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Summary of the Development Plan for the Wind Characteristics Program Element of the Federal Wind Energy Program

by
C. E. Elderkin
L. L. Wendell

October 1, 1977

Prepared for the
U.S. Department of Energy, formerly
the Energy Research and Development
Administration, under Contract EY-76-C-06-1830

Battelle
Pacific Northwest Laboratories

PNL-2501

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UNITED STATES DEPARTMENT OF ENERGY
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy $____*; Microfiche $3.00

*Pages	NTIS Selling Price
001-025	$4.50
026-050	$5.00
051-075	$5.50
076-100	$6.00
101-125	$6.50
126-150	$7.00
151-175	$7.75
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SUMMARY OF THE DEVELOPMENT PLAN FOR THE WIND CHARACTERISTICS PROGRAM ELEMENT OF THE FEDERAL WIND ENERGY PROGRAM

by
Pacific Northwest Laboratory

C. E. Elderkin - Program Administrator
L. L. Wendell - Technical Manager

October 1, 1977

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Pacific Northwest Laboratories
Richland, Washington 99352

Prepared for the U.S. Department of Energy, formerly the Energy Research and Development Administration, under Contract EY-76-C-06-1830.

SUMMARY

The development and commercialization of durable and economically viable Wind Energy Conversion Systems (WECS) is the primary goal of the Federal Wind Energy Program (FWEP). Within this program, the Wind Characteristics Program Element (WCPE) has been established to identify, develop and disseminate information on related wind characteristics. The WCPE is a service for designers, manufacturers, users of WECS, other program elements within the FWEP, and Department of Energy (DOE) staff. Research funded by the WCPE must be directly related to the needs of one of these groups.

The primary role of Pacific Northwest Laboratory (PNL) in the WCPE is the administration of wind characteristics research under the guidance of DOE Headquarters. Research within the WCPE has been grouped into four technical program areas:

- Wind Characteristics for Design and Performance Evaluation
- Mesoscale Wind Characteristics
- Development of Siting Methodologies
- Wind Characteristics for Operations.

In addition, a special studies section has been established for providing direct assistance to the Wind Systems Branch, DOE, in new problem areas needing immediate attention.

The Wind Characteristics Design and Performance Evaluation program area is to provide critical design wind characteristics to DOE/HQ, as well as to assemble general wind and environmental characteristics for WECS design and performance evaluation. The information will be compiled into two handbooks to be used by public and private WECS designers and evaluators: Environmental Design Criteria for WECS, and Wind Characteristics for WECS Performance Evaluation. The first environmental design criteria handbook is scheduled to be completed at the end of FY-1978. Supporting tasks are funded in FY-1978 to provide input to the handbooks.

The Mesoscale Wind Characteristics program area has two main goals. The first is to develop and present analyses of the wind energy potential

over large areas. These analyses are to identify smaller areas of favorable wind characteristics and to quantify the wind energy potential over the whole area. The results of these large area analyses will guide preliminary decisions on WECS implementation. The results will also allow estimation of the reliability of wind energy for single units and for multiple WECS in dispersed arrays. The second major goal of this program area is to analyze the wind energy potential at specified locations, e.g., at sites which are candidates for testing and demonstrating wind machines. Supporting studies will provide additional analytical and data management techniques to improve the large area analyses. These techniques will also improve the evaluation of wind characteristics at candidate sites, where limited data are available.

The Siting Methodologies program area will develop effective and economical methods for selecting good WECS sites. These methods form the basis of siting strategies that will be presented in handbooks. Two interim siting handbooks have been prepared and are being reviewed. They will be published during FY-1978 and updated in the coming year. The current emphasis of the numerical modeling efforts in this program area is on their verification and demonstration.

The Wind Characteristics for WECS Operation program area is to provide wind predictability/uncertainty characteristics needed by those concerned with WECS operations in a power grid. The short-term product of this program area is to report on wind prediction uncertainty. The long-range product of this area is to upgrade specialized forecasting techniques tailored to the needs of WECS operations.

The Program Development Plan document is an internal working document used for Wind Systems Branch, DOE, approval and control of the execution of tasks within the Wind Characteristics Program Element; it is, therefore, subject to changes characteristic of day-to-day program management. The same is true for this summary document.

TABLE OF ACRONYMS

DOE	Department of Energy
DST	Division of Solar Technology
FWEP	Federal Wind Energy Program
FY	Fiscal Year
HQ	Headquarters
LeRC	Lewis Research Center
NASA	National Aeronautic and Space Administration
PAL	Program Area Leader
PDP	Program Development Plan
PM	Project Manager
PNL	Pacific Northwest Laboratory
RFP	Request for Proposal
UTSI	University of Tennessee Space Institute
WCPE	Wind Characteristics Program Element
WECS	Wind Energy Conversion Systems
WSB	Wind Systems Branch

CONTENTS

DEVELOPMENT PLAN FOR THE WIND CHARACTERISTICS PROGRAM ELEMENT FOR FY-1978

1.0 INTRODUCTION

The primary goal of DOE's Federal Wind Energy Program (FWEP) is the development of durable and economically viable Wind Energy Conversion Systems (WECS). The ultimate success of the FWEP depends on commercial development and utilization of WECS in centralized and/or dispersed energy systems.

The Wind Systems Branch (WSB) of the Solar Technology Division of DOE is responsible for the FWEP and has divided the program into several program elements. The focus of this report is on the development of the Wind Characteristics Program Element (WCPE). Pacific Northwest Laboratory (PNL) provides technical and management support for the WCPE (as of May 1976).

As part of the management support, PNL prepares an annual plan for the development of the WCPE. The initial program plan covered Fiscal Year (FY) 1977. The development plan presented here contains a detailed breakdown of the proposed program for FY-1978 and a program overview and projection through FY-1980. The basic document provides a basis for communication between the WSB and the WCPE and will be continually updated as required to accomplish the overall objectives of the FWEP. This summary document is aimed at apprising the participant and user communities of the aims and priorities of the WCPE. It is hoped that this document will bring the work to the attention of the most able potential participants, and that critical review will assist PNL and DOE to improve the future efforts in this area.

2.0 WIND CHARACTERISTICS PROGRAM ELEMENT OBJECTIVES

The WCPE is a service element within the FWEP. To help accomplish the goals of the FWEP, the WCPE has four primary objectives:

1) to describe wind and other meteorological and environmental characteristics important for use in design, performance evaluation and siting of WECS;

2) to analyze and present meteorological data for use in preliminary planning of WECS implementation, and develop methods for estimating the wind energy potential at selected locations;

3) to develop and demonstrate reliable, efficient, and economical techniques for identifying favorable wind energy conversion sites;

4) to describe the day-to-day variability of wind energy in terms of predictability for WECS operations.

These goals are to be pursued through specific research and development activities; the results are to be published in technical reports (see Appendix A) to the communities responsible for the development and implementation of both small and large WECS. These R&D activities must be relevant to the goals of the program with specific products described and justified before work commences. Where applicable, handbooks will be written to aid planning, siting, and in design and performance evaluation. These handbooks will contain summaries of material in the technical reports. They will outline step-by-step procedures to meet the specific needs of planners, engineers and, in the case of small machines, laymen.

To aid in the accomplishment of these objectives, PNL and outside contractors are conducting research and development programs. This work does not include the development of specific pieces of WECS hardware; rather, such work is to provide information that will aid in hardware development and implementation. Within the WCPE, PNL will provide the following services:

- management support for WSB
- technical support for WSB in the area of meteorology
- technical support for other FWEP program elements
- information for other federal and state agencies as well as for the general public, private industry, and public utilities.

To meet the goals listed above, the technical work within the WCPE has been divided into Program Areas, which are described in the following section of this plan. This division is based on the present perception of the needs of the overall program and may be changed as this perception is modified by future developments.

3.0 DEFINITION OF WCPE PROGRAM AREAS

The technical work conducted within the WCPE has been conceptually divided into four groups, each related to a category of users needing wind characteristics information. These groups have been designated for FY-1978 program areas and are:

- Wind Characteristics for Design and Performance Evaluation
- Mesoscale Wind Characteristics
- Development of Siting Methodologies
- Wind Characteristics for WECS Operations.

The program areas are not completely independent; information developed and presented for use in one area may contribute to progress in one or all of the other three areas. In addition to the work conducted within the four technical program areas, there are two service work areas: WCPE Administration; and Special Studies, to deal with new problem areas needing immediate attention. WCPE Administration covers planning and management activities at PNL, while Special Studies is generally a short-term, fast response service that may or may not fall within one of the existing program areas.

3.1 WIND CHARACTERISTICS FOR DESIGN AND PERFORMANCE EVALUATION

The Wind Characteristics for Design and Performance Evaluation program area is concerned with direct interaction between meteorological phenomena and WECS. It is divided into two subareas. The design portion of the program will characterize wind and other meteorological and environmental phenomena. Performance evaluation will define meteorological instrumentation, instrument deployment, data collection, and data analysis techniques. The development of meteorological instrumentation, however, is beyond the scope of the WCPE. The WCPE does not intend to design WECS nor to evaluate their performance; it will provide meteorological support to those involved in such activities. Direct interaction between the WCPE and other FWEP elements is necessary to identify needed WCPE products and to refine them as WECS technology progresses.

The principal products of the Wind Characteristics for Design and Performance Evaluation program area will be reports; the results will be included in a set of handbooks for engineers. Two handbooks are planned which will cover:

1) environmental design criteria for wind energy conversion systems

2) wind characteristics for WECS performance evaluation.

The prime objective of this program area is to provide technical reports to meet current environmental design criteria needs. Where information is not available from other sources, the WCPE will sponsor work to provide this information. The handbooks will be compiled from the results of the technical reports, which will contain the details that support these results.

3.2 MESOSCALE WIND CHARACTERISTICS

The identification of areas of high wind energy potential and quantification of the amount and variability of wind energy available for various types of machines are crucial factors in determining effective wind energy conversion systems. To aid in providing such information, the Mesoscale Wind Characteristics program area is to:

1) develop techniques for analyzing the wind energy potential over large areas (on the order of 1000 km on a side), which will identify smaller areas (on the order of 100 km on a side) of favorable wind energy potential, as well as to quantify the wind energy potential over the whole area;

2) determine wind characteristics at candidate sites selected for potential testing of wind turbine generators;

3) estimate, including error analysis, the energy available for a variety of realistic cut-in and cut-out speeds within favorable wind energy areas and at the candidate sites; and

4) estimate the reliability of wind energy, including the wind energy reliability of multiple WECS in large regional arrays.

The primary products of the Mesoscale Wind Characteristics program area will be documented large area analyses. These analyses will quantify the wind energy potential over the whole area in addition to identifying areas where specific siting methodologies can be applied. These evaluations will also provide information necessary for selecting WECS appropriate for these areas. Candidate sites will be evaluated to assist in the selection of sites for testing large wind turbines. Reports of supplementary studies will provide additional data to support the large area analyses.

The large area analyses are to be more detailed than previous national assessments. They will have finer areal resolution of wind energy, and will incorporate additional data and mesoscale analysis techniques. The analyses will consider a variety of WECS characteristics and wind properties necessary to make preliminary estimates of extractable power. They will also estimate seasonal and diurnal variations of wind power.

The evaluation of wind characteristics at candidate sites will include:

- analyses of data from instruments installed on the site, and
- use of techniques to estimate the availability of wind energy.

This information will allow each candidate site to be evaluated for possible testing of large machines, in either single or multiple units ("farms").

Supporting studies within the Mesoscale Wind Characteristics program area will improve the accuracy and usefulness of both the large area analysis and the candidate site evaluations. These studies involve a wide range of analytical techniques and cover a variety of topographic features, including agricultural areas, complex terrain, and coastal areas.

3.3 DEVELOPMENT OF SITING METHODOLOGIES

The Siting Methodology program area is to devise strategies for selecting specific sites for WECS installation, to develop tools to implement these strategies, and to supply this methodology to WECS users. Siting handbooks are planned for completion in FY-1980. Interim handbooks were

included in the FY-1977 Program Development Plan. These handbooks were sent out for review and will be modified for publication in FY-1978.

To meet its objectives, the Development of Siting Methodologies program area has been divided into three subareas:

- Site Screening and Localization Technique Development
- Verification of Screening Techniques
- Documentation of Siting Strategies.

The technique development subarea is to identify and develop techniques that are useful in the site selection process. Techniques currently being examined include numerical and physical modeling, and the evaluation of vegetative growth patterns to indicate areas of high wind speed. The numerical and physical modeling work involves the adaptation and demonstration of existing models in wind energy applications. The WCPE is not developing basic numerical and physical models.

Technique verification determines the accuracy and relative costs of potential site screening techniques. Techniques will be evaluated by a set of standard siting scenarios so that both accuracy and relative costs can be compared. The results of this subarea will be used to identify the screening strategies most appropriate to typical siting scenarios.

The siting strategy documentation subarea updates the siting handbooks for both small and large systems. In addition, a handbook will be prepared covering the effects of small scale terrain features on wind and is to be completed in FY-1979. This handbook, compiled from existing information, will be useful in assessing the probable effects of subgrid scale terrain features on modeling results. It will also be useful in siting machines in small areas.

After a site has been tentatively selected, wind measurements should be made to confirm the estimates of wind energy potential. This would be especially true for large systems. Thus, consideration is being given to expanding efforts in identifying cost effective techniques for site evaluation during FY-1979.

3.4 WIND CHARACTERISTICS FOR WECS OPERATIONS

The Wind Characteristics for WECS Operations is a FY-1978 addition to the WCPE. Some initial planning effort in this area, for a program of international cooperation, was carried out in FY-1977. It has since become apparent that work in the first three program areas does not help personnel of utility companies anticipate the availability of wind energy. Operations personnel are concerned with predictability of wind energy on a 24- to 36-hour basis to allow effective scheduling of the day-to-day operation of their generating resources and periodic maintenance.

The primary objective of this program area is to provide wind predictability/uncertainty characteristics needed for WECS operations in a power grid. Reports are to be made on forecasting uncertainty for a variety of meteorological conditions and terrain configurations. If the uncertainty analyses show a need for an improved forecasting accuracy, another product of this area will be to upgrade forecasting techniques tailored to the needs of WECS operations. A working group discussion will be held early in FY-1978 to identify the specific needs of utilities in wind forecasting and to relate the types of wind forecasts currently available.

3.5 SPECIAL STUDIES

The Special Studies section is to provide technical assistance to the WSB and other FWEP elements on a fast-response basis. Each study has its own end product. It is not possible to anticipate the nature of new studies because of the dynamic nature of the FWEP. However, two areas that were the subject of special studies in FY-1977 and that are expected to recur in FY-1978 are international cooperative studies, and reviews of reports and programs of other FWEP wind program elements. A third area, candidate site evaluation, has been moved from Special Studies where initial response to WSB was formulated, to Mesoscale Wind Characteristics where similar scheduled evaluations will be continued.

3.6 WCPE ADMINISTRATION

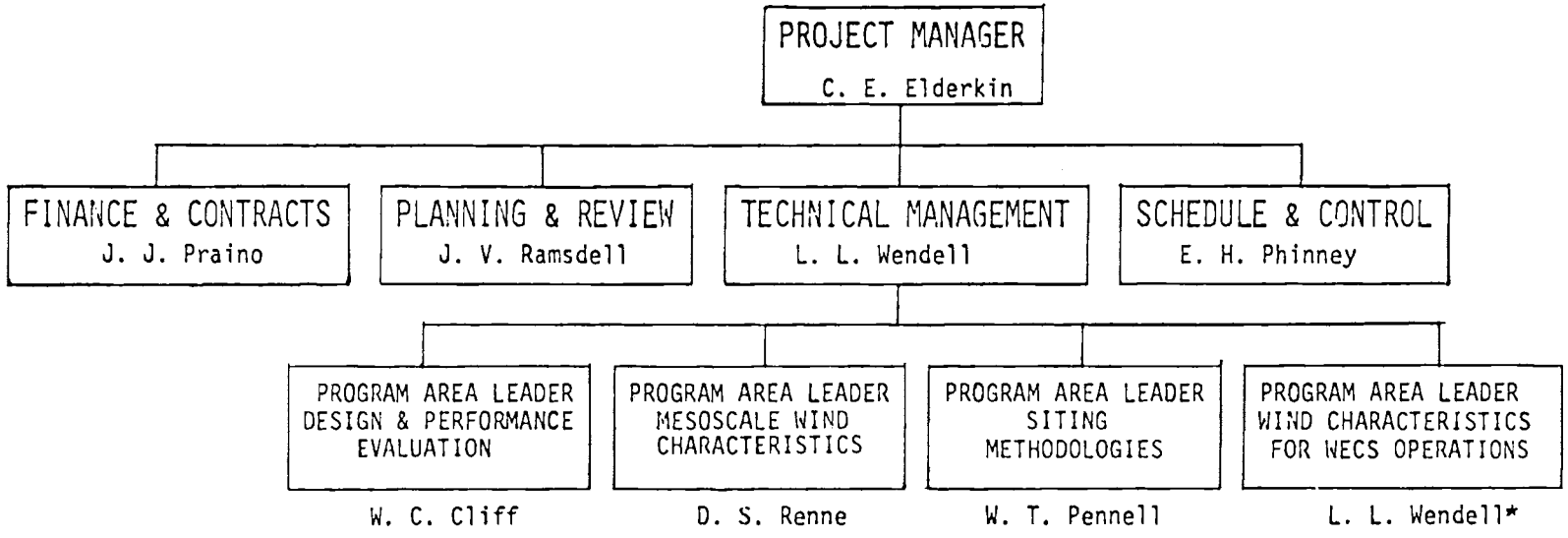
The management of the WCPE has three primary roles:

- Program Planning - formulation and integration of plans for research tasks conducted by PNL and contractors of PNL and DoE.
- Control of Research Tasks and Contract Administration - preparation of RFP's; review of proposals; preparing and awarding contracts; and monitoring technical progress, financial status, and contractual commitments.
- Reports, Information Exchange and Liaison - reporting research results, relating results to needs of other elements of the program and to industry, and identifying new research needs.

To fulfill these management functions, PNL has organized the WCPE management as shown in Figure 1. Four groups report to the Project Manager (PM): Technical Management, Planning and Review, Schedule and Control, and Finance and Contracts.

Under Technical Management, research tasks defined in this Program Development Plan (PDP) will be accomplished according to the schedule. Tasks conducted by contractors will be monitored and the results assimilated under the direction of Program Area Leaders (PAL), each of which coordinates one of the WCPE program areas. Similarly, PALs direct the PNL technical tasks, which in part serve to focus contractor and PNL results on specific needs. The PNL scientific staff carrying out these tasks, including the PALs are, with few exceptions, within the Atmospheric Physics Section of the Atmospheric Sciences Department. The manager of this section serves as Technical Manager (TM) of PNL's wind characteristics tasks. He approves and coordinates the individual Program Area Leader activities, including monitoring outside contracts.

Under Planning and Review, new program directions and tasks are identified and proposed. Initial wind characteristics analyses are performed to establish the type of products most appropriate for various users. Workshops are organized to gain input to initial planning of new program areas. Review of ongoing research and future plans for tasks in established program



*To be replaced by new staff phased in over a several month period

FIGURE 1. WCPE Administration

areas is periodically conducted with the aid of outside consultants. Recommendations for redirection or additional tasks will be made where advisable. These recommendations will be periodically considered by the Program Manager in incorporating and scheduling pertinent and realizable changes into the Program Development Plan (PDP).

Under Schedule and Control, the schedule of all contractors is followed and the delivery of all products is expedited. This assures the review, final preparation, publication and distribution of all reports. The format, structure, and numbering of reports is also checked for conformance with DOE/DST guidelines and for guaranteeing quality control.

Under Finance and Contracts, the placement of contracts is expedited from the reviewed proposal stage through the contracting procedures of either PNL or DOE.

4.0 IMPLEMENTATION

Implementation of the WCPE Program Development Plan is a continuing process that includes research planning, solicitation and review of proposals, awarding and monitoring of contracts, and PNL research. The formal research steps are described in written task statements supplied to the WSB. Informal steps identify FWEP research needs and research conducted by others which is related to those needs.

Research needs of the WCPE and the FWEP are examined by WCPE management and the Program Area Leaders. These individuals meet periodically to discuss the WCPE goals and to identify needed changes in WCPE direction.

WCPE program implementation includes organization and participation in workshops, symposia and working group sessions on wind energy conversion. These meetings provide input to program planning and also provide a mechanism to coordinate the work of WCPE contractors with current goals. Two working group sessions dealing with WCPE program areas planned for FY-1978 are listed in Table 1.

TABLE 1. Summary of Working Group Sessions Planned for FY-1978

Working Group Title	Program Area	Date
Wind Forecasting for WECS Operations	Wind Characteristics for WECS Operations	December 1977
Large Area Wind Energy Analyses	Mesoscale Wind Characteristics	July 1978

The following sections present the details of the implementation plan by program areas. Each section includes a task work schedule.

4.1 DESIGN AND PERFORMANCE EVALUATION

The Design and Performance Evaluation program area (Program Area A) prepares two handbooks. Tasks A1 and A2 are each responsible for one handbook. The remaining tasks within Program Area A support these two tasks. The tasks of Program Area A are shown in Figure 2 along with significant milestones.

The purpose of the handbooks is to present existing meteorological and environmental data in a form which can be used to establish conservative, yet realistic, WECS design criteria. These documents are to contain the results of theoretical and experimental studies. Details of the work leading to results and conclusions presented in the handbooks will be presented in supporting documents for peer review prior to the publication of the handbooks.

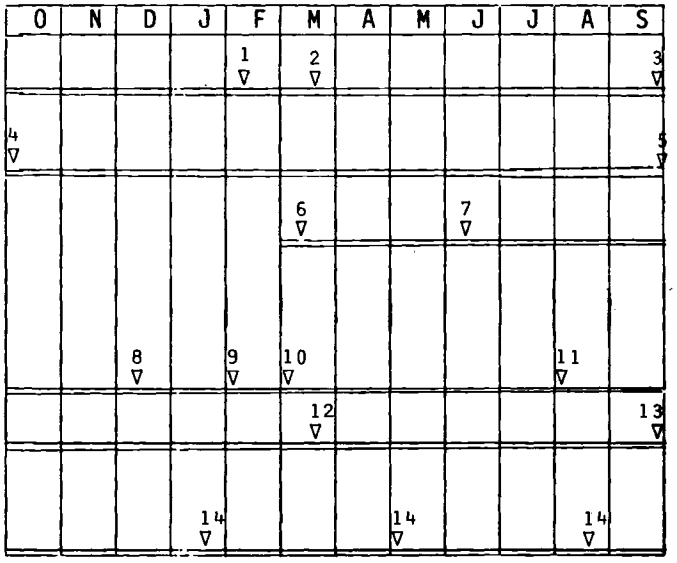
The final FY-1978 product of Task A1a will be an interim handbook. The handbook will concentrate on simple wind characteristics, including relevant information from the Atmospheric Guideline Handbook presently being prepared for the NASA/LeRC by the University of Tennessee Space Institute (UTSI). Information included from the UTSI handbook will be so specified, and PNL will include an error band analysis where appropriate. As designers' codes are modified, the handbooks will be revised to provide appropriate support.

Tasks A1b - A1d will provide input to the Environmental Design Criteria Handbook. Existing wind data will be analyzed in Task A1a for characterizing gusts. Conventional anemometers will be used to estimate the wind field that a rotating WECS blade would experience (Task A1b).

Task A1c, the Turbulence Spectral Model, is designed to produce wind characteristics information and models for use in advanced WECS simulations. Since this task anticipates a future need, it has a lower priority than the other tasks in this area.

In FY-1978 and early FY-1979 the first large WECS should become operational in utility grids and will provide an excellent test bed to measure not only the actual performance of these machines, but the atmospheric flow field surrounding the WECS as well. Measurement of these fields will

Task	Title	Contractor
A1a	Environmental Design Criteria for WECS	PNL+
A1b	Error Band Analyses on Conventional Data	A, PNL
A1c	Turbulence Spectral Model	A
A1e	Flow Through a Vertical Plane	PNL
A2	Meteorological Instrumentation and Data Analysis Requirements for Performance Evaluation	Sandia
A3	Liaison	



MILESTONES

1. Report on Gust Rise Time
2. Interim Report on Persistence
3. Interim Handbook
4. Begin Error Band Analyses
5. Interim Report
6. Begin Effort
7. Award Contract
8. Decision Point on Installation of Large Vertical Array
9. Report on Small Array Experiment
10. Complete Large Array Experiment
11. Report on Large Array
12. Report on Field Test Set-up for Performance Calculation
13. Report on New Methods for Performance Evaluation
14. Quarterly Meetings with NASA/Lewis

NOTES

A Contractor to be selected

FIGURE 2. Tasks and Milestones for the Design and Performance Evaluation Program Area (See Appendix B for Contractor Abbreviations.)

provide needed results to characterize the wind flow over WECS farms. Decision points on utilizing prototype large WECS as test beds for assessing associated wind characteristics will occur in FY-1979. These activities will require close coordination among the engineers testing machine performance and the WCPE.

The end product related to performance evaluation is a handbook describing meteorological instrumentation for performance evaluation and meteorological data analysis for performance evaluation (Task A2). This handbook will cover instrument deployment, data recording, and data quality assurance, as well as meteorological instrumentation. Existing information on the dynamic response of wind instruments and the spatial and temporal characteristics of wind will be used to predict optimum instrument positions. This information will help determine differences in the wind between the anemometer and the WECS. Mathematical techniques for meteorological data analysis as applied to WECS performance evaluation will also be described in the handbook.

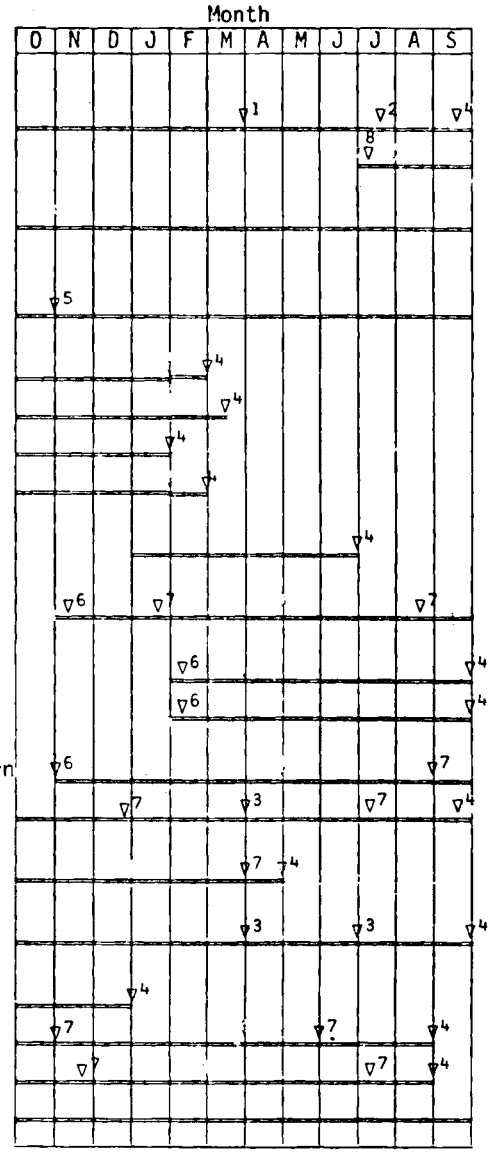
The proper implementation of the PDP for Program Area A requires that close liaison be maintained with those parts of the FWEP developing and those testing WECS hardware.

4.2 MESOSCALE WIND CHARACTERISTICS

The Mesoscale Wind Characteristics program area, as was outlined in Section 3.2, has two main goals. The first is to guide preliminary decisions on WECS implementation by developing and presenting analyses of wind energy potential over large areas. To achieve this goal, a major effort in this program area is to develop and demonstrate techniques to perform large area analyses in much greater detail than was possible in previous national assessments.[1-4] The second major goal in this program area is to analyze the wind energy potential at specified locations, e.g., at sites which are candidates for testing and demonstrating large wind turbines.

Supplementary studies are supported in this program area to provide analytical techniques and results useful to both the large area analyses and the analyses at the candidate sites. The task schedule for FY-1978 for this program area is shown in Figure 3.

Task	Title	Contractor
B1a	Prototype Techniques for Determining Large Area Wind Energy Potential	PNL+
B1b	Selected Large Area Analyses	A
B2a	MOD OA and MOD 1 Candidate Site Meteorological Documentation	PNL*
B2b	Identification and Meteorological Documentation of Potential Sites for Testing Large Turbines and Wind Turbine "Farms"	PNL
B2c	Techniques for Estimating Wind Characteristics at Potential Wind Energy Conversion Sites	Geomet
		SRI
		CEM
		MRI
B2d	Evaluation and Implementation of Wind Prediction Techniques at Potential Sites	PNL (B)
B3a	Locating High Wind Areas by Remote Obs. of Aeolian Features	U. of WY
B3b	Innovative Techniques for Locating and Evaluating High Wind Areas	NAWC
		U of TX
B3c	Survey Methodology and Reliability Analysis for Site Wind Characteristics	Northwestern
B3d	Meteorological Studies for Wind Power	Sandia
B3e	Energy Statistics for Large Wind Turbine Arrays	GIT
B3f	Studies of Wind Characteristics for Agricultural Applications	PNL (C)
B3g	Mesoscale Wind Characteristics in Mountainous Terrain	PNL
B3h	Coastal Zone Wind Energy	U of VA
B3i	Alaska Wind Power Study	U of AK
B4	Liaison	PNL



MILESTONES

1. Techniques developed sufficiently to allow decision on continuation with additional large area studies
2. Working group meeting on Determinations of Wind Energy Potential Over Large Areas
3. Interim or Semi-Annual draft report(s)
4. Final Report
5. Prepare draft PON for candidate sites
6. Award contract(s)
7. Program Review/Site Visit
8. RFP prepared for WSB approval

NOTES

- A Techniques developed in B1a to be applied to additional large areas until entire U.S. complet
- B Evaluation of Task B2c
- C Study coordinated with USDA wind program
- \+ Special service contracts with universities to be included
- * Monthly data analysis and summaries will be continued

FIGURE 3. Task Schedule for Mesoscale Wind Characteristics (See Appendix B for Contractor Abbreviations)

Task B1a is to develop prototype techniques for the analysis of wind energy potential over large areas. This will be coordinated by PNL. The task will analyze the wind energy potential over a large area of the country to identify areas favorable for wind energy conversion and to estimate the wind energy potential over the whole area. This large area analysis will identify specific techniques and problem areas in describing wind power distributions, establish data collection and analytical techniques, and assure comparable analyses in different areas. The large area analysis will cover a region characterized by diverse climatic and topographic features.

Task B1b provides for additional large area analyses for areas yet to be selected in coordination with WSB. The large area analyses, which are planned to continue through FY-1979 and FY-1980, will provide a detailed analysis of areas favorable for wind energy conversion and an estimate of the total wind energy resource in the United States (within specified confidence limits).

A working group discussion on large area analyses is to be held in July 1978. By this time the prototype analysis should be well underway. The working group meeting will provide a forum for discussing problems in the analyses, analytical tools, and data bases available for the analyses. A most important product from this working group will be a set of recommendations: 1) further research required, 2) state-of-the-art research which should continue, 3) research which should be terminated. These recommendations will be published at the same time that many of the supplementary studies supporting the large area analyses will be nearing completion.

The Mesoscale Wind Characteristics program area also emphasizes the development of techniques to evaluate the wind power potential of a given location. The more successful techniques will be part of the evaluation procedures of potential sites for testing large WECS. During FY-1977 the wind characteristics were evaluated for a total of 17 candidate sites, selected from proposals submitted to the WSB by utilities around the country (Task B2a). Several sites have been selected for installation and testing of large wind turbines. During FY-1978 a Program Opportunity

Notice will be issued for establishing additional potential sites to be documented with meteorological data. This information will be used to select candidate sites for the testing of more advanced turbines, including multiple units or "farms" (Task B2b). These tasks will continue through FY-1979 and FY-1980 according to program needs. Results of some supplementary studies (described below) will be used to evaluate the wind characteristics at the sites, including estimates of power (within specified confidence limits) of the energy available for a variety of realistic cut-in and cut-out speeds. By the summer of 1978 sufficient information will be available to determine if additional supplementary studies will be needed to further refine evaluation procedures. This decision point will define the critical research needed to be pursued in FY-1979 and FY-1980.

The supplementary studies referred to above support either the large area analyses or the candidate site evaluations, and in many cases both areas. Tasks B2c and B2d directly support the candidate site evaluations by comparing horizontal interpolation techniques of regional data to a specific candidate site, where there is insufficient data to evaluate potential machine performance. Four contractors, Geomet, Inc., Stanford Research Institute (SRI), the Center for the Environment and Man (CEM), and Meteorology Research, Inc. (MRI), are investigating various statistical and hydrodynamical interpolation techniques. When their studies are completed in January, an evaluation of the various techniques will be undertaken by PNL. A major decision point will be in July FY-1978 concerning the value of these techniques for candidate site evaluations and for any future related research areas. If the techniques appear acceptable, they will be implemented into the Candidate Site Evaluation Tasks (B2a and B2b).

The various supplementary studies under Tasks B3 contribute to the overall goals of the Mesoscale Wind Characteristics program area. Task B3a will produce a comprehensive report describing how certain regional wind characteristics can be determined from satellite imagery of aeolian land

features. The University of Wyoming has been working on this report for the past two years. Other innovative techniques for producing regional wind information will be investigated by several contractors in Task B2b.

Task B3c provides information on wind characteristics at sites where data are limited by comparing them with nearby sites where data are more complete. This task also provides important information on the length of time and number of observations required at a site to obtain mean velocity and power statistics. This information is important both to the regional evaluations, where much of the data may be limited, and to the candidate site evaluations.

Task B3d provides information on the climatological distribution of wind power at selected sites around the country. This study is being performed by Sandia Laboratories. Task B3e investigates the amount and distribution of wind power around the country by utilizing large regional arrays of wind turbines. Information from these two studies provides direct assistance to the large area analyses, and will be useful in FY-1979 when the appraisals are consolidated.

Tasks B3f through B3i are studies of wind characteristics for specific types of regions. Task B3f investigates the vertical wind profiles in agricultural regions, such as the Great Plains, where the surface has been extensively modified by irrigation. The task will be coordinated with studies being conducted by the USDA in agricultural applications of wind machines. It will provide information on the significance of this surface modification, and will help identify the optimum tower height for windmills used in water pumping. Task B3g investigates the wind characteristics along the vertical slope of topographic features in different types of complex terrain. This study will identify early in FY-1978 the state-of-the-art of wind characteristics in complex terrain, and will make recommendations for studies needed to improve our large area analyses. In Task B3h, wind power characteristics in a coastal region are being studies by the University of Virginia using models and analyses of existing data. If this information is adaptable to similar regions around the country, the costs in performing regional appraisals in coastal areas can be greatly reduced.

A survey of wind power in Alaska is being completed by the University of Alaska in Task B3i.

As in other aspects of the WCPE, liaison is an important component in the Mesoscale Wind Characteristics program area. The large area analyses and candidate site evaluations must describe wind characteristics that are important in the preliminary decision-making process. To assure this, Task B4 will maintain communication with utilities and FWEP mission studies.

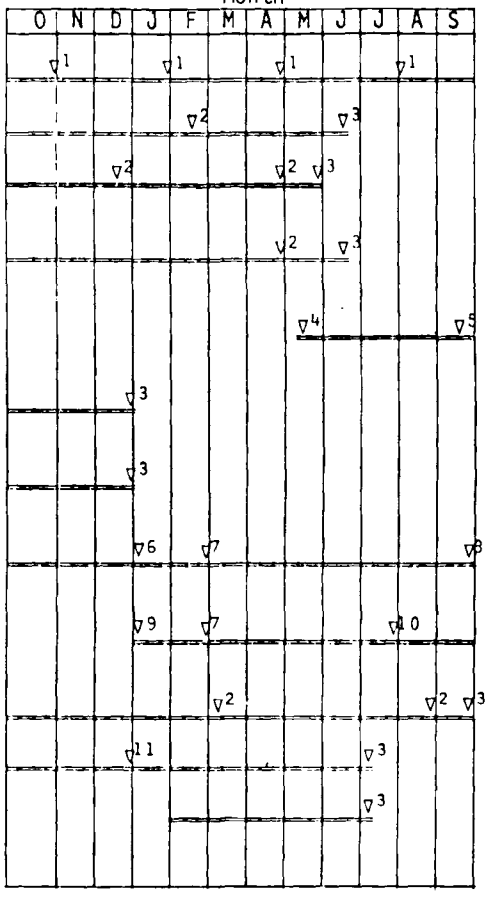
4.3 DEVELOPMENT OF SITING METHODOLOGIES

Program Area C, Development of Siting Methodologies, has been divided into three subareas for implementation. The first subarea covers the identification and development of techniques for site screening and localization, and for estimating the wind energy at specific sites. In the second subarea, site screening techniques will be evaluated to determine their utility, accuracy and cost. Finally, in the third area, siting strategies will be developed and specialized tools, such as computer codes, will be documented and made available for general use. Figure 4 presents a list of the tasks in the Siting Methodology program area and shows significant milestones for each task.

Numerical modeling studies (Tasks C1a and C1b) provide systematic techniques for making maximum use of climatological data in the siting process. Both of these tasks are in a demonstration phase in which the applicability of the model to site selection problems is to be shown. The Lawrence Livermore Laboratory study (Task C1a) includes a field measurement program on the island of Oahu. The purpose is to gather data that can be used for the verification of individual flow models as well as complete siting methodologies.

In Task C1c, physical (i.e., wind tunnel) modeling studies are being conducted of flow characteristics over representative terrain features. The purpose is to classify generic wind characteristics in handbook form. However, it should be recognized that wind tunnel modeling is also a

Task	Title	Contractor
C1a	Wind Power Studies	LLL
C1b	Wind Energy Site Selection Methodology	SAI
C1c	Sites for Wind Power Installations	CSU
C1d	Vegetation as an Indicator of High Wind Velocities	OSU
C1e	Assessing the Local Wind Field with Instrumentation	B
C1f	Technique for Siting Using Statistics on Primitive Equation Model Results	RTI
C1g	Effect of Density Stratification on Siting	PR
C2a	Plan Site Screening Technique Verification and Comparison	PNL
C2b	Site Screening Technique Verification and Comparison	A
C3a	Small-Scale Terrain Effects on Available Wind Energy	FWG
C3b	Update Small System Siting Handbook	PNL
C3c	Update Large System Siting Handbook	PNL
C4	Liaison	PNL



MILESTONES

1. Quarterly Report
2. Program Review
3. Final Report
4. Issue RFP
5. Select Contractor(s)
6. Interim Report - Procedures for Validation of Siting Techniques
7. Briefing of Verification Participants
8. Interim Report - Preliminary Results of Screening Technique Verification
9. Identify Contractors Who Will Participate in the Initial Technique Verification Task
10. Preliminary Model Results Delivered to PNL
11. Interim Report

NOTES

A Contractors selected to participate in verification experiment
B Contractors to be selected

FIGURE 4. Task Schedule for Wind Characteristics for Development of Siting Methodologies (See Appendix B for Contractor Abbreviations)

viable tool for use in specific siting studies, and it should be included with numerical modeling in any technique verification task.

An important aspect of technique development for both numerical and physical modeling is streamlining methods for predicting wind climatologies at specific sites. The expense of most numerical models will preclude developing these climatologies by numerous model runs. An alternative method is being explored by Lawrence Livermore Laboratory in Task C1a. This method employs principal component analysis to identify the most important flow fields for a given area. It also determines the probability of occurrence of a given field. Thus, a climatology could be developed for a specific site by a limited number of model runs which would correspond to these principal flow fields.

Nonmodeling techniques are also being considered for site screening. Task C1a is a study of the effects of wind on various types of vegetation common to the Pacific Northwest. The objective is to obtain quantitative information through the wind calibration of deformed vegetation. Although Task B2a has been included in the Mesoscale Wind Characteristics program area, it is recognized that the remote sensing techniques similar to those developed by the University of Wyoming could also provide information for site screening. In general, nonmodeling techniques may provide the means for rapidly screening large areas for potential rich wind areas. These techniques may also prove useful for site selection and localization on limited budgets.

The next step in site selection is localization, where the effects of specific local terrain features are ascertained. Task C3a will catalogue the effects of small scale terrain features and wind characteristics. In Task C1e, measurement systems for describing the flow field at or in the neighborhood of potential WECS sites will be identified, assembled and evaluated. The purpose is to examine this device as a site localization tool. The final step in any site selection strategy (particularly for larger WECS) must be a program of measurements at the candidate sites. Only through actual measurement can the wind characteristics be accurately determined.

Tasks C1f and C1g are the results of no-cost extensions of Tasks 5c and 5d in the FY-1977 PDP. Task C1f is an attempt to combine historical wind data, a hydrodynamic model, and a statistical model to predict wind characteristics at a particular site. In Task C1g, a simplified hydrodynamic model is being examined for providing inexpensive but useful siting information.

By the end of FY-1978 the major numerical modeling efforts (Tasks C1a and C1b) will be completed. The models will be in a form that could be used for site screening. However, the accuracy, utility and cost-effectiveness of these techniques will not have been determined. The comparison and verification of numerical and physical models as site selection tools will be accomplished in Tasks C2a and C2b. A set of standard siting scenarios will be developed that will enable realistic tests of site selection techniques to be made. Using these scenarios, site screening techniques will be applied to areas where the mesoscale wind field has been described in space and time by actual measurements, and the costs of the various techniques will be evaluated. Accuracy will be determined by comparing measured wind characteristics with the predicted characteristics at the measurement sites.

The planning task C2a is critical to the selection of the data to be used in verification. We need to determine how the various site screening techniques perform as a function of terrain complexity and climatology. Once the validation procedures and data sets have been established, a workshop will be held to present the plan to the developers of the various screening techniques. The application of these techniques to the test cases will be carried out by selected contractors in Task C2b. The balance of Task C2a will be to monitor, coordinate, evaluate, and finally, report on the results of this exercise. Initial comparisons will be made with data from previous field programs; however, such data may prove inadequate for the task. For example, data may be unavailable for a terrain type of particular interest, or measurements may not exist at crucial locations (along ridge lines, on slopes, etc.) or at particular times of day. Thus, a special field program may be required before the validation task can be satisfactorily completed (this would require approval from DOE).

Milestone 6 in Figure 4 represents a major decision point. By this time in the model verification process, it should be possible to determine which methods, if any, show the ability to produce wind characteristics for accurate siting. The direction of the program will depend upon the answers to several questions:

- Should work on modeling continue at all?
- Is further research needed to improve model performance and, if so, what type?
- What further verification work is needed?
- Is a special field program needed?

Each of the tasks in Program Area C will provide information useful in selecting sites for WECS installations. The objective of the subarea on Documentation of Siting Strategies is to make this information readily available in a usable format. Handbooks will be updated for small (Task C3b) and large (Task C3c) system siting. Interim handbooks were prepared as Tasks 8a and 8b of the FY-1977 PDP. These documents are being modified in accordance with outside review comments and are to be published in FY-1978. Task C3a is to prepare a handbook on Small-Scale Terrain Effects on Available Wind Energy. This handbook will compile results of existing boundary layer research on flow over changes of surface roughness and around obstacles, etc. It will be useful in estimating effects of sub-grid scale terrain features on winds predicted by numerical models. It will also be useful as a siting tool by those with small areas for WECS installation. Task C3a is the continuation of a 3-year program. The three handbooks being prepared in this subarea are the end products of the Siting Methodology program area.

4.4 WIND CHARACTERISTICS FOR OPERATIONS

The Wind Characteristics for Operations program area is new to the WCPE in FY-1978. It arises from the need of utilities for detailed information on the day-to-day operation and scheduling of installed WECS.

Reliable wind forecasting would be especially important in the use of wind power as a fuel saver. Some anticipated products in the program area are:

1) a report identifying the specific wind speed and direction forecasting needs in wind power implementation;

2) a report on state-of-the-art wind forecasting uncertainty; and

3) improved short-term local wind forecasting techniques.

To identify the specific utility wind forecasting needs and current wind forecasting capabilities, a workshop is planned for early FY-1978. Operations personnel from utilities and specialists in short-term wind forecasting will be invited to the workshop (Task D2, Figure 5) to discuss various aspects of wind predictability and WECS operations in power grids. These discussions should lead to the identification of specific needs of the utilities for forecast reliability and lead time.

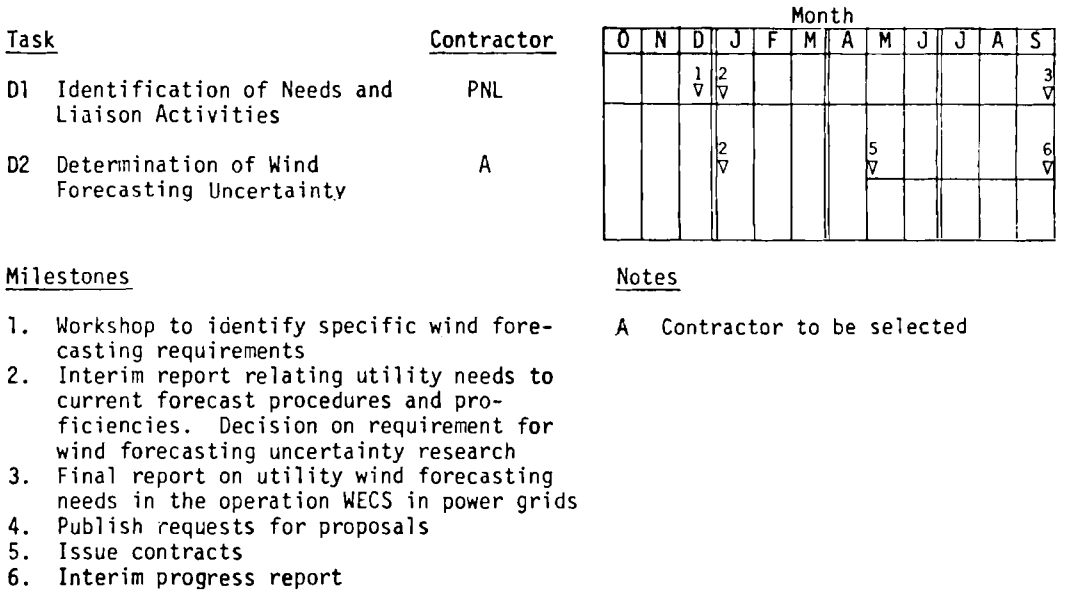


FIGURE 5. Task Schedule for Program Area D, Wind Characteristics for WECS Operations

An interim report will be issued a month after the workshop, describing needed research in wind forecast uncertainty and its effect on WECS operations. If the decision at this time is that a careful analysis of wind forecasting uncertainty is needed, an RFP will be issued for the investigation of wind forecast uncertainty (Task D2). If several proposals of merit are received, possibly multiple awards could be granted to cover different aspects of the problem, such as uncertainty under various meteorological conditions and terrain complexity. The liaison activity (Task D1) would continue throughout FY-1978 to coordinate the contract work. An interim report on the progress in the contract efforts will be prepared at the end of FY-1978. The preliminary results should permit a decision on limiting or expanding the investigation of wind forecast uncertainty.

4.5 SPECIAL STUDIES

The WSB frequently requests information from the WCPE at PNL. The effort required to fill these requests ranges from several manhours to several manmonths. The specific tasks to be undertaken are varied; thus, neither the tasks nor specific end products can be defined. It is, however, important to identify these Special Studies. Based on FY-1977 experience, there are two areas in which continuing requests are anticipated: International Cooperative Studies and Report/Program Reviews. In addition, provision has been made for new studies where the need for wind characteristics information will be scoped for the development and deployment of small machines.

Contacts gained in C1b, Report/Program Reviews, make a positive input to the WCPE program planning effort. In addition to providing input on the progress in other elements of the FWEP, these contacts help PNL determine research needs and identify usable formats for presentation of wind characteristics information.

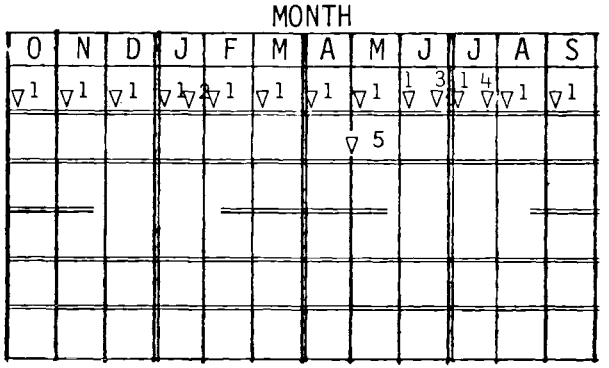
4.6 WCPE ADMINISTRATION

The role of WCPE Administration is to provide support to the WSB in managing research in wind characteristics. This includes: direct management tasks associated with the control of technical tasks, the preparation of reports and general supervision of WCPE directions and policies (F1); planning and procurement tasks (F2); direct assistance to the WSB (F3); and contract monitoring (F4). These tasks are indicated in Figure 6.

As part of the Direct Management Task (F1), PNL prepares monthly administrative reports which describe PNL's activities and the status of the WCPE. A semi-annual technical report is prepared in January and an annual report is prepared in July. In addition, the WCPE is reviewed quarterly. Under the Planning and Procurement Task (F2) research needs are to be identified far enough in advance so that they may be proposed in the Program Development Plan for consideration by WSB. For this reason the PDP will be continually updated, as new needs are identified, even though it is submitted formally on an annual basis. Once proposed areas of research are approved by WSB, action is taken to obtain proposals from qualified firms or institutions to carry out the work.

A small liaison task (F5) is included under WCPE Administration. For FY-1978, the majority of the liaison funding has been assigned to Program Area Leaders. This is reflected in the task schedules for each program area.

TASK		CONTRACTOR
F1	DIRECT MANAGEMENT	PNL
F2	PLANNING AND PROCUREMENT	PNL
F3	DIRECT ASSISTANCE	PNL
F4	CONTRACT MONITORING	PNL*
F5	LIAISON	PNL



MILESTONES

1 MONTHLY ADMINISTRATIVE REPORT

2 SEMI-ANNUAL REPORT OF THE WCPE

3 ANNUAL PROGRAM REVIEW

4 ANNUAL REPORT OF THE WCPE

5 FY 79 PROGRAM DEVELOPMENT PLAN FOR THE WCPE SUBMITTED TO WSB

NOTES

* MILESTONES SHOWN ON PROGRAM AREA TASK SCHEDULES

FIGURE 6. Task Schedule for WCPE Administration

5.0 PROGRAM DISTRIBUTION AND BALANCE

The distribution of the major elements of the proposed funding for FY-1978 within the WCPE is shown in Table 2.

TABLE 2. Major Element Breakdown of WCPE FY-1978 Proposed Budget

		% of Total Costs
PNL	WCPE Administration	15
PNL	Research and Development	27
Other Labs.	Research and Development	11
Private and University	Research and Development	47

One of the major efforts in the administration of the WCPE is to maintain a strong involvement of universities and small business organizations. This involvement constitutes the largest fraction of the program. Special unique capabilities exist at other government laboratories and are utilized, on a limited basis, where necessary to produce specific results. The maintenance of a coherent program from the many separate research and development tasks requires comprehensive planning, monitoring and control efforts by PNL in coordination with the WSB. In-house research is required to allow effective assimilation, synthesis and dissemination of all WCPE research results. Also, significant liaison efforts are required to focus the results on the appropriate areas throughout the FWEP. The PNL research and development efforts in the WCPE are designed to fulfill these requirements.

The balance of research within the WCPE is continually changing. This condition reflects changing requirements of wind characteristics users within the FWEP.

6.0 PROGRAM OVERVIEW AND PROJECTION

To meet the goals of identifying, developing and disseminating information on wind characteristics related to the development and commercialization of durable and economically viable WECS, four technical objectives have been established (Section 2). In summary, these goals are:

1. to describe wind and other meteorological and environmental characteristics important for use in design and performance evaluation of WECS;
2. to present and analyze meteorological information for use in preliminary planning of WECS implementation, and to develop methods for estimating the wind energy potential at a selected location;
3. to develop and demonstrate efficient and economical techniques for identifying favorable wind energy conversion sites; and
4. to describe the day-to-day variability of available wind energy in terms of predictability/uncertainty for WECS operations.

To accomplish these objectives, the technical work within the WCPE has been divided into four corresponding program areas (Section 3). The projection of the program through FY-1980 is shown in Figure 7 in a generalized composite task and milestone chart.

In the Wind Characteristics for Design and Performance program area, emphasis will be placed on a field measurement and analysis study of the flow field near a large operational WECS. Emphasis in late FY-1979 and FY-1980 will shift to technology transfer of the information developed in this program area.

In the Mesoscale Wind Characteristics program area, selected large area analyses (B1) are proposed to begin in late FY-1978. Analyses for other selected areas are proposed for FY-1979. These efforts are proposed to be completed in FY-1980 with a synthesis of the results categorizing the amount, location and reliability of wind

	FY 1978				FY 1979		FY 1980	
	1	2	3	4	5	6	7	8
Wind Characteristics for Design and Performance Evaluation								
A1 Wind Characteristics for Design								
1 Decision point on installation of large vertical plane anemometer array (based on results and conclusions from small array)								
2 Report on gust rise time; termination of effort until further needs identified								
3 Interim report on error band analysis								
4 Interim handbook, Environmental Criteria for WECS Design; decision for continuance of effort								
5 Final report on large vertical plane anemometer array								
6 Decision to plan for measuring flow field near operating large WECS								
7 Field test and theory of flow fields surrounding large WECS complete								
8 Final handbook, Environmental Criteria for WECS Design; if warranted								
A2 Wind Characteristics for WECS Performance Evaluations	1					2		3
1 Report on procedures for WECS performance field test program; decision on report applicability for proposed universal use								
2 Final report on standard software for WECS performance comparison with wind measurement								
3 Final report on techniques for performance evaluation of WECS								
Mesoscale Wind Characteristics								
B1 Large Area Analyses		1	2			2		3
1 Decision to proceed with additional analyses based on progress in a prototype analysis								
2 If warranted, select additional areas for analysis								
3 Completion of all area analyses and production of a national synthesis of the results								
B2 Candidate Site Evaluation	1					2	2	
1 Additional candidate sites selected and instrumented								
2 Annual on-site data analysis and wind characteristics evaluation completed and decision for continuation of measurements								
B3 Supplementary Studies		1	2			3		3
1 Completion of studies for extrapolating of site wind data to the candidate sites. Decision on necessity for immediate implementation of further work on most promising technique								
2 Completion of studies for locating high wind energy areas in selected topographic and climatic regimes; decision on continuance and implementation								
3 Completion of additional supplementary studies and decision for implementation to other program areas								

FIGURE 7. General Task Schedule for Program Overview FY-1978 Through FY-1980

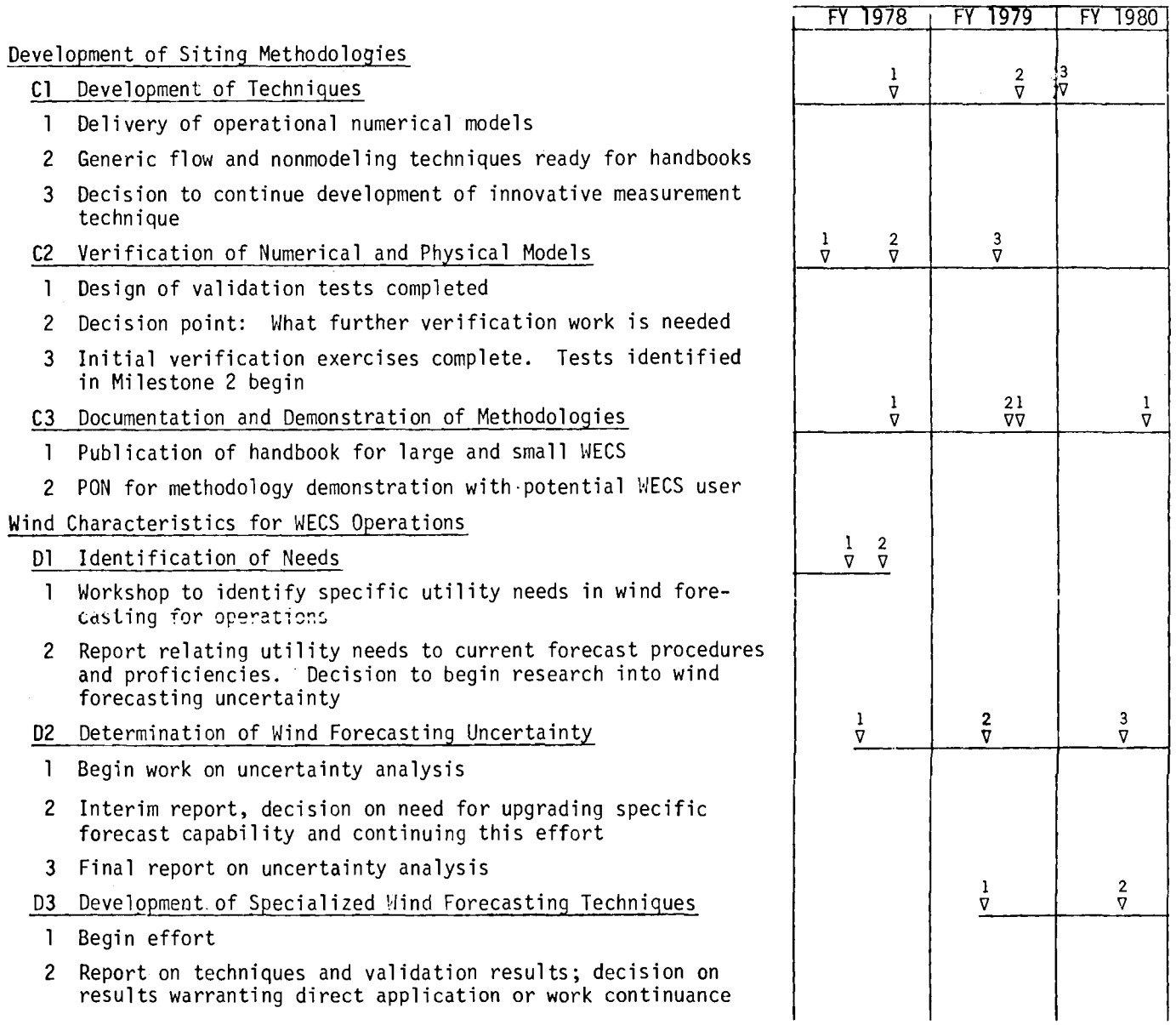


FIGURE 7 (continued)

The Program Development Plan document is an internal working document used for Wind Systems Branch, DOE, approval and control of the execution of tasks within the Wind Characteristics Program Element; it is, therefore, subject to changes characteristic of day-to-day program management. The same is true for this summary document.

energy potential in the United States. This information should be of great value to planners involved in the implementation of both small and large WECS. The analysis activity would be heaviest during FY-1979.

The candidate site effort (B2) in FY-1978 includes the remainder of some technique development efforts begun in FY-1977. These efforts were funded to interpolate data to candidate sites. The FY-1979 and FY-1980 activities will include only the scheduled candidate site effort.

In the Development of Siting Methodologies area, the emphasis, for the three years shown, progresses from technique development (C1) through verification efforts (C2) to demonstration of methodologies. It is proposed that a careful examination be made of the need for a field demonstration program in FY-1980.

In the Wind Characteristics for WECS Operations program area, the emphasis covers the identification of wind forecasting needs of scheduling-personnel in large utilities (D1), a determination of uncertainty in wind forecasting (D2), and upgrading specialized wind forecasting techniques (D3). This area is expected to grow in importance as large utilities begin to factor WECS into their power grids.

The Special Studies area will continue on the assumption that there will be new problems and unanticipated questions which will have to receive immediate attention. The growing interest in small machine development and applications has caused a significant expansion in the program at the Small Systems Test Center at Rocky Flats. The WCPE coordination effort with this program will be increased as needed. As tasks become clearly defined, they will be shifted to the appropriate program area.

The WCPE will be managed as outlined in the administration area, with modifications as needed for increasing effectiveness.

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2. Wind Energy Mission Analysis, Lockheed-California Co., Draft report, ERDA Contract AT(04-3)-1075, 1976.

3. Wind Energy Mission Analysis, General Electric Co. (Valley Forge), Draft report, ERDA Contract E(TT-1)-2578, 1976.

4. D. E. Elliott, Synthesis of National Wind Energy Assessments, ERDA Contract #EY-76-C-06-1830, BNWL-2220 WIND-5, UC-60, Richland, WA, 1977.

APPENDIX A

PUBLISHED REPORTS

WIND CHARACTERISTICS PROGRAM ELEMENT (WCPE)

Reports published, given UC-60 distribution, and available from:

National Technical Information Service
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201-225	8.75
226-250	9.00
251-275	10.00
276-300	10.25

Author	Title	Document No.	Affiliation & Address	Date	No. of Pages
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Wentink, T., Jr.	Study of Alaskan Wind Power and Its Possible Applications	NSF/RANN/SE/AER74-00239/FR-76/1	University of Alaska Geophysical Institute Fairbanks, AK 99701	February 1976	181
Freeman, B. E.	Mathematical Modeling of Topographic Effects on Wind Energy Systems (paper)	BNWL-SA-5935	Science Applications, Inc. P. O. Box 2351 La Jolla, CA 92037	April 1976	Microfiche
Freeman, B. E.	A New Wind Energy Site Selection Methodology	SAI76-614-LJ (NSF Grant)	Science Applications, Inc. P. O. Box 2351 La Jolla, CA 92037	May 1976 (SAI) December 1977 (TIC) (in printing)	233
Meroney, R. N., et al.	Sites for Wind Power Installations: Wind Tunnel Simulation of the Influence of Two-Dimensional Ridges on Wind Speed and Turbulence	ERDA/NSF/00702-75/1	Colorado State University Dept. of Civil Engineering Fort Collins, CO 80523	July 1976	88
Justus, C. G. et al.	Wind Energy Statistics for Large Arrays of Wind Turbines (New England and Central U.S. Regions)	ERDA/NSF-00547/76/1	Georgia Institute of Technology School of Aerospace Engineering Atlanta, GA 30332	August 1976	126
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Corotis, R. B.	Stochastic Modelling of Site Wind Characteristics	ERDA/NSF-00357/76/1	Northwestern University Dept. of Civil Engineering Evanston, IL 60201	November 1976	305

Meroney, R. N. et al.	Sites for Wind Power Installations: Wind Tunnel Simulation of the Influence of Two-Dimensional Ridges on Wind Speed and Turbulence--Tabulated Experimental Data	RLO/2438-76/1	Colorado State University Department of Civil Engineering Fort Collins, CO 80523	December 1976	68
Freeman, B. E. et al.	Development of a Wind Energy Site Selection Methodology	RLO/2440-76/4	Science Applications, Inc. P. O. Box 2351 La Jolla, CA 92037	December 1976	150
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Verholek, M. G.	Summary of Wind Data from Nuclear Power Plant Sites	BNWL-2220 WIND-4	Battelle P. O. Box 999 Richland, WA 99352	March 1977	339
Orgill, M. M.	Survey of Wind Measurement Field Programs	BNWL-2220 WIND-3	Battelle P. O. Box 999 Richland, WA 99352	May 1977	57
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Elliott, D. L.	Synthesis of National Wind Energy Assessments	BNWL-2220 WIND-5	Battelle P. O. Box 999 Richland, WA 99352	July 1977	58
Elderkin, C. E. Ramsdell, J. V.	Annual Report of the Wind Characteristics Program Element for the Period April 1976 Through June 1977	BNWL-2220 WIND-10	Battelle P. O. Box 999 Richland, WA 99352	July 1977	137
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Corotis, R. B.	Stochastic Modeling of Site Wind Characteristics	RLO/2342-77/2	Northwestern University Department of Civil Engineering Evanston, IL 60201	September 1977 (in printing)	152

Cliff, W. C.	The Effect of Generalized Wind Characteristics on Annual Power Estimates from Wind Turbine Generators	PNL-2436	Battelle P. O. Box 999 Richland, WA 99352	October 1977 (in printing)	49
Doran, J. C. et al.	Accuracy of Wind Power Estimates	PNL-2442	Battelle P. O. Box 999 Richland, WA 99352	October 1977	26
AWEA	Survey of Historical and Current Site Selection Techniques for the Placement of Small Wind Energy Conversion Systems	BNWL-2220 WIND-9	American Wind Energy Association c/o Windworks P. O. Box 329, Route 3 Mukwonago, WI 53149	December 1977 (in printing)	150

APPENDIX B

CONTRACTOR ABBREVIATIONS

APPENDIX B

CONTRACTOR ABBREVIATIONS

CEM	Center for the Environment and Man, Inc. 275 Windsor Street Hartford, Connecticut 06120
CSU	Colorado State University Fort Collins, Colorado 80523
FWG	FWG Associates, Inc. R. R. 3 Box 331 Tullahoma, Tennessee 37388
Geomet	Geomet, Inc. 15 Firstfield Road Gaithersburg, Maryland 20760
GIT	Georgia Institute of Technology Atlanta, Georgia 30332
LLL	Lawrence Livermore Laboratory University of California P. O. Box 808 Livermore, California 94550
MRI	Meteorology Research, Inc. Box 637 Altadena, California 91001
North-western	Northwestern University Evanston, Illinois 60201
NAWC	North American Weather Consultants Goleta, California 93017
OSU	Oregon State University Corvallis, Oregon 97331
PNL	Pacific Northwest Laboratory P. O. Box 999 Richland, Washington 99352
PR	Poseidon Research 11777 San Vicente Blvd. Suite 641 Los Angeles, California 90049

RTI	Research Triangle Institute P. O. Box 12194 Research Triangle Park, North Carolina 27709
Sandia	Sandia Laboratories Division 5443 P. O. Box 5800 Albuquerque, NM 87115
SAI	Science Applications, Inc. P. O. Box 2351 La Jolla, CA 92038
SRI	Stanford Research Institute, Int'l Menlo Park, California 94025
U of AK	University of Alaska Fairbanks, Alaska 99701
U of TX	University of Texas Austin, Texas 78712
U of VA	University of Virginia Charlottesville, Virginia 22903

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