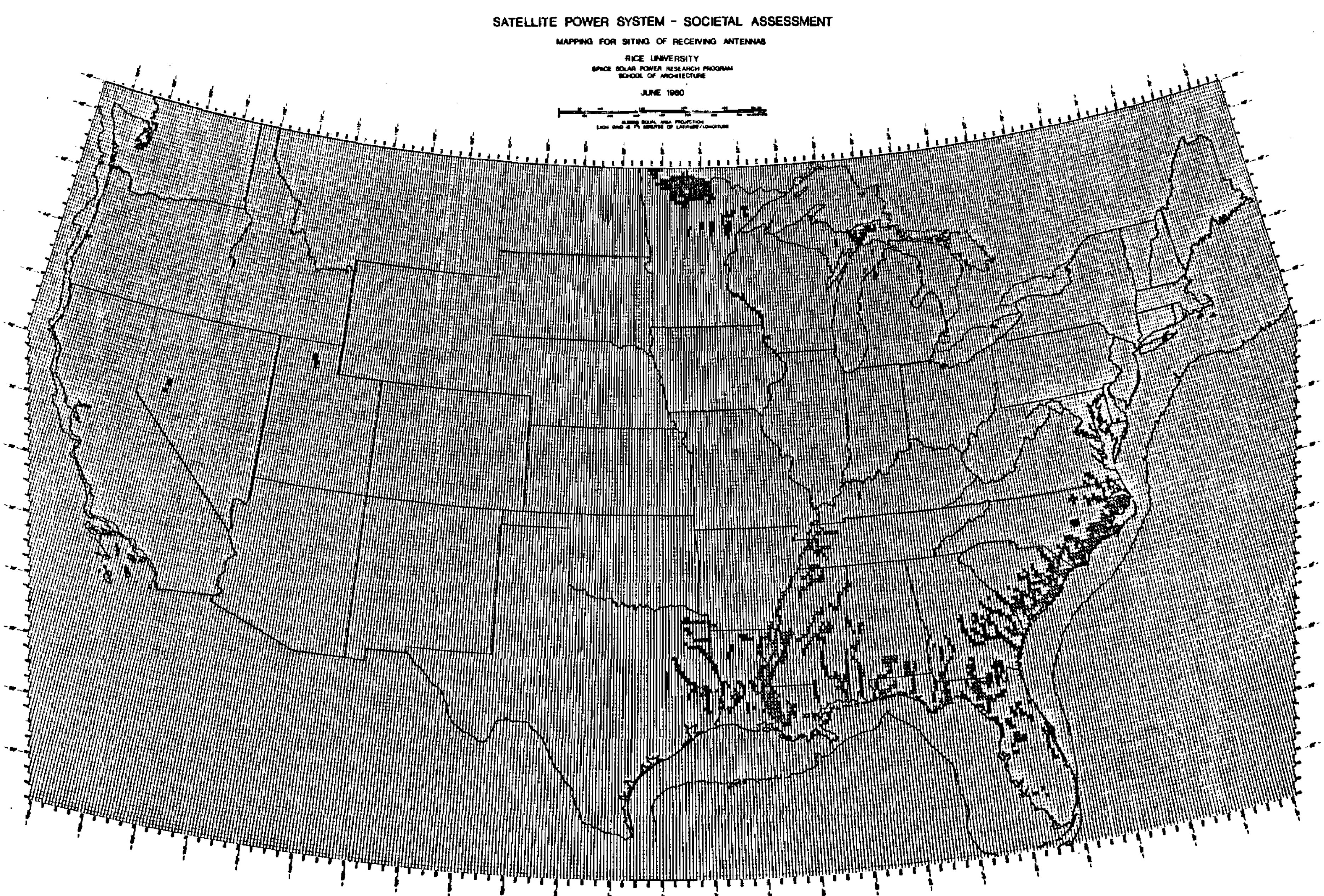


Exhibit A-11 PERENNIALLY FLOODED AREAS

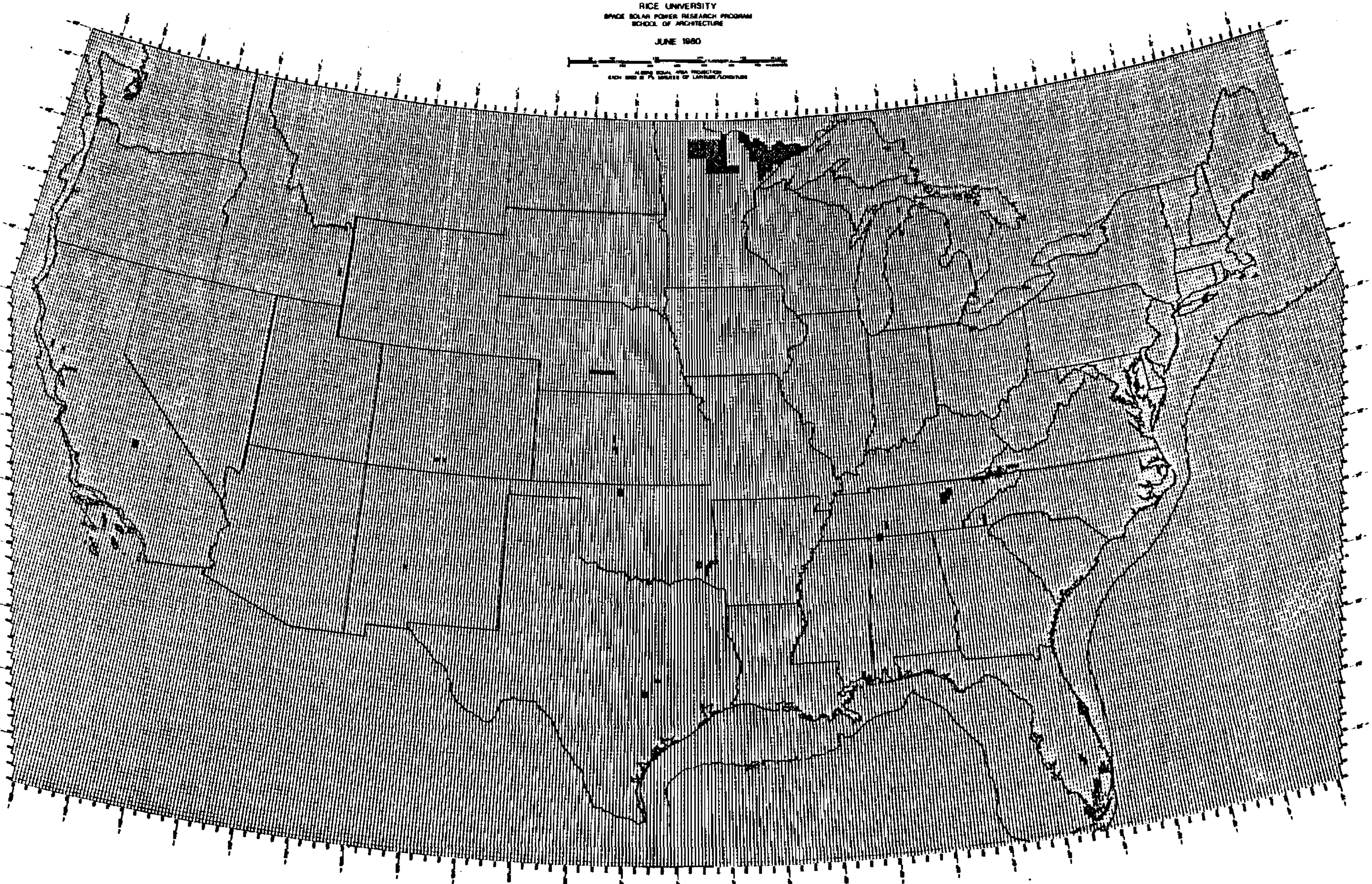


Exhibit A-12 ENDANGERED SPECIES DESIGNATED HABITAT

A.6. INTERSTATE HIGHWAYS

Interstate Highways were mapped from a U. S. Department of Interior map titled "Indian Reservations". This was found to be a very accurate source in pre-validation exercises. Interstate Highways were coded as being present if they occurred in any grid cell. A possible problem exists when the highways have paths that are diagonal, but the presence of interstate Highways in adjacent grid squares would be nominal. 4451 grid squares were coded as Interstate Highways, which are shown in Exhibit A-13.

A.7. NAVIGABLE WATERWAYS

Navigable waterways were mapped from the U. S. Army Corps of Engineers National Waterways Study Map #1. This map is considered to be highly accurate and up to date. A grid cell was coded if the navigable waterway appeared in the cell. In all, 1311 grid cells were coded for navigable waterways which are shown in Exhibit A-14.

A.8. TOPOGRAPHY

A detailed discussion of the topographic variables and the maps depicting various aspects of topography are presented in Appendix D.

A.9. ELECTROMAGNETIC COMPATIBILITY

A detailed discussion of the electromagnetic compatibility variables and the maps depicting the 7 EMC variables are presented in Appendix C.

A.10. WILD AND SCENIC RIVERS

Wild and Scenic Rivers were mapped upon a base map of the rivers of the United States from data presented in the National Geographic Society's "Wild and Scenic Rivers" map. This information is considered to be highly accurate. A grid cell was coded if a wild and scenic river ran through the cell. In all, 1084 grid cells were coded for wild and scenic rivers which are presented in Exhibit A-15.

A.11. CROPLANDS

Two categories of croplands were mapped in this study. These were irrigated croplands and "mostly croplands". The intent of this mapping exercise was to identify prime farmlands and unique farmlands. However, no national-scale maps exist which describe prime and unique farmlands. The United States Soil Conservation Service is preparing such maps but they were not available in time for inclusion in this study. The data utilized in this study indicates areas that should be classified as prime or unique farmlands, but the spatial coverage of prime and unique farmlands is greater than is depicted in this map. The source of the mapped information used

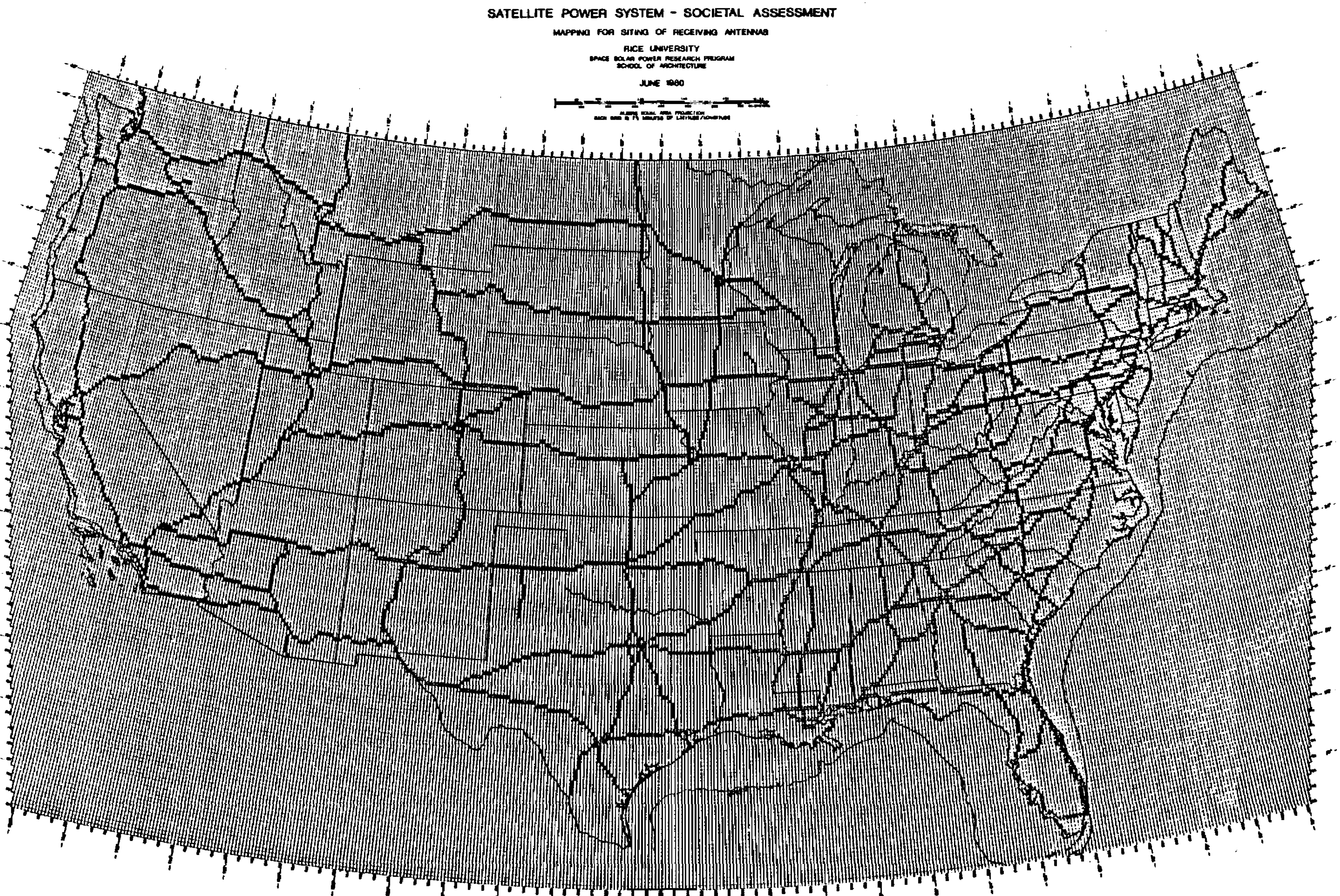


Exhibit A-13 INTERSTATE HIGHWAYS

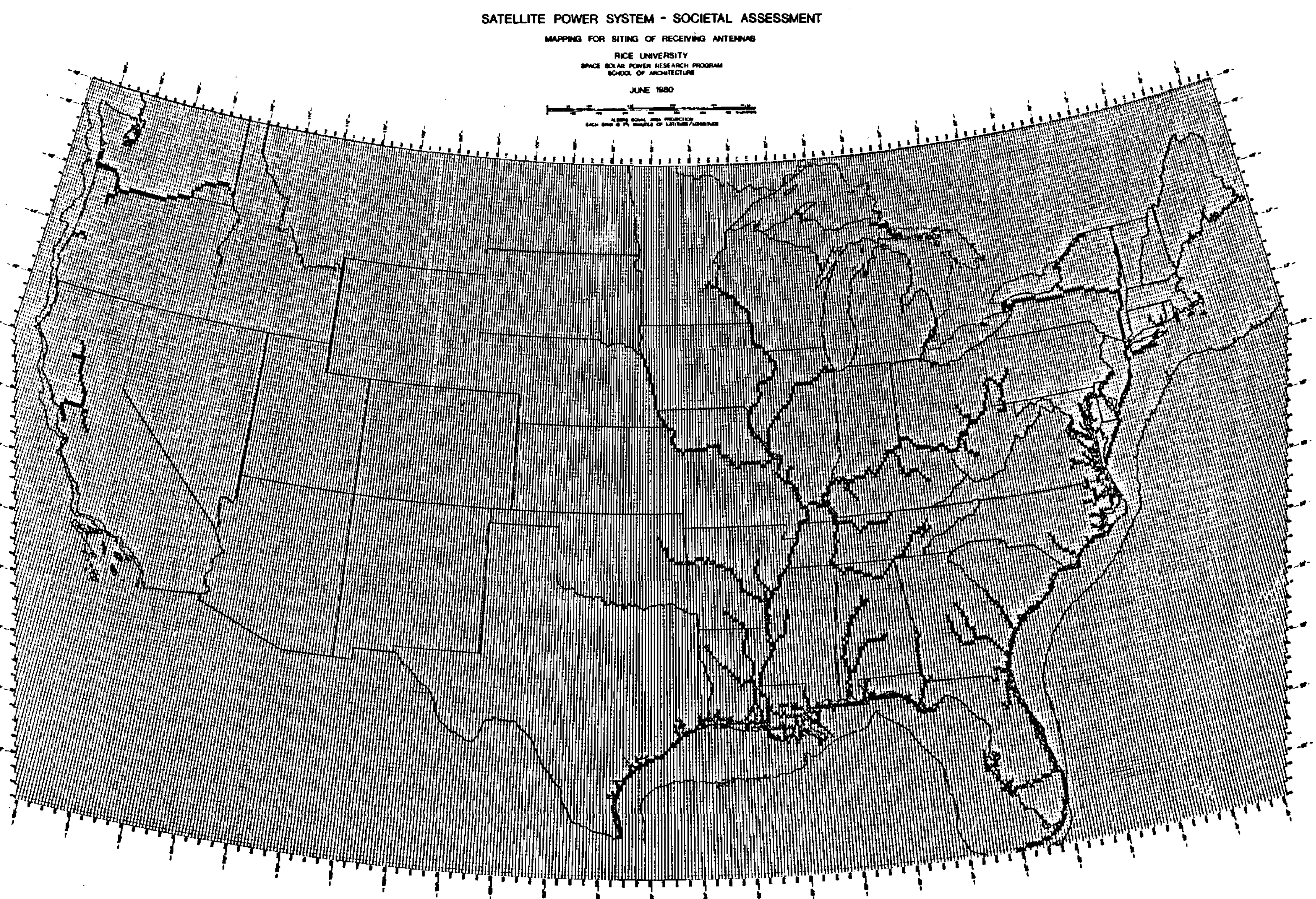


Exhibit A-14 NAVIGABLE WATERWAYS

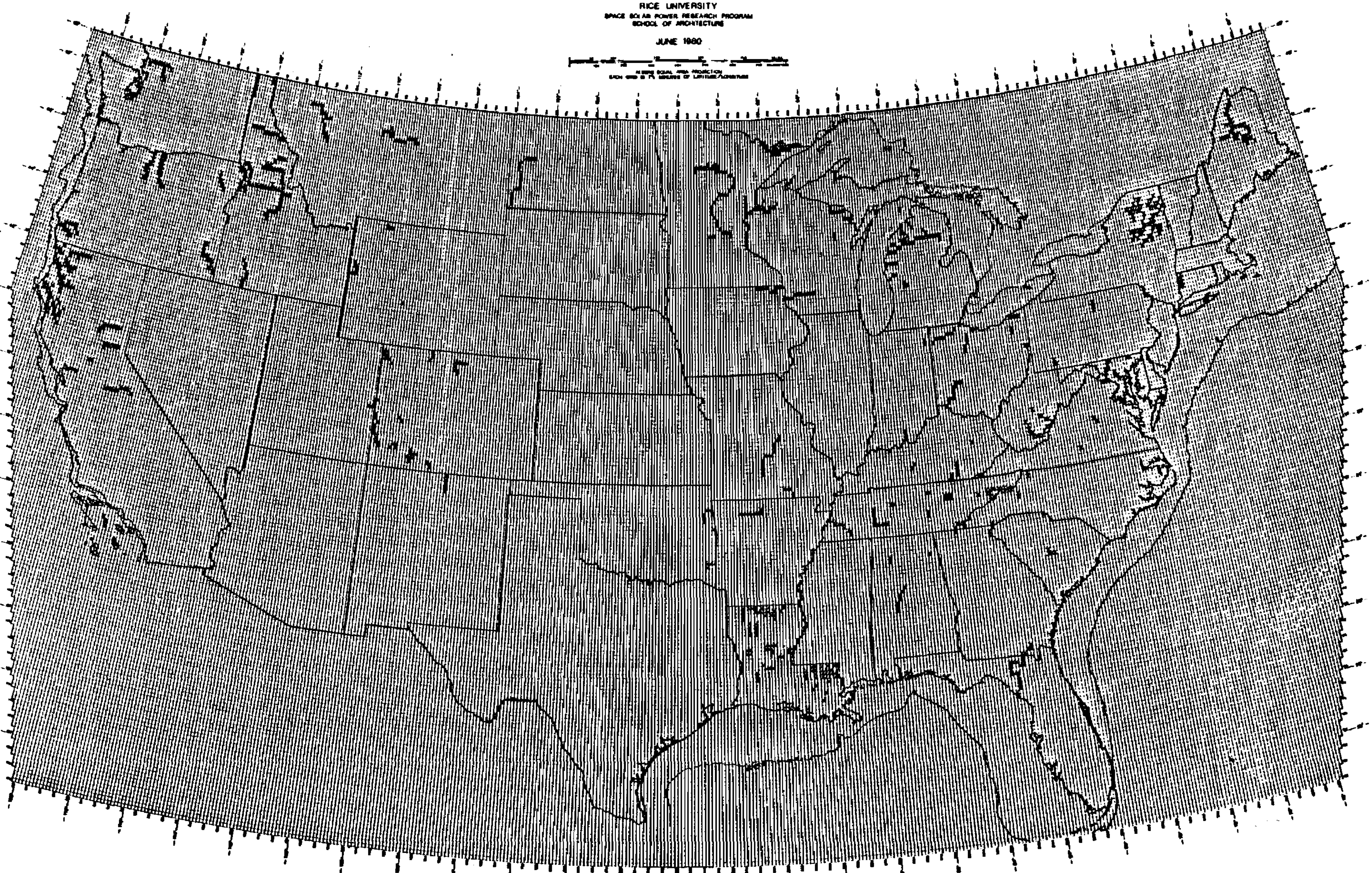


Exhibit A-15 WILD AND SCENIC RIVERS

in this study was the U.S.G.S. map titled "Major Land Uses". The irrigated farmlands are shown in Exhibit A-16 and cover 962 grid cells. The variable titled "mostly croplands" occurs in 8490 grid cells and is presented in Exhibit A-17.

A.12. FLYWAYS OF MIGRATORY WATERFOWL

The issue of microwave impacts as well as a discussion of the various flyways utilized in this study are presented in Appendix C.

A.13. TIMBERED AREAS

Timbered areas were also mapped from the U.S.G.S. map titled "Major Land Uses". Kuchler's map of "Natural Potential Vegetation" was not utilized because it is concerned with the type of vegetation that would exist absent human manipulation. For purpose of depicting coverage of timbered areas, rather than the species of vegetation, the U.S.G.S. Major Land Uses map was considered to be a more accurate source. The spatial coverage of the timbered areas variable is greater than is shown on this mapped data. However, the intent of this presentation was to show areas that were mostly timber lands. Timbered areas covered 11862 grid cells and are shown in Exhibit A-18.

A.14. TORNADO OCCURRENCE

The data concerning tornado occurrence was taken from information presented in the Climatic Atlas of the United States which identified the number of tornados occurring from 1955-1967. The data presented is considered accurate. However, a map depicting the probability of tornado occurrence or a more defined risk map would have been preferred. The information about tornados shown in Exhibit A-19 presents five incidences of tornados from 1955-1967. These were 300+ tornados (160 grid squares), 200-300 tornados (1411 grid squares), 100-200 tornados (9211 grid squares), 50-100 tornados (10618 grid squares) and 10-50 tornados (11873 grid squares).

A.15. SEISMIC RISK

The map depicting seismic risk was prepared from data presented in the Department of Energy's Energy-Environment Data Book. In this map, areas with major risks of seismic hazards and areas with moderate risks of seismic hazards are shown (Exhibit A-20). This information is considered accurate and was verified by cross-referencing a book titled Man And His Geologic Environment. 5564 grid squares were scored for major seismic risks and 25,724 grid squares were scored for moderate seismic risk.

A.16. SNOWFALL LOADING FACTORS

Snowfall loading factors were mapped from documentation provided in a book titled Time Saver Standards: A Handbook of Architectural Design Data.

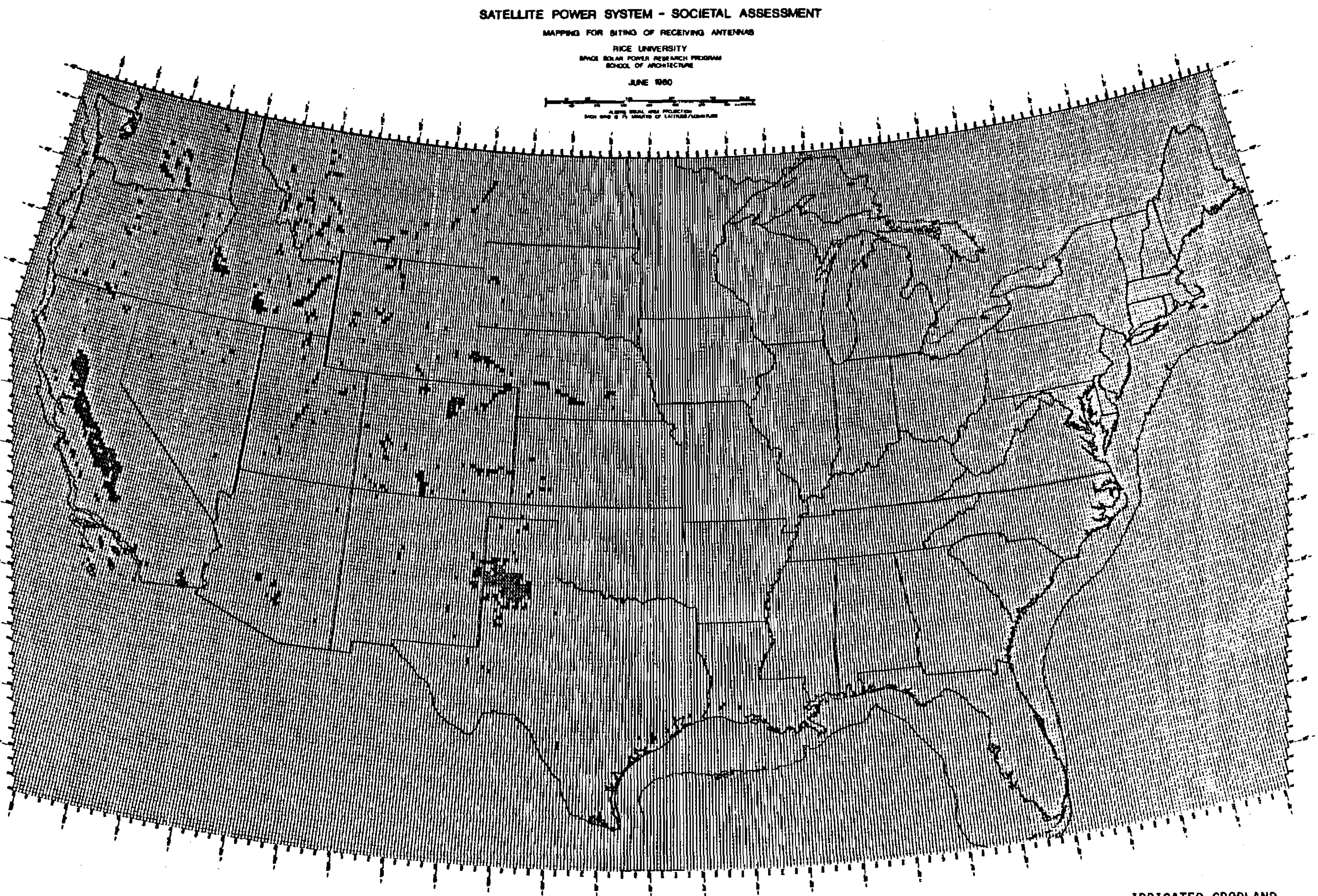


Exhibit A-16 IRRIGATED CROPLAND

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

MAPPING FOR SITING OF RECEIVING ANTENNAS

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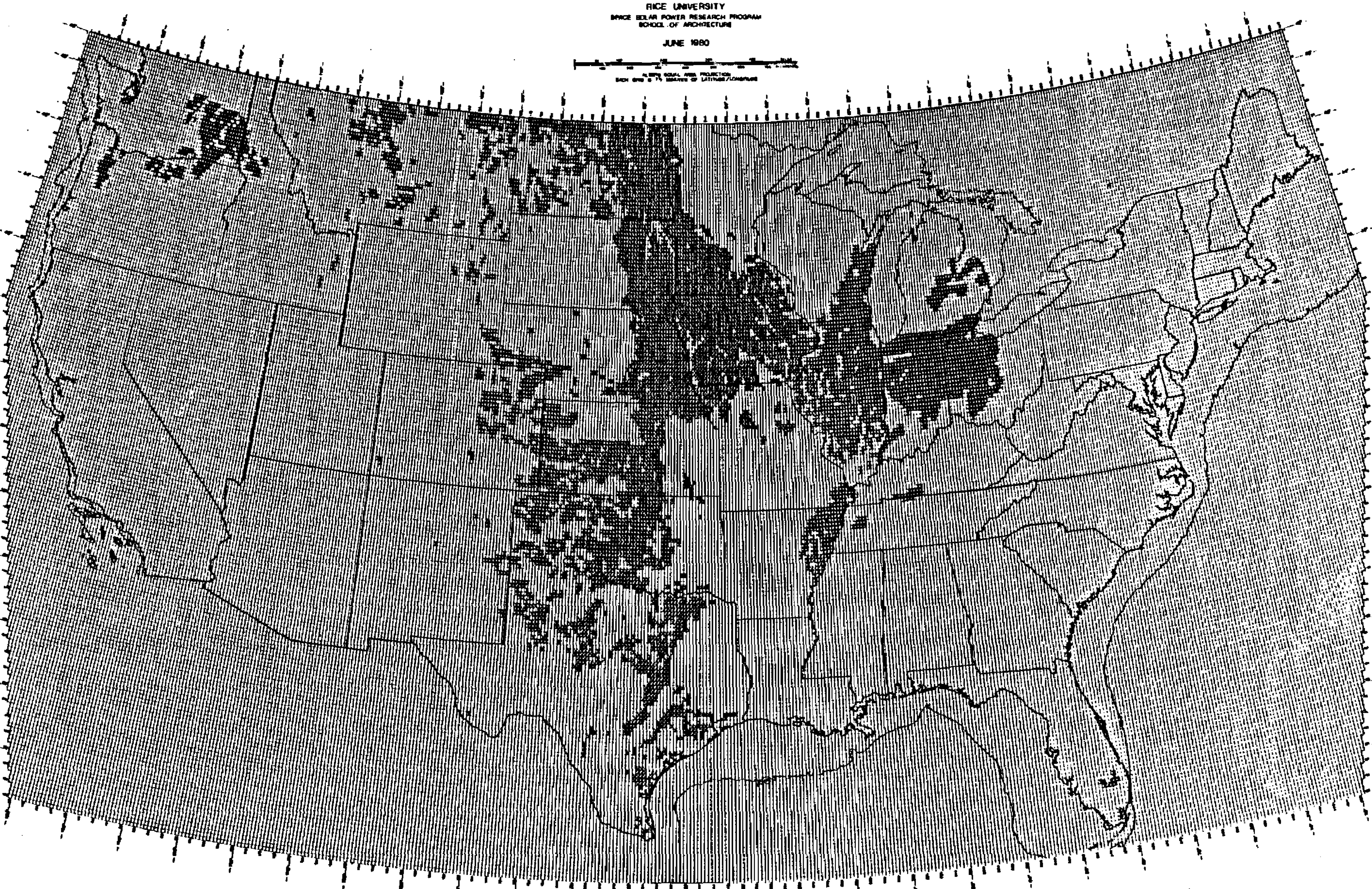

Exhibit A-17 CROPLANDS

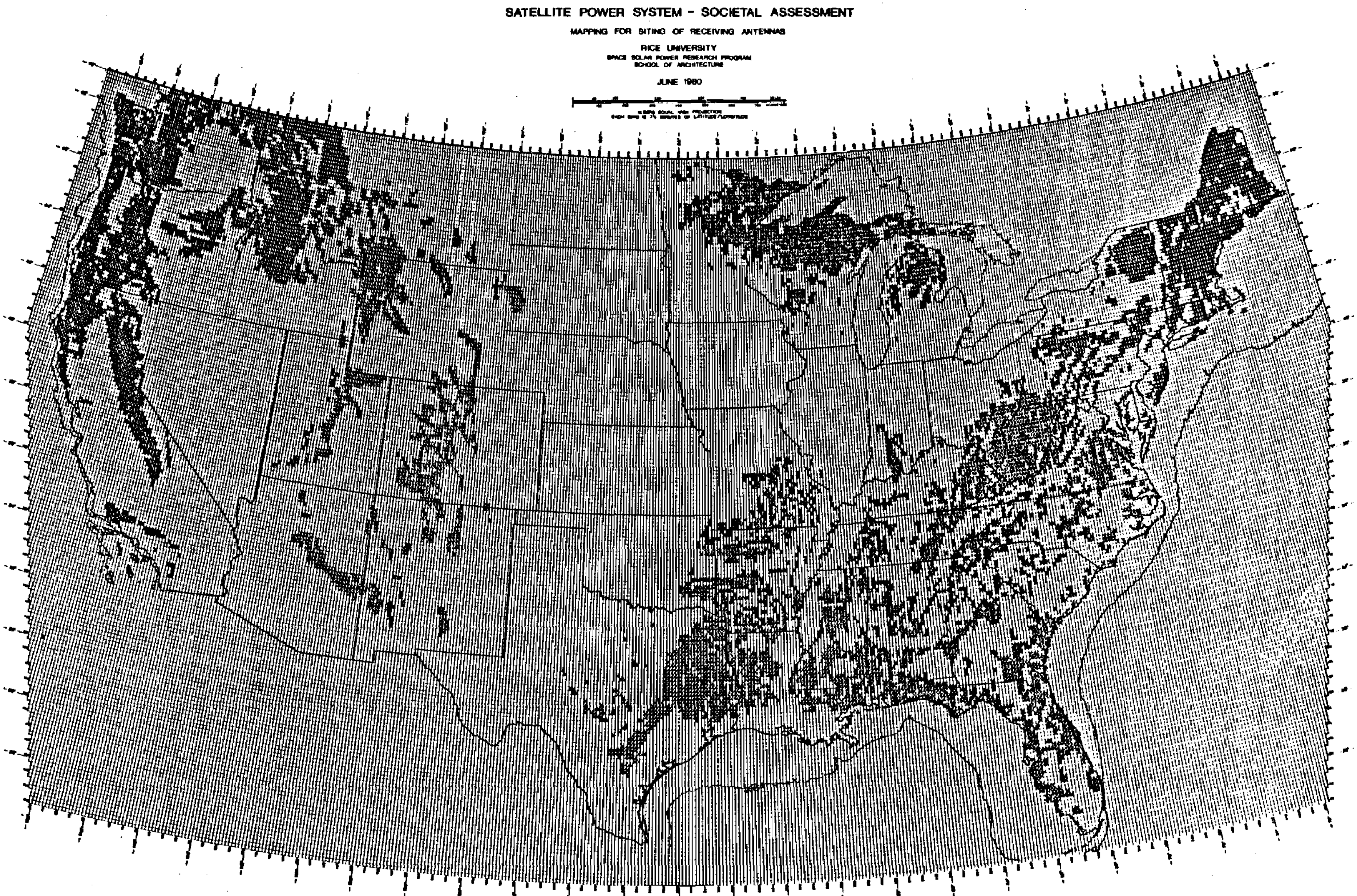

Exhibit A-18 TIMBERED AREAS

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

MAPPING FOR SITING OF RECEIVING ANTENNAS

RICE UNIVERSITY

SPACE SOLAR POWER RESEARCH PROGRAM

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JUNE 1980

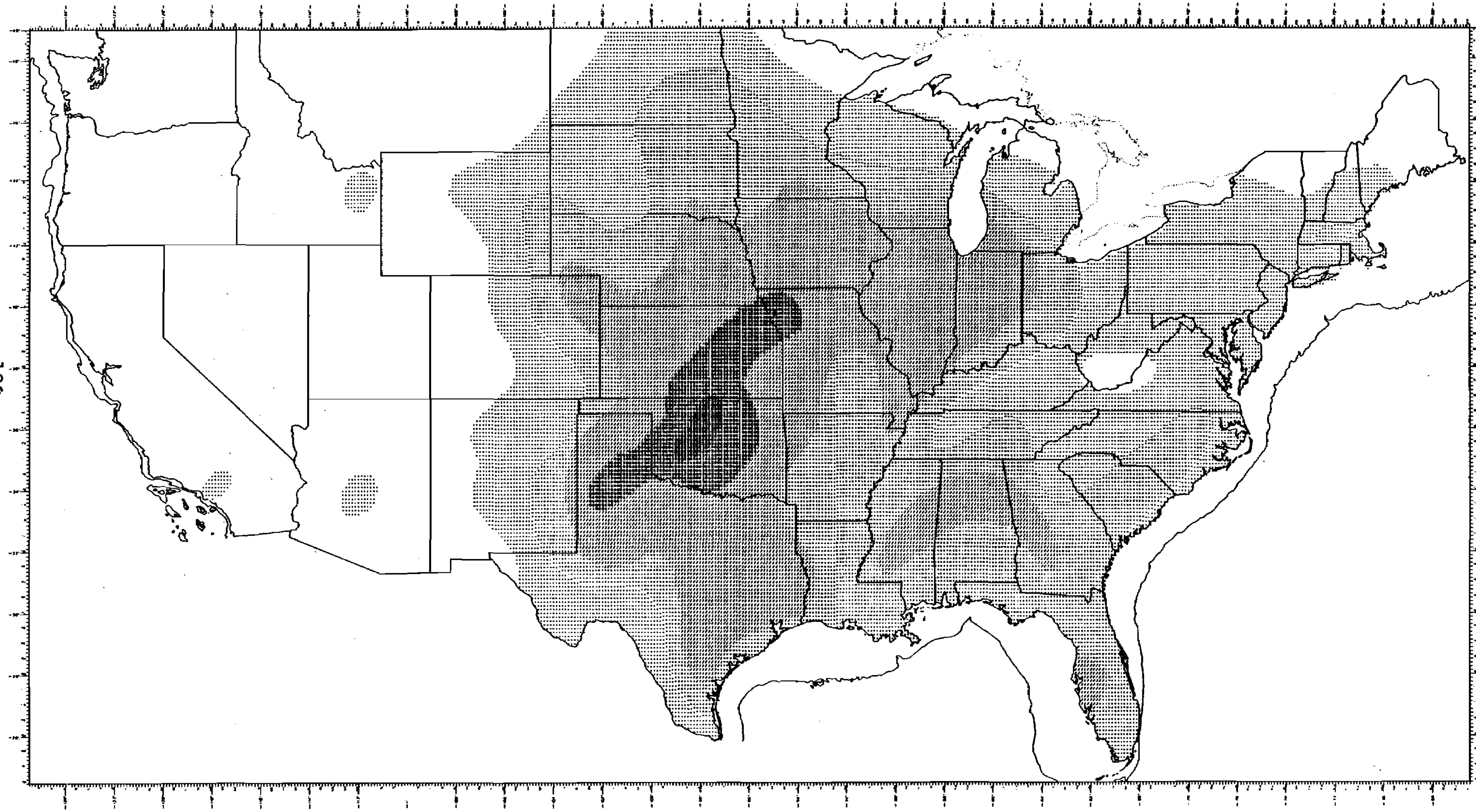

Exhibit A-19 TORONADO OCCURRENCE 1955-1967

• 10-50
= 50-100
/ 100-200
θ 200-300

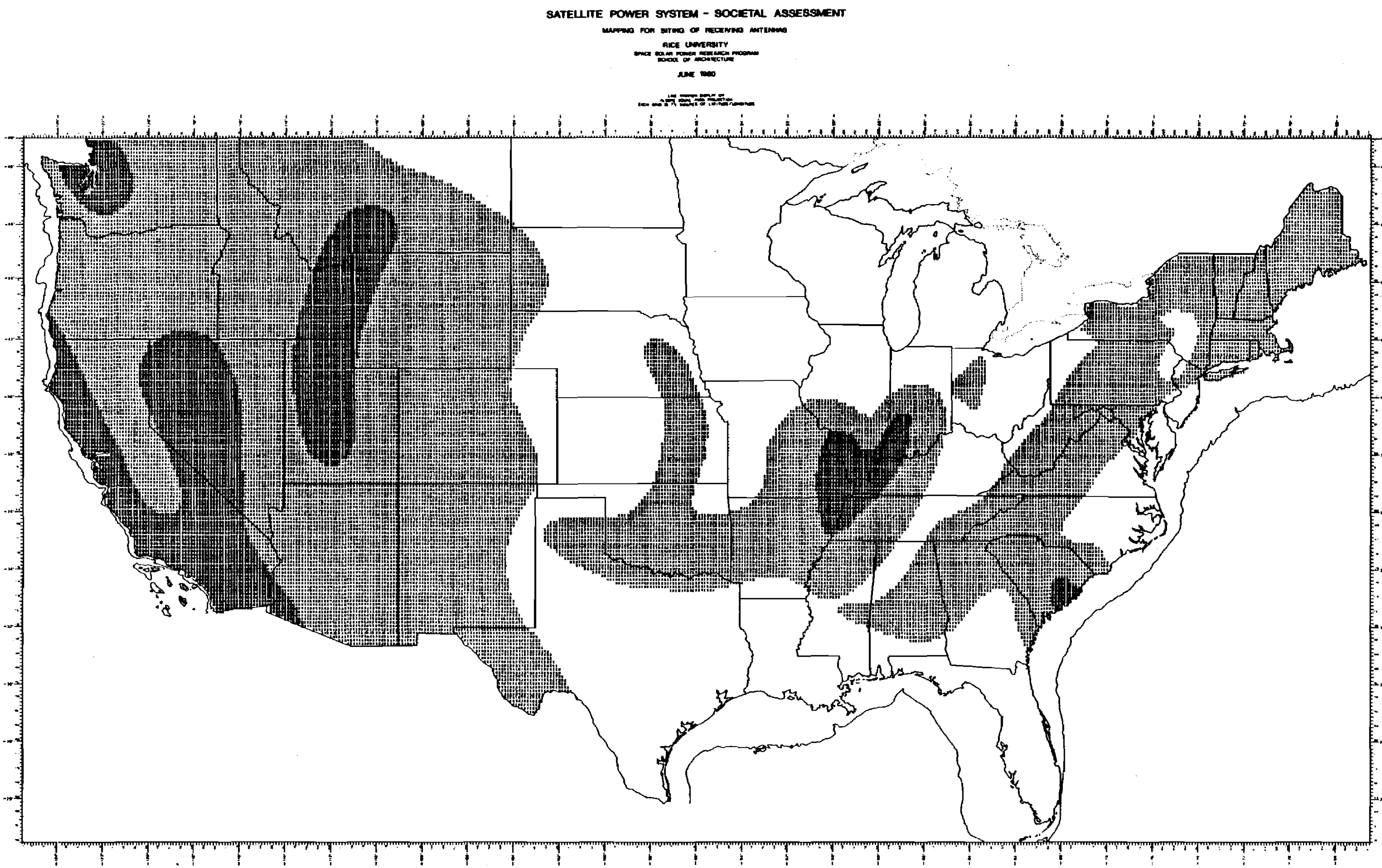

Exhibit A-20 SEISMIC HAZARDS

▮ major damage
X moderate damage

Four classifications of snowfall loading factors were mapped. These were areas with less than $10\#/ft^2$ snowfall loading factor, areas with $10\text{-}30\#/ft^2$, areas with a snowfall loading factor greater than $30\#/ft^2$ and areas where detailed site-specific analyses are required. Respectively, these four variables covered 15,604, 17,642, 4,088 and 15,145 grid squares. This mapped information is shown in Exhibit A-21.

A.17. SHEET RAINFALL

Sheet rainfall was defined in terms of amounts of rain greater than 700 gallons/square mile/year. This data was compiled from the Climatic Atlas of the United States and was mapped as a single variable. Sheet rainfall pours upon 14,147 grid squares and is shown in Exhibit A-22.

A.18. FREEZING RAINFALL

The presence of freezing rainfall was shown in two contours. These were 1-8 days of freezing rainfall and 8+ days of freezing rainfall. These data were taken from the National Atlas of the United States and are considered reliable. Freezing rainfall, 1-8 days, occurred in 31,005 grid squares, and freezing rainfall, 8+ days, occurred in 14,853 grid squares. This information is shown in Exhibit A-23.

A.19. MAXIMUM EXPECTED WINDS

The maximum expected winds, 50 year recurrence interval, were mapped from data presented in the National Atlas of the United States. These data are considered accurate, although information concerning the 100 year recurrence interval windstorms was the first choice with regard to wind data. Three windstorm levels were mapped. These were windspeeds from 70 mph to 80 mph, windspeeds from 80-90 mph and windspeeds in excess of 90 mph. These three ranges of windspeeds respectively covered 23,428, 14,344 and 1,518 grid squares and are shown on Exhibit A-24.

A.20. LIGHTNING DENSITY

Data concerning lightning density was provided by Dr. Arthur Few of Rice University. Dr. Few developed the data shown in Exhibit A-25 from raw data with interpolation of the contours from data points. The quality of the information is considered to be excellent with the only limitation being the number of recording stations for this type of information. Two densities of lightning were presented in this study. These are 10-20 flashes/km^2/year (17,358 grid squares) and 20+ flashes/km/yr (1,624 grid squares).

A.21. WATER AVAILABILITY

Data concerning water availability was secured from the U. S. Water Resources Council publication titled The Nation's Water Resources 1975-2000.

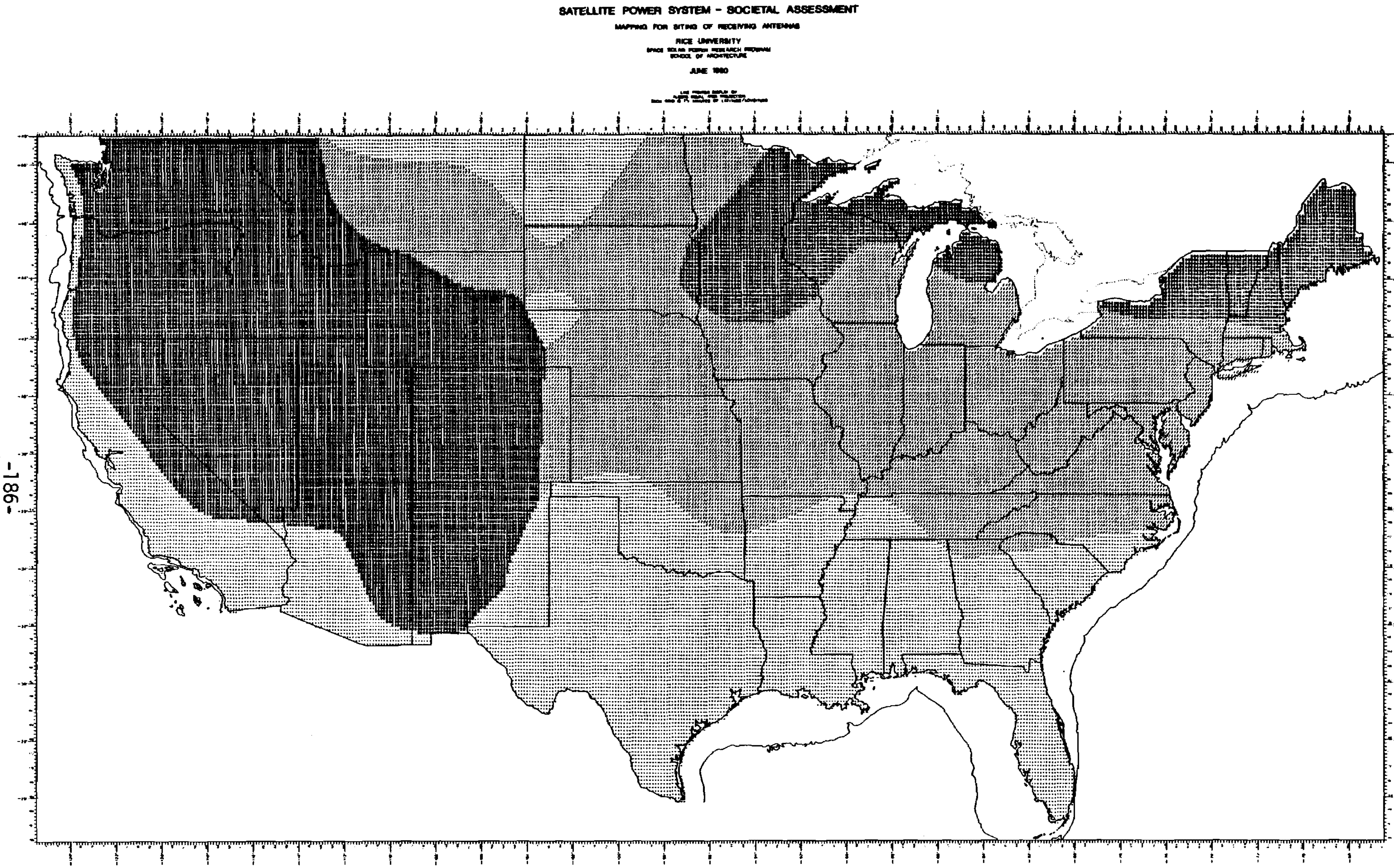

Exhibit A-21 SNOWFALL LOADING FACTOR

- • $10\#/ft^2$ or less
- / $10\#/ft^2$ - $30\#/ft^2$
- θ greater than $30\#/ft^2$
- ▮ detailed analysis required

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MAPPING FOR SITING OF RECEIVING ANTENNAS

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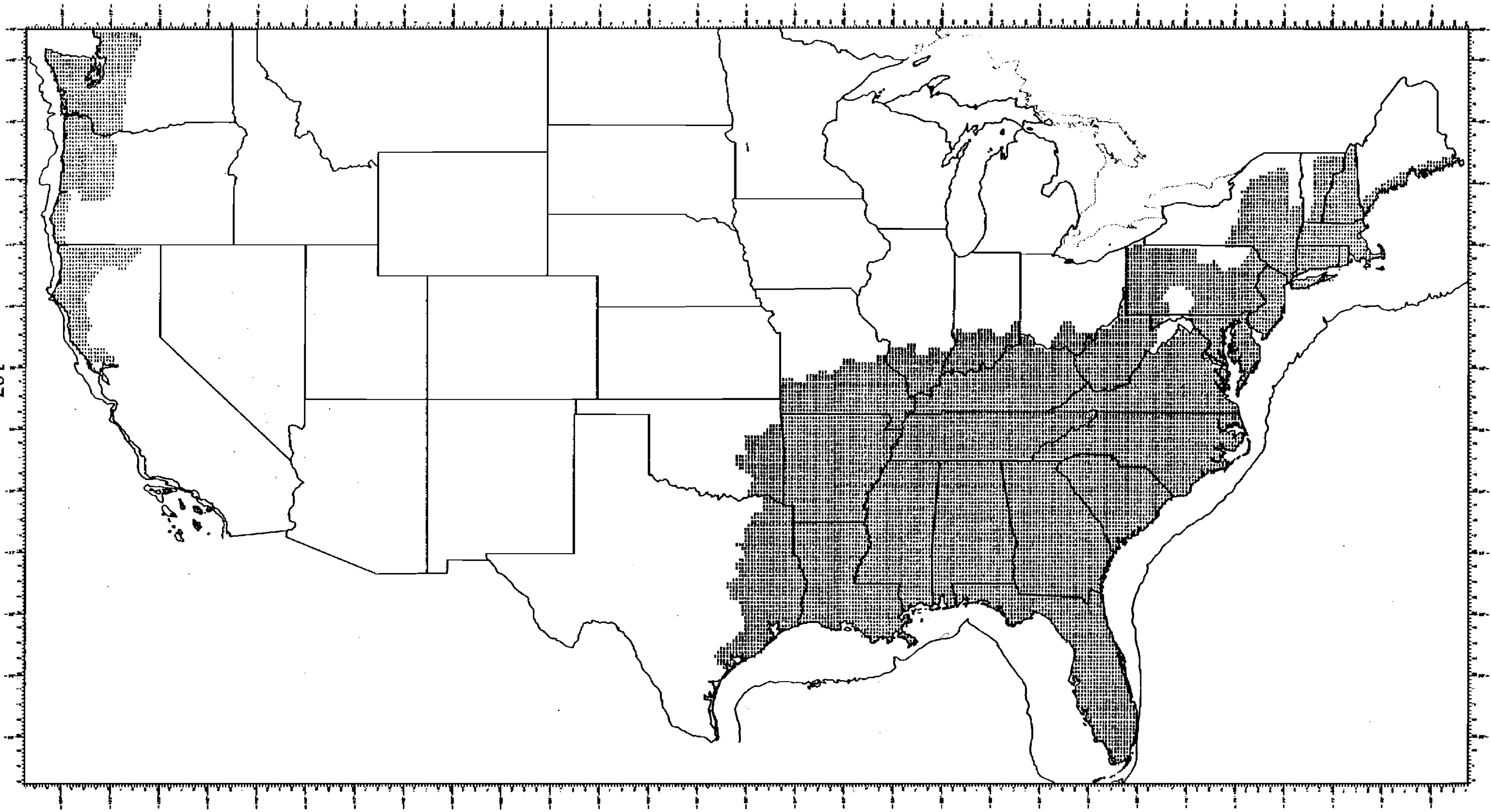

Exhibit A-22 SHEET RAINFALL

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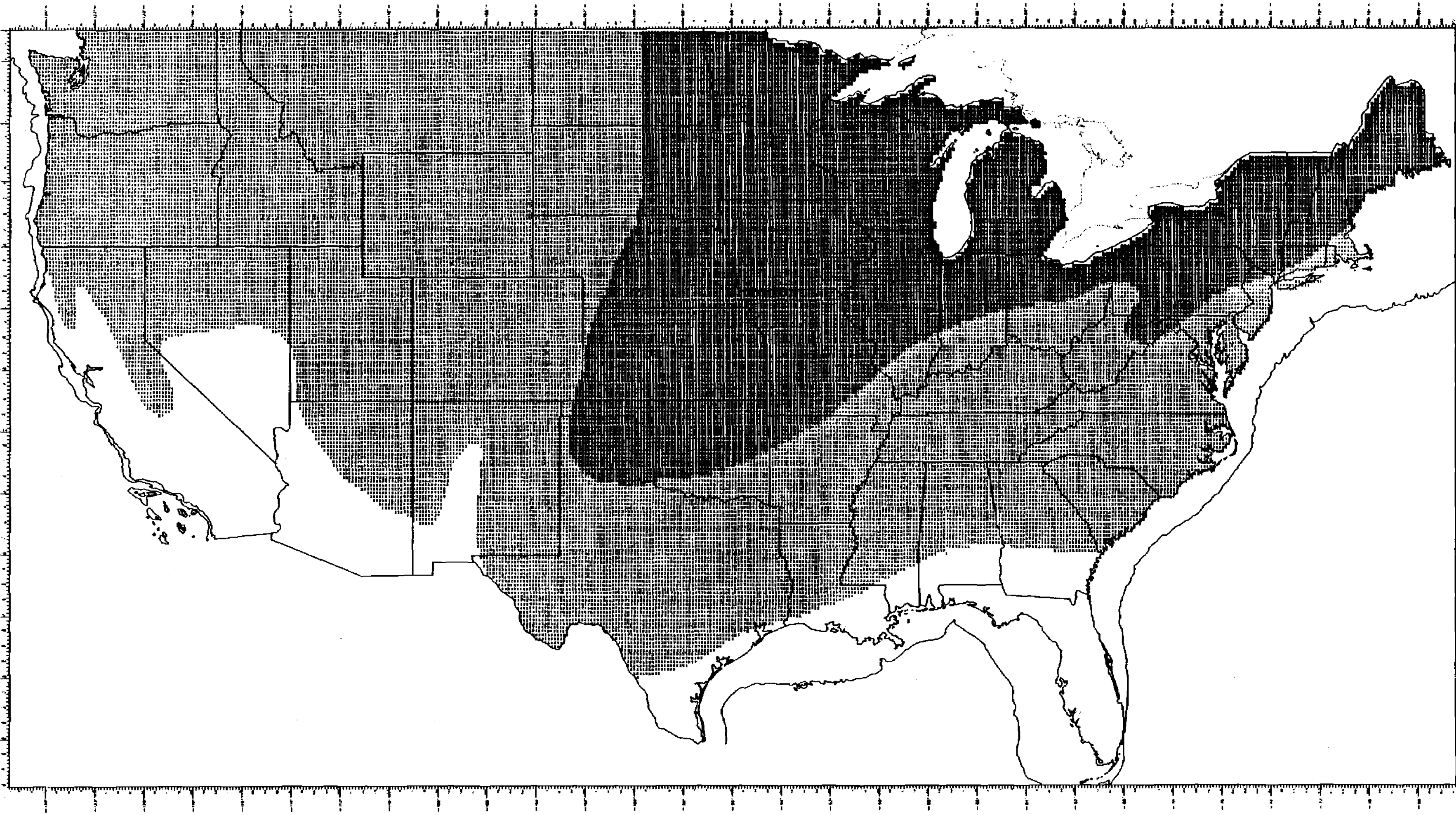

Exhibit A-23 FREEZING RAIN

█ 8+ days per year
X 1-8 days per year

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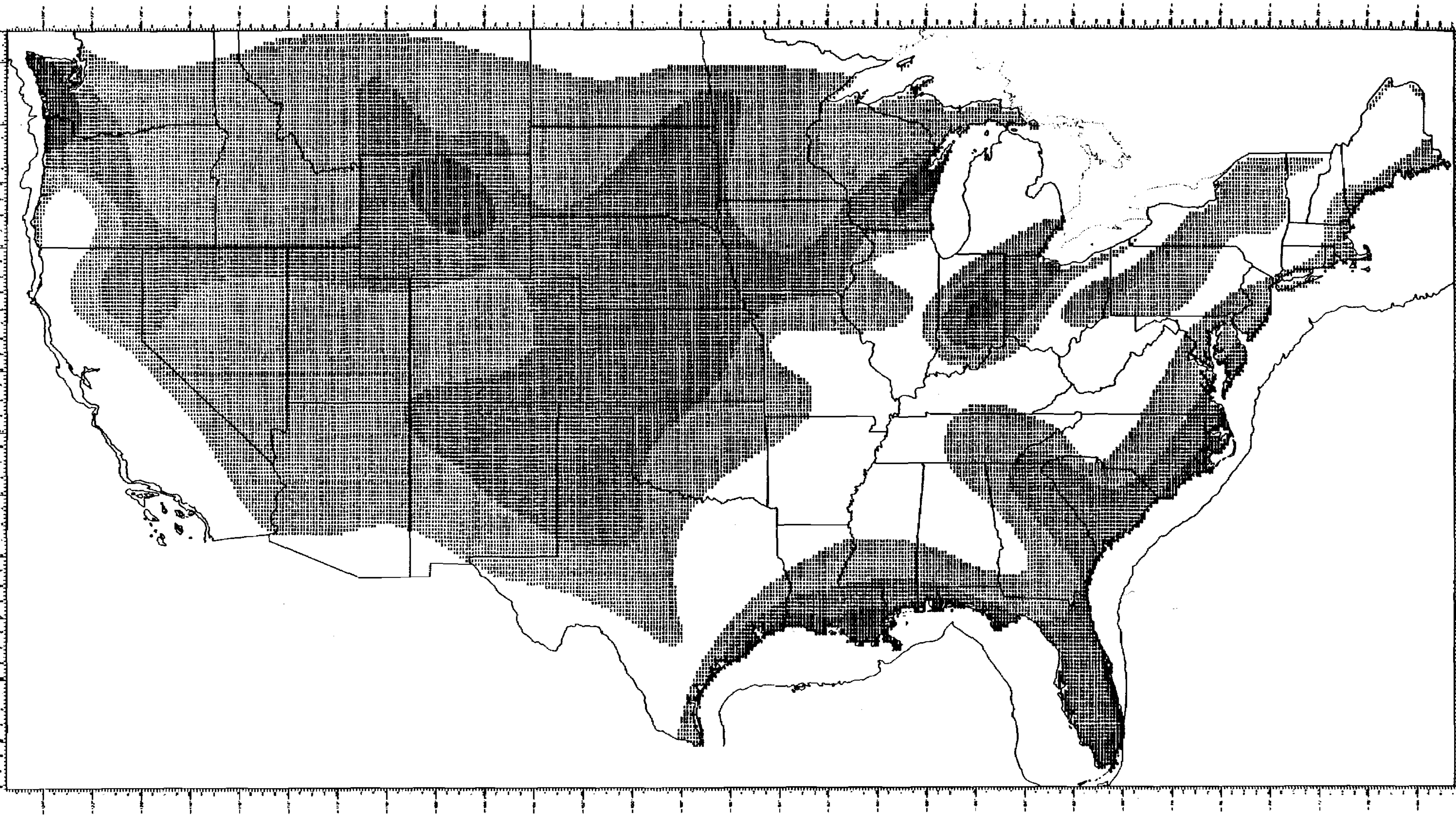

Exhibit A-24 MAXIMUM EXPECTED WINDS
50 year mean recurrence

X 70 miles per hour
θ 80 miles per hour
■ 90+ miles per hour

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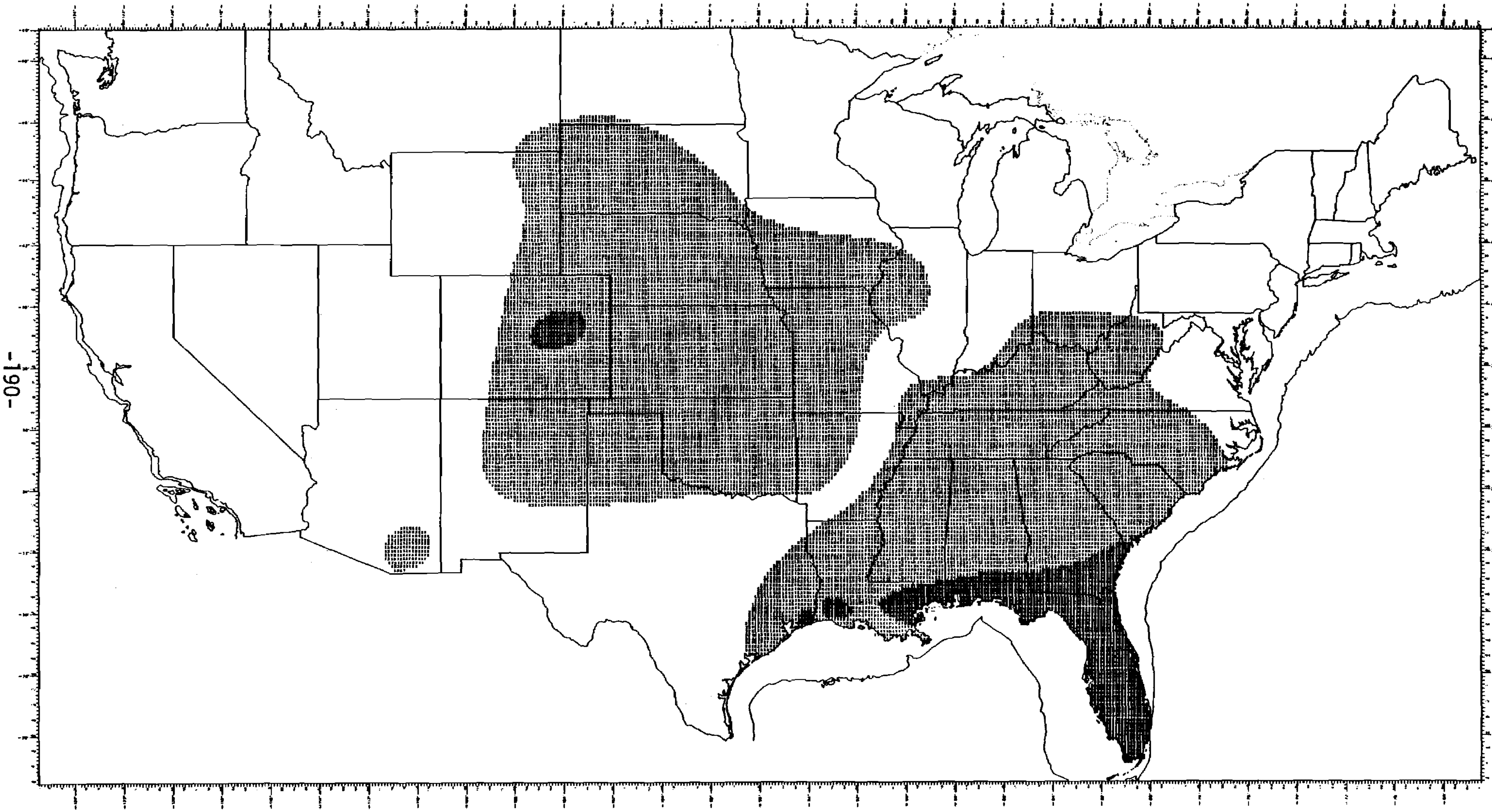

Exhibit A-25 LIGHTNING DENSITY

X 10-20 flashes per year per sq. km.
█ 20+ flashes per year per sq. km.

Three water availability variables were mapped. These were areas with groundwater overdraft problems, areas with surface water supply problems in and average year and areas with surface water supply problems in a dry year. This information is considered to be the best available indicating of water supply problems. The groundwater overdraft area covered 9,296 grid squares, the surface water supply problems in an average year occurred in 9,982 grid cells and dry year supply problems covered 4,923 grid cells. All three are shown in Exhibit A-26.

A.22. COAL

Coal resource areas were taken from mapping provided as a part of the U. S. Corps of Engineers National Waterways Study. This information is considered to be highly reliable and up to date. Coal resource areas covered 8,166 grid squares and are shown in Exhibit A-27.

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MAPPING FOR SITING OF RECEIVING ANTENNAS

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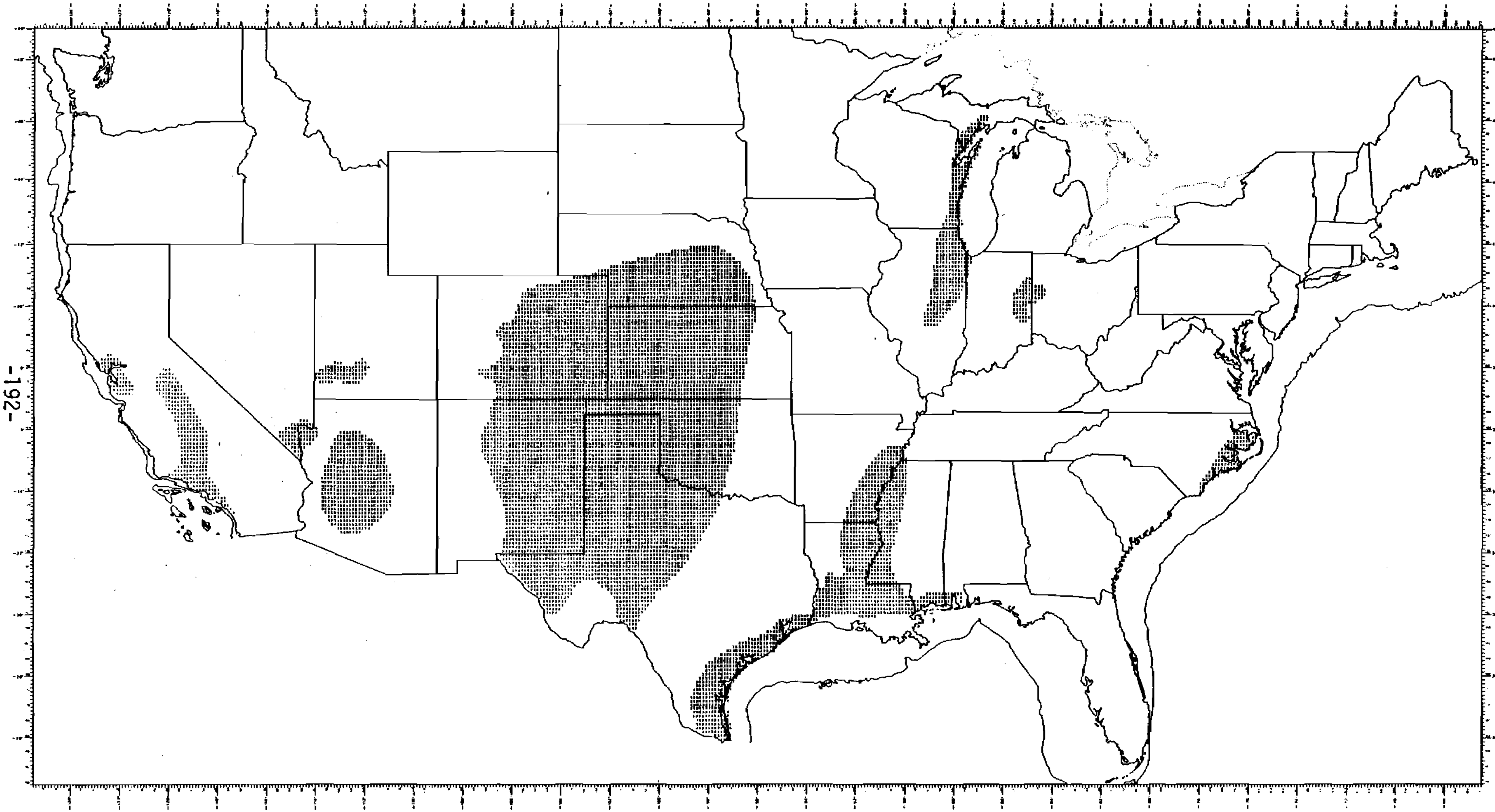

Exhibit A-26 GROUND-WATER OVERDRAFT

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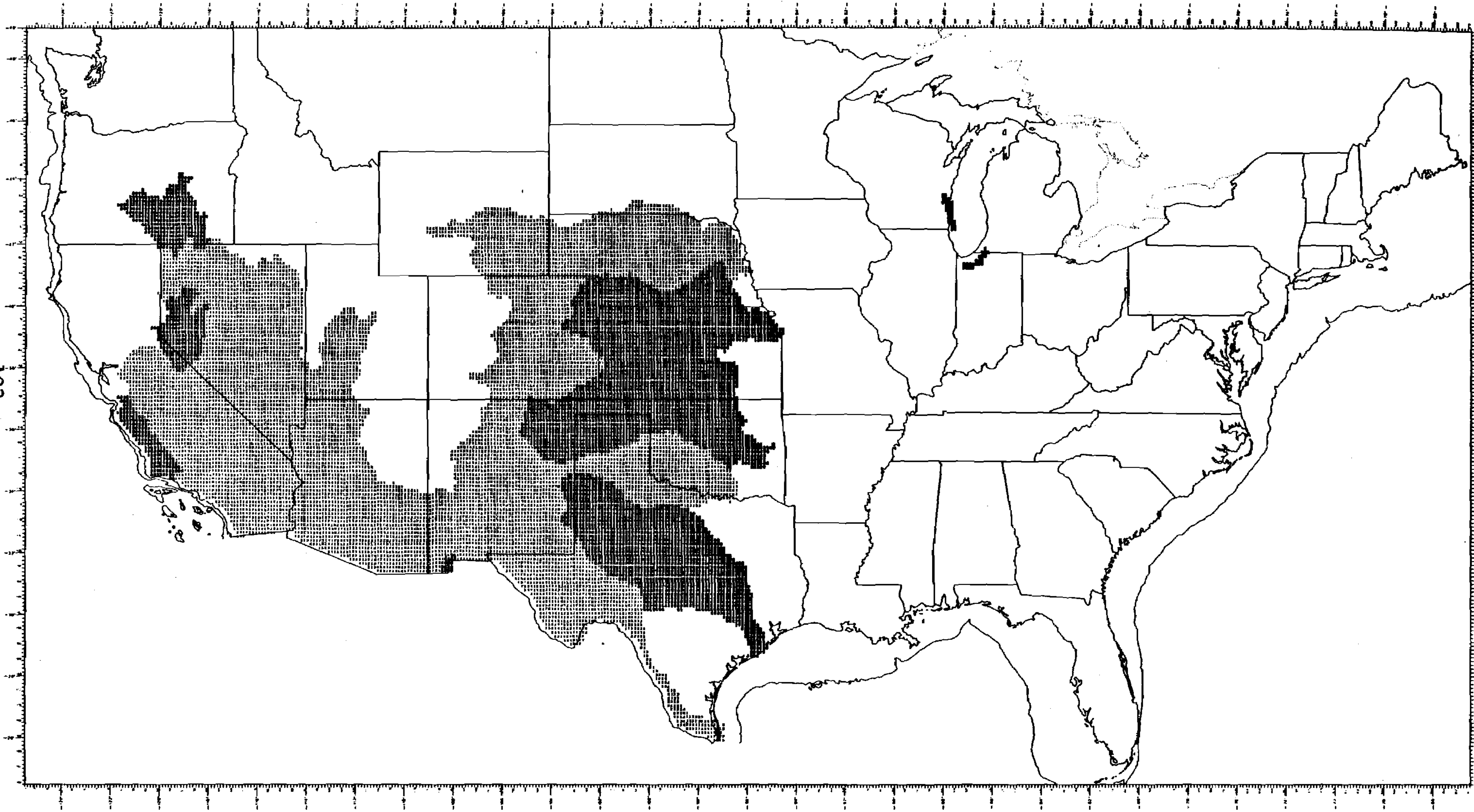

INADEQUATE SURFACE WATER SUPPLY

X 70% depleted - average year
█ 70% depleted - dry year

SATELLITE POWER SYSTEM - SOCIETAL ASSESSMENT

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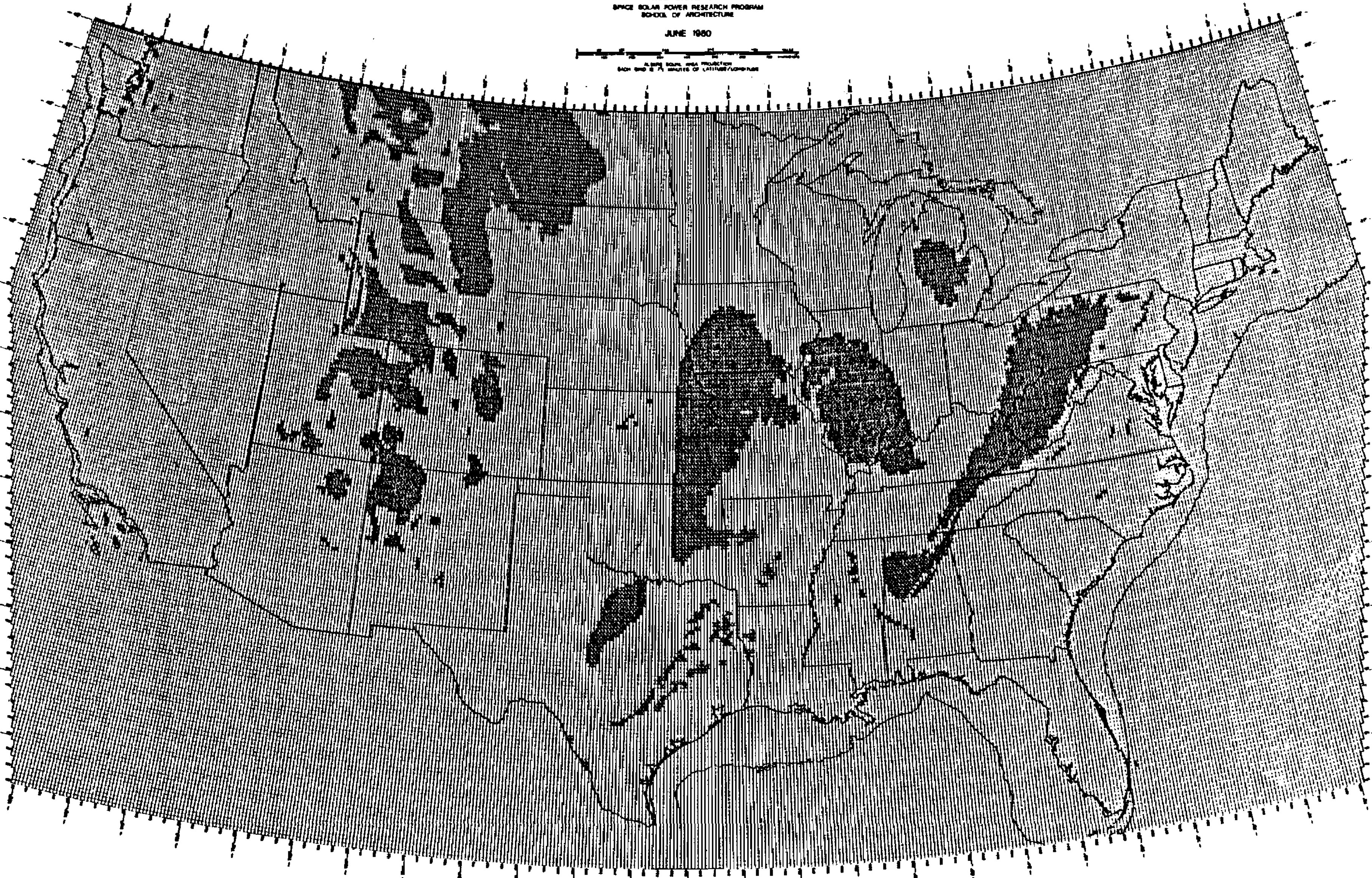


Exhibit A-27 COAL PRODUCTION AREAS

APPENDIX B: ELECTROMAGNETIC COMPATIBILITY (EMC) VARIABLES

B.A. INTRODUCTION

B.A.1. Background

The transmission of electrical energy from the Solar Power Satellite to the rectenna ground receiving station by way of microwave generates a tremendous amount of electromagnetic energy in the atmosphere, not all of which is confined to the transmission beam. The amount of energy exposure or, more accurately, microwave illumination, of the earth associated with 60 such satellites is a source of numerous potential problems. This is true, even though the beam density, i.e. the intensity of the signal, is relatively weak at 23 milliwatts per square centimeter (mW/cm^2). At the edge of the rectenna, the beam density is much weaker at 1 mW/cm^2.

The potential problems are not limited simply to users of radio frequencies at or near the proposed frequency for the microwave transmission of the SPS power (2.45 gigahertz). The exposure of a variety of equipment, much of it designed to operate on very weak electrical or radio signals, to microwave illumination may interfere with its operation. The general term covering not only radio users but other electrical equipment effected by this type of exposure to microwave energy, is electromagnetic compatibility, hereinafter abbreviated as EMC.

EMC problems exist with respect to: radio communications transmissions in a variety of civilian and military applications; sensing equipment used in industrial, medical and nuclear processing facilities; and remote control equipment in which sensors and control mechanisms are operated over long distances.

The full extent of potential EMC problems and, more important, the uncertainties surrounding them, represent technical issues well beyond the scope of this study. Fortunately, a parallel DOE-sponsored research effort is now under way to examine SPS EMC effects at the Institute for Telecommunications Sciences (ITS) in Boulder, Colorado under contract to Argonne National Laboratories. Since the objective of this study is simply to identify siting constraints, there has been no independent evaluation of EMC effects in this study, nor has there been any attempt to review literature or findings other than those provided by ITS.

The exclusion variables developed from the analysis of EMC problems differ in several important respects from other exclusion variables in this analysis. Because of the highly technical nature of this subject and the fact that it is being independently studied elsewhere in the SPS evaluation effort, there has been no attempt in this case to independently validate the accuracy of the input. Where for most other variables, the research team has sought to identify and check the accuracy and reliability of input, the technical nature of this problem precluded such an independent check and instead forced almost complete reliance on a single outside source.

An equally important distinction between EMC variables and other variables in this analysis concerns their geographic coverage. For all other variables a boundary condition showing the extent of the exclusion variable and therefore the extent of the exclusion area was essentially defined by the presence or absence of this particular condition. In the case of EMC variables because the propagation of radio energy over wide distances, the actual boundary of the effect is a radius or circle around the actual facility. For example, a particularly sensitive communication facility may occupy only a single grid square on the map. If, however, in the opinion of ITS, the required separation between this sensitive communication facility and the nearest rectenna was 60 kilometers, then the excluded area for rectenna locations would not be simply the grid square in which the communications facility was located but rather a circle with a radius of 60 kilometers (approximately 5 grid squares around the actual location). This effect, particularly in situations where the required separation is 100-150 kilometers, creates large and regularly shaped excluded areas around sensitive facilities that would be adversely affected by microwave exposure. Among other things, this creates a distinctly different visual profile of EMC exclusion than for the exclusion areas for other variables. Also it tends to give EMC exclusion variables an impact far out of proportion to the actual land area occupied by the affected facilities.

B.A.2. Methodology

B.A.2.a. Exclusion Criteria Definition

The primary objective of this study was to organize the widely varied EMC effects into a manageable number of exclusion variable categories. Two major factors controlling the definition of such categories were:

1. The distance (separation) between the affected facility and the rectenna.
2. The severity or, alternatively stated, the potential for mitigation of the adverse effect.

Because there is such a wide range of effective uses, no attempt was made to categorize each potential use, e.g. civilian communications, military communications, transportation communications and control, as an exclusion variable. Instead a series of general classes of EMC use were examined and a framework was derived in which a simple two-way classification could be applied.

With respect to distance, four categories were established based on information provided by ITS. These represented separation of the affected facility from the nearest rectenna by distances of 50 kilometers, 60 kilometers, 100 kilometers and 150 kilometers.

The categorization with respect to severity or mitigatability of impact was much more difficult. In order to maintain consistency with other parts of the analysis, the distinction between "absolute" and "potential" exclusion variables was maintained. The basic assumption was that due to the substantial lead time between now and the time at which the SPS will be developed, there would be ample opportunity for technical and physical mitigation on many of the adverse effects. Among the types of mitigation available are the installation of small metal screens above the affected equipment, the installation of filters in radio equipment, and minor redesign of the equipment to minimize its exposure or sensitivity to microwave illumination in the relevant frequency spectrum of the SPS. Consequently, the default condition was that all EMC variables are to be considered as potential exclusions because of the extended opportunities for mitigation and/or because the adversely effected use or facility was not intimately involved with human life, human safety, or with activities essential to the proper functioning of the national economy or the preservation of national security.

In general, those EMC variables classified as "absolute" exclusions were limited to:

1. Situations, primarily involving military communications in control, where any attempts to significantly mitigate the adverse impacts of the microwave illumination would impair the effectiveness and reliability of the military operation or testing procedure involved.

2. Situations in which there was significant opportunity for mitigation but where the risks associated with even a trivial increase in the probability of failure were unacceptable, e.g. nuclear power plants and nuclear processing facilities.

B.A.2.b. Classifications of Affected Facilities

The analysis of the general areas in which facilities would be affected by microwave radiation was developed in the form of 6 general categories by ITS:

1. Military operational testing and evaluation.

2. Military developmental testing and evaluation.

3. Military operations.

4. Transportation (civilian).

5. Sensitive facilities (civilian), specifically including nuclear power plants and nuclear processing facilities.

6. Special research facilities, e.g. radio and optical astronomy, and space communications (civilian).

In each of these six classes specific types of facilities affected by microwave radiation were identified and categorized as to severity and distance.

B.A.2.c. Mapping Procedure

For all of the affected military installations, precise location and/or boundaries of affected areas were provided by Mr. E.L. Morrison of ITS. Mr. Morrison was also the source for locations of most of the special research and civilian space communications facilities. The nuclear power plants were mapped by the research team from a list provided by the Nuclear Regulatory Commission. Unfortunately this list indicated only the county. Plotting locations to the nearest grid square required individual verification through telephone calls and larger scale maps. In the area of civilians communications and transportation, the sensitive radar facilities maintained by the FAA for civil air transport were transferred from an FAA map provided by ITS.

B.A.3. Limitations of Analysis

Perhaps the most significant limitation of this analysis is the fact that the microwave impact or EMC effects of multiple SPS transmissions are larger than and different from the effects of a single SPS microwave transmission. This interactive effect is being separately studied under the sponsorship of ITS and is not being considered in this analysis.

Another limitation is that detailed consideration of side lobe effects, i.e. individual points at specified distances from the beam center at which beam intensity increases sharply over a small space, have not been considered in this analysis.

A third and final important qualification is, in part, a restatement of the major difference between this analysis and the analysis of all other exclusion variables. In this instance, the identification of exclusion variables and their classification as between "absolute" and "potential" was not based on any independent research but reflected the judgement of another group investigating the SPS from a different point of view.

B.B. CLASSES OF AFFECTED FACILITIES

B.B.1. Military Operation Testing and Evaluation

This general category of affected facilities refers to facilities used in military exercises for already operational equipment. The testing and evaluation is related to readiness and to personnel and should be distinguished sharply from developmental testing and evaluation which is related to the development process of weapons and defense systems before they are fully operational.

Within this general category of facilities, there are specific functions or sub-facilities including monitoring, tactics, safety, and command and control. In each of these areas there are the specific systems or functions that are involved in the exercises conducted as part of operational testing and evaluation. Much of this testing and evaluation is heavily involved with electronic communication, electronic detection, and electronic countermeasures, all of which operate over a wide range of the electromagnetic spectrum. There is a high degree of sensitivity to microwave illumination from the SPS.

Of particular importance in this group or class of facilities is the fact that the mitigation necessary to eliminate adverse effects from SPS microwave illumination would itself impair the accuracy and reliability of many of the sensitive detection mechanisms. To this extent, the effects are considered unmitigatable and the categorization of exclusion is considered as "absolute" because of the critical importance of these type of exercises to national security, according to ITS.

The result of this, as shown in Exhibit B-1, is that all affected facilities, including the air space involved in approaching or leaving these areas (egress/ingress zone), represents an exclusion area for not only the facility itself but for 150 kilometers around it. Hence its classification as an "A-150" exclusion variable.

B.B.2. Military Development Testing and Evaluation

As shown in Exhibit B-2, there are two major aspects of military development testing and evaluation which may be adversely affected. One is safety and the other is command and control systems. The monitoring of air space and telemetry, i.e. the transmission of data from one point to another, are important areas potentially affected by microwave radiation. The air space monitoring effects have a sensitive distance of approximately 60 kilometers and hence are classified as potential 60 or P-60 exclusion variables. The air space corridors involved for command and control have a slightly larger sensitive area (60 kilometers) and hence are classified as potential-60 or P-60 exclusion variables.

According to ITS, the primary distinction between military developmental testing and evaluation as opposed to operational testing and evaluation is that the mitigating steps required for minimizing adverse impacts of microwave illumination can be identified and adjusted for in a developmental environment where one is not trying to simulate so consistently in real time the random and deliberately confusing characteristics associated with operational testing or war games. Furthermore, national security is marginally less sensitive to compromises made in developmental process than it is to any compromises in their periodic exercising for operational training.

B.B.3. Military Operations

Military operations, particularly the Air Force and Air Defense Systems, rely heavily on radio communications, many of them in a frequency range specifically sensitive to (harmonics of) the proposed SPS frequency of 2.45 gigahertz.

EXHIBIT B-1

DERIVATION OF EMC EXCLUSION VARIABLES:
MILITARY OPERATIONS/TESTING & EVALUATION

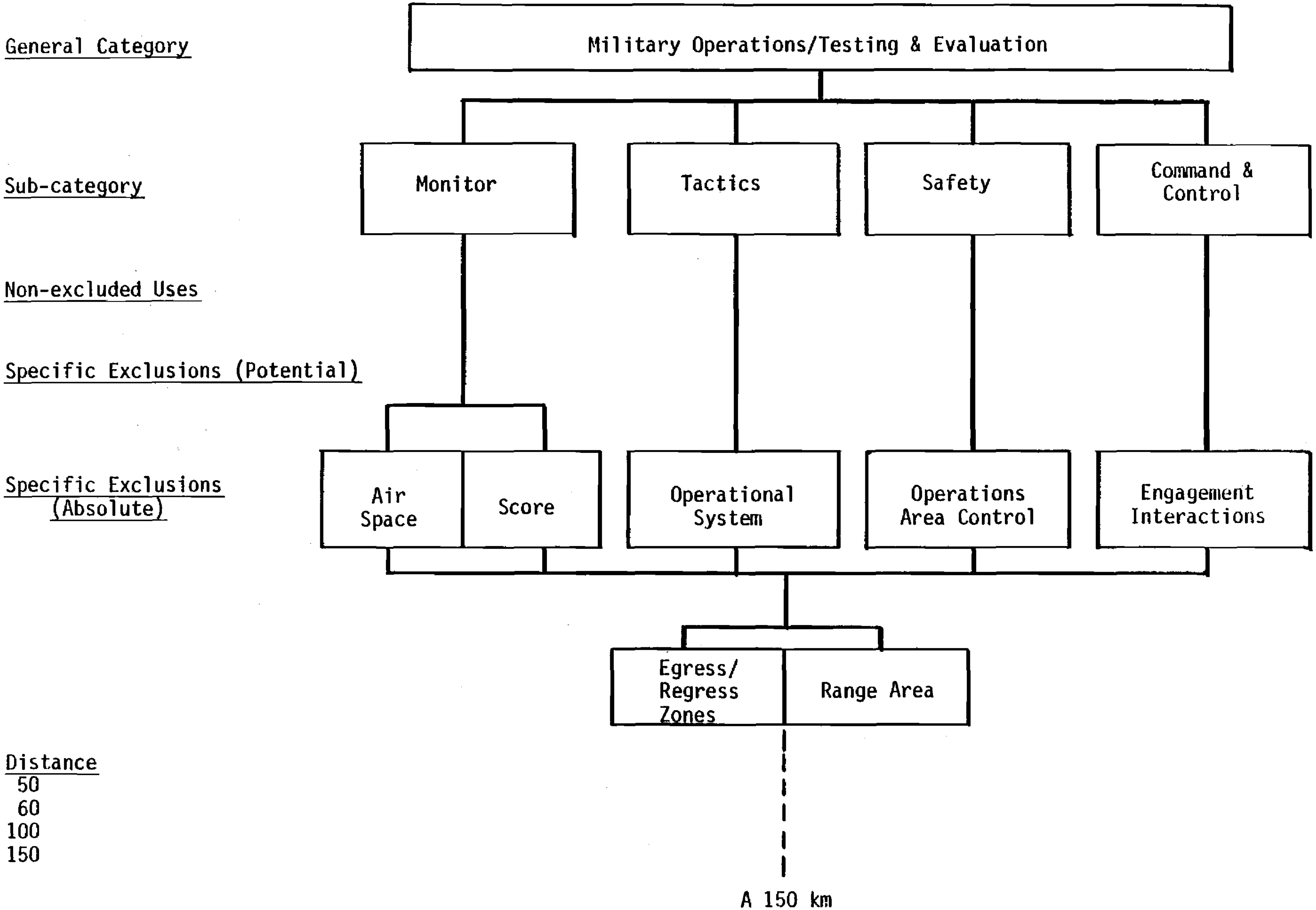
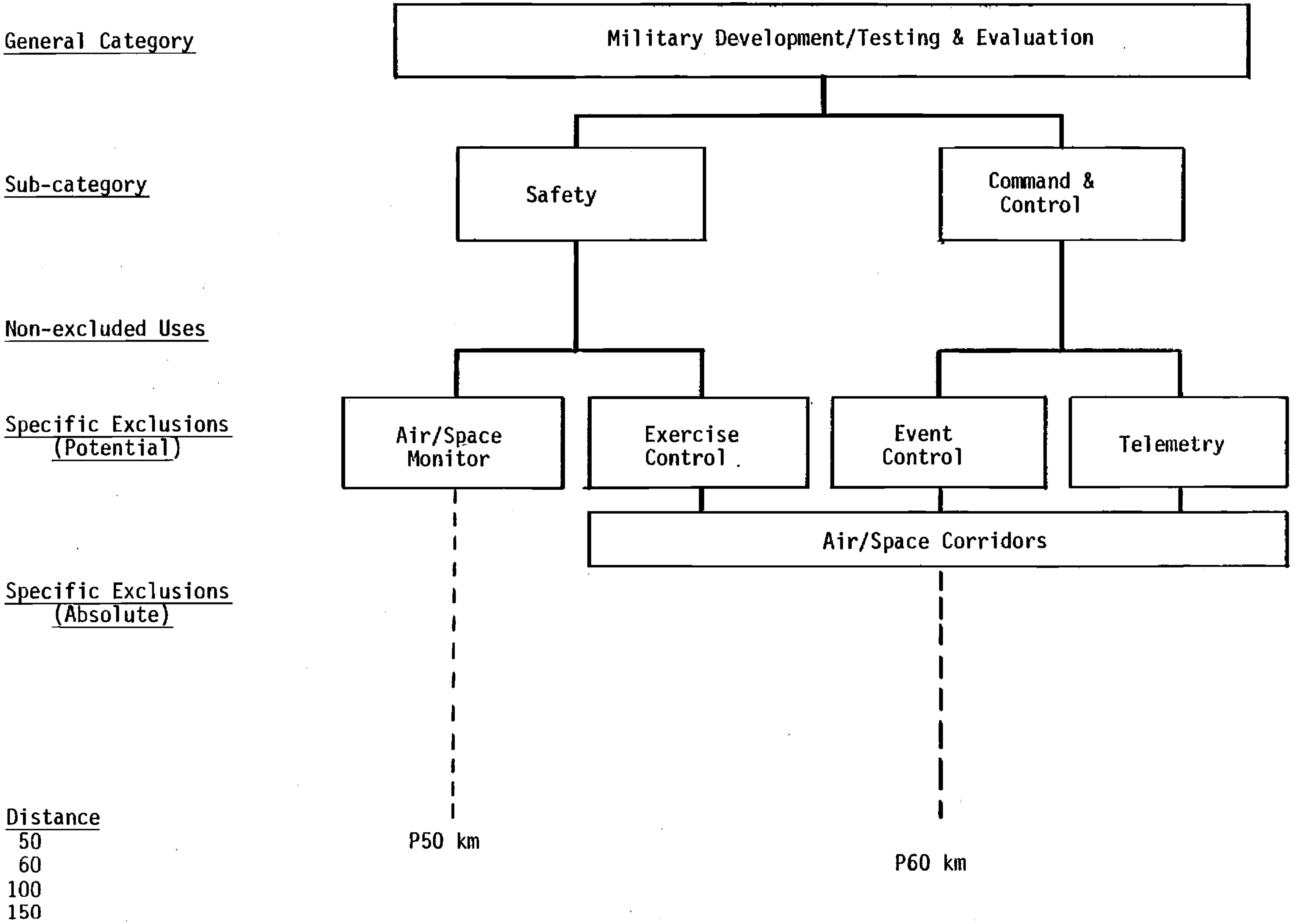


EXHIBIT B-2

DERIVATION OF EMC EXCLUSION VARIABLES:
MILITARY DEVELOPMENT/TESTING & EVALUATION



As shown in Exhibit B-3, ballistic missile defense systems and air defense in general are particularly sensitive with respect to monitoring and control systems. Consequently these two types of facilities are considered absolute exclusion variables over a radius of 100 kilometers around them.

Military space communications, while critical, do have some opportunities for redundancy and mitigation. Also space communication facilities are not sensitive over such a wide distance. Consequently, military space communications facilities are classified as P-50 variables representing potential exclusions over a radius of 50 kilometers.

B.B.4. Transportation (Civilian)

Within the general field of civilian transportation, safety systems and command and control systems are of particular interest. For each of those, there are two major sub-groups, air traffic control, and urban mass transit operation monitoring and remote sensing. This refers to the wide monopoly of communication and sensing equipment that permits modern mass transit systems, e.g. subways to be remotely controlled and directed and to have automatic sensing and failsafe mechanisms.

As shown in Exhibit B-4 the only one of this group that represents an exclusion criteria in and of itself is the FAA radar maintained for air traffic control. These represent potential exclusions because the opportunities for mitigation and redesign over the lead time of SPS and also due to the fact that there are extensive opportunities for redundancy. Consequently these are classified as potential-60 or P-60 exclusion variables. Urban mass transit sensing and safety mechanisms would also be of considerable interest. They are not, however, independently classified as exclusion areas, since urban areas defined very broadly are already an absolute exclusion variable. The geographic effect or sensitivity of such urban mass transit systems would be fully accounted for within the already very generous definition of population exclusion employed in the analysis.

B.B.5. Sensitive Facilities

The use and control of nuclear materials either for the generation of power, the reprocessing of spent fuel, or research, involves a variety of sensing mechanisms designed to detect extremely low intensities of radiation in the electromagnetic spectrum both of the non-ionizing and ionizing type. These include infrared sensors, photo multipliers, digital control devices and a variety of other technical elements which can be adversely affected by microwave illumination.

While there exists substantial opportunities for mitigation, any increase in the risk of operation associated with nuclear power plant, no matter how small, was deemed by ITS to be totally unacceptable and therefore to be classified as an absolute exclusion variable. Consequently, every nuclear power plant in the United States, both

EXHIBIT B-3

DERIVATION OF EMC EXCLUSION VARIABLES: MILITARY OPERATIONS

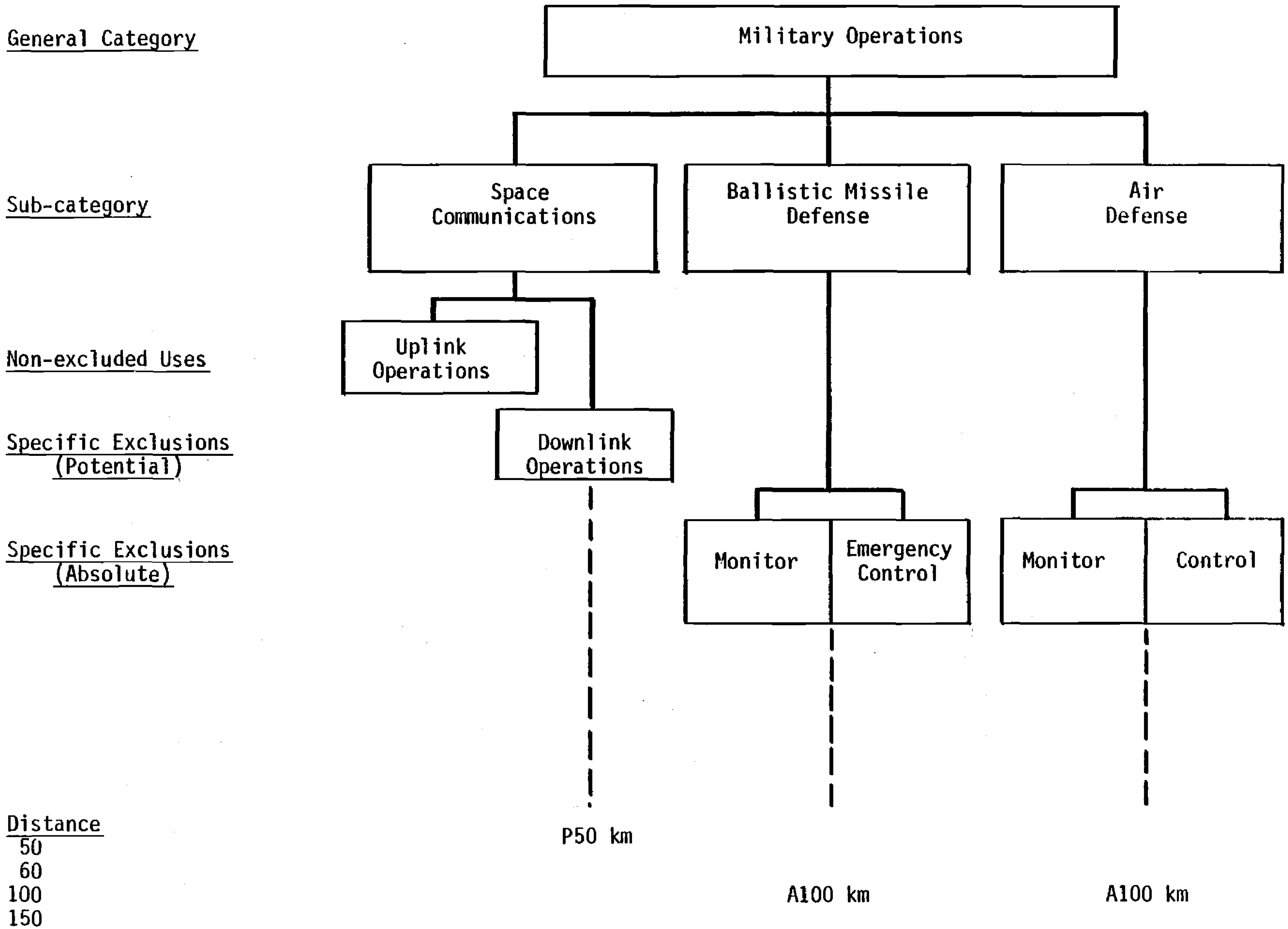
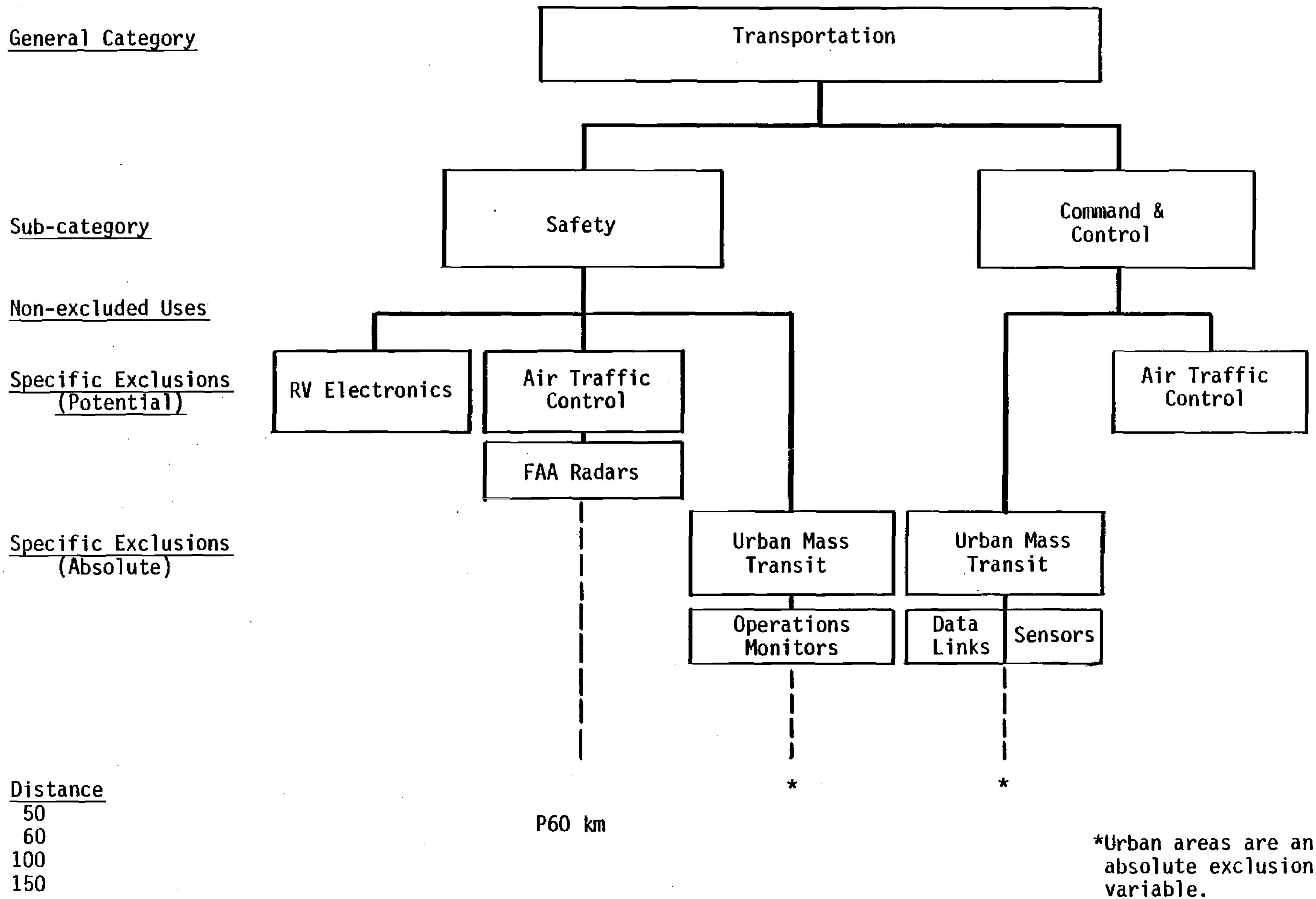


EXHIBIT B-4

DERIVATION OF EMC EXCLUSION VARIABLES: TRANSPORTATION



*Urban areas are an absolute exclusion variable.

existing and approved but not built, represents the center of an exclusion area with a 50 kilometer radius. All nuclear power plants are A-50 variables. The same is true with respect to nuclear material processing plants.

In the case of nuclear research, the lower level of sensitivity, and the much smaller volumes of radioactive material and the opportunities for shutting down the operation, combined to change the classification from absolute to potential but with the same 50 kilometer radius effect, as shown in Exhibit B-5.

B.B.6. Special Research Facilities

The SPS or, more accurately, 60 independent SPS systems, will represent considerable potential interference with earth communication with space. This will affect astronomy of all types and civilian (NASA) space communications. These are the elements considered in Exhibit B-6 which describes the special research facilities' defects.

Radio astronomy facilities will be particularly adversely affected. Radio telescopes are designed to pick up very weak radio signals and the extensive, albeit weak, radiation from a series of SPS's will inevitably impair and possibly disable their ability to receive and interpret signals from very distant stars. At this time there appears no way to mitigate this problem for earthbound radio telescopes although some compensation may be provided by future developments in spaceborne radio astronomy. This variable has a large distance effect in that any rectenna location within 150 kilometers of a radio astronomy facility would seriously impair it.

Because radio astronomy does not directly involve human safety or a national security, this variable has been classified as a potential 150 notwithstanding the inability to mitigate the adverse effects of the SPS.

Optical astronomy will also be affected by the SPS electromagnetic effect the reason for this is that optical telescopes use very sensitive equipment to multiply, augment, and analyze the optical signals they receive. Photo multipliers, infrared sensors, and various spectrometry equipment would all be adversely affected by the SPS microwave illumination. These types of facilities, have a somewhat lower separation threshold of 60 kilometers and are therefore classified as P-60 exclusion variables.

Within the United States, there are two major civilian space communications centers through which all or most of the critical NASA communications to and from space are processed. These are the Goldstone and Goddard facilities. Because they must receive and interpret extremely weak signals from extremely distant satellites and locations, these facilities are apparently unmitigatably exposed to impaired operations by virtue of SPS illumination. Over a distance of at least 100

EXHIBIT B-5

DERIVATION OF EMC EXCLUSION VARIABLES: SENSITIVE FACILITIES

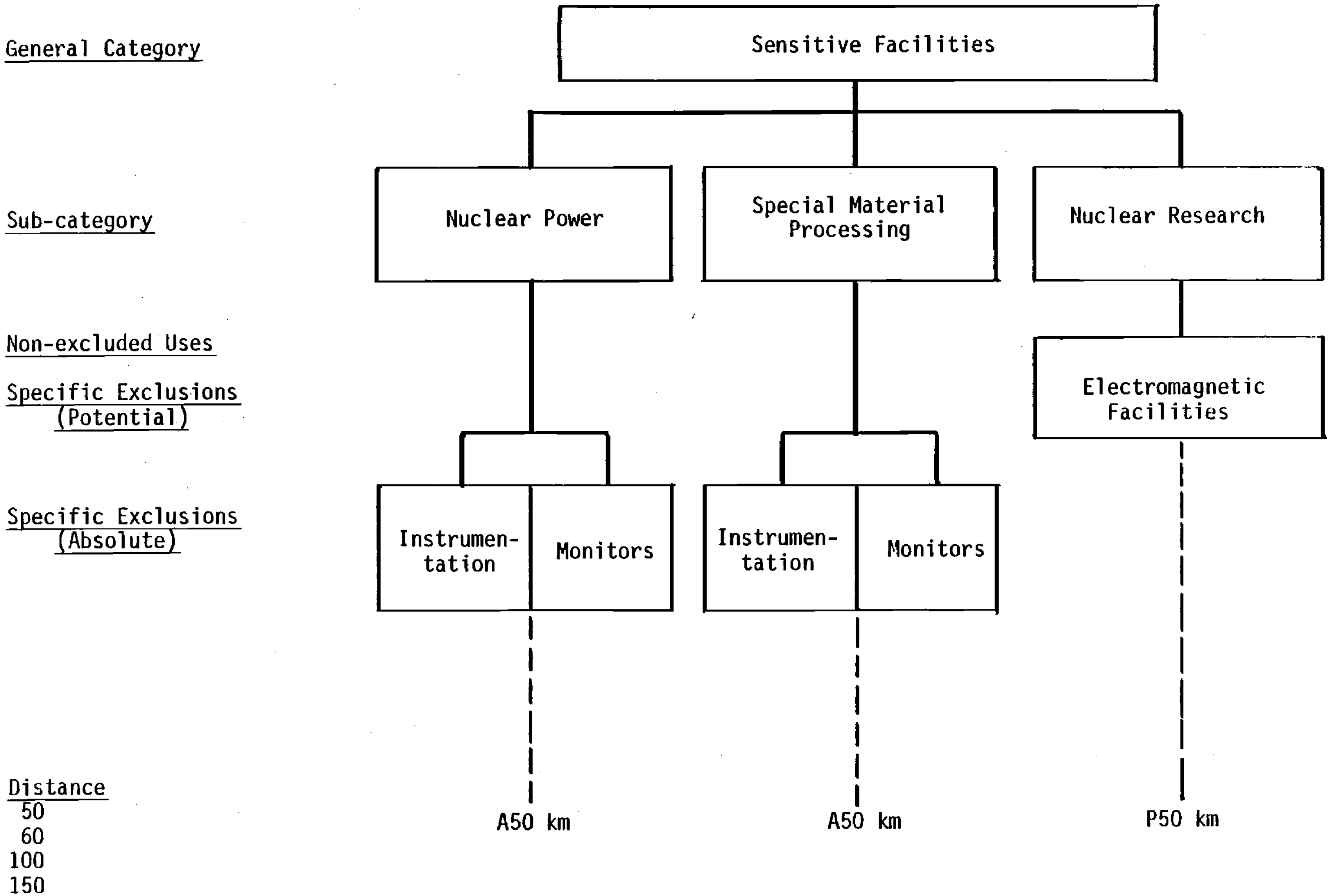
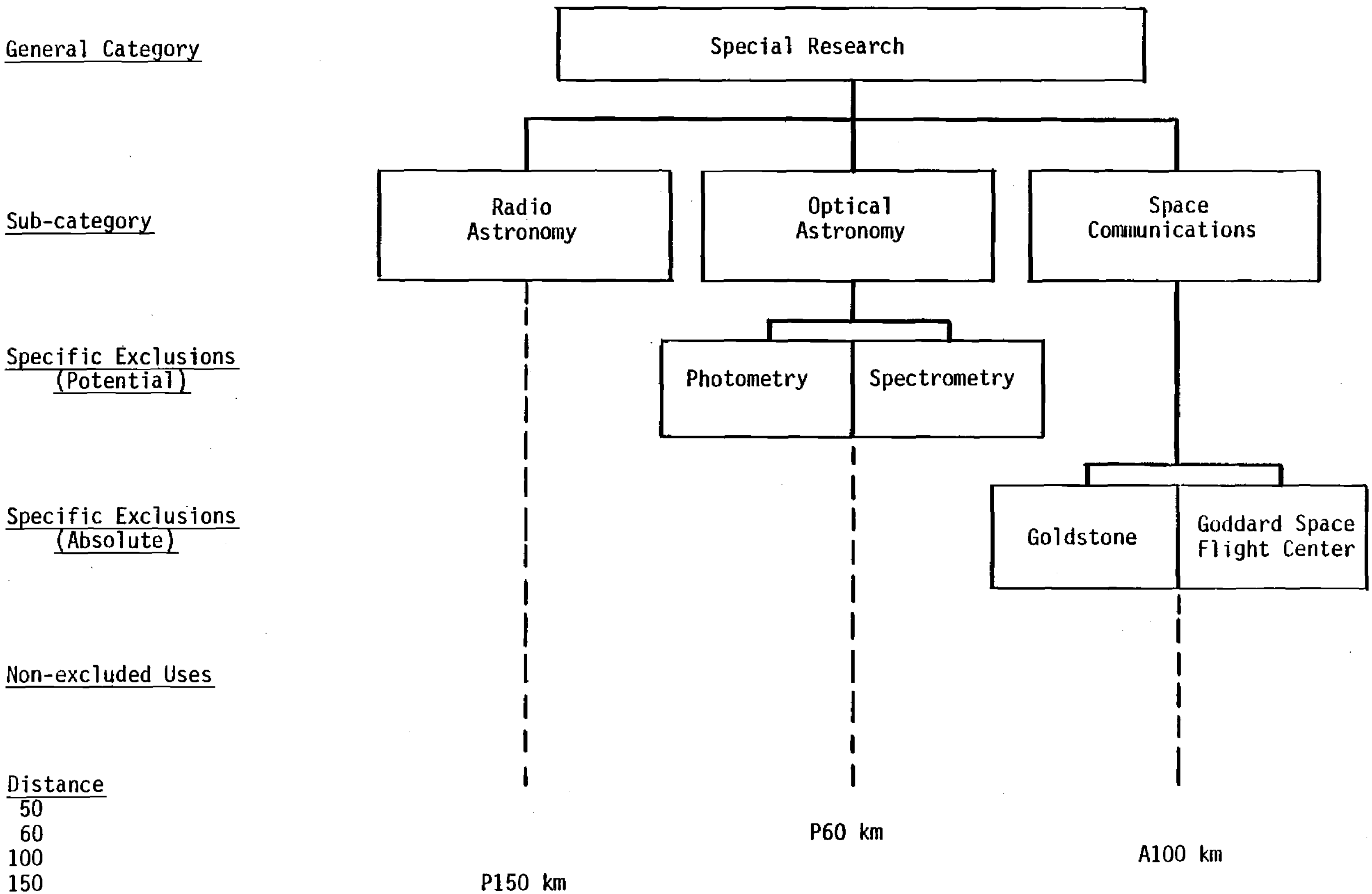


EXHIBIT B-6

DERIVATION OF EMC EXCLUSION VARIABLES: SPECIAL RESEARCH



kilometers, the weak radiation exposure associated with the SPS would interfere with and interrupt space communications.

Because this is a largely unmitigatable affect and because human health and safety is vitally affected in situations involving manned space flight, this has been classified as an absolute 100 (A-100) exclusion variable.

B.C. AFFECTED FACILITIES BY EXCLUSION CLASSIFICATION

The previous discussion of affected facilities by class or type of facility can be summarized in terms of the various exclusion classifications developed. A definition of each of the seven exclusion classifications (A-150, A-100, A-50, P-150, P-100, P-60 and P-50) together with a tabulation of the number of such facilities by class may be found in Exhibit B-7.

As shown in Exhibit B-7 there are a total of 126 absolute exclusions, 6 of which are in the A-150 category, 2 in the A-100 category and 106 in the A-50 category. The large number in the A-50 category is clearly attributable to all existing and approved permits for nuclear power plants.

In addition, there are a total of 145 potential exclusion sites, with 125 in the P-60 category which includes all air traffic control radar, and 14 in the category of P-50 encompassing optical astronomy, military space communications and nuclear research. There are only 4 potential 150 exclusions each representing major radio astronomy facilities in the United States and 2 P-100 exclusions.

For each facility in each of the 7 categories, a radius circle or radius boundary representing the appropriate distance was drawn around the facility to depict the exclusion area. These exclusion areas were subsequently mapped and encoded in the computer according to their variable classification.

Since the entire analysis in this report is based on the grid square concept of the base map, it was necessary to reduce the analysis of radius distance to grid square equivalents. Exhibit B-8 shows the manner in which each of the four distance categories (150, 100, 60, and 50 kilometers) were reduced to grid square equivalents. Specific allowance was made for the fact that in many instances the facility actually represents only a few hundred or a few thousand acres and a very small proportion of a grid square. Consequently, allowance was made for a tolerance of one-half grid square (approximately 6.5 kilometers) in establishing the excluded area boundaries measured in grid cells.

For each of the seven categories of exclusion variables, a separate tabulation of the actual facilities encoded has been developed by state. In addition, each of the seven variables was independently mapped, although in two cases, there was some overlap of the maps where only a

EXHIBIT B-7: SUMMARY OF EMC EXCLUDED FACILITIES

	Absolute Exclusion Variables			Potential Exclusion Variables				
	A-150 (Rectenna Sites Excluded Within 150 km.)	A-100 (Rectenna Sites Excluded Within 100 km.)	A-50 (Rectenna Sites Excluded Within 50 km.)	P-150 (Rectenna Sites Excluded Within 150 km.)	P-100 (Rectenna Sites Excluded Within 100 km.)	P-60 (Rectenna Sites Excluded Within 60 km.)	P-50 (Rectenna Sites Excluded Within 50 km.)	Total
Military/Operations Testing & Evaluation	6							6
Military Development/ Testing & Evaluation								
Command & Control Safety[1]						11		11
Military Operations								
Air Defense		2						2
Ballistic Missle Defense		2						2
Space Communications							1	1
Transportation								
Safety						114		114
Sensitive Facilities								
Nuclear Power			106					106
Special Material Processing			12					12
Nuclear Research							4	4
Special Research								
Radio Astronomy				4				4
Optical Astronomy							9	9
Space Communications					2			2
TOTAL	6	4	118	4	2	125	14	273

1 Plotted with Civilian Air Safety under Transportation

EXHIBIT B-8

GRID SQUARE EQUIVALENTS OF EXCLUSION BOUNDARIES STATED IN KILOMETERS

NOMINAL EXCLUSION DISTANCE	AFFECTED CATEGORIES (ABBREVIATION)	EQUIVALENT NORTH-SOUTH(1 DISTANCE, MEASURED IN GRID SQUARES OF 13KM	MATHEMATICAL RECONCILIATION(2
150 km	A 150	11	(11 x 13) + 7 = 150
100 km	A 100 P 100	7	(7 x 13) + 7 = 98
60 km	P 60	4	(4 x 13) + 7 = 59
50 km	A 50 P 50	3	(3 x 13) + 7 + 46

(1 Measured at due North and due South from boundary of site where boundary is considered as outer edge of any grid cell any part of which is in the facility or sensitive area. Other directions scaled equivalent to North South.

(2 Reconciliation provides for a 7-km boundary error factor since all grid squares with even a trivial affected area are considered to part of the site (7 km = .5 x average cell cross section 13 km).

Source: ITS and KRI

small number of facilities were involved. The succeeding sub-sections of this report provide a brief discusssion and detailed tabulation of EMC exclusion variables by exclusion category.

B.C.1. EMC A-150 Exclusion Variables (Military O, T, & E)

Military operational testing and evaluation is the sole facility classification within the A-150 exclusion criteria. There are a total of six such facilities which are shown as large and somewhat irregularly shaped exclusion areas on the map in Exhibit B-9. The six facilities listed by state are:

California, Fort Erwin

California, Fort Ord

Florida, Egland Air Force Base

Nevada, Nellis Air Force Base

Texas, Fort Hood

Utah, Wendover Air Force Base and Dugway Proving Grounds

B.C.2. EMC A-100 Exclusion Variables (Ballistic Missile Defense)

This exclusion category consists of air defense and ballistic missile defense (BMD) facilities maintained by the Air Force. There are two BMD facilities shown as large regularly shaped circles in North Dakota on the map in Exhibit B-10. The two facilities are located at Minot and Grand Forks, North Dakota. In addition there are two air defense facilities, one at Provincetown, Massachusetts and the other in Sacramento, California.

B.C.3. EMC A-50 Exclusion Variables (Nuclear Power Plants and Processing Facilities)

Of the two component elements in this exclusion variable, by far the largest is nuclear power plants. Nuclear processing facilities account for only 12 of 118 total locations mapped for this variable. The nuclear processing facilities, listed alphabetically by state, are:

California, Seal Beach

Idaho, Idaho Falls

Kentucky, Paducah

Ohio, Portsmouth

Pennsylvania, Apollo

Pennsylvania, McKeesport

South Carolina, Aiken

Tennessee, Erwin

Tennessee, Oak Ridge

Texas, Saint Francis-Amarillo

Washington, Richland

Washington, Bremerton

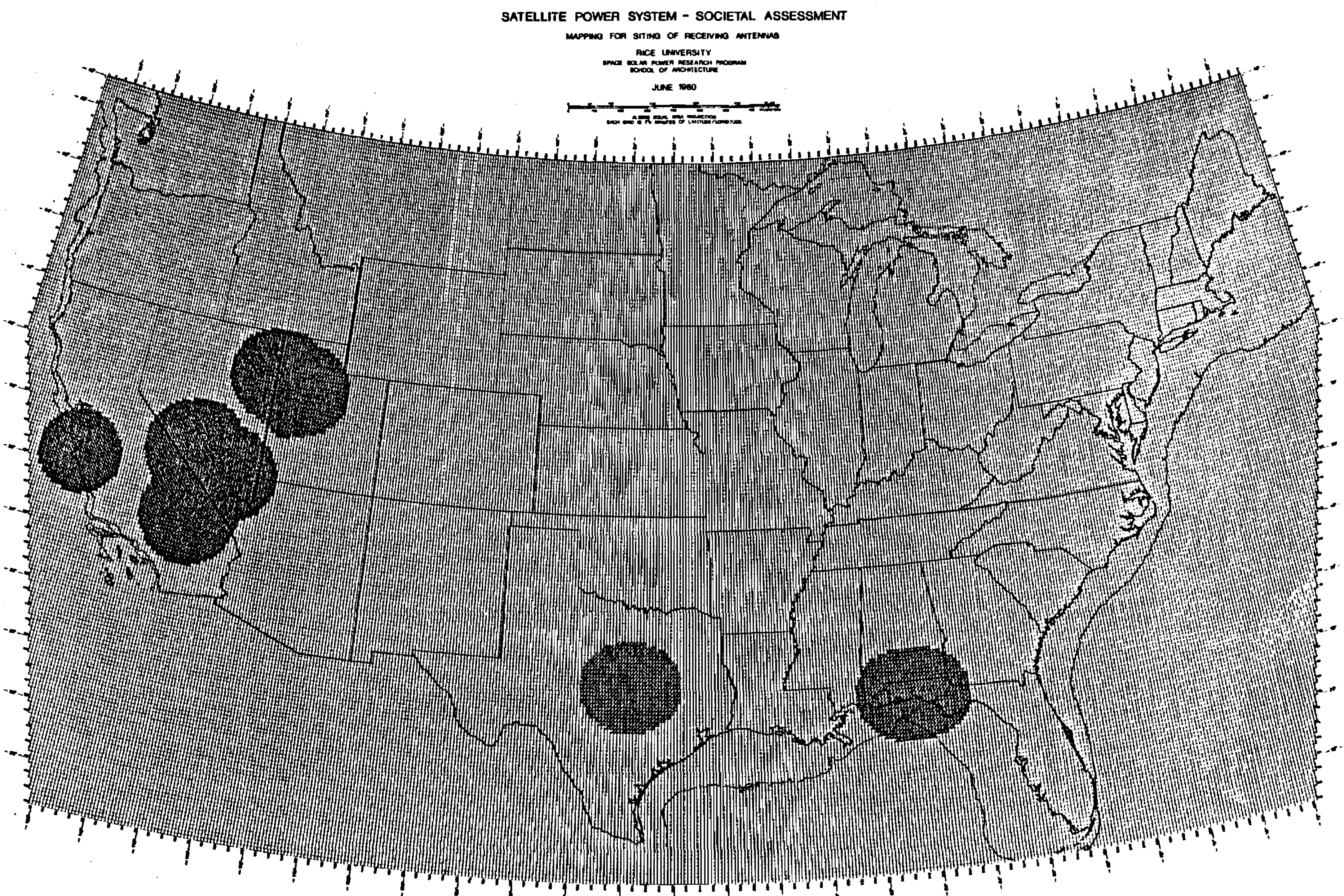


Exhibit B-9 ELECTROMAGNETIC COMPATIBILITY A150

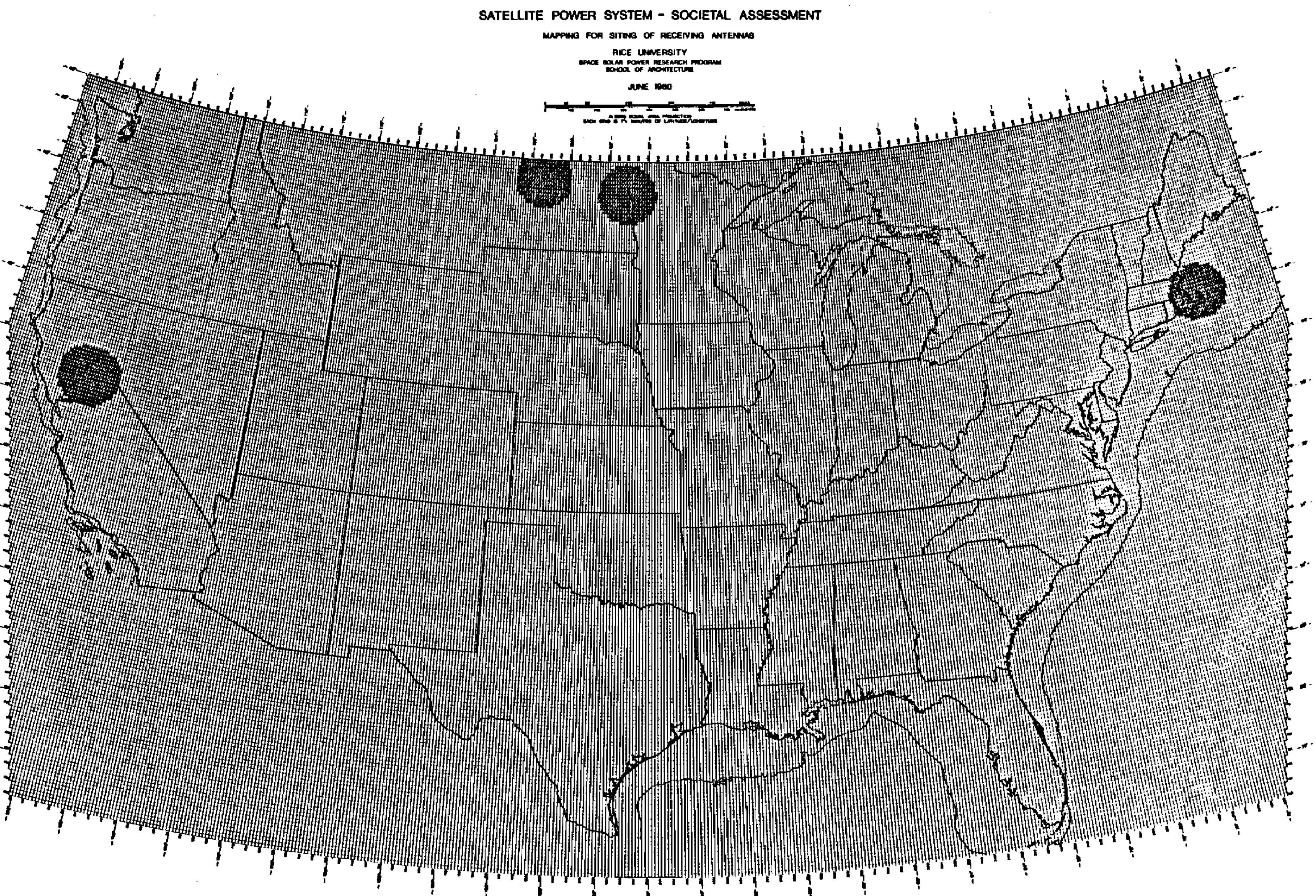


Exhibit B-19a ELECTROMAGNETIC COMPATIBILITY A100

The entire 118 facilities that comprise this exclusion variable are mapped in Exhibit B-11. In addition, Exhibit B-12 provides a directory of all nuclear power plant sites within the Continental United States. This directory, developed from a U.S. Nuclear Regulatory Commission document, is divided into two parts. The first part deals with licenses or construction permits that are now in effect and accounts for all but 14 of the 106 mapped locations. The second part of the directory includes applications for construction permits that are pending. For ease in reference to the map, both parts of the directory are listed by state in alphabetical order. For each location, the state, county, applicant/ operator name, plant name and NRC docket number are provided.

Substantial resistance to the licensing and/or construction of nuclear power plants has emerged. To the extent that this resistance continues and proves effective, it may be considered unreasonable to include as a siting constraint power plants just beginning construction or power plants for which construction permits are still pending. It is important to remember that this is an exercise intended to be largely illustrative in nature. While one or more of the power plants shown on the exhibit may in fact not materialize, there exists some reasonable probability that there will be other power plants emerging over the time span between this report and the initial operation of the SPS. To this extent, it is felt to be more appropriate to over-represent nuclear power plant locations than to under-represent them. This is particularly true insofar as many of the energy forecasts employed elsewhere in this analysis assume continued expansion of nuclear generation over the relevant time period.

B.C.4. EMC P-150 Exclusion Variables (Radio Astronomy Facilities)

The location of each, together with the 150-kilometer radius exclusion area around them is shown in exhibit B-13. The four facilities, listed by state, are:

Arizona, Tucson, (Kitt's Peak)

California, Palo Alto (Stanford)

New Mexico, Plains of Saint Augustine

West Virginia, Green Bank

B.C.5. EMC P-100 Exclusion Variables

There are only two facilities in this exclusion classification. They are both centers for civilian space communication maintained by the National Aeronautics and Space Administration (NASA). One is located at Goldstone, California and the other is the Goddard Space Flight Center in Maryland. The locations of both, together with the 100-kilometer radius exclusion area, is shown on Exhibit B-14.

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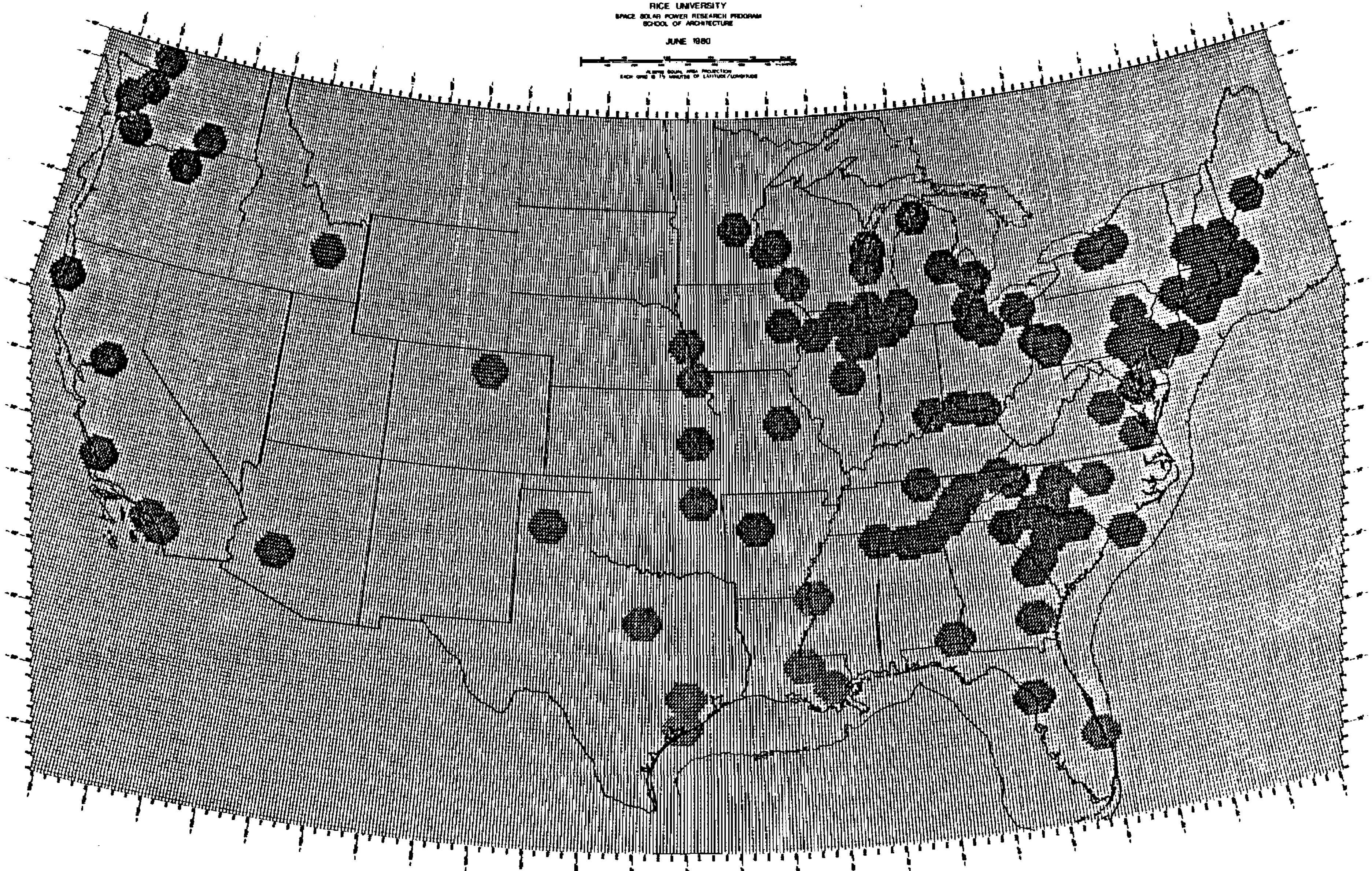

Exhibit B-10 ELECTROMAGNETIC COMPATIBILITY A 50

EXHIBIT B-12
DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part One: Licenses or Construction Permits in Effect)

State	County	Applicant/Operator	Plant Name (s)	Docket No.	Map Code*
Alabama	Houston	Alabama Power Co.	Farley 1[2], 2[2]	50-348,364	45,91
	Jackson	TVA	Bellefonte 1[2], 2[2]	50-438,439	81
	Limestone	TVA	Browns Ferry 1, 2, 3	50-259,260,296	34
Arizona	Maricopa	Arizona Public Service	Palo Verdo 1[2], 2[2], 3[2]	50-528-29-30	46
Arkansas	Pope	Arkansas Power & Light	Arkansas 1, 2	50-313,368	92
California	Humboldt	Pacific Gas & Electric	Humboldt Bay [1]	50-133	24
	Sacramento	Sacramento Mun. Utility Dist.	Rancho Seco	50-312	32
	San Diego	Southern Calif. Edison	San Onofre 1	50-206	33
	San Luis Obispo	Pacific Gas & Electric	Diablo Canyon 1[2], 2[2]	50-275,323	73
Colorado	Weld	Public Service of Colorado	Ft. St. Vrain	50-272	29
Connecticut	Middlesex	Connecticut Yankee Atomic Power	Connecticut Yankee	50-213	3
	New London	Northeast Nuclear Energy	Millstone 1, 2, 3[2]	50-245,336,423	21
Florida	Citrus	Florida Power	Crystal River 3	50-302	10
	Dade	Florida Power & Light	Turkey Point	50-250	12
	St. Lucie	Florida Power & Light	St. Lucie 1, 2[2]	50-335,389	11
Georgia	Appling	Georgia Power	Edwin I. Hatch 1, 2	50-321,366	13
	Burke	Georgia Power	Vogtle 1[2], 2[2]	50-424,425	60
Illinois	De Witt	Illinois Power	Clinton 1[2], 2[2]	50-461,462	63
	Grundy	Commonwealth Edison	Dresden 1, 2, 3	50-10,237,249	97
	Lake	Commonwealth Edison	Zion 1, 2	50-295,304	2
	La Salle	Commonwealth Edison	La Salle 1[2], 2[2]	50-373,374	52
	Ogle	Commonwealth Edison	Byron 1[2], 2[2]	50-454,455	51
	Rock Island	Commonwealth Edison	Quad Cities 1, 2	50-254,265	1
	Will	Commonwealth Edison	Braidwood 1[2], 2[2]	50-456,457	50

*Reference code for initial draft mapping: not noted on final maps.
[1]Shut down.
[2]Construction Permit in effect.

Source: Facilities License Application Record, U.S. Nuclear Regulatory Commission, April 30, 1979 (Document OMPA: NDL:598).

EXHIBIT B-12

DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part One: Licenses or Construction Permits in Effect)

State	County	Applicant/Operator	Plant Name (s)	Docket No.	Map Code*
Indiana	Jefferson	Pub. Service of Indiana	Marble Hill 1[2], 2[2]	50-546,547	78
	Porter	Northern Indiana Pub. Service	Bailly Station[2]	50-367	71
Iowa	Linn	Iowa Electric Light & Power	Duane Arnold	50-331	15
Kansas	Coffey	Kansas City Power & Light	Wolf Creek[2]	50-482	65
Louisiana	St. Charles	Louisiana Power & Light	Waterford 3[2]	50-382	67
	West Feliciana	Gulf States Utilities	Riverbend 2[2]	50-459	61
Maine	Lincoln	Maine Yankee Atomic Power	Maine Yankee	50-309	17
Maryland	Calvert	Baltimore Gas & Electric	Calvert Cliffs 1, 2	50-317,318	93
Massachusetts	Franklin	Yankee Atomic Electric	Yankee-Rowe	50-29	41
	Plymouth	Boston Edison Co.	Pilgrim 1	50-293	94
Michigan	Berrien	Indiana & Michigan Elec.	D. C. Cook 1, 2	50-315,316	14
	Charlevoix	Consumers Power Co.	Big Rock Point	50-155	5
	Midland	Consumers Power Co.	Midland, 1[2], 2[2]	50-329,330	53
	Monroe	Power Reactor Development	Fermi 1[3]	50-16	43
	Monroe	Detroit Edison Co.	Fermi 2[2]	50-341	43
	Van Buren	Consumers Power Co.	Palisades	50-255	6
Minnesota	Goodhue	Northern States Power	Prairie Island 1, 2	50-282,306	22(a)
	Wright	Northern States Power	Monticello	50-263	22
Mississippi	Claiborne	Mississippi Power & Light Co.	Grand Gulf 1[2], 2[2]	50-416,417	68
	Tishomingo	T.V.A.	Yellow Creek 1[2], 2[2]	50-566,567	86
Missouri	Callaway	Union Electric Co.	Callaway 1[2], 2[2]	50-483	88

*Reference code for initial draft mapping: not noted on final maps.

[1]Shut down.

[2]Construction Permit in effect.

[3]Not Operating.

Source: Facilities License Application Record, U.S. Nuclear Regulatory Commission, April 30, 1979 (Document OMPA: NDL:598)

EXHIBIT B-12

DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part One: Licenses or Construction Permits in Effect)

State	County	Applicant/Operator	Plant Name (s)	Docket No.	Map Code*
Nebraska	Nehema	Nebraska Public Power Dist.	Cooper Station	50-298	19
	Washington	Omaha Public Power Dist.	Ft. Calhoun	50-285	23
New Hampshire	Rockingham	Public Service Co. of N.H.	Seabrook 1[2], 2[2]	50-443,444	76
New Jersey	Ocean	Jersey Central Power & Light	Oyster Creek 1	50-219	16
	Ocean	Jersey Central Power & Light	Forked River 1[2]	50-363	16
	Salem	Public Service Electric & Gas	Hope Creek 1,[2] 2[2]	50-354,355	30
	Salem	Public Service Electric & Gas	Salem Station 1, 2[2]	50-272,311	30
New York	Oswego	Niagara Mohawk Power	Nine Mile Point 1, 2[2]	50-220,410	20
	Oswego	Power Authority of the State of N.Y.	Fitzpatrick	50-333	20
	Oswego	Rochester Gas & Electric	Sterling 1[2]	50-485	79
	Suffolk	Long Island Lighting	Jamesport 1[2], 2[2]	50-516,517	66
	Suffolk	Long Island Lighting	Shoreham Stn.[2]	50-322	66(a)
	Wayne	Rochester Gas & Electric	R.E. Ginna 1	50-244	31
	Westchester	Consolidated Edison of N.Y.	Indian Point 1*,2	50-3,247	4
	Westchester	Power Authority of the State of N.Y.	Indian Point 3	50-286	4
North Carolina	Brunswick	Carolina Power & Light	Brunswick 1, 2	50-325,324	95
	Mecklenburg	Duke Power	McGuire 1[2], 2[2]	50-369,370	55
	Wake & Chatham	Carolina Power & Light	Harris 1[2], 2[2], 3[2]	50-400,401,402	47
Ohio	Clermont	Cincinnati Gas & Electric	Zimmer 1[2]	50-358	48
	Lake	Cleveland Electric Illuminating	Perry 1,[2] 2[2]	50-440,441	49
	Ottawa	Toledo Edison	Davis-Besse 1	50-346	35
Oregon	Columbia	Portland General Electric	Trojan	50-344	26

*Reference code for initial draft mapping: not noted on final maps.
[1]Shut down.
[2]Construction Permit in effect.

Source: Facilities License Application Record, U.S. Nuclear Regulatory Commission, April 30, 1979 (Document OMPA: NDL:598).

EXHIBIT B-12

DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part One: Licenses or Construction Permits in Effect)

State	County	Applicant/Operator	Plant Name (s)	Docket No.	Map Code*
Pennsylvania	Beaver	Duquesne Lt.	Beaver Valley 2[2]	50-412	58
	Dauphin Co.	Metropolitan Edison	Three Mile Island 1, 2[1]	50-289,320	18
	Luzerne	Pennsylvania Power & Light	Susquehanna 1[2], 2[2]	50-387,388	74
	Montgomery	Philadelphia Electric	Limerick 1[2], 2[2]	50-352,353	75
	York	Philadelphia Electric	Peach Bottom 1[1], 2, 3	50-277,278	25
South Carolina	Cherokee	Duke Power	Cherokee 1[2], 2[2], 3[2]	50-491,492,493	57
	Darlington	Carolina Power & Light	H.B. Robinson 2	50-261	96
	Fairfield	S. Carolina Electric & Gas	Summer 1[2]	50-395	80
	Oconee	Duke Power	Oconee 1, 2, 3	50-269,270,287	8
	York	Duke Power	Catawba 1[2], 2[2]	50-413,414	56
Tennessee	Hamilton	T.V.A.	Sequoyah 1[2], 2[2]	50-327,328	84
	Hawkins	T.V.A.	Phipps Bend 1[2], 2[2]	50-553,554	83
	Rhea	T.V.A.	Watts Bar 1[2], 2[2]	50-390,391	85
	Trousdale & Smith	T.V.A.	Hartsville 1[2], 2[2], 3[2], 4[2]	50-518,519,520, 521	82
Texas	Matagorda	Houston Lighting & Power	South Texas 1[2], 2[2]	50-498,499	62
	Somervell	Texas Utilities Generating	Comanche Peak 1[2], 2[2]	50-445,446	87
Vermont	Windham	Vermont Yankee Nuclear Power	Vermont Yankee	50-271	36
Virginia	Louisa	Virginia Electric & Power	North Anna 1, 2[2], 3[2], 4[2]	50-338,339,404 405	37
	Surry	Virginia Electric & Power	Surry 1, 2	50-280,281	38
Washington	Benton	Washington Public Power Supply System	WPPSS 1[2], 2[2], 4[2]	50-460,397,513	90
	Grays Harbor	Washington Public Power Supply System	WPPSS 3[2], 5[2]	50-508,509	102

*Reference code for initial draft mapping: not noted on final maps.
[1]Shut down.
[2]Construction Permit in effect.

Source: Facilities License Application Record, U.S. Nuclear Regulatory Commission, April 30, 1979 (Document OMPA: NDI :598).

EXHIBIT B-12

DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part One: Licenses or Construction Permits in Effect)

State	County	Applicant/Operator	Plant Name (s)	Docket No.	Map Code*
Wisconsin	Dunn	Northern States Power	Tyrone 1[2]	50-484	72
	Kewaunee	Wisconsin Public Service	Kewaunee	50-305	40
	Manitowoc	Wisconsin-Michigan Power	Point Beach 1, 2	50-266,301	39
	Monroe[4]	Dairyland Power Cooperative	Lacrosse	115-5; 50-409	7

*Reference code for initial draft mapping: not noted on final maps.

[1]Shut down.

[2]Construction Permit in effect.

[4] Possibly located in Vernon County

Source: Facilities License Application Record, U.S. Nuclear Regulatory Commission, April 30, 1979 (Document OMPA: NDL:598).

EXHIBIT B-12
DIRECTORY OF NUCLEAR POWER PLANT SITES

(Part Two: Applications for Construction Permits Pending)

State	County	Applicant/Operator	Plant Names (s)	Docket No.	Map Code
Massachusetts	Franklin	Northeast Nuclear Energy Co.	Montague 1, 2	50-496,497	110
	Plymouth	Boston Edison	Pilgrim 2	50-471	104
Michigan	St. Clair	Detroit Edison	Greenwood 2, 3	50-453	105
New York	Oswego	New York Electric & Gas	NYE & G 1, 2	50-596	20
North Carolina	Davie	Duke Power	Perkins 1, 2, 3	50-488,489,490	106
Ohio	Erie	Ohio Edison	Erie 1, 2	50-580,581	111
	Ottawa	Toledo Edison	Davis-Besse 2, 3	50-500,501	35
Oklahoma	Rogers	Public Service of Oklahoma	Black Fox 1, 2	50-556,557	114
Oregon	Gilliam	Portland General Electric	Pebble Springs 1 , 2	50-514,515	112
Rhode Island	Washington	New England Power & Light	New England 1, 2	50-568,569	108
Tennessee	Roane	Project Management	Clinch River	50-537	113
Texas	Austin	Houston Lighting & Power	Allens Creek 1	50-466	107
Washington	Skagit	Puget Sound Power & Light	Skagit 1, 2	50-522,523	98
Wisconsin	Milwaukee	Wisconsin Electric Power Co.	Haven 1	50-502	100

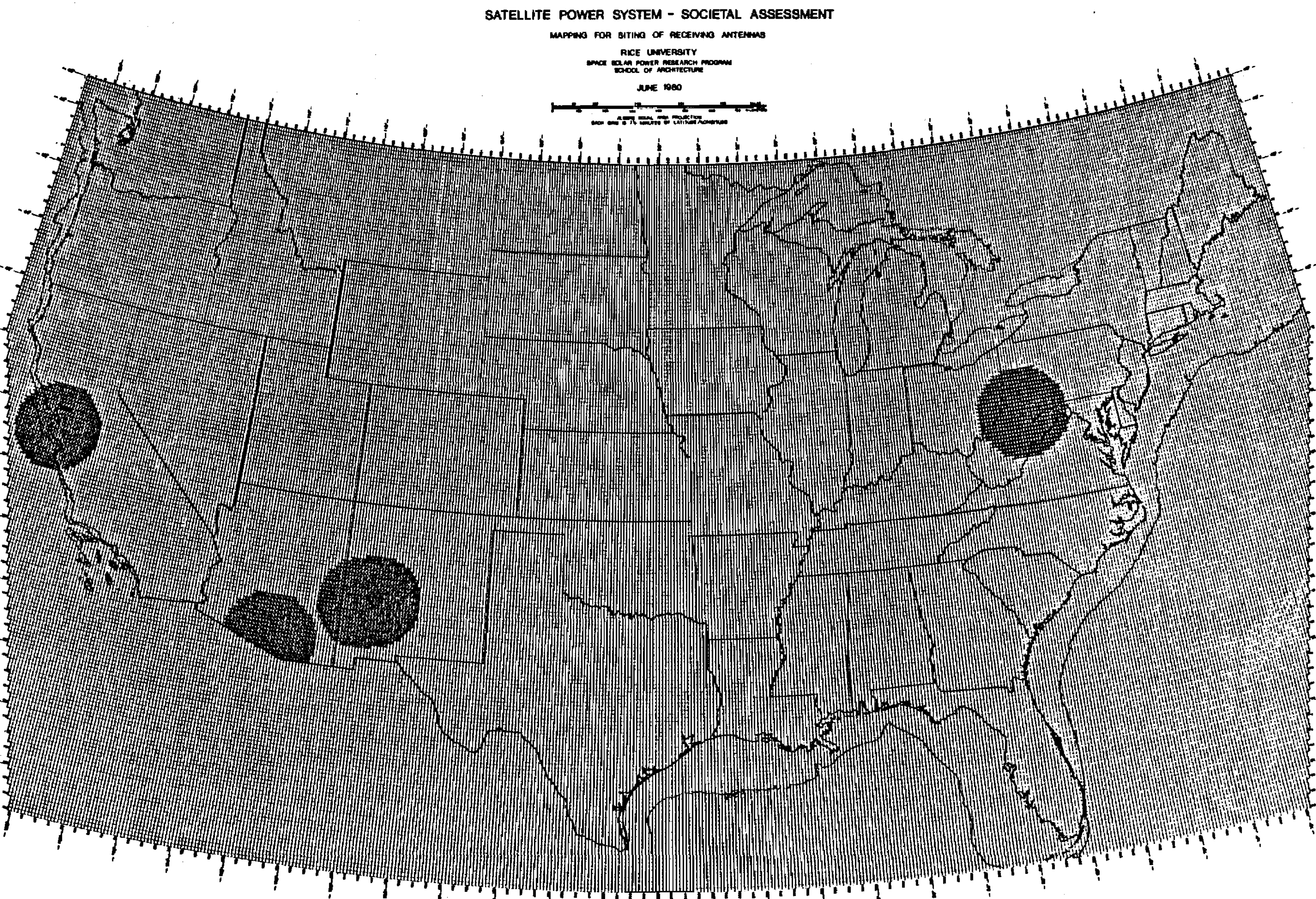

Exhibit B-12 ELECTROMAGNETIC COMPATIBILITY P150

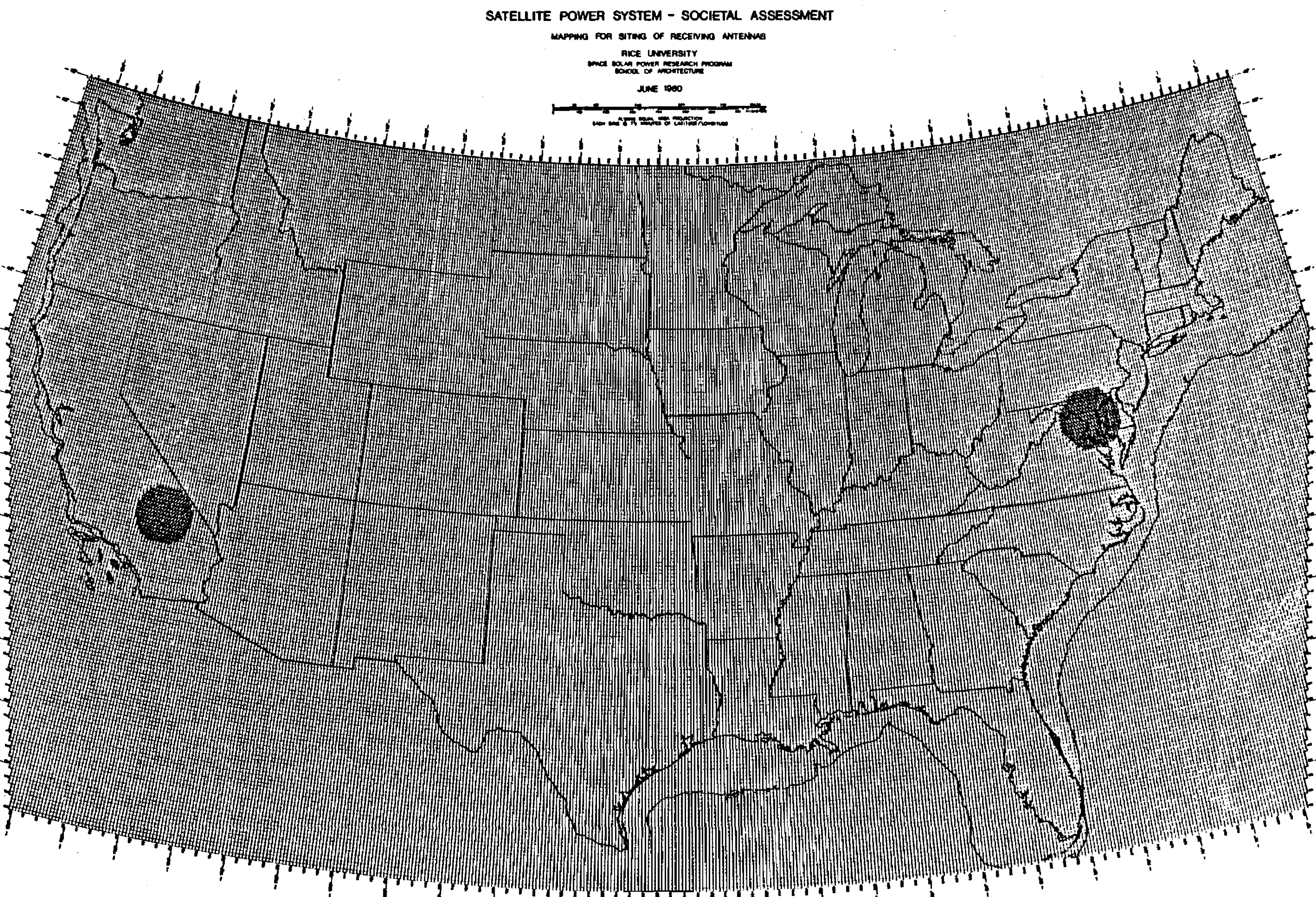

Exhibit B-13 ELECTROMAGNETIC COMPATIBILITY P100

B.C.6. EMC P-50 Exclusion Variables (Optical Astronomy, Nuclear Research, Etc.)

There are three types of facilities which make up this exclusion variable:

Optical Astronomy Facilities

Nuclear Research Facilities

Military Space Communications.

Of these three types of facilities, Military Space Communications is represented on the map in Exhibit B-15 by a single facility which is at Aurora, Colorado.

The P-50 exclusion facilities include nine optical astronomy facilities:

Arizona, Flagstaff

Arizona, Tucson (Catalina)

Arizona, Tucson (Mount Hopkins)

California, Mt. Wilson

California, Palomar

Massachusetts, Cambridge (Smithsonian-Harvard)

Texas, Fort Davis

Wisconsin, Racine (Yerkes)

The balance of the EMC P-50 exclusion sites are composed of four nuclear research facilities located as follows:

California, Livermore

Illinois, Argonne

New Mexico, Los Alamos

New York, Long Island (Brookhaven)

B.C.7. EMC P-60 Exclusion Variables (Military D, T, & E and FAA Traffic Control)

There are 125 facilities which fall into this exclusion variable classification. All locations, together with the 60-kilometer radius exclusion areas, are plotted in Exhibit B-16. Eleven facilities are military development testing and evaluation facilities. Their locations, by state, are as follows:

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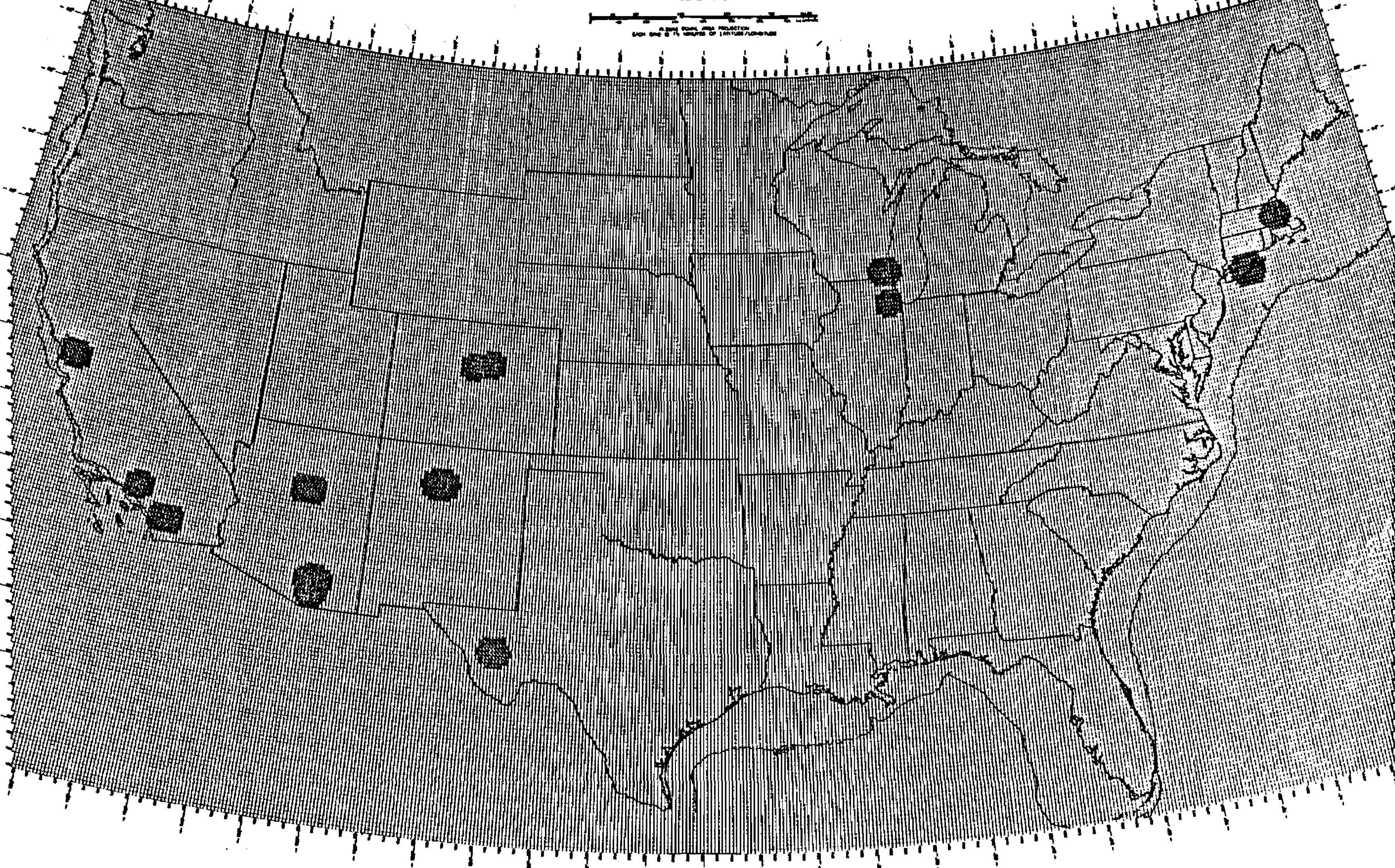

Exhibit B-13a ELECTROMAGNETIC COMPATIBILITY P 50

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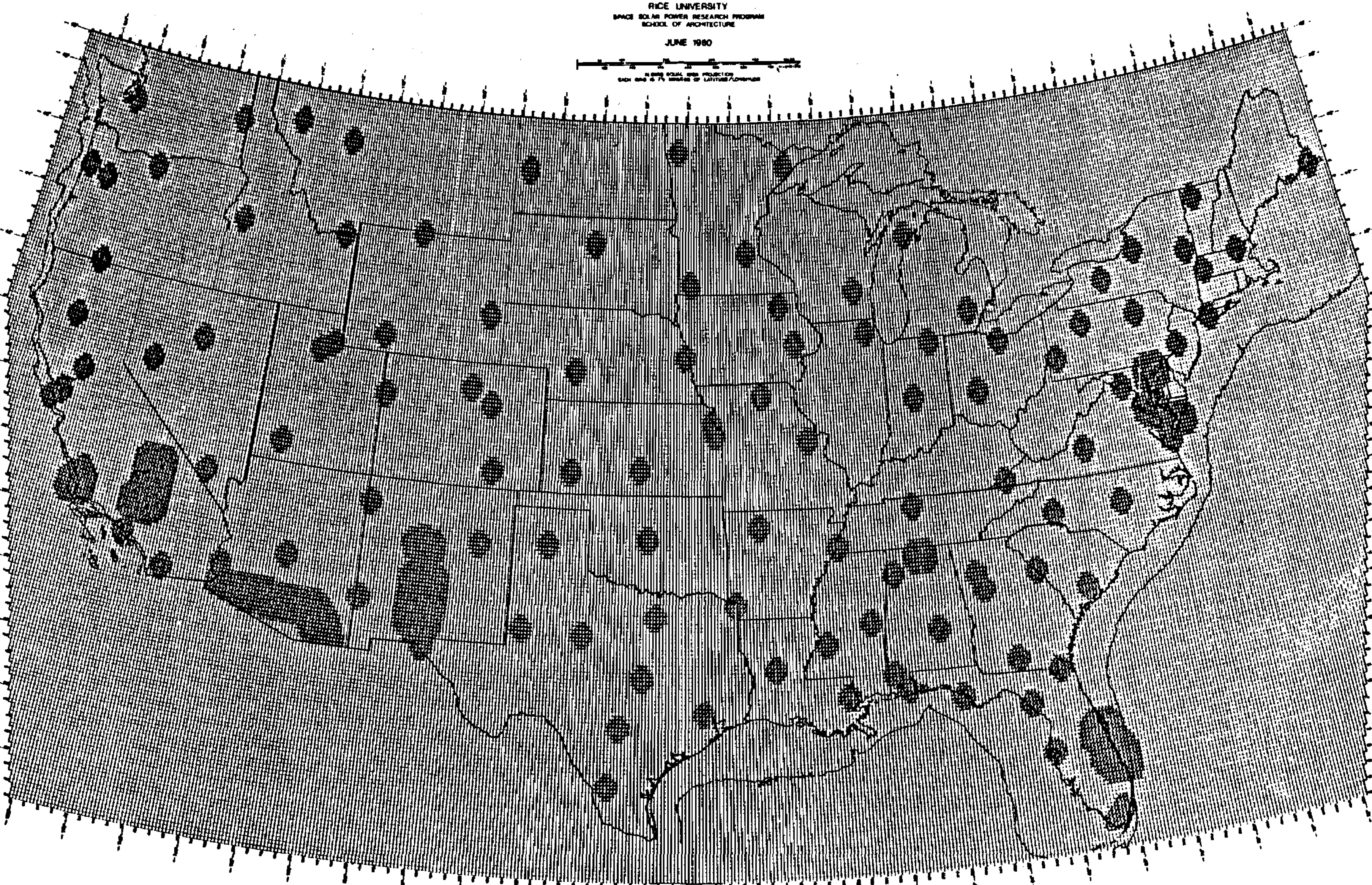

Exhibit B-14 ELECTROMAGNETIC COMPATIBILITY P 60

Alabama, Huntsville (Redstone)

Arizona, Yuma Test Facility to Wachuca

California, China Lake

California, Lancaster (Edwards Air Force Base)

California, Santa Maria (Vandenberg Air Force Base)

Florida, Titusville (Fort Pierce)

Maryland, Aberdeen Proving Ground

Maryland, Patuxent Naval Testing Range

New Mexico, Albuquerque (Kirkland Air Force Base)

New Mexico, White Sands Missile Range

Virginia, Wallops Island

Air traffic control systems and the microwave lengths that connect them, represent potentially sensitive facilities to SPS microwave illumination, according to ITS. To a large extent, adverse effects can be mitigated and there already exists significant redundant systems and monitoring and checking mechanisms that should further mitigate the impact of minor instantaneous interference. Nevertheless, these have been classified as potential exclusion variables with an exclusion radius of 60 Kilometers. There are a total of 114 air traffic control facilities which are mapped as P-60 variables. There are two basic types the air route surveillance radars which track commercial and general aviation en route from one point to another (ARSR) and military surveillance radars which perform similar functions for military aircraft (FPS). The information on location of these facilities was obtained from an FAA map entitled "En Route Radar Locations" (publication E-31601-IA, January 1976). The distribution of these facilities by state is as follows:

State	Count	State	Count
Alabama	4	Nebraska	2
Arizona	2	Nevada	3
Arkansas	2	New Mexico	5
California	8	New York	4
Colorado	4	North Carolina	2
Florida	6	North Dakota	1
Georgia	3	Ohio	2
Idaho	2	Oklahoma	1
Illinois	1	Oregon	4
Indiana	2	Pennsylvania	4
Iowa	2	South Carolina	2

Kansas	4
Louisiana	2
Maine	1
Maryland	1
Massachusetts	2
Michigan	2
Minnesota	4
Mississippi	2
Missouri	2
Montana	2
South Dakota	1
Tennessee	2
Texas	9
Utah	3
Vermont	1
Virginia	4
Washington	2
Wisconsin	1
Wyoming	3

APPENDIX C: RECTENNA SITING AND BIRD MIGRATION

In this study of areas from which receiving antennas are excluded, a subject of special research attention is bird migration and bird migratory pathways. To date, no research has been funded that directly addresses the issue of microwave effects on birds. However, it is apparent that birds and other flying creatures may put themselves into contact with the microwave energy being transmitted to the receiving antenna. If it becomes apparent that birds are negatively impacted by the microwave beam, then areas of major bird activity should be considered in rectenna site selection. On the other hand, if research indicates that birds will not be negatively affected, then considerations relating to birds would be less important. In this examination of the relationship between bird migration and rectenna siting, two specific issues were addressed. First, the issue of potential impacts upon birdlife by the rectenna and the SPS system was addressed. Second, the issue of the relationship of siting to bird activities was addressed. In the first instance, consideration was given to several areas of potential impact with much of the consideration being speculative (i.e., no specific source can be cited for the issue of concern). In the second instance, an assumption of impact was made and the research concentrated upon areas to be avoided. Information from the second investigation is of the most relevance to siting.

C.1. Potentials For Impact Upon Birds

Through research and reading of literature relating to birds, four potential negative impacts may be posited. Two of these are directly related to siting activities, one is potentially related to siting and the fourth is unrelated to siting. Three of the concerns are related to migration and a fourth is related to the general distribution of bird species. Prior to a detailed discussion of these potential impacts, it is critical to note that detailed experimental research will be required to determine the validity of the concerns raised in this paper and it is possible that no impacts will accrue to migratory bird species. However, any discussion of impacts upon birds must be conducted in light of the absence of definitive impact information.

C.1.a. Impact Regardless of Rectenna Location

The potential exists that birds could be negatively impacted regardless of where the receiving antennas are located. The underpinnings of this assertion are based upon theories concerning bird migration. It is important to note that no agreement exists with regard to migratory mechanisms; in the sources investigated in detail, at least eight theories have been advanced to explain how birds travel from breeding areas to wintering areas. Among the theories set forth are:

1. Visual recognition of physical features
2. Navigation using a sun-compass
3. Navigation using the stars
4. Navigation based upon the earth's magnetic field
5. Navigation based upon the earth's rotation/coriolis force
6. Navigation based upon atmospheric sensitivity
7. Navigation by an "internal navigation" system
8. Navigation by "extrasensory perception"

This researcher does not possess sufficient knowledge or experimental background to evaluate the myriad of experiments offered in support of one theory or another. My personal supposition is that different species use varying mechanisms and many species use more than one mechanism. However, this issue is better left to trained ornithologists.

The major point of this section of the report is to address the issue of stellar navigation. The positioning of 60 satellites in geostationary orbit will result in an alteration of the night sky. 60 stellar bodies two to three times brighter than Venus will be added to the night sky. These new skylights will be near the horizon and should not obscure the more northern stars and constellations. However, the potential exists that these new stars could interfere with the stellar navigation of migratory birds.

Experimental data appears inconclusive with respect to those stars utilized for navigation. According to Mathews (1968):

> The main disappointment in the planetarium experiments is that little progress has been made in discovering which constellations are necessary for compass orientation. Emlen (1967b) reports preliminary experiments in blocking out portions of the artificial sky. These suggest that constellations within 35 degrees of Polaris are important to the orientation process, whereas those in the southern half of the sky can be dispensed with. (at 49).

If Mathews assertion is correct, then an alteration of the southern sky should not affect bird migratory patterns. This issue may be resolved in planatarium experiments and it is our recommendation that such experiments be undertaken if future SPS research is funded.

C.1.b. <u>Impact Unrelated to Migration</u>

A second issue of concern involves the relationship between the receiving antenna and nesting bird species. In particular, the receiving antenna may be viewed as a 25,000 acre array of potential nesting and roosting sites. At this time, it is impossible to assess whether in fact birds would be attracted to the receiving antenna. The possibility exists that birds would perceive the high microwave levels and avoid the receiving antenna.

However, it is equally reasonable that they would utilize the structure for roosting and nesting. If the latter situation occurs, then both adults and juveniles would be exposed to power densities ranging from 23 mw/cm^2 to 1 mw/cm^2 for extended periods of time. To date, no research has been conducted to determine (a) whether birds would be attracted to the rectenna or (b) whether birds would be impacted by exposure to these microwave levels for several months.

It is not clear how this problem relates to siting. Of course, if no negative impacts are observed in experiments, then one would suppose that the issue does not affect siting. If negative impacts ensue, then the presumption is that the rectenna should be sited in areas of low bird density. Unfortunately, in the research conducted to date, no map has been found that describes the density of birdlife across the United States. Further, an expectation is that the potential impacts would be related to the size of the bird exposed to the microwave beam and the relative attractiveness of the rectenna to various species. Therefore, one would ideally utilize a map which highlights the distribution of species that would be attracted to and impacted by the rectenna.

Another possibility is that the rectenna could be designed and operated in a manner that discourages birds from nesting and roosting thereon. This may be necessary for energy efficiency reasons unrelated to avian impacts. Other land uses facing the problem of attracting birds have utilized mitigation measures such as predator bird calls and similar dissuasions. These alternatives will have to be evaluated in later phases to determine their practicality and effectiveness.

C.1.c. Impacts Upon Migratory Species

Two distinct issues exist with respect to impacts of rectenna location upon migratory birds. Initially, a question exists about the impact of the microwave beam upon birds that pass through the beam. Secondly, a question exists about the impact of the microwave beam upon senses used by birds during migration. As with the other issues discussed in this section, the impact of the rectenna (or more specifically the microwave beam) is not known. However, the major alternative for avoiding impacts, if any occur, relates to the siting of the rectenna in areas of low migratory activity.

Unlike the situation discussed earlier where birds would roost or nest upon the rectenna, thereby being exposed to the microwave beam for extended periods, birds passing through the microwave beam would be exposed for a very short time period. However, extremely large numbers of birds could be exposed for short length of time. For example, corridors have been identified that are utilized by more than five million ducts, not to mention other bird species. Therefore, if there is a negative impact from short term exposure, that impact could accrue to millions of birds. Again, it is impossible to speculate upon the impact of this exposure without detailed experimental research.

A second potential impact of the receiving antenna (or microwave beam) upon migratory species relates to the impact of the beam upon migratory senses. As discussed earlier, there are several theories concerning the mechanism of bird migration. Certain of these theories indicate that perception of the electromagnetic spectrum may be involved. Given this hypothesis, it seems reasonable to assume that a microwave beam operating at 2.45 GHz could interfere with migratory processes. In many respects, this theory of impact is similar to the concept of electromagnetic comaptibility discussed in other sections of this report. At this time, it is impossible to state whether this theory of negative impact has any validity. Additional research will be necessary to determine the issue's validity.

C.1.d. Summary

In summary, four mechanisms have been identified whereby birds may be impacted by the rectenna/microwave beam. One impact mechanism is related to the alteration of the night sky implicit in the placement of 60 50 km^2 satellites in geostationary orbit. This mechanism would exist independent of the site chosen for receiving antennas. A second impact mechanism is related to the attractiveness of the rectenna to bird life, either for roosting or nesting purposes. Although the siting of rectennas could respond to this issue, insufficient spatial information exists to make an informed decision at this time. The third and fourth impact mechanism, however, relate to migration paths. In the following section, the findings of research concerning migration paths will be discussed.

C.2. The Migratory Pathways

The issues of migration pathways can be divided into two parts. First, one can discuss the migration pathways of ducks and geese. These pathways have been researched extensively and a high degree of confidence can be attached to statements regarding these pathways. Second, one can address the pathways of all other migratory birds. These pathways have not been extensively researched and a low degree of confidence would attach to conclusions drawn from the existing literature unless the researchers compiled the migration paths of each individual specie. This compilation was considered to be beyond the scope of this research effort on bird migration.

C.2.a. The Migration of Ducks and Geese

Substantial research has been conducted upon the migration patterns of ducks and geese. A major reason for this research is the importanct of ducks and geese as recreational resources. Additionally, federal laws give the United States government the power to set bag limits and otherwise manage recreational waterfowl. Further, groups such as Ducks Unlimited exist for the purpose of enhancing the population of ducks and geese. The important point is that ducks and geese are sufficiently important as resources to generate research monies to investigators interested in understanding these birds.

Of the sources investigated, the most comprehensive (and most often cited) source is Bellrose's Ducks, Geese and Swans of North America. In this book, Bellrose sets forth the major migration corridors of ducks and geese. Although these migration corridors include all of the major flyways (Atlantic, Mississippi, Central and Pacific), the emphasis of Bellrose's approach is more upon the concentration of ducks utilizing various corridors rather than large-scale, regionally-oriented concepts such as flyways. For informational purposes, maps showing the various flyway systems are included as Exhibits C-1 through C-4.

As stated above, Bellrose's approach varies substantially from the flyway approach. Bellrose's mapping indicates the number of birds using various corridors, thereby creating density gradations across the United States. As can be seen in Exhibit C-5, there are significant differences in the numbers of ducks using various corridors. For example, from 5,250,000 to 9,000,000 ducks utilize two corridors in the central United States, whereas less than 750,000 ducks utilize the corridor extending from the North Carolina coast south to Florida and the Bahamas. If one cross-references the flyway maps with Bellrose's maps, the importance of Bellrose's approach becomes apparent. Not only does he offer defined corridors but he gives some indication of the relative usage. If one used only the flyway maps, then the implication would exist that all pathways are of equal importance to migratory birds.

If it is determined that birds would be negatively impacted by the microwave beam, then a map such as Bellrose's would be useful in specifying areas of high usage to be avoided to the siting of rectennas. However, the use of density information does raise one major issue where does one draw the line between impactable densities? In other words, if one assumes that there would be an impact from exposure to the microwave beam, then a decision would have to be made concerning how many birds should be allowed to be exposed to the beam. Does one only exclude the land areas underlying the highest density corridors? Is over 751,000 too many and under 750,000 acceptable? Does one exclude all areas shown on the Bellrose map? Fortunately, this decision does not have to be made at this time. However, it is certainly apparent that the exclusion of the receiving antenna from all of the land areas underlying Bellrose's migration corridors would eliminate a substantial portion of the United States as potential sites.

A second Bellrose map is also shown in Exhibit C-6. This is the map of the goose migration corridors. As can be seen from the legend, the total number of geese utilizing the corridors is an order of magnitude lower than

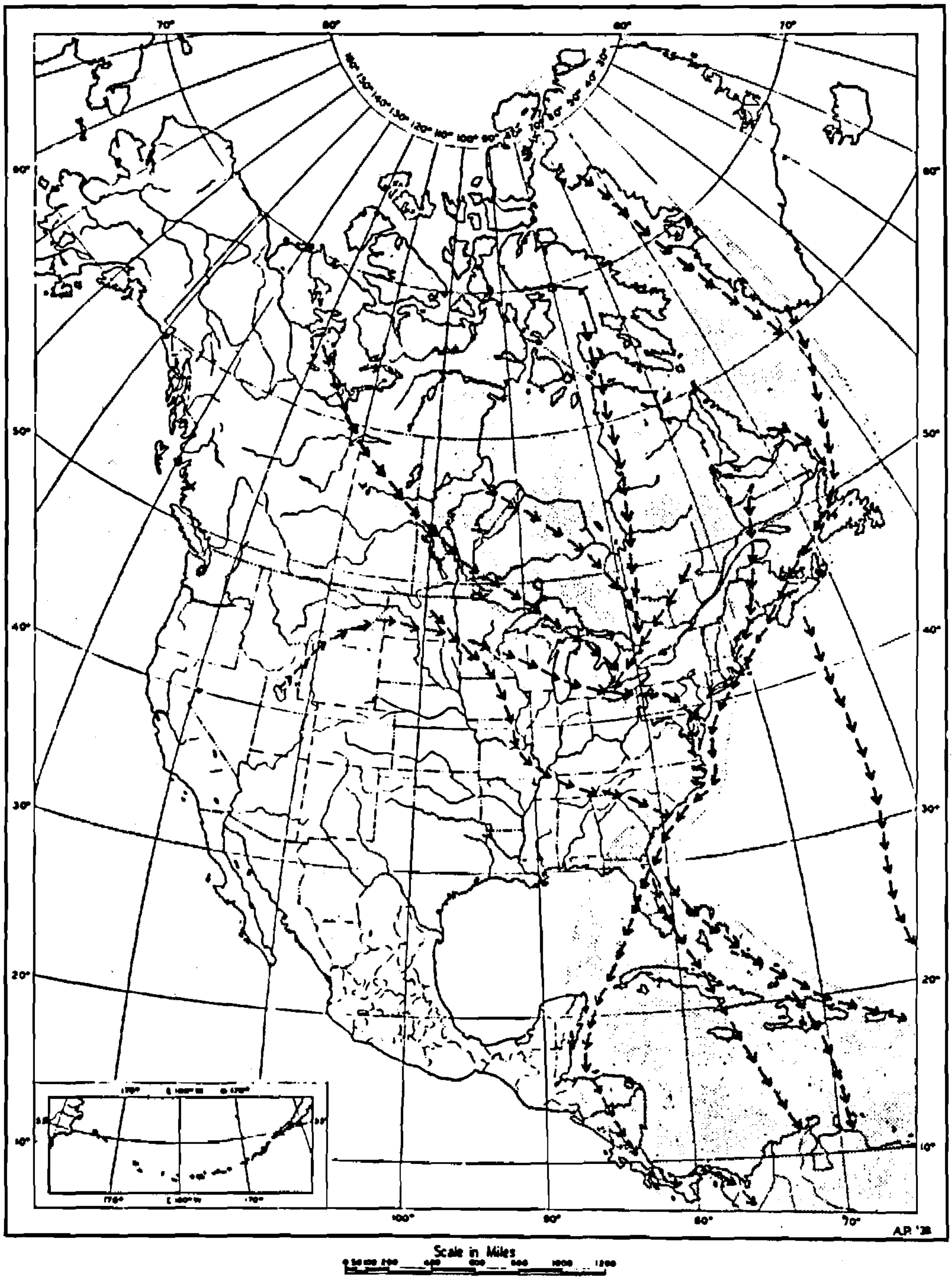

Exhibit C-1 The Atlantic Flyway

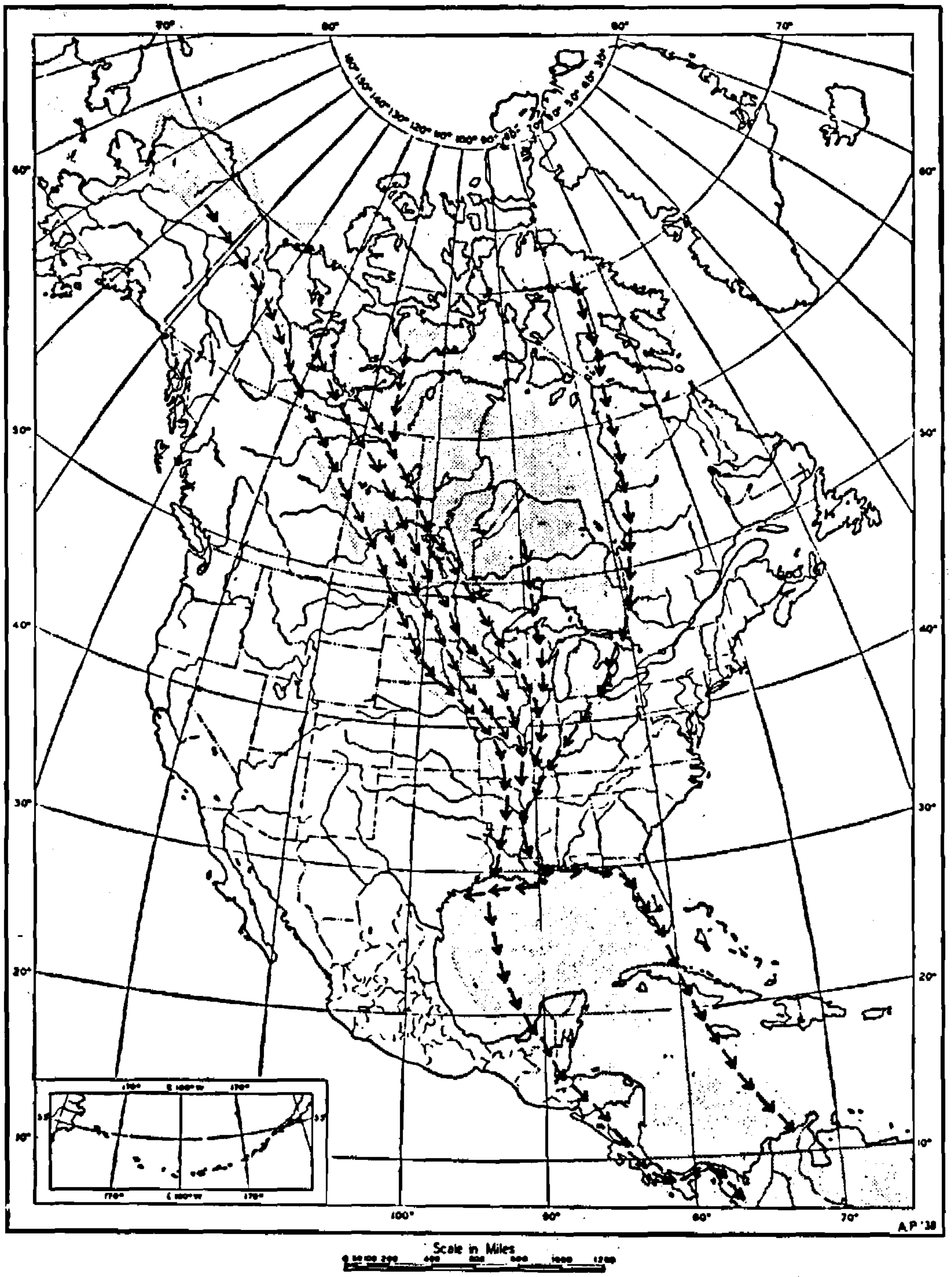

Exhibit C-2 The Mississippi Flyway

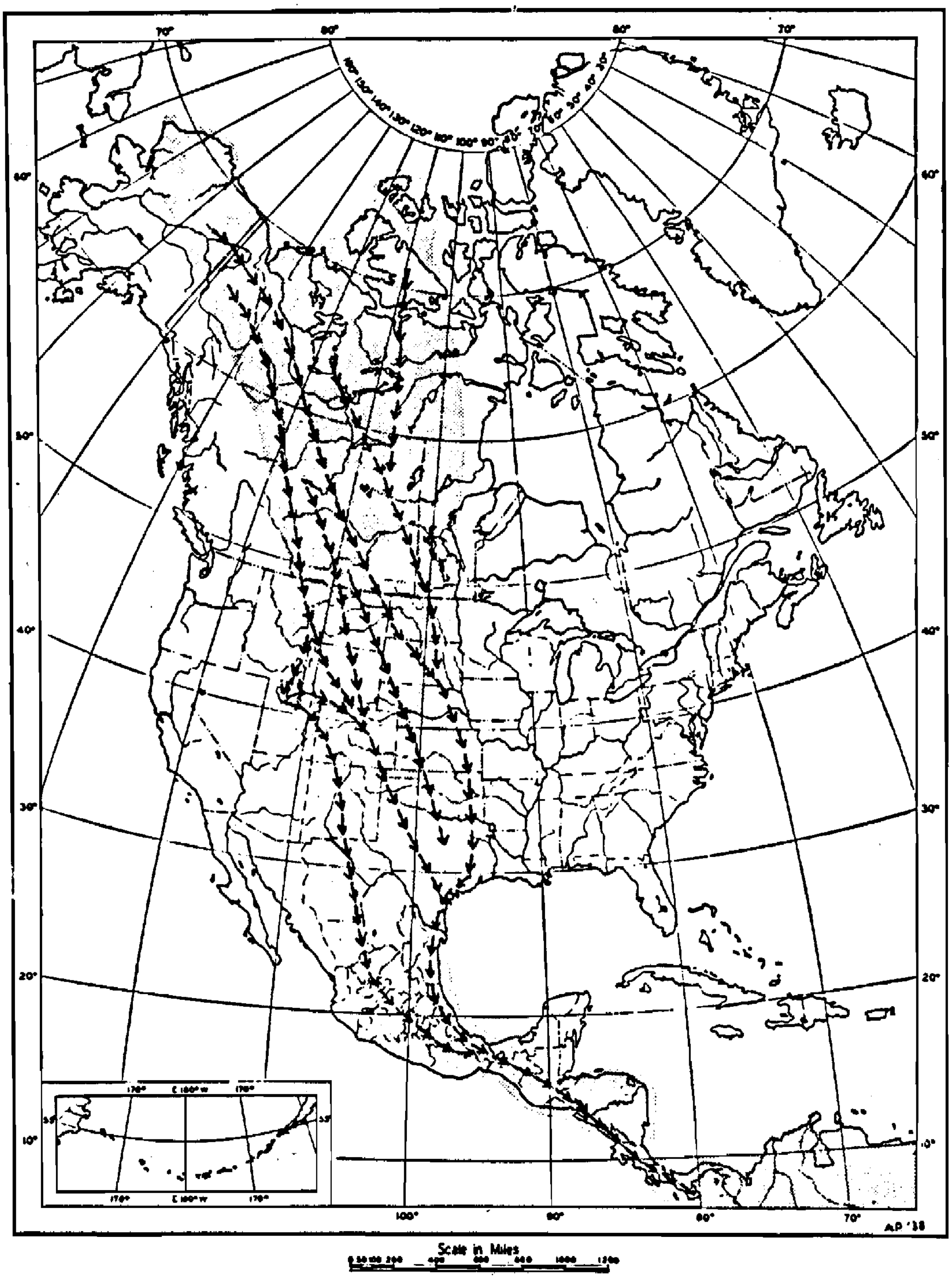

Exhibit C-3 The Central Flyway

Exhibit C-4. The Pacific Flyway

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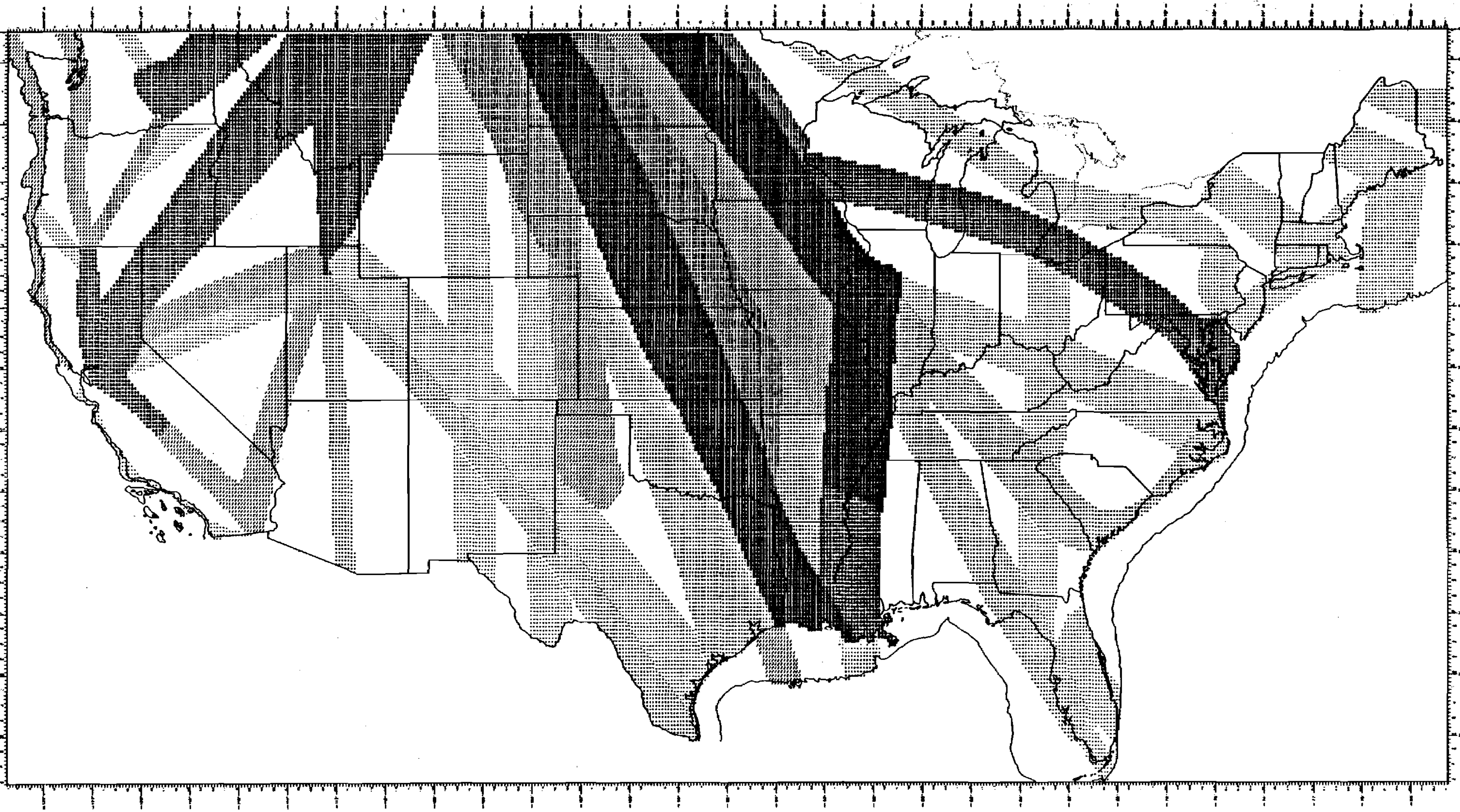

Exhibit C-5 FLYWAYS OF MIGRATORY WATERFOWL
DUCKS

• 50,000 - 225,000 ducks	X 1,510,000 - 3,000,000 ducks
= 256,000 - 750,000 ducks	θ 3,010,000 - 5,250,000 ducks
/ 751,000 - 1,500,000 ducks	█ 5,250,000 - 9,000,000 ducks

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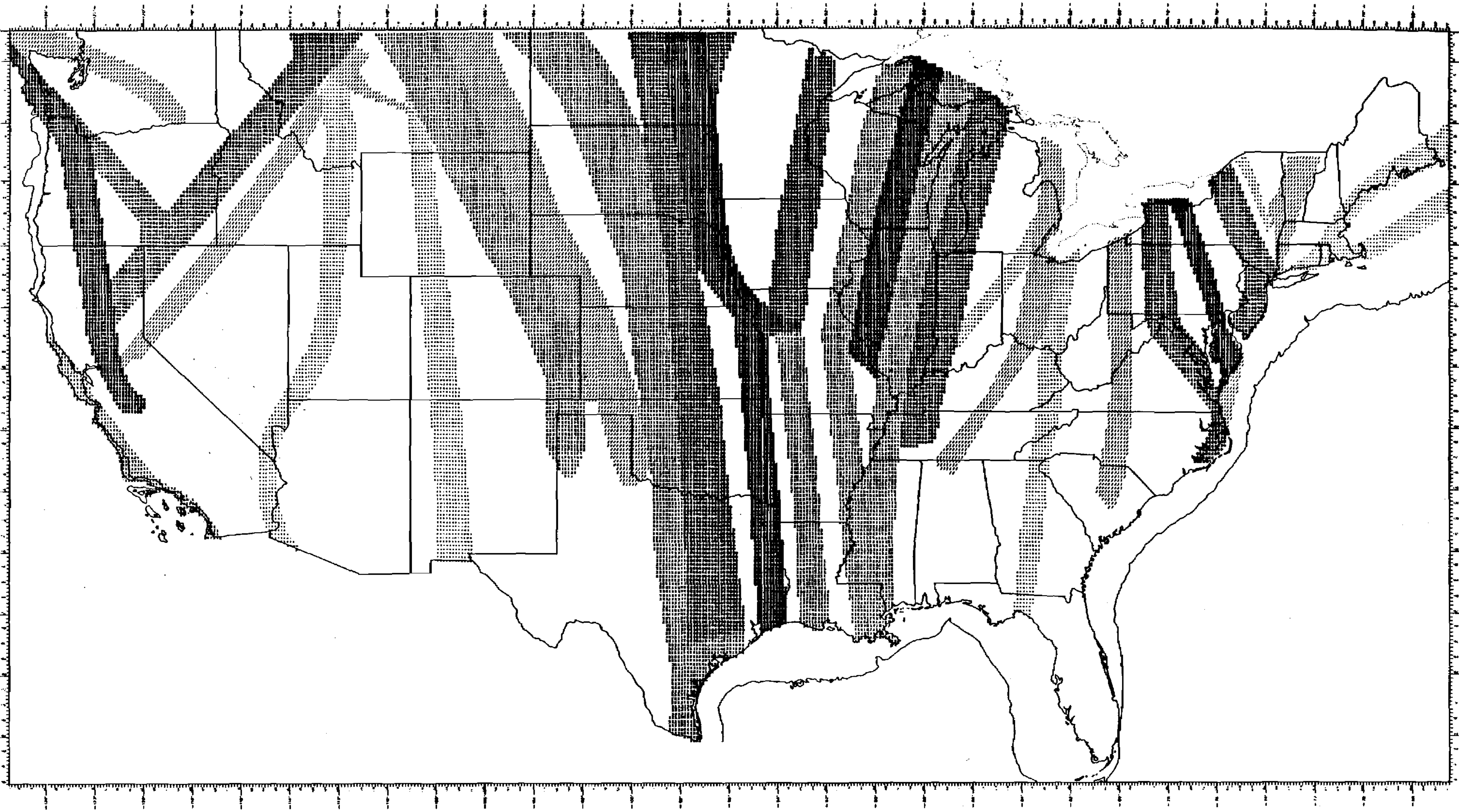

Exhibit C-6 FLYWAYS OF MIGRATORY WATERFOWL
GEESE

= 5,000 - 25,000 geese
/ 26,000 - 75,000 geese
X 76,000 - 150,000 geese
θ 151,000 - 300,000 geese
█ 301,000 - 500,000 geese

the number of ducks found in certain corridors. Also, while the routes are generally similar, they do vary spatially. This variance may be observed in the pathways followed (i.e., the Great Salt Lake appears less important to goose migration than to duck migration) and one also can see a variance from duck pathways with respect to the corridors of highest use. Again, one gains a level of specificity that is far superior to that found on general maps of the flyways.

In summary, it can be seen that the migration corridors of ducks and geese have been well defined by Bellrose, both with respect to their spatial coverage and with respect to the density of use. In the following section, the migration of other bird species will be discussed.

C.2.b. Other Migratory Bird Species

In Bellrose's discussion of the migration patterns of ducks, geese and swans, he provides detailed discussions of 55 bird species that fall within these three groups. He does not address other bird species in this excellent book. It has been estimated that there are 660 nesting species in the United States and that two-thirds of these species migrate. Therefore, an important inquiry concerns the pathways of the 385 bird species not included in Bellrose's description of ducks, geese and swans. At this point, it is interesting to note that estimates of the total bird population of the United States indicate that there are some six to seven billion birds during breeding season. Assuming that two thirds of these birds migrate (this may not be true), then one can see that upwards of 4.6 billion birds could be affected by rectenna siting decisions.

In the literature reviewed in this study, one finds two kinds of information about the migration paths followed by birds other than ducks, geese and swans. The information is either very general or extremely specific. Much of the discussion concerns flyways (shown in Exhibits C-1 - C-4). The issue of the flyway is best addressed by Lincoln in his book titled The Migration of American Birds. Concerning flyways, he states:

> Since complete discussion cannot be given presentation for all of the 768 species of North American birds, the account of each flyway will include only typical migration routes. Also, it is well to remember that despite certain appearances of sharp definition, migration routes and flyways are of varying width and should not be taken too literally. The Western Hemisphere, in its entirety, constitutes a vast mass of the earth's surface, and lines on small-scale maps indicating routes of migration may well represent sections of the country hundreds of miles in width. A migration route may be anything from a narrow path that adheres closely to some definite geographical feature, such as a river valley or a coastline, to a broad thoroughfare that leads in the desired direction and follows landmarks only a general way.

> Moreover, aside from the main routes of a flyway, there are always a multitude of tributary and separate minor routes. The valley of every little stream is, in fact, a migration route of some importance to individual birds of that watershed. In fact, the entire continent of North America is crossed and recrossed by lines of migratory flight, the different groups or species frequently following routes that may touch or intersect those taken by others of their own kind or by other species.

Although Lincoln's work was published in 1939, nothing in the recent work refutes his assertion. In fact, the major feature of more recent works is their interest in migratory processes and relative disinterest in the migration paths. Those works that have concentrated upon migration paths do so only on a species by species basis.

From a survey of the literature generally, it is impossible to specify migration pathways without engaging in a compilation of the paths of individual species. This effort is considered to be beyond the scope of this investigation. However, it is important to note that many of the individual migration paths differ from the flight lines identified in the flyway maps and from the corridors identified by Bellrose. Therefore, while generalizations can be made about bird migration, the need exists for a summary map of the migration routes and densities of the various bird species.

In summary, one must again emphasize the importance of research efforts concerning microwave effects. From previous discussion, it is apparent that migratory bird activity covers a large portion of the United States. If it becomes apparent that birds are adversely impacted by the microwave beam, then a major research effort will be necessary to determine those areas to be avoided as rectenna sites. If, however, the research indicates that no negative impacts ensue from short-term exposure, then detailed analysis of bird migration paths will not be necessary for SPS rectenna siting purposes.

APPENDIX D. EXTENDED ANALYSIS OF TOPOGRAPHY

D.A. INTRODUCTION

In the initial specification of exclusion variables, "topography unacceptable" was established as one of several absolute exclusion variables. This designation was predicated on a general acknowledgement that it would be very difficult if not impossible to build rectenna sites in or on steep mountains. In addition, there was some very limited information in the rectenna design set forth in various NASA publications. In one case for example, it was stated that a rectenna could be constructed "anywhere a bulldozer can go". Predicated on this rather broad definition and the fact that an absolute exclusion variable was intended to be a very stringent test, unacceptable topography was essentially restricted to the major mountain ranges in the United States. These were areas identified with substantial relief on the shaded relief map of the United States prepared by the U.S. Geological Survey. Even with this rather narrow definition of topography, almost 20% of the land area in the United States was eliminated.

The problems with this rather general definition became apparent only in the process of validation. An initial attempt was made to establish an operating definition or threshold for unacceptable topography. It became obvious that no detailed analysis had been done of the earth moving costs and design problems associated with topography. All existing cost estimates and plans were apparently predicated on essentially flat land.

As a working assumption, a test of 10% of the land area with over 10% slope was established as a preliminary basis for reclassifying apparently eligible grid cells as excluded in the validation exercise. It became obvious that with this test 80% or more of the eligible areas would be reclassified as excluded. Since the 10%-10% test was itself rather arbitrary and drawn from very tentative conclusions developed in the course of the Prototype Environmental Assessment for the SPS (ERG, 1980), further research was indicated.

This further research consisted of four major elements:

1. The systematic development of an operationally defined threshold for topographic exclusion.

2. The application of this revised threshold to the entire sample of 180 randomly selected "eligible" validation cells.

3. The development from other published maps of more refined topographic classification of the land area of the United States.

4. The systematic testing of these more refined classifications using the same basic validation methodology in order to establish what proportion of each classification was likely to remain eligible upon closer more detailed examination.

Because this issue is so sensitive and because the research methodology was developed and modified in the course of this study, each of these four tasks are described in this appendix. This is in addition to a summary treatment of the problem in Section VII.C.

D.B. DEVELOPMENT OF REFINED EXCLUSION THRESHOLDS

Preliminary investigation revealed that the major problem associated with topography was the expense of extensive earth moving. The volume and cost of earth moving associated with various slopes was not addressed in any of NASA literature on the reference concept SPS. Furthermore, neither the major sub-contractors, e.g. General Electric or Rockwell, had specifically explored this problem. Nor was it possible to obtain meaningful responses from engineering firms which had studied at least peripherally the SPS rectenna construction problem. These included United Engineers of Philadelphia and Brown and Root in Texas. An effort was made to identify and contact an engineering firm with extensive experience in major earth moving for large scale projects. Mr. Steve Hammitt, a Senior Civil Engineer from the Ralph M. Parsons Company was interviewed at length and briefed thoroughly on the general specifications of the SPS. This briefing was conducted by Dr. John Hill of the Environmental Resources Group who was specifically familiar with many of the construction problems by virtue of his participation in the prototype environmental impact statement for the SPS.

The initial premise on which the establishment of a new exclusion threshold for topography was based was one of cost. With a nominal budget of \$2-\$2.5 billion for the receiving antenna, a threshold of \$250 million in additional cost was established as a probable level at which topography would render a site unacceptable. Within this framework the main objectives of the extended briefing and review with the representative of the Ralph M. Parson Company were as follows:

1. Develop rule(s) for determining from data presented on USGS topographical maps whether total earthwork costs would exceed \$250 million, or about 10% of rectenna cost.

2. Acquire a basic understanding of civil engineering practices employed to evaluate the suitability of a site, estimate earthwork volumes and earthwork costs.

3. Critically evaluate a number of USGS topographical maps of eligible cells, and to classify these cells, in terms of topography, as acceptable, unacceptable or indeterminate.

Working towards these objectives, the research team consisting of a Dr. Hill and Mr. Hammitt developed the following general principles with respect to the problems and costs of large scale earthwork:

1. Unit sitework (earthwork) costs vary by ± 20% throughout the U.S.

2. Earthwork which can be performed by a scraper (a large machine which simply "scrapes" soil off the surface) costs $3.00/yd^3. This includes a haul of 1,500 feet, and compaction at the fill site. This figure assumes that the scraper will not require assistance from a bulldozer (or other equipment) for either excavation or transportation. This cost could be roughly 40-50% lower due to economies of scale, but large uncertainties prevail. If a "ripper" is needed to break the soil, add $.30-.60/yd^3.

3. If drilling and blasting are required, costs are much higher rising to perhaps $24/yd^3. Again, economies of scale may reduce this 40-50%, but the uncertainties in final costs would depend on haul distance, rock/soil type and other site-specific factors.

4. Earthwork volumes are generally computed by one of two means: Average and area method, and reservoir method. The former is most commonly employed and consists in constructing two parallel cross sections (A_1 & A_2) and multiplying their average area by their separation h:

$$V = \frac{(A_1 + A_2)\, h}{2}$$

   For precision this is often done on a fine scale with h being only a few to several feet; contour maps with very small intervals (i.e., 1-5 feet) may be prepared for such work. It is appropriate to envision earthwork volumes in terms of pyramids, cylinders, cones, wedges, hemispheres, etc. in order to approximate earthwork volumes.

5. Other factors which will affect earthwork costs, but which cannot be assessed via topographical map data are: soil types (the presence of rocky soils may be indicated by quarries), drainage, water table depth, forestation/vegetation, and weather.

6. Earthwork costs increase significantly for slopes in excess of 25-30% due to the difficulty of moving equipment. If earthmoving costs are to remain under $250 million, one would exclude sites with significant amounts of such slopes, other than mere drainage incisions.

The foregoing dollar estimates are in 1980 dollars and are drawn from "Building Construction Cost Data 1980", R.S. Means Company, Inc., Kingston, Massachusetts. It should be stressed that the foregoing analysis is significantly limited in its application since poor soil conditions can tremendously increase the above referenced costs. Soils data is, unfortunately, not readily available on a national scale and was not mapped.

Based on the principles described above and extended inspection of specific maps in large scale to determine empirically the feasibility of building a rectenna, the following rules were evolved for subsequent application:

1. A site may have as much as 90% of its area at up to 20% slope; provided that drainage incisions are not excessive.

2. A site is unacceptable if it has slopes in excess of 25-30% in areas other than small drainage incisions.

D.C. RECLASSIFICATION RESULTS USING REVISED TOPOGRAPHY TEST

In the national sample of fifty randomly selected cells, a total of 27 (54 percent) were excluded based on this more refined topographic test. For the regionally weighted sample of 180 validation cells, the porportion was very similar with 97 cells (53.9 percent) reclassified as excluded due to topography. In the national sample, 3 of the 27 reclassified cells would have been reclassified anyway. In the regional sample 12 of the 97 reclassified cells would have been reclassified in any case for nontopographic variables. Stated alternatively, the net reclassification or elimination impact of topography in the national sample was 24 cells out of 50 or 48%. In the regionally weighted sample it was 85 cells or approximately 47%.

These national data as well as the regional impact of topography are shown in Exhibit D-1. As may be seen from this Exhibit, the largest impacts from topography were felt in proportional terms in the Northeast (NPCC), Mideast (ECAR) and West (WSCC).

D.D. DEFINED CATEGORIZATIONS OF TOPOGRAPHY

To a limited degree, the foregoing analysis does not significantly alter the basic principle underlying absolute exclusion variables. It may be argued that topography remains a design/cost variable insofar as there is no national policy, national security or safety reason precluding development of rectennas in difficult topography. At the same time, however, it became apparent that some finer gradation of topography was needed. Such refinement would help to establish just how severe this problem was and to what extent significant redesign of the rectenna would be needed to establish widespread site availability. A three-level topographic classification was developed. The primary source for this classification was the U.S. Geological Survey's "Classification of Land Surface Forms" (U.S.G.S., 1970).

The three classifications which evolved from this source were:

1. Flatlands as designated by the U.S.G.S.

2. Mostly flatlands as designated by the U.S.G.S.

3. A residual classification of intermediate topography as evolved by subtracting from the total land area of the United States the flatland and mostly flatland in the U.S.G.S. source and the originally identified severe relief definition of unacceptable topography.

Maps showing the distribution of unacceptable topography, flatland, mostly flatland, and intermediate (residual) topography, are shown in Exhibits D-1, D-2, D-3, and D-4. A simultaneous plot of all types of topography is shown in Exhibit D-5. This map uses a slightly different projection and plotting technique which permits different densities. A simple visual inspection of the maps clearly indicated that flatland and mostly flatland was fairly widely distributed and no regions would be totally eliminated. There was, however, a critical underlying assumption which was that the level of reclassification in flat and mostly flatlands would be much lower if these areas were subject to the same detailed examination as the original validation sample.

A test to determine this assumption was devised. All flatland and mostly flatland were mapped on the national grid square base map. Grid squares from the original national and regional samples used during the eligible area validation exercise that occurred in either of the terrain categories were noted and reexamined. Seventy-nine of the original sample groups of 187 fell into one of the categories. Of these 25 were flatland squares and 54 were categorized as mostly flatland topography. an additional 25 random grid squares were selected from the flatlands regions in order to further substantiate the significance of the findings. This increased the total sample to 104.

The results of this revised landform classification on the topographic eligibility findings were encouraging. Only two of the 50 topographic quadrangles sampled for the flatlands category were eliminated by the same terrain criteria applied during the eligible areas validation procedure. This 4.0% rate of reclassification contrasts markedly with the 54% average reclassification during the first test. The flatlands classification seems to provide a considerably more accurate depiction of acceptable topographic regions of the United States.

The "mostly" flatlands category samples yielded different results. Of the 54 eligible squares samples, 36 (66.7%) were topographically acceptable, a noticeable improvement over the average 46% in the initial eligible area validation.

It appears that eligible areas selected from the flatlands and mostly flat lands categories described above would be consistently more acceptable when measured against the constraints of the topographic exclusion variable.

A third category, "intermediate topography" can be defined as a residual. It consists of those originally defined "eligible" areas that were not flat or mostly flat. There were 108 cells in the original validation sample. Of these 108, only 26 or 24% are topographically eligible.

Considered together there are four topographic categories representing a clear gradient:

Category	Sample	Percent Topographically Eligible	Tolerance of Estimate (one standard deviation)
Flat	50	96%	+ 2.8%
Mostly flat	54	67%	+ 6.4%
Intermediate	108	24%	+ 4.1%
Initial "unacceptable exclusion"	-	Assumed 0	-

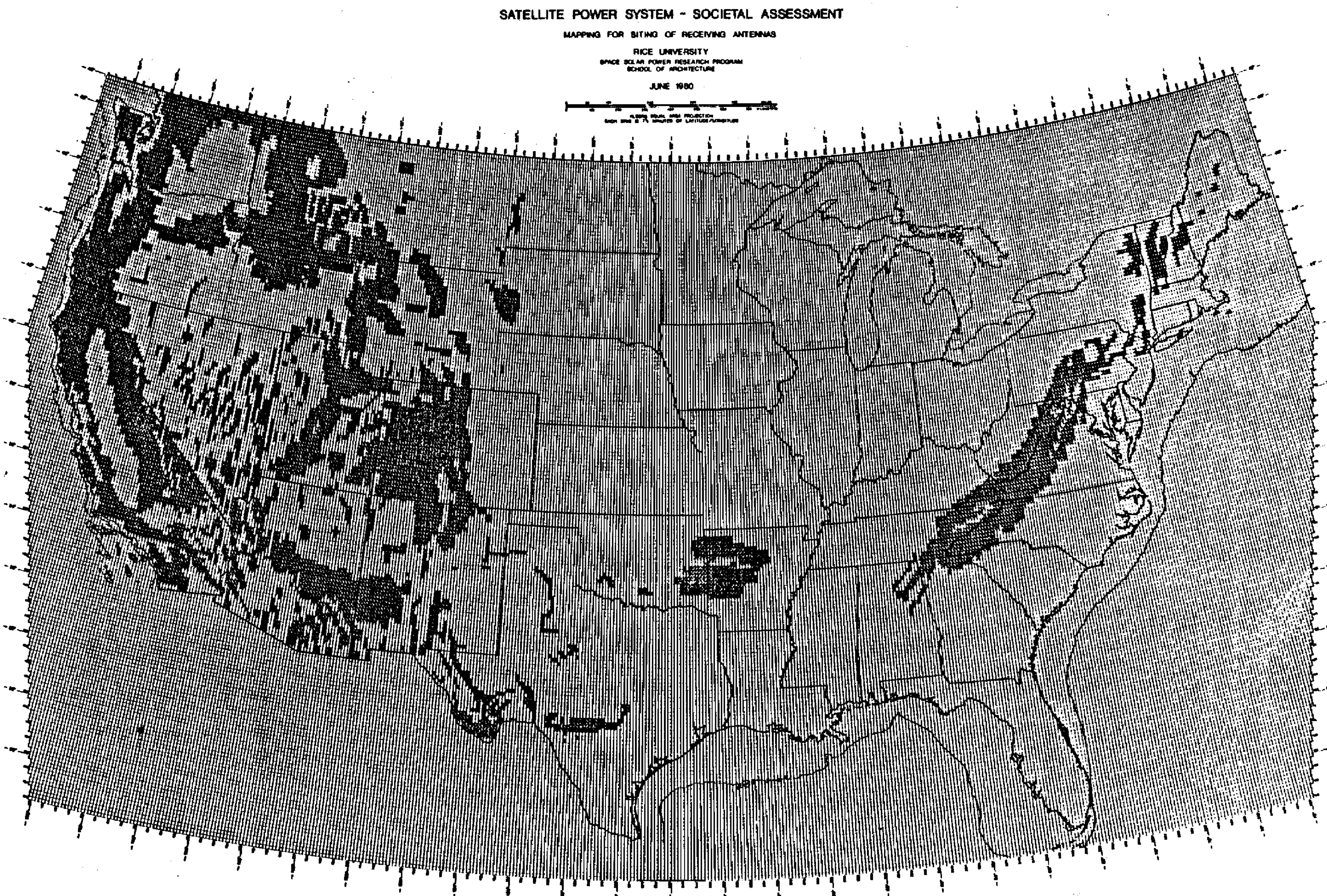

Exhibit D-1 **UNACCEPTABLE TOPOGRAPHY**

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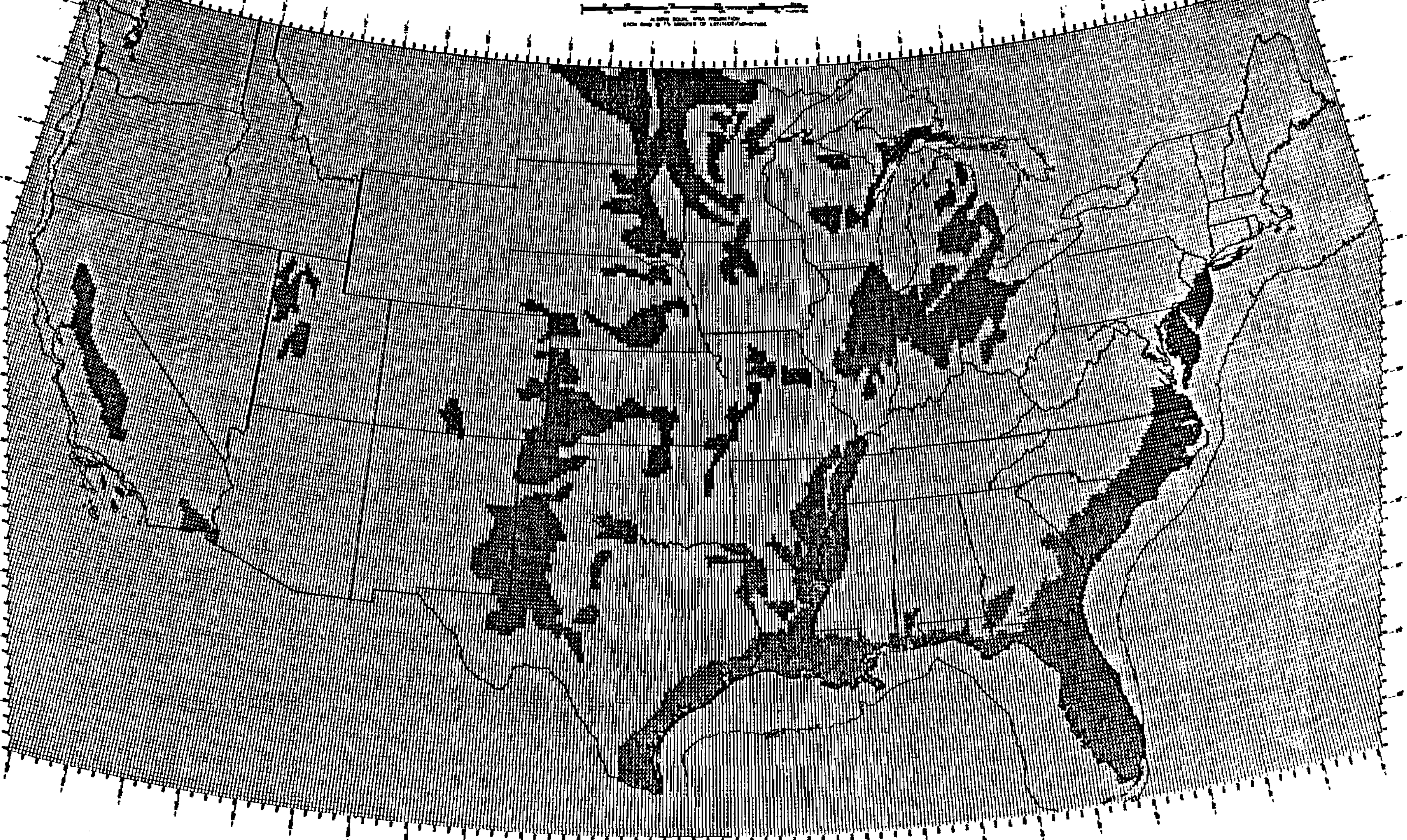

Exhibit D-2 FLATLANDS

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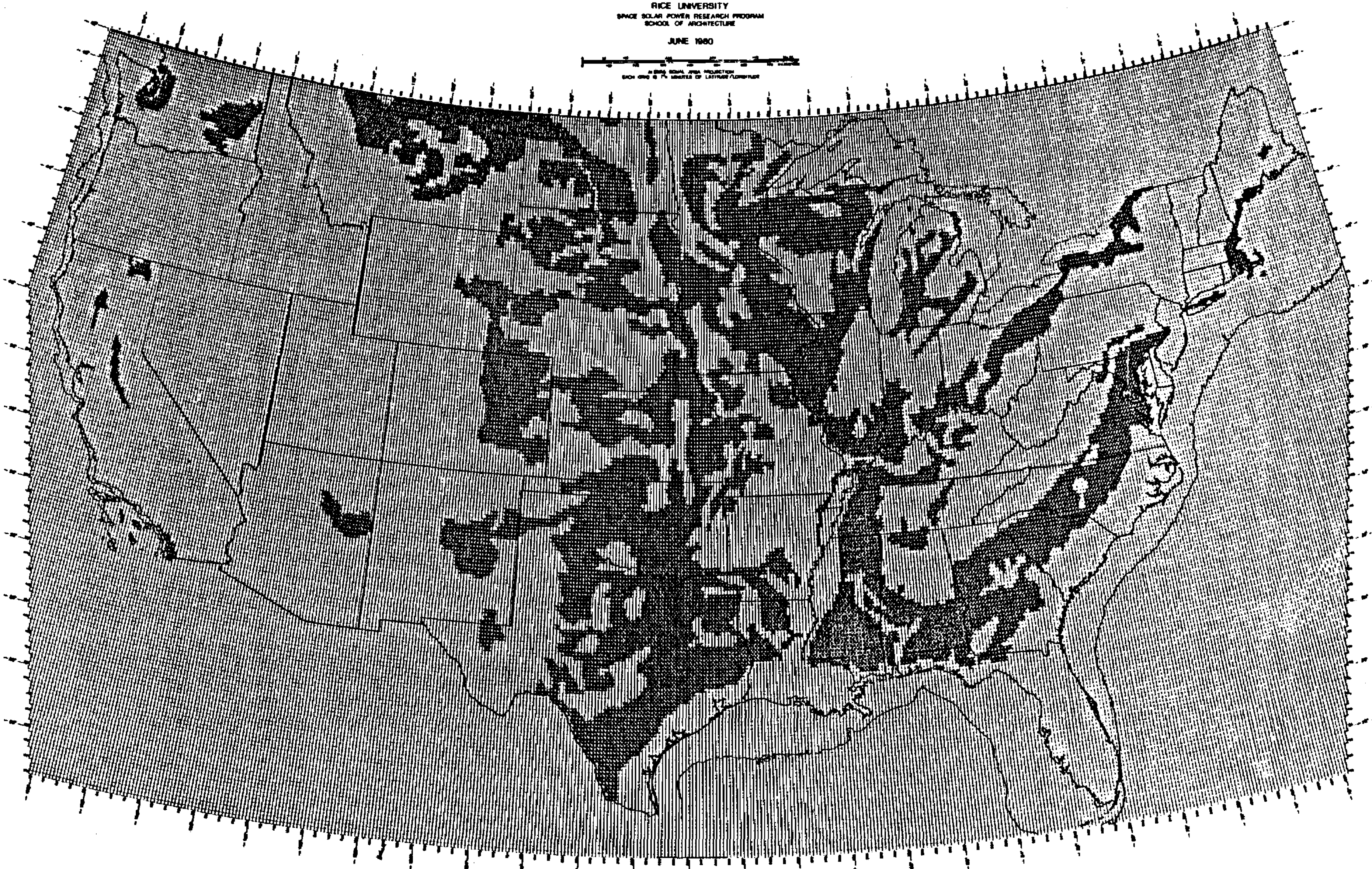

Exhibit D-3 MOSTLY FLATLANDS

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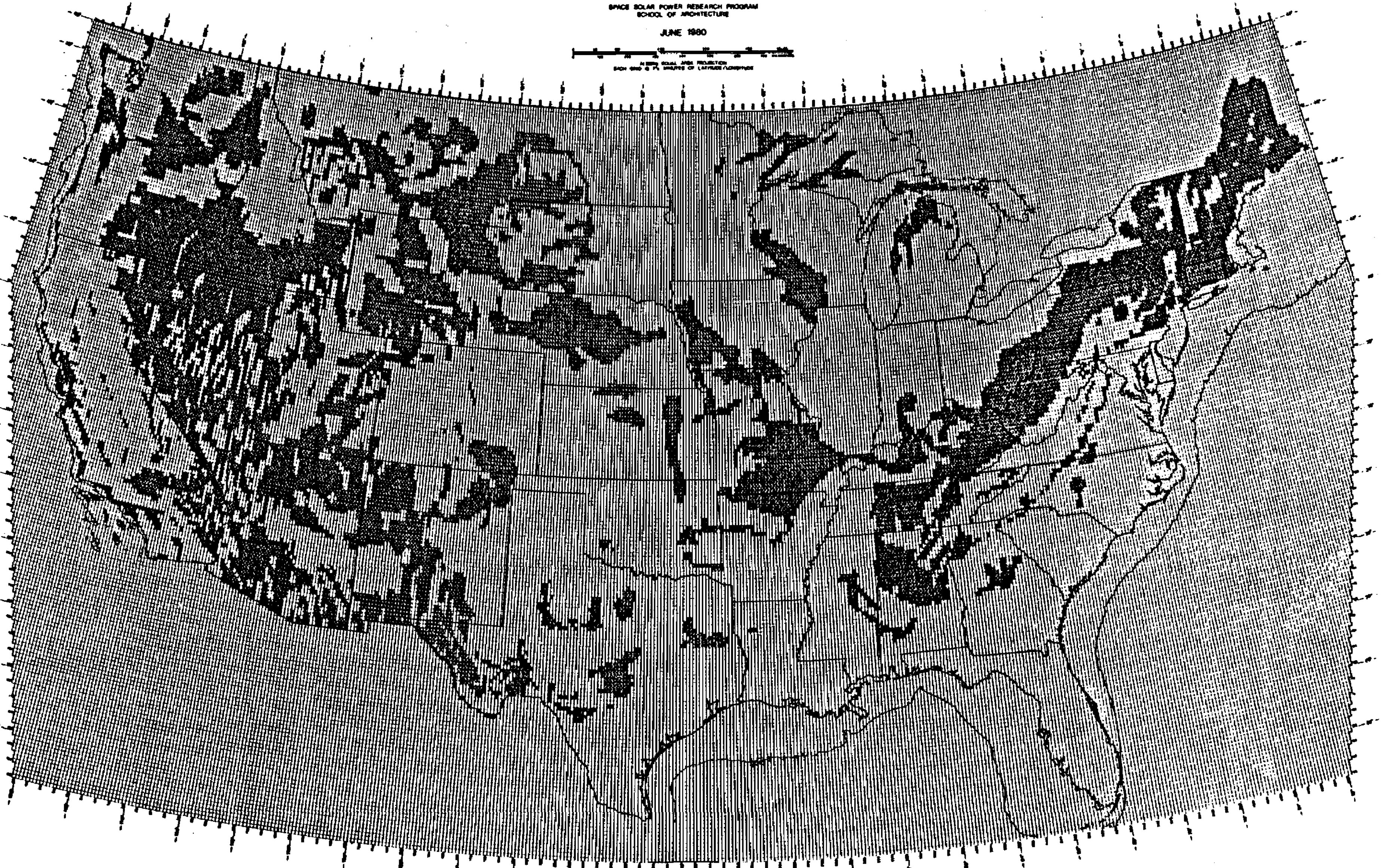

Exhibit D-4 RESIDUAL LANDS

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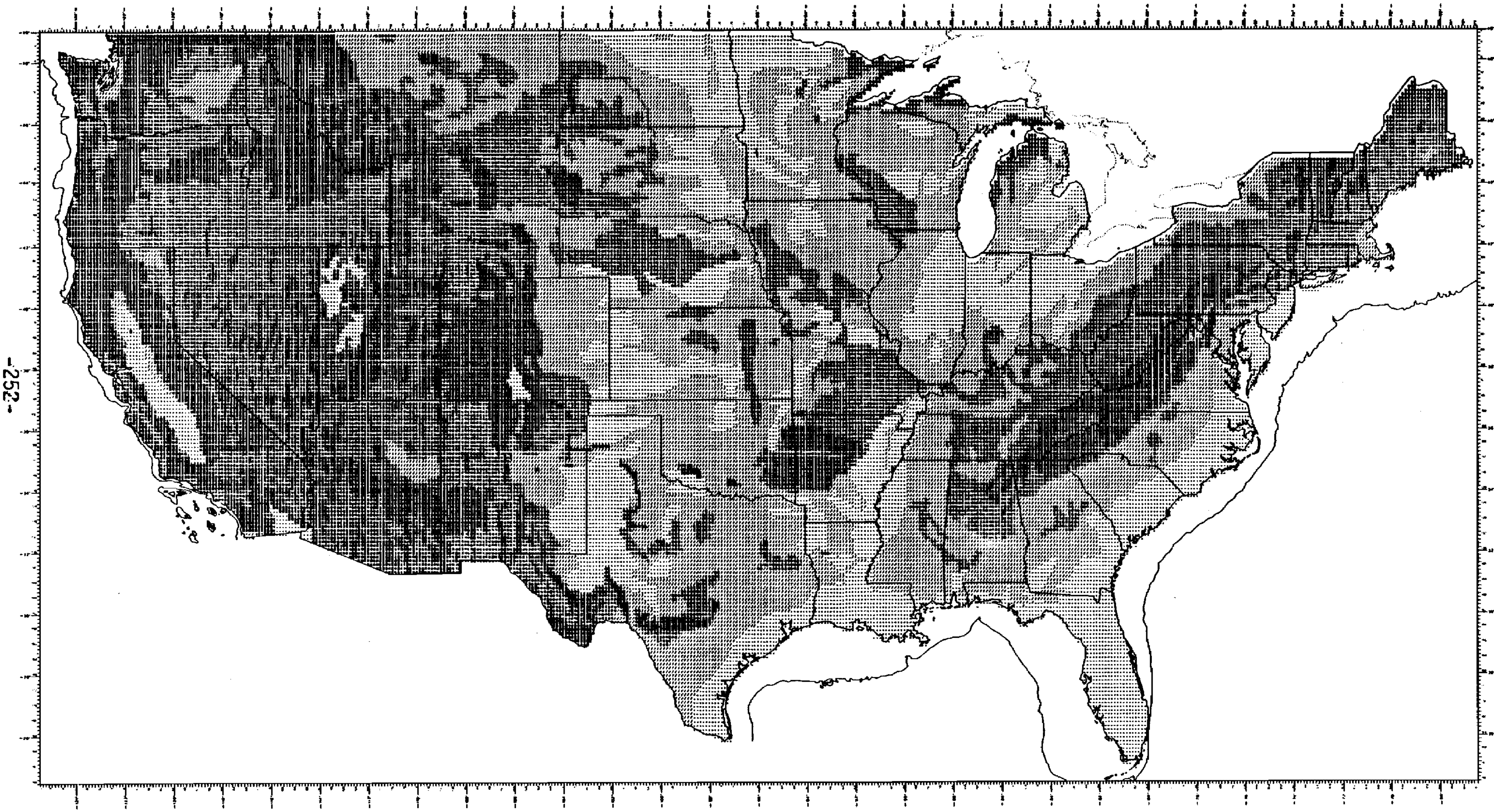

Exhibit D-5 TOPOGRAPHY

∘ flatlands

/ mostly flatlands

θ residual lands

█ topography unacceptable

APPENDIX E. DATA MANAGEMENT

E.A. INTRODUCTION

Data management for this project was executed with a family of programs loosely referred to as the Rice Architecture Geographic Information System (RAGIS). RAGIS resulted from a series of programs developed for research at Rice University and were initially presented in thesis form (Bavinger, 1976). These programs have subsequently been applied to several research projects requiring spatial data analysis (Blackburn and Bavinger, 1978; Bedient, et.al., 1978; Rowe, et.al., 1977; Rowe and Bavinger, 1977). The first phase of research on the SPS rectenna siting utilized RAGIS without modification (Blackburn and Bavinger, 1978). RAGIS is dependent on a computer language named Speakeasy (Cohen and Pieper, 1979), which was originally developed at Argonne National Laboratory during the 1960's. Due to an internal data structure size limit within Speakeasy, several new programs were developed to manage the input and output to RAGIS of the increased number of grid cells used for this project. No modifications to the basic analysis programs within RAGIS were required.

The sections of RAGIS that were used for this project originated from the concept of spatial data coding and storage as image structures instead of numerical values. Individual data patterns were coded as either present or absent within grid cells which define the base map. Input data was stored and analyzed in binary data structures in the computer resulting in substantial savings over other forms of spatial data capture. There were other advantages to the binary form of spatial data coding which seemed well suited to this study. Most importantly, the relationships between large amounts of spatial data could be analyzed and perceived clearly and comprehensively. Also, the level of effort to code and check data was much less than other systems. Disadvantages resulting from not having numerical values in the grid cells could be overcome by interfacing the image data base with existing numerical data bases. While not utilized in this project, the interface capabilities of RAGIS would be important to subsequent siting studies. In addition to coding and analyzing data for this study, RAGIS was seen by the project researchers as forming the basis of a generalized methodology capable of managing data from diverse sources within a comprehensive framework.

E.B. SPEAKEASY

Speakeasy is at the same time both an easily learned, user-oriented, English syntax language and one of the most powerful interactive computational languages in use today. In Speakeasy the language processor is separated from the mathematical operators and specialized commands (words) that represent current on-line capabilities at any time. Thus the power of Speakeasy is twofold: its organization, which is not dependent on its language syntax, and its extensive vocabulary of distinct operations which at this time consists of over 600 words and is growing (Cohen, 1977).

Speakeasy executes in either Time Sharing Option (TSO) or Batch and is managed in the conventional mathematical notation of operators, operands, and resultants. Problems can be formulated, explored with the desk calculator mode that is always available, and processed very interactively with either existing operators or user developed programs that become new operators. Operators are compiled programs in standard system supported languages (Fortran, Assembly, etc.) that are dynamically linked to Speakeasy's language processor. These linked load modules are called linkules. To the user, linkules are a vocabulary of English language key words, as the programs are called and executed by their names. Any sequence of operators in the processor is also an operator - the compound operator corresponding to the application of the elementary operators belonging to the sequence. It is the capability to create compound operator sequences, and thus modify individual operators, which is one of the fundamental properties of dynamic data processing. Operators can be modified without being rewritten. In practice, there is a critical mass of operators beyond which the necessity for writing new operators diminishes.

In dense data management applications there is a need to handle data as large structured objects (arrays, matrices, vectors, etc.). This allows large groups of data to be referred to simply, yet it maintains the relative positional integrity of each datum through any involved operations. Speakeasy is based on dynamic Named Storage (Cohen, 1964) and its I/O system provides support for large structured objects as they are retrieved from partitioned data sets (PDS) and loaded into the named storage allocator. The expandable configuration of the storage allocator, combined with the interactive but automated loading and storage of objects through standardized commands, makes Speakeasy capable of manipulating large amounts of data in varying analysis structures. Essential in this process are the tags attached to each object denoting its structure, shape, size, and data type. In this manner, the language processor allows the user to refer to objects in main memory, manipulate PDS directories and move objects alone or in groups between main memory and multiple disk and tape libraries.

Another series of PDS libraries contain executable load modules (linkules) in a format which allows the processor to dynamically link to them at any point in the interactive analysis stream. These linkules are usually Fortran functions which, by means of an extensive argument string as well as accessory functions callable by the linkule, are able to communicate with the language processor. These linkules are far more powerful than standard subroutines. They can, for example, dynamically access Named Storage, creating, reshaping, expanding or deleting objects as needed.

Data and analysis routines (both existing programs and newly created ones) are incorporated into a common English language framework. Thus, a user-oriented interactive environment for diverse data processing is integrated under the umbrella of Speakeasy. Because the language processor and attached libraries are kept separate, each new addition will not increase overhead. Even with very modular systems this is a problem. The use of attached libraries of programs via the dynamic link to the language processor provides a system with easily expandable capabilities in a way that neither constrains the growth nor increases the basic structure of the language.

Availability

Speakeasy: Dr. Stan Cohen
Speakeasy Computing Corporation
222 West Adam Street
Chicago, Illinois 60606
(312) 346-2745

Speakeasy leases for $4,800 per year ($1,600 for academic sites)

The constraint on distribution is no secondary distribution.

Speakeasy is in use at over 100 sites around the world.

Speakeasy was first distributed in 1968 and operates on IBM 360 or 370 computers operating under OS, TSO, VM/CMS, or MTS, also translated for use on FACOM-230, PDP-10 and PDP 11/40, and a CDC version is in progress.

Reference Manuals Available

1. The Speakeasy-III Reference Manual/Level Nu
2. The Speakeasy Help Documents/Level Nu
3. The Speakeasy Example Documents
4. A Guide to TSO Speakeasy
5. A Speakeasy Sampler
6. Fedeasy/Speakeasy Help Documents
7. Gspeak: A Data Management Facility for Speakeasy
8. Relational Data Base Manipulation in Speakeasy

E.C. RAGIS

The Rice Architecture Geographic Information System consists of over 250 individual programs designed to execute various aspects of geographic information management. The programs are primarily written in FORTRAN and in many cases call Assembly language subroutines. The programs are dynamically linked to Speakeasy's processor and are call linkules. Because

RAGIS linkules have been developed to explore a broad and sometimes diverse range of concepts related to spatial data management, no singular description of the system is possible. The following description of the major linkules and their calling sequences by task area provides the clearest insight to the nature of RAGIS:

TASK AREA

LINKULES	CALLING SEQUENCE

ARRAY AND MATRIX BUILDERS
these configure data for input into defined functions

Concat - concatenates half vectors into single arrays	ARRAY=CONCAT(NAMES1, (NAMES2), LENGTH1),(LENGTH2)
Rbvld - builds a column major array	ARRAY=RVBLD(NAMES,LENGTH,(FILE))
Logpv - calculates association matrix of logical patterns	MATRIX=LOGPV(ARRAY1,(ARRAY2),(MASK))
Rho - calculates matrix of gradient data using Spearman's rho	MATRIX=RHO(NAMES, LENGTH,(INDEX),(FILE))

CONVERSION FORMATS
these shift internal storage formats

Logout - converts logical*1 to real*8	REAL*8=LOGOUT(LOGICAL*1)
True - converts any array to logical*1	LOGICAL*1=TRUE(ANY ARRAY)
Bits - converts logical*1 to a packed bit string	PACKED BIT STRING=BITS(LOGICAL*1)
Bytes - converts a packed bit string to logical*1	LOGICAL*1=BYTES(PACKED BIT STRING)

LOGICAL OVERLAY ROUTINES
these comprise the set of logical operators

And, Or - the logical and, or of bit patterns	NEW PATTERN=AND, OR (PATTERN1,PATTERN2,....)

Vand, Vor - the logical and, or of indexed array rows or bit patterns	NEW PATTERN=VAND, VOR(ARRAY, INDEX)
Not - the logical not of bit patterns	NEW PATTERN=NOT (PATTERN)
Bytand, Bytor - the logical and, or of byte strings	LOGICAL*1=BYTAND, BYTOR(STRING1, STRING2,....)

INPUT/OUTPUT AND ENCODING FORMATS
These input and access binary data patterns

In or Retin - these are the input routines which allow for the creating and altering of patterns	IN((NAME)) or PATTERN=RETIN((NAME))
Out - displays patterns	OUT(NAME)

FACTORING FUNCTIONS
these work together to find major factors or dimensions within a matrix

Colin - inserts an estimated communality sum into a matrix	ESTIMATED COMMUNALITY SUM=COLIN (MATRIX)
Ncolin - no communality insertion	NCOLIN(MATRIX)
Vary - finds key variable upon which to build dimensions	PIVOT(4)=VARY(MATRIX)
Define - finds dimension group index where thresh is minimum group mean and minimum is the group minimum	GROUP=DEFINE(MATRIX;APIVOT,THRESH)
Extract - calculates each variables' correlation with the dimension defined by the group where 'factsum' is the revised communality sum and is incremented if defined	FACTOR=EXTRACT(MATRIX,GROUP)
Remove - reduces the matrix by a factor so that future factors will be orthogonal to this factor	REMOVE(MATRIX,FACTOR)

CLUSTERING
these define similar members of a hyperspace into groups that are similar across the data

Density - finds hyperdensity immediately adjacent to each sample across the data	DENSITY GRADIENT=DENSITY(ARRAY, THRESHOLD,INNER THRESHOLD)
Sim - finds hyperspace distance to an arbitrary sample	SIMILARITY=SIM(ARRAY,CENTROID)
Wabit - find hyperspace distances to indexed samples	SIMILARITY=WABIT(ARRAY,CENTROID, INDEX)

<u>MATRIX CLUSTERING</u>

Alink - clusters matrix by absolute linkage, controlling thresholds are: minimum group means minimum group minimum minimum group seed	GROUPED=ALINK(MATRIX,(DIRECTORY), MAXIMUM GROUPS),THRESHOLDS)

<u>VISUALIZATION OF VARIABLE RELATIONSHIPS</u>
these display the subspaces of a factored matrix on a theoretical manifold of a hypersphere

Augment - defines hyperspherical configurations	AUGMENTED FACTORS=AUGMENT(FACTORS)
Spaces - defines subspaces and creates 'spaclogs' and 'spaces3d' as defined output	SPACES(AUGMENTED FACTORS, SUFFICIENCY)
Reflect - conforms subspace factors to visual format	POINTS=REFLECT(SPACE#,FACTORS)
Rotate - calculates rotation for maximum point spread	ROTATION MATRIX=ROTATE(SPACE#, AUGMENTED FACTORS)
Sphere - plots subspace	SPHERE(SPACE#,POINTS,FRAME,(PRINTLOG))
Calsph - plots grouped subspace for a calcomp plotter	CALSPH(SPACE#,POINTS,FRAME,(PRINTLOG), (GROUPS))

<u>MAPPING FORMATS</u>
these configure the output from various routines for the system lineprinter

Olap - prints assigned character(s) where any of a series of variable(s) is present: each variable overlays the others and the maps can be printed in a range of sizes	OLAP(NAMES,CHARACTERS,(TITLE),(FILE))

Gray - represents a gradient as a visual gray scale and prints maps in a range of sizes	GRAY(GRADIENT,(CHARACTERS/LEVELS),(TITLE1),(TITLE2))

ACCESS MODEL
these simulate probable developmental paths based on nodes and access

Sources - creates and updates a network array	ARRAY=SOURCES(#SOURCES,(#PATHS)); SOURCES(ARRAY)
Access - calculates the relative access density	GRADIENT=ACCESS(ARRAY,XCOORDS,YCOORDS,MULTIPLIER#,(MASK))

GRADIENT SMOOTHING ROUTINE

Surface - calculates continuous gradient from array of discrete points	GRADIENT=SURFACE(ARRAY,XCOORDS,YCOORDS,VALUE#,(MASK))

DYNAMIC FILE KEEPING (DIRECTORY MANIPULATION)
these allow for continuous access to tabular information during and at the end of processing any combination of routines

Meld - Inserts name alphabetically	NEW DIRECTORY=MELD(DIRECTORY,NAMES)
Prefix - Inserts a defined character before each name in a list	PNAMES=PREFIX(CHARACTERS,NAMES)
Adjust - locates global index within array(s)	INDEX/ARRAY=ADJUST(INDEX,ARRAY BOUNDS)

Speakeasy is internally limited to data structures of no more than 32,767 elements. Because the data structures for this project consisted of 92,512 grid cells, several programs were developed to manage the input and output of data to Speakeasy. Once the 92,512 element data structures for this project were compressed into byte strings (11,564 element data structures), Speakeasy and the RAGIS linkules performed without modification. The following is a description of the programs developed for this project.

PROGRAM	DESCRIPTION
Codedata	An independent Fortran program.

	Registers the base map and gets input points from Tektronix 4954 graphic tablet, packs them into 11,564 element byte arrays and saves them on a Speakeasy readable data set.
Plot	An independent Fortran program. Reads Speakeasy data set and produces a Calcomp pen plot of coded data points.
Getrow	A Speakeasy linkule (Fortran). Returns the indices of coded grid cells by row from a data pattern.
Rowcol	An independent Fortran program. Reads a list of row column, indices and a list of data names and produces a detailed list for each row column index showing whether or not each data pattern was coded.
Albers	A Speakeasy program. Produces the X, Y coordinate points for all of the grid squares on the base map based on the Albers Equal Area Projection (Richardus and Adler, 1972).
Doitall	An independent Fortran program. Reads a list of variable names and the corresponding Speakeasy data sets containing the patterns and the states, and produces the following: 1) an overlay of the variables as a composite map - stored as a Speakeasy data item 2) a table showing the on grid counts by state of each variable 3) a gray level output of the exclusion map indicating the number of times each grid was contained in each individual data pattern.

In summary, the major characteristics of RAGIS are as follows:

1. flexible and economic data storage and retrieval,

2. support for analytical and modeling applications,

3. exploration of spatial data for the purpose of defining, inherent structures and relations,

4. interface and compatability with other forms of geographically related data storage; i.e. statistical, graphical, and image-based systems

One of the principal ideas behind the development of RAGIS was to view a geographic information system more as a communications medium than as a fixed set of procedures. To this end RAGIS has been thought of as being a "medium" capable of "naturally" supporting a full range of data processing functions. A clear description of the nature of this concept of a "medium" has to date eluded the best efforts of the researchers involved with RAGIS. The preceeding description of linkules and task areas best defines the scope of RAGIS in its present state.

E.D. DATA PROCESSING

This section describes the application of RAGIS to this project in detail.

The data processing for this project was performed on an Itel AS-6 (IBM-370 compatable) computer at the Institute for Computer Services and Applications (ICSA) at Rice University.

Coding

Special consideration was given to the selection of a spatial reference system for this project. The spatial reference system would mathematically define how the data was located on the base map and stored in coded form in the computer. A number of systems have been developed to represent the curved surface of the earth on a flat map. The Albers Equal Area Projection system with two standard parallels was selected mainly because it is a standard spatial reference system in use by many government agencies. The actual base map for the project came from the United States Department of the Interior Geological Survey and is titled Key to National Topographic Maps of 1:250,000 Series, July 1976. The selection of the size of the grid originated from a desire to set the grid square size to the approximate area needed for a single receiving antenna. As it turned out, the USGS 7-1/2 minute quad series of maps were close to the desired size for a grid cell. Therefore the decision to use 7-1/2 minutes of latitude and 7-1/2 minutes of longitude for a grid cell size was made. One large advantage of this decision was that the base map was the same as the USGS map series and thus provided compatability with and access to one of the most comprehensive systems of maps maintained by the government. The mathematics used in the projection were taken from the book Map Projections for Geodesists, Cartographers and Geographers by Peter Richardus & Ron K. Adler, 1972. (Note: A publisher's error exists in a formula on p. 166 in the 1972 edition which is corrected in the 1974 edition.) The final base map contains 92,512 total grid squares of which 52,479 were in the continental United States.

The base map was plotted on a Calcomp pen plotter and was photographically reproduced onto individual film transparencies. Individual data patterns were coded on separate base maps using colored pencils. The coded maps were taped to a Tektronix 4954 graphic tablet (30" x 40") and a 4-button "mouse" cursor was used to code the data. The program CODEDATA was called using a Tektronix 4010 CRT terminal and the map was registered to the tablet and data was coded using the four buttons on the "mouse". Button 1 coded or turned on an individual cell. Button 2 opened a row of cells. Button 3 closed an opened row of cells. Button 4 deleted an individual cell. After the data was coded, it was assigned a code name and stored in a compressed data format. Individual gradient levels of gradient data such as topography were coded as separate data patterns.

Checking

The program PLOT was the primary tool for checking data. PLOT produced a Calcomp pen plot of individual coded data patterns using "X"'s in cells that were coded, or on. Thus, check plots could be directly overlayed on the original data maps for correcting. Data patterns to be corrected were called by the program CODEDATA for editing. An alternative method of checking was by manually matching printouts of row, column indices to the base data maps. Because of the availability of the pen plotter, this method of checking was rarely used.

Analysis

The major data structures used in RAGIS for this project were BIT STRINGS, where each grid was stored in each byte of the string, and COMPRESSED BIT STRINGS (or BYTE STRINGS) where 8 grids were stored in each byte. Thus, the BIT STRINGS were 92,512 bytes long and the COMPRESSED BIT STRINGS were 11,564 bytes long. This form of data storage was highly efficient and allowed a very large and complex data base to be analyzed comprehensively. The following is a technical description of these data structures and the RAGIS linkules that manage them.

Data Structure Information

I. LOGICAL *1 OPERATORS
   BYTE LOGICAL
   KLASS = 5 (usually)

1. REAL*8=LOGOUT(LOGICAL *1)
   returns 0 or 1 in same shape as input

2. LOGICAL *1=TRUE(ANY ARRAY)
   converts input values above 0 to LOGICAL *1 "TRUE", "FALSE" otherwise

3. OUT *1 = BYTAND(S1*1,S2*1....Sn*1)
   BYTOR
   returns AND, OR of byte strings of the same length

4. PACKED BIT STRING = BITS(LOGICAL *1)
   returns kind = 8, klass = 1 string with each bit (8 per byte) set on or off according to input values. Warns of invalid bits at the end of the last output byte if the input length was not a multiple of 8 (turns invalid bits off). All other linkules dealing with bit strings presume that kind = 8, klass = 1 and that there are no invalid bits. Bit arrays are kind = 8, klass = 6.

II. BIT STRING OPERATORS (klass = 1)

1. LOGICAL *1 = BYTES (BIT STRING)
   unpacks bit string

2. INDEX *4 = BITNDX(BIT STRING)
   returns index (integer *4) of "on" bits in input string

3. BIT STRING = AND(STRING1, STRING2, STRING3, ...STRINGn)
   OR
   performs and, or of input strings of same length

4. BIT STRING = NOT(STRING)
   performs not of input string

5. PACKED BIT STRING = CNTRCT(BIT STRING)
   compresses (packs) a BIT STRING into a byte object, 8 bits per byte.

III. BIT ARRAY OPERATORS

1. BIT ARRAY = CONCAT(NAMES1, (NAMES2), (LENGTH1), (LENGTH2), (LIB1), (LIB2))
   builds or concatenates single bit string objects in attached library into a single array. Takes list(s) of object names, length(s) and filename(s). If only one namelist is passed, an array is built of the named strings. Two namelists will perform string concatenation before building the array. Library names default to mykept.

2. BIT STRING = VAND(BIT ARRAY, (INDEX *8))
   BOR
   performs and, or of bit strings in array if index is passed, operates only on indexed strings

The major form of analysis in the project was map overlay or sieve analysis. This was accomplished using the RAGIS programs AND (intersection), OR (union), and NOT (binary opposite of individual data patterns). For example, the Standard Metropolitan Statistical Areas map could be added to the Adjusted Population Density map with the following syntax:

NEWMAP = OR (ASMSA, ADOT)

where ASMSA and ADOT are data code names.

The grid cell profile tables of each summary map by state were produced with the program DOITALL which counts the number of grids turned on for any data pattern by state. Each individual state was coded as a separate data pattern and stored in the data base.

Another form of analysis was performed by the program ROWCOL which produced a detailed list across the data base from selected grid cells indexed by their row, column position on the base map.

Density maps showing the spatial density distribution of several data patterns were produced by the program DOITALL. Different gray tones produced by overstriking characters on a high speed line printer represented different densities. For example, if 5 data patterns were being analyzed, then grid cells containing all 5 patterns would print darkest. Grid cells containing no patterns would not print, and other gray tones would be used to represent other combinations of the data by grid. These maps were used in the analysis of design/cost data patterns.

A final form of analysis called pairs analysis was performed by the RAGIS programs AND and COUNT. This form of analysis was used to determine the locational significance of individual data patterns to each other. A diagonal matrix of the intersection of each data pattern to every other data pattern in an analysis group was calculated.

E.E. CONCLUSION

RAGIS is an experimental geographic information system and contains other capabilities which were not needed for the execution of this project. However, a brief discussion of these concepts provides some notions that might be relevant to future siting studies.

Other concepts within RAGIS are those of spatial adjacency and spatial structure in complex data sets. The main groups of programs that explore these concepts are categorized under the following headings: (1)clustering, which produces maps showing which grid cells are performing similarly across the data; (2)cluster/factoring, which produces scattergrams showing which data patterns are performing similarly spatially; (3)adjacency or connectivity, which produces gray maps showing spatially the density of association between groups of data; (4)spatial context, which produces gray maps ranking spatial context association; and (5)surface finding programs which create continuous contours from individual point data.

Other data management capabilities are based on Speakeasy's relational data base called Rspeak (Schlicting, 1977). There are three general conceptual models for data management: hierarchical (tree), network (complex), and relational (tabular). Of these three models the relational seems to offer many advantages (Date, 1977). Relations are straightforward, relatively easy to understand, and their uniformity of representation allows an operational simplicity that is much more easily managed than either the network or hierarchical models. Also, since its organization does not depend on physical analogs, or pointers, to create relations between data the relational model offers a minimum of organizational or informational bias. The network approach, from which heirarchical models can be considered a special case, has many constructs which are essential in the data set. This one fact establishes the difference between relational and network models: relations are simple because they have one uniform construct, networks are complex because they have many operational constructs, all of which are necessary for data management and manipulation.

The introduction of Rspeak and the concepts of relational data management have allowed the perception of the interrelationships between the results of analysis and the raw data describing the original problem context. These capabilities are implemented very simply by adding attributes (columns) containing the results of various kinds of analysis to tables of attributes in Rspeak containing data (relations). Thus in addition to finding relationships between data, it is possible to find relationships both between various kinds of analysis and data, and among the results of the analyses. The merger of Rspeak with RAGIS analysis capabilities has allowed perceptions through first order data organizations to a second order of relationships describing the first order.

The development of computer based mapping systems has occurred at a very fast rate and has resulted in many different approaches of varying complexities. In general, geocoding systems have evolved from simple grid cell systems to more complex polygon systems, and more recently to raster based systems. Many times these systems are methodologically more complex than the problems to which they are applied. Generalized approaches to integrating information between various systems are not common. The image based data coding methodology in RAGIS offers a potentially clear method for integrating spatial data from various systems. This is primarily based on the fact that a data image in RAGIS would be an unambiguous index to spatial data in other forms. Two directions currently being explored are access to statistical data and to Landsat data. Further siting studies related to this project will require a spatial data management methodology capable of integrating many types of information from various systems and at various scales. RAGIS has always been perceived not so much as a collection of discrete capabilities but more as a generalized medium capable of managing information independent of context.

RAGIS has not yet reached a point of development where it is an externally usable system. The major reasons for this are its complexity, lack of complete documentation, and program support. At present RAGIS is used solely for applications and research in the Rice Architecture Computer Lab.

The data for this project is maintained in compressed bit string form on computer tape. The following is a list of data and data code names.

MAP TITLE	VARIABLE	CODE NAME
1. STATES	STATES	S + 2 LETTER STATE ABBREVIATION
2. ELECTRICAL RELIABILITY COUNCIL AREAS	WESTERN SYSTEMS COORDINATING COUNCIL	EWSCC
	MID-CONTINENT AREA RELIABILITY COORDINATION AGREEMENT	EMARCA
	SOUTHWEST POWER POOLS	ESPP
	AREA RELIABILITY COUNCIL OF TEXAS	EERCOT
	SOUTHEASTERN ELECTRIC RELIABILITY COUNCIL	ESERC
	MID-AMERICA INTERPOOL NETWORK	EMAIN
	EAST CENTRAL AREA RELIABILITY COORDINATION AGREEMENT	EECAR
	MID-ATLANTIC AREA COUNCIL	EMAAC
	NORTHEAST POWER COORDINATING COUNCIL	ENPCC
3. LAND & WATER	LAND	STATES
	OUTER CONTINENTAL SHELF	WATER1
		WATER2
		WATER3
		WATER4
		WATER5
	INLAND LAKES	WATERIN
4. FEDERAL LANDS	MILITARY RESERVATIONS	AFMIL
	ATOMIC ENERGY COMMISSION LAND	AFATOM
5. FEDERAL LANDS	NATIONAL RECREATION AREAS	AFREC
6. POPULATION	STANDARD METROPOLITAN STATISTICAL AREA	ASMSA
	ADJUSTED POPULATION DISTRIBUTION	ADOT
7. WETLANDS	MARSH VEGETATION	AMARSH
	PERENNIALLY FLOODED LANDS	AFLOOD
8. ENDANGERED SPECIES	DESIGNATED HABITAT	AHAB
9. INTERSTATE HIGHWAYS	INTERSTATE HIGHWAYS	AHIGH
10. NAVIGABLE WATERWAYS	NAVIGABLE WATERWAYS	ANAV
11. TOPOGRAPHY UNACCEPTABLE	TOPOGRAPHY UNACCEPTABLE	ATOPO
12. FLATLANDS	FLATLANDS	FLAT2
	MOSTLY FLATLANDS	FLAT1
	RESIDUAL LANDS	FLAT
13. ELECTROMAGNETIC COMPATABILITY	EMCA 100	A100
	EMCA 150	A150
14. ELECTROMAGNETIC COMPATABILITY	EMCA 50	A50
15. ELECTROMAGNETIC COMPATABILITY	EMCP 100	PE100
	EMCP 50	PE50

16. ELECTROMAGNETIC COMPATABILITY	EMCP 60	PE60
17. ELECTROMAGNETIC COMPATABILITY	EMCP 150	PE150
18. FLYWAYS OF MIGRATORY WATERFOWL - DUCKS	5,250,000 - 9,000,000 DUCKS	PFLYD1
	3,010,000 - 5,250,000 DUCKS	PFLYD2
	1,510,000 - 3,000,000 DUCKS	PFLYD3
	751,000 - 1,500,000 DUCKS	PFLYD4
	256,000 - 750,000 DUCKS	PFLYD5
	50,000 - 225,000 DUCKS	PFLYD6
19. FLYWAYS OF MIGRATORY WATERFOWL - GEESE	301,000 - 500,000 GEESE	PFLYG1
	151,000 - 300,000 GEESE	PFLYG2
	76,000 - 150,000 GEESE	PFLYG3
	26,000 - 75,000 GEESE	PFLYG4
	5,000 - 25,000 GEESE	PFLYG5
20. FEDERAL LANDS	INDIAN RESERVATIONS	PFIND
	NATIONAL FORESTS	PFFOR
	NATIONAL GRASSLANDS	PFGRA
21. AGRICULTURAL LANDS	IRRIGATED AGRICULTURAL LANDS	PCIRR
	CROPLANDS	PCROP
22. TIMBERED AREAS	TIMBERED AREAS	PTIM
23. WILD & SCENIC RIVERS	DESIGNATED RIVERS	PDRIV
24. LAND & WATER OVER 40° LATITUDE	LAND & WATER OVER 40° LATITUDE	OVER 40
25. TORNADO OCCURRENCE 1955-1967	300+	DT300
	200-300	DT200
	100-200	DT100
	50-100	DT50
	10-50	DT10
26. ACID RAINFALL	Ph BETWEEN 5.0 & 5.5	DACID6
	Ph BETWEEN 4.0 & 5.0	DACID5
	Ph LESS THAN 4.0	DACID4
27. HAIL	4 OR MORE DAYS/YEAR	DHAIL
28. SEISMIC HAZARDS	MAJOR DAMAGE	DSEIS1
	MODERATE DAMAGE	DSEIS2
29. SNOWFALL LOADING FACTOR	10#/FT^2 OR LESS	DSNOW1
	10#/FT^2 - 30#/FT^2	DSNOW2
	30#/FT^2	DSNOW3
	DETAILED ANALYSIS REQUIRED	DSNOW4
30. SHEET RAINFALL	SHEET RAINFALL	DRAIN

31.	FREEZING RAIN	8+ DAYS PER YEAR	DICE8
		1-8 DAYS PER YEAR	DICE1
32.	MAXIMUM EXPECTED WINDS 50 YEAR MEAN RECURRENCE INTERVAL	70 MILES PER HOUR	DWIND7
		80 MILES PER HOUR	DWIND8
		90+ MILES PER HOUR	DWIND9
33.	LIGHTNING DENSITY	10-20 FLASHERS PER YEAR PER SQ KM.	DLT10
		20+ FLASHERS PER YEAR PER SQ KM.	DLT20
34.	GROUND-WATER OVERDRAFT	GROUND-WATER OVERDRAFT	DWAO
35.	INADEQUATE SURFACE WATER SUPPLY	70% DEPLETED - AVERAGE YEAR	DWAINA
		70% DEPLETED - DRY YEAR	DWAIND
36.	OFFSHORE	NAVIGATION LANES	OANAV
		NAVAL DEDICATED AREAS	OASUB
		OCEAN HAZARD AREAS	OAHAZ
		MISSILE RANGES	OAMIS
		WILDLIFE REFUGES	OAWILD
37.	COAL PRODUCTION AREA	COAL FIELDS	COAL

* CODE NAME PREFIX KEY:

A = ABSOLUTE EXCLUSION
P = POTENTIAL EXCLUSION
D = DESIGN
S = STATE
E = ELECTRICAL AREA
O = OFFSHORE DATA
W = OFFSHORE AREAS
FLAT, OVER40, COAL = EXCEPTIONS

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