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Proposal for 1977-78

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DESERT BIOME

PROPOSAL FOR 1977-78



SEPTEMBER 1976

Utah State University

Logan, Utah

PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION


for

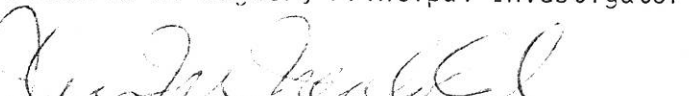
THE DESERT BIOME PROGRAM

January 1, 1977-June 30, 1978

Frederic H. Wagner, Principal Investigator

September 1, 1976


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INTRODUCTION

With initial funding for field research in 1970, the Desert Biome has addressed the general objective of elucidating the structure and function of North American desert ecosystems. The program has moved forward, with participation by scientists in some two dozen western universities, to amass a huge accumulation of observational data, and to develop an array of hypotheses and generalizations about U.S. arid lands.

Field research is being completed in calendar 1976. While efforts to synthesize the accrued data were begun as early as 1973, and have increased steadily up to the present, a great deal of effort still remains to combine Biome observations with published work on deserts for the purpose of crystallizing the significant principles of desert ecosystem structure and function.

This proposal sets forth an 18-month program for completing synthesis, and publishing the results. It requests 18-month funding at a level of \$397,973 to support modeling, data processing, editorial, and administrative staff for completing the activity.

PROJECT OBJECTIVES

The general objectives of the Desert Biome program -- to elucidate the structure and function of North American desert ecosystems and to develop simulation models thereof -- were particularized most explicitly in the proposal for the 3-year program of 1974-76. Obviously the total structure and function are extensive and three aspects were selected for primary attention:

- (1) The carbon cycle
- (2) The nitrogen cycle
- (3) The hydrologic cycle

Investigation of these phenomena was focused on five research sites -- two in Utah, one in New Mexico, one in Arizona, and one in Nevada -- and the

constituent processes studied by investigators in some two dozen universities and agencies. In addition, state measurements convertible into carbon, nitrogen, and water equivalents were made periodically through each year on the sites. These measurements were made of both the biotic and abiotic components of the ecosystems on the sites.

Development of models was begun at the start of the program and continued throughout. By the time of the 1974-76 proposal, considerable dialogue and experimentation with modeling approaches had made it clear that several approaches were possible, and the selection of any one depended on the use to which it would be put. Accordingly, two approaches were set forth as objectives for the 1974-76 period.

EXECUTION

By the time field research closes at the end of 1976, 82 individual process studies will have been carried out over the five sites (Table 1). Each of these was continued over a span of 1 to 7 years, and hence the number of individual project-years will total somewhere around 250 by the end of 1976. Those projects which continued several years accomplished certain objectives in their first 2 or 3 years, then were modified to new related objectives. A better estimate of the number of discrete research projects would fall somewhere between 82 and 250, perhaps near the midpoint.

One full set of site, state measurements (hereinafter termed validation studies) was begun in 1970, as were two partial programs. From 1971 through 1976, four full programs were carried out while one partial validation study was continued from 1973-1976, inclusive. Consequently, 25 full and 6 partial site-years of effort will have been completed by the end of 1976.

The process studies have been addressed to the individual physiological, demographic, and ecological processes involved in moving carbon, nitrogen,

TABLE 1
Individual Process Studies Carried Out in the Desert
Biome Between 1970-1976

Subject of Project	No. Projects by Desert Type ¹				Total
	Great Basin	Chihuahuan	Sonoran	Mohave	
<u>Carbon Cycling</u>					
Perennial plants	5	2	3	3	13
Annuals	2	1	1	-	4
Cryptogams	1	-	1	-	2
Rodent population and bioenergetics	6	-	2	5	13
Granivory	1	-	-	4	5
Herbivorous insects	3	3	4	1	11
Detritivory	-	1	1	2	4
Birds	-	-	1	-	1
Reptiles	-	-	-	1	1
	—	—	—	—	—
Totals	18	6	13	16	54
<u>Nitrogen Cycling</u>	7	3	3	1	14
<u>Water Cycling</u>	3	-	5	2	10
<u>Aquatic Systems</u>	3	-	-	-	3
<u>Remote Sensing</u>			1		1

¹Each of these projects was subcontracted to an individual principal investigator. Most of them were continued for periods ranging from 2 to 7 years. During these periods, initial objectives were met and new ones addressed. Hence the actual number of individual research objectives posed and attained considerably exceeds the 82 projects listed here.

or water within the cycles for each of these entities. They have endeavored to measure the rates at which these processes go on as functions of the environmental factors which affect them. Mathematical formulations of these functions are the building-blocks out of which the models are structured.

The validation measurements have been carried out for four purposes. The first is to provide an array of state measurements which can serve as starting points from which the models can simulate the changes in the ecosystems on each site over time. The second is to provide measurements of the inputs of exogenous variables -- solar energy, precipitation, immigration, etc. -- over time which can be used to "drive" the models much as the variables themselves actually "drive" the ecosystems. The third is to provide measurements of the state of the system on each site at points in time which can be compared with the simulated values of the models in order to check the realism, or "validate", the models.

The fourth purpose of the validation measurements is to supplement the process studies with rate measurements. A rate can be calculated from two state measurements separated in time. With several dozen species each of plants and vertebrates on each site, as well as several hundred species of invertebrates, the total number of needed process studies is obviously very high. Project resources have not been sufficient to carry out this number of process studies, and the rate estimates derived from the state measurements have contributed to the total need.

The two modeling approaches differed in complexity. A "question-oriented" model was designed to answer the question: "What is the effect of doubling or halving the long-term mean precipitation on the above-ground primary production?" Developed in a total ecosystem framework, this model could be constructed in the most complexity in those areas relating to the moisture effects, and plant

processes involved in above-ground production. Decomposition and nutrient processes, animal function, and such processes of the plant itself as reproduction could be modeled at lower levels of resolution, thereby economizing on modeling and computational costs. The drawback of this approach is that each model is highly specialized and capable of addressing only the question around which it is structured.

The general-purpose modeling effort has attempted to build a complex, whole-ecosystem model which would contain comparable levels of resolution in all its parts. Its purpose would be to address a posteriori questions which were not explicitly in mind at the time the model was designed. Its tradeoff might be the predictive precision possible in a narrowly defined model structured to answer an a priori question.

ACCOMPLISHMENTS TO DATE

Accomplishments of the Biome research projects have been reported in detail annually in its Research Memoranda throughout the tenure of the program. The most recently published RM's are submitted with this proposal. However, to set perspective in this document for the proposed 1977-78 program, the research accomplishments are described in brief and general form in the following sections.

Carbon Cycling and Energy Flow

The number of individual projects designed to address carbon cycling (or its parallel, energy flow) has been larger than the number committed either to nitrogen or water cycling (Table 1). Approximately a third of these have studied the vegetation trophic level, with emphasis on the perennials. The projects began with gas-exchange studies of photosynthetic input, and several expanded into an elaboration of the carbon-budget patterns within the plant, including allotments to respiration, to vegetative and root growth,

and to reproduction. Four studies of annual-forb production and demography, two studies of soil-surface cryptograms, plus the periodic vegetation state measurements on the sites will have the vegetation portion of the system fairly thoroughly researched by the end of 1976.

The animals, because of their diversity in form, function, and taxonomy, have been more difficult to encompass. Certain functional groups and species have received emphasis:

(1) The small-mammal component has been examined with some thoroughness.

(2) Since annuals and their seeds are an important fraction of the total primary production in deserts, and since a conspicuous guild of granivores has evolved into this resource, the process of granivory has been given some emphasis.

(3) As in other terrestrial systems, the fraction of primary production consumed as living tissue by herbivores in deserts is very small, perhaps less than 5 percent. Much of the plant material dies unconsumed and desert sites characteristically contain a considerable amount of standing-dead vegetation. As a result, most of the primary production moves through the detritus pathways, and some attention has been focused on the detritivorous invertebrates. On two of the sites, the amount of carbon consumed by termites alone approaches the amount fixed in primary production.

(4) Several projects on herbivorous insects have been carried out with the emphasis on their role as regulators of the system rather than as conveyors of energy and material. But the total number of these species is so great that the research conducted under Biome auspices has constituted a miniscule fraction of the subject.

Once again the state measurements on the validation sites will supplement the animal process studies, and assist in elucidating the animal role in carbon

and energy movement to the degree that this component of the system can be described.

Nitrogen Cycling

Because desert soils are nitrogen deficient, the decision was made at the beginning of the program to emphasize nitrogen studies. Nitrogen fixation, denitrification, proteolysis, and nitrification have been explored in some detail, with major emphasis on Great Basin soils. This has been an effective area of inquiry, and the unique character of the nitrogen cycles in the Great Basin and Mohave deserts has been uncovered.

The Hydrologic Cycle

This topic was an obvious one for investigation in deserts, and has constituted the third area of Biome emphasis. The processes of run-on and runoff, evapotranspiration, and soil-water movement have been investigated and modeled in several U.S. desert sites. These studies have provided the collective knowledge for synthesizing the general form of the hydrologic cycle in the region and comparing it with the cycle in other biomes.

Modeling

As mentioned above, Biome modelers have explored several approaches to the development of desert simulation models. By the end of 1976, the total approaches or forms experimented with will include not only the two whole-system models described above, but more restricted subsystem or question-oriented models. Four examples of these latter are:

- (1) A generalized photosynthesis model.
- (2) A model of soil-water movement.
- (3) A model of forage selection and vegetation effects by sheep.
- (4) A model of the carbon budget in *Larrea tridentata*.

The general-purpose model is being developed both for the terrestrial systems and an ephemeral stream in Curlew Valley. The intermediate complexity, question-oriented model is being developed for the water-response question and variants of this general pattern.

REMAINING PROGRAM NEEDS

General Comment

As the observational phase of the Desert Biome draws to a close, the program will of course not be complete until the data are fully analyzed and meaningful inferences and generalizations about the structure and function of North American desert ecosystems drawn from those data and published. These analytic and publication functions have been underway from the beginning of the program. Individual investigators agreed in their subcontracts to conduct preliminary analyses of each year's data, and to set forth the results in the annual progress report series entitled "Research Memoranda."

Furthermore, each investigator was urged to publish his results in the open scientific literature as soon as they had matured to that point. A list of publications which had appeared by early 1976 is included herein as Appendix A. At the time this list was compiled, other publications were of course in preparation or in press.

The RM's and the early open-literature publications are products of individual efforts and do not generally include the interdisciplinary syntheses of ecosystem phenomena for which the Biomes were designed. These efforts began at the outset in the form of the modeling activities. They were expanded at the annual Biome conferences where interdisciplinary groups developed integrated approaches to ecosystem phenomena and formulated plans for synthesis publications.

It is these broad syntheses which are the major remaining task of the program. This proposal seeks support for staff and logistics to guide, facilitate, carry out, and publish the synthesis efforts on which the Biome has already embarked and approaches completion to varying degrees. These efforts, and the degree to which they are completed, are now discussed in some detail.

Synthesis Volumes

Four volumes are projected for bringing together important, synthetic aspects of desert ecosystem structure and function.

(1) The most advanced of the four is a volume entitled "Nitrogen Processes of Desert Ecosystems" and edited by Neil E. West and John J. Skujins. This volume was conceived, outlined (see Appendix B), editors elected, and authors decided upon at the Biome's 1973 annual conference.

As this proposal is being written, all chapters but one have been written, sent out to peer reviewers, returned and revised, and are now being typed. The outline has been approved by the IBP Publications Committee and the manuscript should be submitted to them by the fall of 1976.

The work describes in some detail the individual processes involved in the desert nitrogen cycle, those descriptions being written by Biome investigators who studied each of the processes. The last three chapters synthesize the character of the desert nitrogen cycle from the preceding chapters, twice with the use of models and finally with a verbal description of what is known of the cycle and what future research is needed to further enhance our understanding.

This volume only needs a final reading and editorial treatment by the Biome directorate, and submission to the Publications Committee for approval and transmission to the publisher. Hopefully this will take place around the first of 1977.

(2) The second most advanced volume is the water volume. This volume was also conceived and editors selected at the 1973 Biome conference. Beyond this decision to consider such a volume, no further action was taken until 1976. Water projects were fewer in number than nitrogen projects, and it was not clear until 1975 that the research had been sufficiently successful and comprehensive to warrant the volume.

Entitled "The Hydrologic Cycle of Desert Ecosystems" and edited by Daniel Evans and John Thames, the undertaking gathered momentum in early 1976 with the selection of chapter authors. These authors presented chapter outlines at the Biome conference in early June 1976, modified and agreed on the volume outline (Appendix C), and promised to submit first drafts by fall 1976. Manuscripts are expected to go out for peer review around the end of the year, revisions accomplished by mid 1977 and submitted to the Publications Committee for approval and advance in the publication procedure at that time.

Assistance and logistics needed by this operation include travel support for the authors to attend one meeting to review progress; and typing, drafting, and editorial assistance at Biome headquarters. This volume has considerable momentum, strong authors, and high promise of being an effective piece of work.

(3) A third volume presently in the planning stage is one that will synthesize the results of the validation studies. The role of the validation studies has changed as the program objectives have evolved over time. The objectives at the beginning of the program were solely to develop large, general-purpose models of the system. At that stage, the validation measurements were conceived only as providing an extensive array of periodic state measurements which would (a) provide the initializing values from which the models would simulate ecosystem dynamics over time, (b) provide the periodic

exogenous inputs into the models, and (c) provide periodic measurements of the real world against which the simulated values could be compared and the models "validated."

However, as the program proceeded, the participating scientists were increasingly disposed to develop the traditional, inductive generalizations about the systems on which they worked. Hence this traditional scientific approach became an objective or modus operandi parallel to the modeling.

In this context, it became evident early in the program that the detailed and extensive, periodic measurements on the sites provided a rich data set with which to describe the structures of the ecosystems on the sites. And to the degree that rates of change can be inferred from periodic state measurements, the site data sets also provided considerable basis for describing the dynamics of the systems.

While site data have been tabulated and summarized annually in the progress reports, much of the work has been done by technicians. Hence the data have not received the mature, scientific analyses and interpretation which the process studies, each conducted by an established senior scientist, have had. Generalizations and publications from this large component of the program have been relatively few compared with the process studies.

In 1975 an outline for analysis and generalization of site data was drawn up and included in the 1976 prospectus (proposal) volume submitted to N.S.F. Early in 1976 three postdoctoral fellows were employed to supervise the site data analyses and syntheses. These efforts have progressed during 1976, and at the time this is written, the synthesis outline has been modified and plans developed for combining the syntheses into a volume.

Appendix D is a chapter outline being used for each site. Each of these chapters will characterize the systems on a site, and a final chapter will discuss the common characteristics of U.S. deserts, point out the unique features of each, and discuss the environmental and historic causation underlying the commonalities and differences.

The effort is being coordinated by James MacMahon and the three post-doctoral fellows -- Judith Warner at Utah State University, Paul Flavill at New Mexico State University, and Robert Epting at U.C.L.A. -- and the three site coordinators at the Jornada, Silver Bell, and Rock Valley sites (Walter Whitford, John Thames, and Frederick Turner). The effort is expected to continue through 1977 and perhaps part of 1978. It will require considerable assistance from the Biome Data Processing group, some help from the modeling staff, and considerable typing, drafting, and editorial support.

(4) Least advanced among the four, projected Biome volumes is one on vegetation function. More resources have been committed to vegetation studies than any other single facet of the carbon-energy flow aspect of the system. This volume has progressed to the stage of selecting an editorial committee comprised of the following:

Duncan Patten, Chairman, Arizona State University

Arthur Wallace, U.C.L.A.

Gary Cunningham, New Mexico State University

Brien Norton, Utah State University

James MacMahon, Utah State University

The committee met at the 1976 Biome conference, and has considered several early drafts of an outline. All of these are highly tentative at this stage.

In general, the plant process studies have given insights to the adaptive mechanisms of desert plants in addition to the empirical information on eco-

physiological processes as functions of environmental variables. These mechanisms include:

- (a) High acclimation flexibility of Great Basin shrubs to ambient temperatures with temperature optima for photosynthesis shifting monthly.
- (b) Extremely heavy commitment of carbon (up to 85 percent) to roots in Great Basin shrubs along with rapid turnover in root structure.
- (c) No greater efficiency of Great Basin shrubs with C₄ photosynthetic pathways than of C₃ species, contrary to current theory.
- (d) Demographic responses to abiotic factors and competition in Great Basin annuals which explain successional patterns and community dominance.
- (e) The almost complete ephemerality and aseasonality in *Larrea tridentata* along with threshold labile carbon levels above which reproduction can take place.
- (f) The crassulacean acid metabolism (CAM) of cacti with which they are able to recycle metabolic carbon into photosynthesis, enabling them to keep their stomates closed during dry periods, and the possible homology of CAM, C₃, and C₄ patterns.
- (g) Water- and temperature-response thresholds of Chihuahuan Desert annuals along with the homology of annual and perennial life forms.
- (h) Stem photosynthetic patterns in microphyllous shrubs of the Sonoran Desert.
- (i) Commensal relationships between Sonoran Desert annuals and shrubs.

Members of the vegetation-volume committee have been considering an approach which explores these mechanisms, and postulates their collective influence in determining the production levels and water-use efficiencies which have been measured in desert plant communities.

Since this effort is at an early stage, considerable support will be needed. This includes funds for the editors and authors to travel to one or two meetings, honoraria for whoever is (are) selected as editor(s), and the usual editorial, typing, and drafting support. The group producing this volume will do well to finish it by June 30, 1978.

No other volumes are planned at this time. The four listed here may well fulfill the broad synthesis needs of the program. But we are leaving open the possibility of a single, overall synthesis volume on the structure and function of North American desert ecosystems.

Monograph Series

At the 1973 Biome conference, the Executive Committee decided to develop a Desert Biome Monograph series. This series was adopted to provide a publication outlet for lengthy, detailed, often highly specialized treatises too long for journal articles, too specialized and short for synthesis volumes, and perhaps too esoteric or regional in interest for the traditional media which accommodate monograph-length works. Each Monograph will be peer reviewed with the reviewers' names prominently displayed on the title page. The series will be published by the Utah State University Press.

Because of the complexity and diversity of the animal components on the five sites, the animal process studies which have been conducted have elucidated on a small, fragmentary portion of the consumers. There is no generalized basis for a consumer volume, or even of a combined vegetation-

consumer volume which delineates the total carbon-energy flow pattern in the desert.

Nevertheless, the individual consumer studies include some excellent research and we have elected to publish the large reports of these studies in the Monograph series. The first one -- Energy Utilization by a Desert Lizard (*Uta Stansburiana*) by Frederick B. Turner, Philip A. Medica, and Bruce W. Kowalewsky -- appeared in 1976. Copies are submitted with this proposal.

Others are in the outline or planning stage. One will cover the excellent termite work carried out by William Nutting and colleagues at the University of Arizona. The preliminary outline for this report is included herewith as Appendix E. Another one tentatively planned will cover the Idaho State University and Utah State University studies on Deep Creek in Curlew Valley, herein tentatively outlined in Appendix F. Other consumer Monographs under consideration include works on the Biome granivory studies, on soil nematodes, and possibly others.

As the Biome modeling efforts come to a conclusion, three publication needs arise in their regard:

(1) The models themselves need to be published with detailed descriptions of their design and structure, their capabilities, and instructions on how to operate them.

(2) Model development proceeds only after detailed explication of the biological systems which they represent. Modelers who develop such simulation models have a unique, explicit perspective of the system, and in running the models develop counterintuitive insights of those systems. In effect they disclose characteristics of the system not apparent to the individual scientists who conducted the research and produced the data out of which the models

are built. Consequently it is important that these insights are published as part of the total reporting function of the scientific venture.

(3) The spirited dialogue on modeling approaches which has continued throughout the history of the Desert Biome, and the experimentation with alternate approaches has produced some philosophical and conceptual advances to the modeling art. These need to be published.

For these publication needs, several Biome Monographs are under consideration. A preliminary outline of the question-oriented, water-response model is included herein as Appendix G.

The editorial burden of the Monographs is much higher than that of the synthesis series. The latter is assumed by the volume editors on a general level while Dowden, Hutchinson and Ross assumes responsibility for copy editing and the mechanics of publication. In the case of the Monographs, the entire editorial load falls on the Biome editorial and administrative staffs. And since they are published on campus, the editorial staff carries out much of the publication mechanics. Hence, the Monographs will make considerable demand on Biome personnel and funds throughout the 1977-78 period covered in this proposal.

Research Memoranda

Progress reports for the 1975 field research in the Research Memorandum series are nearly completed and published as this is being written. But the principal investigators' progress reports for the 1976 field research will not be submitted until early 1977. The first half of that year will be needed to publish the last Research Memoranda for the program. This, as usual, will require editorial, typing, drafting, and publishing effort.

Modeling

The dialogue on modeling approaches in the Desert Biome has turned around the point of modeling objectives. At its outset, the program proceeded on the assumption that a large, highly generalized yet detailed model of desert ecosystems could be constructed which would be capable of answering a large array of a posteriori questions not explicit at the time of model development. After 6 months of effort toward development of such a model by a team of four individuals, considerable uncertainty began to arise about the undertaking.

This uncertainty particularly related to the question of model resolution. A desert ecosystem contains several dozen species of plants, several species of vertebrate animals, and several hundred species of invertebrates. These interact with each other directly, indirectly through effects on species which interact with them, and with their physical environments. The latter contain an array of chemical and physical processes important to the biota. Presumably, if representations of all of these processes and interactions could be incorporated into a single model, the result would be a highly resolved, isomorph of the real world. It should be able to answer almost any a posteriori question about the effects on the system of nearly any perturbation.

But two unanswered questions and one insurmountable obstacle presented themselves in developing such an isomorph. The questions were (1) the time and manpower needed to build such a model, and (2) the research time and manpower needed to supply the biological detail required by it. The major obstacle was the inability of any existing computer to accommodate a model of this magnitude and the prohibitive computing costs associated with such a model even if a large enough computer existed.

Although there was no basis for answering the questions, the decision was made in 1972 to proceed on two separate but parallel modeling pathways

in order to circumnavigate the obstacle of computer size. In early 1972, the program was only beginning its third year and there was some hope of longevity sufficient to take care of the two questions. These two pathways are now discussed in some detail.

(1) Pathway 1 has come to be known as the "question-oriented" modeling approach. Its rationale is as follows. If a highly detailed isomorph of the real world is too large for computing purposes, some simplification is necessary. But there are no abstract or a priori criteria for simplification. One could combine species into functional groups, or trophic levels, or some other combinations. But these would be arbitrary decisions. If a posteriori questions about individual species, or combinations of species other than those of the a priori groups were asked, they could not be answered.

The extreme solution to this problem would lie in developing models only in response to questions. An organization would not presume to have already built, cook-booked models on the shelf which could be used upon request by computer technicians or even biologists. Rather, it would employ a resident modeling staff who would be waiting in the wings for some modeling request, and then develop a model only sufficient to answer some question which had arisen.

In exploration of this philosophy, a portion of the Desert Biome modeling staff spent most of 1971-73 in developing highly resolved models of limited subsystems. A question would be posed about the effects of some perturbation on one or a few components or processes in a desert ecosystem. A model would then be developed which would simulate the causal chain linking perturbation and target component or process. No attempt was made to model any part of the ecosystem except that involving the causal pathway.

This early approach had two, somewhat similar failings, one from the standpoint of systems theory and the other from the standpoint of US/IBP biome objectives. The theoretical inadequacy was that, in a number of cases the early, simple models did not provide for feedback effects from portions of the ecosystem outside the causal pathway. The programmatic inadequacy was that the biome projects were instituted for the purpose of studying and simulating whole ecosystems. Aside from the experience of learning to model limited subsystems, the early question-oriented effort was not addressing the broader purpose.

Although several early, narrowly defined models were built in the first 3 years, and are now available in early versions as part of the Desert Biome modeling accomplishments, the question-oriented effort was modified in early 1974 to eliminate its two failing inadequacies. The decision was made to develop question-oriented models which would be total systems. The problem of size would be avoided by modeling in detail the causal pathway between effect and response, while the remainder of the ecosystem would be modeled at a highly generalized and simplified level of resolution. The first model embarked upon, hereinafter termed the "Water Response Model" (WRM), was designed to address the question: "What is the annual effect (± 1 field-determined standard deviation 80 percent of the time) of halving or doubling the long-term mean annual precipitation with either natural or irrigated increases. The characteristics of this model are as follows:

- (a) The model simulates the whole ecosystem with emphasis on plants.
- (b) Driving variables are based on daily records (temperature, precipitation, insolation, wind, humidity, rain intensity, fraction possible sunlight), and stochastic generation of these over time for simulation purposes.
- (c) A simple decomposition submodel removes organic matter from the system.

- (d) A simple, but realistic 2-compartment submodel simulates nitrogen processes.
- (e) The soil-temperature profile is simulated by a difference-equation scheme which uses measured thermal conductivities with mean air temperature as the main driving variable.
- (f) The soil water-potential profile is simulated by a version of John Hanks' soil-water model using measured hydraulic conductivities and water-release curve. Driving variables are precipitation, evaporation, transpiration, runoff, loss or gain through caliche layer.
- (g) An animal submodel acts as a vegetation-removal submodel.
- (h) The annual-plant submodel simulates biomass through time of five organs for each of two functional groups (early and late). Major processes simulated as functions of various driving variables include germination, growth, transpiration, phenology and mortality.
- (i) The perennial-plant submodel simulates biomass through time of six organs for up to four functional groups. Major processes simulated as functions of various driving variables include photosynthesis, phenology, respiration, transpiration, carbohydrate allocation, death.

The model is now operational for the Curlew Valley and Rock Valley sites. But completion of the following efforts are deemed necessary for ultimate completion of this model:

- (a) Simulate the Jornada site.
- (b) Test the model further to examine (i) sensitivity to structural changes (e.g. change transpiration, evaporation, growth algorithms) and (ii) long runs (5-10 years) to disclose long-term sensitivity to perturbations.

- (c) Simulate lag times between precipitation events and rises in soil-water potential.
- (d) Examine production vs. total carbohydrate produced and elucidate patterns of variation.
- (e) Simulate amount of precipitation used by plants as functions of precipitation cover, and other variables.
- (f) Put limits on effects of increased ultraviolet-B radiation (280-320 nm) which would be expected for North American deserts.

The last remaining activity in connection with WRM is to complete the monograph mentioned above and outlined in Appendix G.

If time permits, some further development of whole-system, question-oriented models is desirable. Two questions which have been posed, and which could be the focus to the next models are:

- (a) What are the effects of different grazing patterns by domestic animals on the patterns of carbon flow?
- (b) What is the effect of changing mean precipitation patterns on the nitrogen cycle and nitrogen constraints on plant growth?

Finally, the performance of these question-oriented models needs to be compared with the performance of the general-purpose model, and certain theoretical insights which have been learned during the course of this modeling effort need to be published, as will be discussed below.

(2) Pathway 2 is an attempt to develop a general model of the ecosystem which is capable of answering an undefined array of a posteriori questions. The problem of size is being circumvented by a modular scheme. Vegetation and animal submodels are being developed as modules of the whole, and in three versions or levels of complexity. If an a posteriori question about vegetation response is asked, a high-resolution plant module can be used while low-resolu-

tion versions of the animal and abiotic submodels can be used, thereby reducing the total computing load.

Thus, to some degree this approach is convergent with the whole-system, question-oriented approach. Begun in 1972, the general-purpose modeling effort proceeded on two fronts. One is the terrestrial model, henceforth termed "Desert II", which has accomplished the following:

- (a) The model is completely written, the code consisting of many small subroutines rather than a few large ones.
- (b) It is written in the American National Standards Institute version of FORTRAN, and so can be run on virtually any full-sized computer in the world.
- (c) It is fully responsive to environmental variables.
- (d) The soil model contains a decomposition submodel, and water- and heat-flow models.
- (e) The animal submodel simulates only domestic herbivores.
- (f) The entire package has been fully documented in a combination model description-user's manual. The model has been exercised primarily with Rock Valley data, but also a few times with Curlew Valley data. Model elaboration has continued concomitantly with simulation trials. Although for a while the model seemed to have reasonable qualitative behavior, it now exhibits a pathological oscillation in the values for annual net primary production. Standing-crop values, on the other hand, behave reasonably.

Although termed a general-purpose model, Desert II can in fact only address a limited set of questions. Some of these are:

- (a) What is the net primary productivity and the standing crop of each organ of each plant species, over a period of years during which

successional changes are not significant, and how are these variables affected by temperature, precipitation (or irrigation), nitrogen fertilization, and grazing by domestic herbivores.

- (b) What will be the secondary production under a given grazing management scheme and under given climatic conditions.
- (c) What will be the effect of specified changes in exogenous input (temperature, precipitation, fertilization) on any of the processes (photosynthesis, phenology, etc.).

Some of the questions that the model cannot address are:

- (a) Anything relating to wild animals (or pathogens).
- (b) Anything relating to soil nutrients other than nitrogen.
- (c) Change in community structure over time.

The following additional actions are needed before Desert II effort can be considered complete:

- (a) The cause of the oscillation of the annual, net-primary productivity values must be located and corrected.
- (b) An attempt must be made to give the model the capacity to exhibit a differential increase in the production of perennials and annuals in response to an increase in precipitation.
- (c) The phenology model needs careful examination and probably improvement.
- (d) Extensive analysis of model performance including sensitivity testing. We should vary the initial conditions and exogenous variables during a series of simulations enough so that we know the full range of behavior patterns that the model can exhibit. We should then find cogent cause-and-effect explanations for those behavior patterns,

regardless of whether they (the behavior patterns) are reasonable or unreasonable. If they are unreasonable, we should try to determine what should be done to correct the problem. "What should be done" may involve rewriting a section of the model using present theory and data or it may involve designing a new field experiment or data-collection program. We may not be able to do any of these things in the framework of the Biome, but we should be able to say what ought to be done.

An aquatic model is also being developed in the general-purpose mode. Deep Creek is a small stream which arises in the hills surrounding Curlew Valley, runs southward through agricultural floor of the northern half of the Valley, and disappears at about its midpoint. Its flow is subject to heavy, seasonal variation in precipitation, to heavy irrigation withdrawal, and to heavy input of allochthonous organic matter and organic runoff from the surrounding agricultural lands.

Only one modeler has been working on this model, and hence it is not as far along as WRM and Desert II, but considerable progress has been made. Begun in 1972, the objective was to create a general model to cover permanent springs and streams, and temporary waters represented by a playa and intermittent streams. In July of 1973 a cooperative use and development of the model was undertaken between the Desert Biome personnel and those of the Cooperative Fisheries Unit of Utah State University who were interested in predicting effects of reduced water flows on stream ecosystems. It was felt that the model should be general enough to cover streams located in different biomes, and thus modeling efforts were to be centered on moving water. This generality was accomplished not by building an all-inclusive ecological model of a specific ecosystem, but by building a model framework. That framework explicitly contains the types of components found within a stream ecosystem as well as functions describing the major fluxes between these com-

ponents. The actual components used for a particular ecosystem, as well as parameters for the functions, are left to be specified by the user at execution time. Because of common usage, the word "model" is used hereinafter in place of "model framework".

The model has proven itself, on the bases of qualitative evaluations, to be worthy of more consideration, study, and use. The range of output is such that its representation of ecosystem function as well as structure can be analyzed. Beside producing output in the form of values for state variables, all exchanges of energy between major components of the ecosystem and along the ecosystem boundary are tracked, all exogenous variables may be followed, and values for other variables of interest are available. In addition, most variables are available in both tabular and graphical form, and cross classification of many variables allows study of the ecosystem structure at different levels of resolution.

Based on the number of biological components included in the Deep Creek model, it is of high resolution when compared to other aquatic ecosystem models. In a recent survey of aquatic ecosystem models, 162 were listed. None of those listed had as many or more major components as the Deep Creek model.

The stream ecosystem model is now at a point where it needs to be analyzed and evaluated further. But the fact that it is of high resolution with discontinuous and nonlinear functions, makes it nearly impossible to analyze with current analytical techniques. However, Walter Valentine recently stated:

"... if we sacrifice complexity and realism in a model for a structure which is amenable to a variety of analytical techniques, we may end up analyzing something that is of little or no ecological interest. We should seek to create real-

istic models and recognize that we will likely have to analyze them with simulation techniques rather than analytical techniques."

The Deep Creek model is such a model and it is such an analysis that is the objective of this proposed work.

The next steps will be to simulate the Deep Creek ecosystem at different levels of resolution and to compare model output with observed values, i.e. model validation. For this purpose, the objective function will contain un-weighted variables which will be compared at different points in time, thus keeping ambiguity to a minimum. The completed effort should:

- (a) Validate the model at different levels of resolution.
- (b) Show whether or not there is a relationship between model complexity and predictability for the Deep Creek model.
- (c) Compare model predictability at the species, para-species, and possibly functional-group level.
- (d) Use the model to test some current concepts in ecology.

From the spring of 1970 to the fall of 1972 data were collected at four stations on Deep Creek in Curlew Valley on the Utah-Idaho border. These collections were made by a team headed by G. Wayne Minshall of Idaho State University. Another data collection is being made from the spring of 1975 to the fall of 1976 as part of an experiment to study the effects, on an ecosystem scale, of a light manipulation. This manipulation is being carried out at one of the stations that was sampled from 1970 to 1972. It includes separating the station into three experimental units: one which will act as a control, one which will have approximately 70% of the incoming radiation removed, and one which will be completely shaded.

The data normally collected are the masses of: (a) aquatic macrophytes at the species level; (b) benthic diatoms; (c) invertebrates, measured at 1 mm.

size intervals to the lowest practicable taxonomic category; (d) vertebrates; (e) particulate matter, both suspended and benthic, organic and inorganic; (f) dissolved materials, both organic and inorganic; and (g) all materials drifting into and out of a section. Also measured regularly are certain physical factors such as water depth and velocity, and driving variables such as radiation and temperature. Since many of the invertebrates are measured to size classes within a taxonomic category (most to the species level) they can easily be manipulated into different hierarchical categories. Plants are measured at the species level and two size classes of detritus are measured, so these components can also be used in different hierarchical categories.

For validation, the values of the predicted as well as observed parameters are graphed. In addition six statistical tests will be used as follows:

- (a) The difference squared between each observed value and its predicted counterpart for the same time period summed for each variable will be calculated. The average difference square is also given. Summations for the same two figures are also calculated for all variables of interest.
- (b) Thiel's (1961) inequality coefficient is calculated for each variable as well as all variables of interest.
- (c) Kapoor's (1968) inequality coefficient is calculated for each variable as well as all variables of interest.
- (d) The percentage difference for each pair of predicted and observed values is calculated and summed within user-specified ranges.
- (e) The parameters for the linear equation

$$P = mA + b$$

are calculated using conventional regression techniques.

The intersection of this equation with the equation for perfect prediction

$$P = A$$

is also calculated. This information can be used to analyze whether the predicted data are systematically different from observed data.

A number of simulations will be necessary, but each simulation for the most part will contain the same sets of driving variables.

Model complexity can be increased in three ways: By subdividing the state variables, by including more processes, or by taking into account more influencing variables for a given process. The present model structure is built in such a way that all three of these changes can be incorporated with a minimum of changes to the model. As an example, all invertebrates lumped together may be simulated. This one state variable may then be split into major taxonomic groups and simulated, and a further splitting into size classes may also be made. Comparison of variables will be made at the least complex level by adding the state variables after simulation so that the same variables are compared. The functional group simulation will be calculated as a result of the other work, for the model internally computes the percentages of food coming from different functional areas. Predictions from all simulations will be compared to measured values.

If satisfactory results are gained from the validation, then a series of computer experiments are planned to test the effect to the ecosystem of removing certain species, "guild", or trophic levels. Interesting results may be used to plan further field work (not necessarily Biome funded) which

would act as further model validation as well as elucidating present ecological theory. A manipulation of driving variables of the model is also planned for the same reasons.

Beyond completion of these models, two activities remain in order to achieve the maximum contribution of the Desert Biome modeling effort. The first is to sum up and publish what has been learned through this dual, interactive modeling program, about modeling theory.

One aspect of this will be to compare WRM and its successors with Desert II. The same questions can be asked of Desert II as have been asked of the question-oriented models. It will be of interest to compare the precision with which each addresses the same question, and the range of questions which Desert II is capable of answering. The results should also shed light on the validity of the modular mode. Ideas are also crystallizing about generality of models, and of individual processes (e.g. photosynthesis appears more general or uniform across species than phenology).

A second task remaining at least to be explored is that of modeling temporal changes in community structure. All of the Desert Biome models -- and in fact, all of the mechanistic models in the other biomes -- simulate year-to-year variations in essentially unchanging systems. There are one or two successional models, but these are essentially empirical rather than mechanistic.

More than anything else, the inability to model community change mechanistically is due to inadequate biological understanding. No operating models of community change will be developed until the biological data base needed to parameterize such models is available. But modelers could develop the structure of models which have this capability, and thereby focus the research needed to fulfill them. Some effort, in the 2 years remaining for the Desert Biome, is proposed for the modeling staff.

Finally, a modeling staff is needed through June 30, 1978 to assist the other synthesis activities and construct small models where these are needed. This proposal requests support for a modeling staff - 2 postdoctoral fellows, 2 Ph.D. students, and partial support for Dr. George S. Innis -- plus funds to support computer costs and other logistics so that the modeling tasks described above can be completed.

PROGRAM REQUESTED FOR 1977-78

The major tasks remaining for the period January 1, 1977 to June 30, 1978 are (1) synthesis and publication, and (2) completion of the modeling program. These require five basic operations, each in turn requiring a staff and logistic support.

(1) Synthesis itself. We are requesting a 1-year stipend for one post-doctoral fellow, and 2 half-year stipends for two fellows. These fellows will be assigned almost entirely to the site syntheses described above. The full-year person will reside at Utah State University, conduct the Curlew Valley and Silver Bell syntheses. The half-year persons will conduct the Jornada and Rock Valley syntheses.

Additional syntheses will be carried out by individual investigators as needed in connection with their own research, and by the volume editors. Each of the latter will be given a \$2,000 honorarium while peer reviewers will be given \$200 to \$500. Authors and individual investigators will not receive reimbursement.

Various aspects of particular syntheses, plus total-biome syntheses will be conducted by the three members of the Biome directorate, Frederic H. Wagner, James A. MacMahon, and Brien E. Norton.

All synthesis activities will need some travel support, secretarial and drafting help, assistance with data processing, and on occasion modeling.

(2) Editorial and Publications. The editorial load will be heavy, primarily in connection with the Biome monographs and the remaining year's Research Memoranda. This will be carried out by the Biome editorial staff which is expected to remain fully intact through 1977, and partially so in the first half of 1978. Assistant Director Brien Norton and Director Frederic Wagner will also assume a substantial share of the editorial effort.

Editorial and publications activities will require secretarial help, publication costs including printing, paper, etc.

(3) Modeling. This has been outlined in some detail. A full modeling staff is requested through June 30, 1978. Supporting costs include machine rental, computer charges, some secretarial costs, and some travel.

(4) Data storage and retrieval. During 1976, a major effort has been directed to checking all data sets stored in the Biome data bank, and making certain that they are in a condition for retrieval and ready use at some future date. The results of the field research being conducted in 1976 will remain to be deposited in the data bank during 1977. Hence, this remains as a task for data-bank personnel in the first half of the year.

Beyond this, data processing personnel will be needed throughout the synthesis period to assess data stored in the bank, to provide programming services, and to provide statistical analyses on various tests conducted as part of synthesis activities.

Support costs will include computer charges, machine rental, and secretarial costs.

(5) Administration and coordination. All of these activities will require direction and coordination, and some fiscal accounting. These

activities will be carried out by Director Frederic Wagner, for whom 5 months' support is being requested, Assistant Director James MacMahon (2 months' support), Assistant Director Brien Norton (8 months' support), and Assistant to the Director Fred Walk (2 months' support).

Needed logistic support includes secretarial help, travel, and other miscellany.

The budgets for these activities are attached hereto as Appendix H.

APPENDICES

PRESENTATIONS, PUBLICATIONS AND REPORTS

The remainder of this Newsletter is a set of listings of presentations and open literature publications reporting Desert Biome research, doctoral theses completed under the Biome program, and annual Biome progress reports (Research Memoranda) covering everything in the program up to the end of the 1975 year of funding. We wish to maintain these lists in a current condition, so please check over the presentations and publications and report any errors, omissions or additions to Leslie Ratti (Ecology Center, UMC 52, Utah State University, Logan, Utah 84322). Please send Leslie two reprints of any unlisted new publications and keep her informed of presentations given at professional meetings.

DESERT BIOME PRESENTATIONS

- ACKERMAN, T. L., and S. A. BAMBERG. Phenology studies in the Mohave Desert at Rock Valley Nevada Test Site, Nevada. Amer. Inst. Biol. Sci., 25th Annu. Meeting, Symp. on Phenology and Seasonality, Minneapolis, Minn. 1972.
- BALDING, F. R. The distribution of desert shrubs along a moisture gradient in an arroyo system. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Tempe, Ariz. April 22-24, 1971.
- BALPH, D. F. Curlew Valley validation sites. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Tempe, Ariz. April 22-24, 1971.
- BAMBERG, S. A., and G. E. KLEINKOPF. Comparative photosynthetic production of Mohave Desert shrubs. IBP Synthesis Meeting. Aberystwyth, Wales, U.K. April 19, 1973.
- BAMBERG, S. A., and A. WALLACE. Gaseous exchange rates of Mojave Desert shrubs: seasonal and diurnal patterns. Amer. Inst. Biol. Sci., Minneapolis, Minn. Aug. 26 - Sept. 1, 1972.
- BECKER, H., and W. G. WHITFORD. Ecological comparisons of montane cattle tanks. Amer. Inst. Biol. Sci., Fort Collins, Colo. Aug. 30 - Sept. 2, 1971.
- BELLOWS, T. S., JR. Insect populations and host-plant phenology on two desert shrubs, *Prosopis glandulosa* and *Larrea tridentata*. Southw. Entomol. Soc., El Paso, Texas. Feb. 12-13, 1975.
- BELLOWS, T. S., JR. Insect communities in desert shrubs. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Los Alamos, New Mexico. April 23-26, 1975.
- BJERREGAARD, R. S., and M. M. CALDWELL. The nitrogen cycle of two salt desert shrub communities of western Utah. Amer. Inst. Biol. Sci., Fort Collins, Colo. Aug. 30-Sept. 2, 1971.
- BOHART, G. E., and G. F. KNOWLTON. The bees of Curlew Valley. Utah Acad. Sci., Arts, and Letters, Biol. Sci. Sec., Logan, Utah. April 13, 1973.
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- BRIDGES, K. W., and J. DEACON. An energy-flow model for Saratoga Springs, Death Valley National Monument. Amer. Assoc. Adv. Sci., Pacific Coast Div., Berkeley, Calif. June 1970.
- BRIDGES, K. W., C. WILCOTT, M. WESTOBY, R. KICKERT, and D. WILKIN. Nature: a guide to ecosystem modeling. Amer. Inst. Biol. Sci., Ecosystem Modeling Symp., Minneapolis, Minn. Aug. 26 - Sept. 1, 1972.
- CABLE, D. R. Soil moisture use by mature velvet mesquite (*Prosopis juliflora* var. *velutina*). Soc. Range Manage., 28th Annu. Convention, Mexico City. Feb. 12, 1975.
- CALDWELL, M. M. Gas exchange of shrubs. Int. Symp. on Useful Wildland Shrubs, Logan, Utah. July 12-16, 1971.
- CALDWELL, M. M. Adaptability and productivity of species possessing C₃ and C₄ photosynthesis in a cool desert environment. Int. Symp., Leningrad, USSR. June 7-19, 1972.
- CALDWELL, M. M. Carbon balance and productivity of two cool desert communities dominated by shrubs possessing C₃ and C₄ photosynthesis. First Int. Congr. of Ecology, The Hague, Netherlands. 1974.
- CALDWELL, M. M. The carbon balance and water use of cool desert shrub communities dominated by plants possessing C₃ and C₄ photosynthesis. Int. Assoc. Plant Physiol., Wurzburg, West Germany. 1974.
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- CRAWFORD, C. S. and R. C. WOOTEN, JR. Population studies of a desert millipede *Orthoporus ornatus*. Entomol. Soc. Amer., Montreal, Canada. Nov. 27-30, 1972.
- CRAWLEY, M. Modelling and the synthesis of ecological systems. Amer. Inst. Biol. Sci., Fort Collins, Colo. Aug. 30 - Sept. 2, 1971.
- CRUSERE, F. M. Seasonal activity of bufonid and pelobatid toads around a desert playa. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Los Alamos, New Mexico. April 23-26, 1975.
- CUNNINGHAM, G. L. Two models for the prediction of net CO₂ exchange rates in desert grasses. US/IBP Gas Exchange Workshop, Oak Ridge, Tenn. April 1972.
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- CUNNINGHAM, G. L. A model for the prediction of net CO₂ exchange rates of C₄ grasses. Amer. Assoc. Adv. Sci., Lubbock, Texas. April 1973.
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- CUNNINGHAM, G. L., and J. H. BARK. The effect of carbonate deposition layers ("caliche") on the water status of *Larrea divaricata*. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Tempe, Ariz. April 22-24, 1971.
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- DELSON, J., and W. G. WHITFORD. Population ecology of tiger salamanders in ephemeral cattle tanks. Amer. Inst. Biol. Sci., Fort Collins, Colo. Aug. 30 - Sept. 2, 1971.
- DEPREE, E. M., and J. A. LUDWIG. Productivity patterns of desert willow, *Chilopsis linearis*, in a desert wash of southern New Mexico. Amer. Assoc. Adv. Sci., Southw. and Rocky Mtn. Div., Los Alamos, New Mexico. April 23-26, 1975.
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APPENDIX B

Outline of Desert Biome Synthesis Volume

NITROGEN PROCESSES OF DESERT ECOSYSTEMS

edited by

Neil West and John Skujins

1.0	Introduction	Neil West and John Skujins
2.0	Structural Distribution in Desert Ecosystems	Neil West and James Klemmedson
3.0	Symbiotic Fixation	F. B. Farnsworth, Evan Romney, and Arthur Wallace
4.0	Free Fixation	Robert Rychert, Donald Porcella, and John Skujins
5.0	Decomposition	Peter Comanor and Eugene Staffeldt
6.0	Proteolysis and Deamination.	Robert O'Brien
7.0	Nitrification	John Skujins
8.0	Denitrification.	Curtis Tucker and Robert Westerman
9.0	Volatilization (Ammonia)	Brian Klubeck, B. Eberhardt, and John Skujins
10.0	Plant Uptake	Arthur Wallace, Evan Romney, Richard Kleinkopf, and D. Soufi
11.0	Animal Breakdown	Clayton Gist and Pasquale Sferra
12.0	Physical Input (rainfall, dust, foliar leaching)	Neil West
13.0	Erosional Transport.	D. Sorenson, Joel Fletcher, and Donald Porcella
14.0	Modeling I (Theoretical)	David Goodall and Hanna Parnas
15.0	Modeling II (Operational)	Clayton Gist, Neil West, and R. McKee
16.0	Summary and Conclusions (Including future research needs)	Neil West and John Skujins

APPENDIX C

Outline of Desert Biome Synthesis Volume

THE HYDROLOGIC CYCLE OF DESERT ECOSYSTEMS

edited by

Daniel Evans and John Thames

1.0 Desert Systems -- John Thames and Daniel Evans

An introductory chapter presenting the purpose, justification and scope of the publication, as well as the definition, extent and general characteristics of deserts.

2.0 Physical Features of Deserts

2.1 Climatic -- Harry Bailey

2.2 Soils, Geology and Hydrology -- William Bull

Including the physical features of deserts with emphasis on those features pertaining to sources of water and the behavior of water under desert conditions.

3.0 Characteristics of Desert Plants -- Grant Harris and Gaylon Campbell

A description of desert plant characteristics relating to water distribution and usage including above ground and rooting characteristics for individual plants and plant communities.

4.0 Modeling Soil-Water-Plant-Atmosphere Desert Systems -- Gaylon Campbell and Grant Harris

Constructed around an idealized world model of a desert ecosystem showing processes and storages in the system, complexities of the system and the limitations to mathematical modeling of the system.

5.0 Precipitation in the Desert -- Martin Fogel

A coverage of spatial and temporal distribution of precipitation (rainfall and snow) including stochastic modeling of the processes.

6.0 Soil Water Under Desert Conditions

6.1 Physical Processes and Parameters -- W. A. Jury, John Letey and L. H. Stolzy

A presentation of soil-water flow equations and water-storage characteristics including measured parameters such as hydraulic conductivity, diffusivity, infiltration rate, water potential, soil-water content, condensation and evaporation.

6.2 Modeling the Soil-Water System -- John Hanks

A detailed presentation of a model of the soil-water system as developed by Hanks and others, including calibration and validation results.

7.0 Surface Hydrology Under Desert Conditions -- Jack Fischer

A coupling of rainfall-runoff model with soil-water model with calibration results for specific locations and a treatment of channel transmission losses.

8.0 Evapotranspiration Under Desert Conditions

8.1 Potential Evapotranspiration -- Lloyd Gay

A presentation of methods of estimating potential evapotranspiration, including estimated values, and relationship to areas of phreatophytes and playas.

8.2 Estimates of Actual Evapotranspiration -- Daniel Evans, Theodore Sammis and Dwight Cable

A presentation of methods of estimating actual evapotranspiration and values obtained from lysimeters, soil-water extraction, patterns and energy balance.

9.0 Water and Plant Behavior -- James MacMahon

A presentation of data and observations of the plant characteristics as related to water availability, such as plant-water potential, diffusion resistance, growth, etc.

10.0 Discussion -- Daniel Evans and John Thames

Including the present state of knowledge and research needs for a better understanding of desert ecosystems.

APPENDIX D

Chapter Outline of Desert Biome Synthesis Volume

STRUCTURE AND FUNCTION OF THE ECOSYSTEMS ON THE VALIDATION SITES

INTRODUCTION

- I. Location
- II. Physical setting
- III. Prior land use and/or research
- IV. Questions addressed particularly at this site

METHODS

- I. Data: Collection designs
 - A. Time-series data (dynamics)
 - B. Single-point data (characteristics)
 - C. Site studies
- II. Instrumentation

RESULTS

- I. Abiotic dynamics
 - A. Air temperature
 1. Long-term records
 2. For years of study at site
 - B. Precipitation
 1. Long-term records
 2. For years of study at site
 - C. Wind
 1. Velocity
 2. Annual and monthly runs

D. Radiation

1. Calculation of radiative environment
2. Incoming solar radiation
3. Comparison of calculated and measured radiation

E. Climographs

1. Conventional
2. H. Walter climographs

II. Soils

A. Description

1. Organic matter; bulk densities
2. Horizons; root zones
3. Biota; microbial biomass
4. N - C flux; algal crust and N cycling

B. Temperature

1. Profiles
2. Physical properties

C. Moisture

1. Profile
2. Moisture vs. abiotic patterns
3. Physical properties

D. Phosphatase; dehydrogenase

E. Chemical analysis and soil survey

III. Ecosystem Structure

A. Vegetation

1. Species composition and functional groups
2. Diversity
3. Spatial distributions
4. Biomass and phenology of growth forms
5. Energy and nutrient pools

B. Animals

1. Invertebrates

- a. Species composition and functional groups
- b. Diversity
- c. Phenologies

2. Vertebrates

- a. Species composition and functional groups
- b. Diversity
- c. Phenologies

IV. Ecosystem Function

A. Energy (or carbon) flow

1. Primary production

- a. Production by species
- b. Production by functional groups
- c. Production phenology
- d. Production as a function of moisture
 - (1) Rainfall amount and seasonality
 - (2) Actual evapotranspiration

2. Secondary production

- a. Herbivore population dynamics
 - (1) Vertebrates
 - (2) Invertebrates
- b. Herbivore bioenergetics
 - (1) Vertebrates
 - (2) Invertebrates
- c. Total secondary energy flow

3. Tertiary production (same as 2 for carnivores)
 4. Decomposition
 - a. Detritivore energy flow
 - b. Bacterial and fungal activity
 - c. Decomposition as a function of actual evapotranspiration
 - d. Total energy flow of decomposition
 5. Total ecosystem energy flow
- B. Mineral cycling
1. C-N-P fluxes in the vegetation
 2. Animal fluxes
 3. Mineralization and release
- V. The Jornada Playa: Study in Ephemerality

DISCUSSION

LITERATURE CITED

APPENDICES

APPENDIX E

Outline for a Desert Biome Monograph
ROLE OF TERMITES IN A DESERT ECOSYSTEM
by William Nutting et al.

- 1.0 Abstract
- 2.0 Introduction
- 3.0 Termite Fauna of the Sonoran Desert
 - 3.1 Dry wood
 - 3.2 Subterranean
- 4.0 Termite Populations
 - 4.1 Measurement problems
 - 4.2 Foraging density estimates
 - 4.3 Foraging territories
 - 4.4 Total density estimates
- 5.0 Foraging Activity
 - 5.1 Daily
 - 5.2 Seasonal trends
 - 5.3 Correlation with environmental factors
 - 5.4 Soil movement and modification
- 6.0 The Food of Termites: Cellulose Materials
 - 6.1 The flora of the desert
 - 6.2 Production of dead wood
 - 6.3 Relation between the distribution of dead wood and foraging populations
 - 6.4 Chemical composition of dead wood
- 7.0 Removal of Dead Plant Material
 - 7.1 Laboratory measurement of feeding rates
 - A dry-wood termite
 - A subterranean termite

- 7.2 Field measurements
- 7.3 Estimation of consumption rates by field populations
- 8.0 Seasonal Production of Winged Reproductives
 - 8.1 Phenology of dispersal flights
 - 8.2 Field measurements on five species
 - 8.3 Correlation of flights with environmental factors
 - 8.4 Termites as prey
 - Chemical assays
 - Biological assay
- 9.0 Food-Energy Relations and Energy Flow
 - 9.1 Physiological measurements on a dry-wood species
 - 9.2 Quality of materials presented to lower trophic levels by a dry-wood termite
 - 9.3 Estimates on energy flow through field populations of subterranean and dry-wood termites
- 10.0 Functional Significance of Termites in the Sonoran Desert

APPENDIX F

Outline for a Desert Biome Monograph

THE DEEP CREEK ECOSYSTEM

by G. Wayne Minshall et al.

1.0 Introduction

1.1 General background

- Objectives
- Location
- Duration of study

1.2 Early conceptualization of the Deep Creek system and general approach of the study

1.3 Integration of laboratory and field work

- Routine field measurements
- Question-specific field studies
- Experimental manipulations
- Laboratory investigations
- Modeling

2.0 Ecosystem Structure

2.1 Character of the system

- The desert stream environment
- The desert stream community
- Comparisons between stations and years
- Seasonal variations

2.2 Effects of, and responses to, environmental factors

- Light
- Temperature
- Substratum
- Flow, including flood

- Drought
- Nutrients

3.0 Ecosystem Function

- 3.1 Major functional groups and component taxa
- 3.2 Food preference studies
- 3.3 Individual energy budgets and functional group production rates
- 3.4 Processing transformations (e.g. conversion from coarse to fine particles by detritivore feeding)
- 3.5 Energy fluxes and ecological efficiencies
- 3.6 Derivation of energy and nutrient budgets
- 3.7 Comparisons between sites of differing energy inputs and physical control
- 3.8 Effects of nutrient addition and light limitation

4.0 Model formulation and testing

- 4.1 Validation
- 4.2 Predictive ability
- 4.3 Results of hypothetical manipulations
 - Light (both incoming and in situ)
 - Temperature
 - Nutrients
 - Functional-group removal
 - Herbicide treatment (xylene)
 - Feedlot drainage
 - Riparian vegetation removal
 - Flow regulation (cooperative venture with Central Utah Project)
- 4.4 Comparison with the aquatic models (especially Coniferous Biome IBP version)
- 4.5 Adequacy of the Desert Biome model

- 4.6 Heuristic and practical value of the modeling effort
- 4.7 Suggestions for future studies
- 5.0 Ecological Advances and Implications
 - 5.1 Comparison with other stream ecosystems
 - 5.2 New insights gained about the structure and function of stream ecosystems
 - 5.3 Autotrophy vs. heterotrophy
 - 5.4 Structure of benthic communities in different biomes
 - 5.5 Usefulness of the functional-group approach
 - 5.6 Importance of catastrophic events as reset mechanisms
 - 5.7 Relation to, and compatibility with, the river-continuum hypothesis

APPENDIX G

Outline for a Desert Biome Monograph

WATER RESPONSE MODEL

by Paul Lommen, Bradley Gilbert, and John Heasley

1.0 General Description

Introduction, objectives of model and a general description of each submodel showing assumptions and ideas, biological and abiotic, which make up overall model.

2.0 Detailed Description

Translation of objectives, ideas and assumptions into computer code (FORTRAN). Will also contain users' guide so model could be run for other sites without going through more than a minimum of model's details.

3.0 Curlew Valley Implementation

How values of parameters were determined; graphs, tables of tuning, and validation runs; 5-year simulations with and without modified precipitation.

4.0 Rock Valley Implementation

Same as for Curlew Valley

5.0 Sensitivity Testing

Sensitivity of model to changes in values of certain parameters and sets of parameters. What can be said about ecosystem sensitivity from model sensitivity?

6.0 Discussion and Conclusions

Were objectives met? What was learned, and what might be learned from further model testing? Are present modeling techniques more limiting than data shortages and general lack of understanding?

APPENDIX H

DETAILED BUDGET FOR JANUARY 1, 1977-JUNE 30, 1978.

WITH A BREAKDOWN OF NEW FUNDS
REQUESTED OF N.S.F. AND CARRY-OVER
1976 FUNDS TO BE USED DURING
THE FIRST HALF OF 1977

BUDGET SUMMARY FOR JANUARY 1, 1977-JUNE 30, 1978

At the end of calendar 1975, the Biome recovered an unencumbered balance of approximately \$70,000, or almost exactly 5 percent of its total budget. This balance could not be foreseen on September 1, 1975 when a new budget was submitted to N.S.F. for calendar 1976.

This unencumbered balance was programmed into Biome expenditures in the first half of 1976, thereby easing the demand on the 1976 budget by this amount. On the assumption that we can carry this surplus through 1976, and that an equal savings can be effected in 1976, we are postulating a total, unencumbered balance by the end of 1976 of \$140,191.

The budget summary which follows sets forth the support needed to complete the program proposed in the preceding pages, with a breakdown of funding for calendar 1977 and for the first half of calendar 1978. On the assumption that we can carry over the anticipated 1976 balance for use in the first half of 1977, that balance has been deducted from the support needed for the whole of 1977. The remainder, plus the amount needed for the first half of 1978, constitute the total support requested of N.S.F. herewith.

	Needed Support			Requested of N.S.F.			
	1977	1978	18-Mo. Total	Anticipated ¹ 1976 Balance	1977	1978	18-Mo. Total
Salaries and wages	182,679	65,862	248,541	23,701	130,278	65,862	196,240
Fringe benefits	36,228	13,192	49,420	4,140	36,228	13,192	40,776
Supplies	13,860	6,850	20,710	5,500	8,330	6,850	15,210
Domestic travel	10,000	3,500	13,500	22,000	3,000	3,500	6,500
Publications	16,000	5,000	21,000	6,000	10,000	5,000	15,000
Computer costs	21,900	9,300	31,200	21,000	930	9,300	10,200
Consultants	8,000	-	8,000	9,900	-	-	-
Rentals, communic.	4,600	2,300	6,900	5,030	-	2,300	2,300
Indirect	109,607	39,517	149,124	14,220	63,686	39,517	111,777
Subcontracts	-	-	-	38,931	-	-	-
TOTALS	402,874	145,521	548,395	150,422	252,452	145,521	397,973

¹Subtotal, but not individual values, will sum with N.S.F. request to equal 18-month needed support

DETAILED BUDGETARY BREAKDOWN

IAH STATE UNIVERSITY

CENTRAL OFFICE - CENTRAL OFFICE MANAGEMENT AND ADMINISTRATION
 PROPOSAL 2.1.1.
 FISCAL YEAR 1977

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	6	0	\$16,000.00	\$0.00
B. FACULTY ASSOCIATES				
MACHAHON, JAMES A. ASST. DIRECTOR	0	5	\$6,220.00	\$0.00
NORTON, BRIEN E. ASST. DIRECTOR	9	0	\$15,000.00	\$0.00
SUBTOTAL			\$37,220.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
A. RESEARCH ASSOCIATES-POSTDOCTORAL				
ADMINISTRATIVE ASST.	0	0	\$3,124.00	\$0.00
E. SECRETARIAL-CLERICAL				
2 SECRETARIES			\$16,500.00	\$0.00
TOTAL SALARIES AND WAGES			\$56,844.00	\$0.00
FRINGE BENEFITS				
TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)			\$11,389.00	\$0.00
EXPENDABLE EQUIPMENT AND SUPPLIES				
SUBTOTAL			\$68,233.00	\$0.00
TRAVEL				
1. DOMESTIC				
20 TRIP(S) @ \$320.00/TRIP			\$8,000.00	\$0.00
BIOME MEETINGS			\$8,000.00	\$0.00
BUDGET 1977 1978 ATTACHMENT B			\$6,400.00	\$0.00

SUBTOTAL	\$6,400.00	\$0.00
i. PUBLICATION COSTS		
	\$10,000.00	\$0.00
SUBTOTAL	\$10,000.00	\$0.00
4. COMPUTER COSTS		
	\$700.00	\$0.00
SUBTOTAL	\$700.00	\$0.00
J. TOTAL DIRECT COSTS (C THROUGH I)		
	\$93,333.00	\$0.00
K. INDIRECT COSTS 50.00 % OF A		
	\$34,106.00	\$0.00
L. TOTAL COSTS (J PLUS K)	\$127,439.00	\$0.00

UTAH STATE UNIVERSITY

CENTRAL OFFICE - DATA PROCESSING AND RETRIEVAL
 PROPOSAL 2.1.2.
 FISCAL YEAR 1977

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
1. SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	0	0	\$0.00	\$0.00
B. FACULTY ASSOCIATES				
ROMESBURG, CHARLES OFFICER IN CHAR	8	0	\$11,160.00	\$0.00
SUBTOTAL			\$11,160.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
B. NON-FACULTY PROFESSIONALS				
MARSHALL, KIM A. SENIOR PROGRAMMER	1	0	\$11,500.00	\$0.00
SHINN, VICKI SENIOR PROGRAMMEY	3	0	\$2,750.00	\$0.00
E. SECRETARIAL-CLERICAL				
1 KEYPUNCH OPERATOR			\$900.00	\$0.00
TOTAL SALARIES AND WAGES.			\$26,310.00	\$0.00
3. FRINGE BENEFITS				
			\$4,934.00	\$0.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)				
			\$31,244.00	\$0.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES				
			\$360.00	\$0.00
SUBTOTAL			\$360.00	\$0.00
F. TRAVEL				
1. DOMESTIC				
6 TRIP(S) @ \$100.00/TRIP			\$600.00	\$0.00
BIOME MEETINGS				
BUDGET 1977 1978 ATTACHMENT B				

SUBTOTAL	\$600.00	\$0.00
1. COMPUTER COSTS		
SUBTOTAL	\$7,200.00	\$0.00
	\$7,200.00	\$0.00
2. TOTAL DIRECT COSTS (C THROUGH I)		
	\$39,404.00	\$0.00
3. INDIRECT COSTS 0.00 % OF A		
TOTAL COSTS (J PLUS K)	\$15,786.00	\$0.00
	\$55,190.00	\$0.00

UTAH STATE UNIVERSITY

CENTRAL OFFICE MODELLING
 PROPOSAL 2.1.3.
 FISCAL YEAR 1977

	MAN-MONTHS		N.S.F.		GRANTEE	
	CAL	ACAD	SUM	N.S.F.		
1. SALARIES AND WAGES						
1. SENIOR PERSONNEL						
A. PRINCIPAL INVESTIGATOR						
WAGNER, FREDERIC H. BIOME DIRECTOR	440	26	4106	0	0	\$0.00
B. FACULTY ASSOCIATES						
INNIS, GEORGE S.	461	50	0816	3	0	\$4,525.00
SUBTOTAL						\$4,525.00
2. OTHER PERSONNEL (NON-FACULTY)						
A. RESEARCH ASSOCIATES-POSTDOCTORAL						
LOMMEN, PAUL	477	44	3820	12	0	\$18,000.00
VALENTINE, WALTER	024	34	3903	10	0	\$14,000.00
C. GRADUATE STUDENTS						
HEASLEY, JOHN						\$2,700.00
WLOSIMSKI, JOE						\$4,000.00
TOTAL SALARIES AND WAGES						\$43,225.00
B. FRINGE BENEFITS						
						\$8,645.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)						
						\$51,870.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES						
						\$2,000.00
SUBTOTAL						\$2,000.00
F. TRAVEL						
1. DOMESTIC						
4 TRIP(S) J						\$250.00/TRIP
BUDGET 1977						1978 ATTACHMENT B
						\$1,000.00
						5

BIOME MEETINGS									
SUBTOTAL								\$1,000.00	\$0.00
COMPUTER COSTS									
SUBTOTAL								\$12,000.00	\$0.00
OTHER COSTS *									
4. OTHER ITEMS (RENTALS, ETC.)									
COMMUNICATION COSTS									
SUBTOTAL								\$4,600.00	\$0.00
TOTAL DIRECT COSTS (C THROUGH I)								\$71,470.00	\$0.00
INDIRECT COSTS 50.00 % OF A								\$25,935.00	\$0.00
TOTAL COSTS (J PLUS K)								\$97,405.00	\$0.00

1. CONSULTANTS OF A SPECIFIC NATURE. 2. SUBCONTRACTS PERTAINING TO THAT PARTICULAR PROJECT.
3. MAINTENANCE. 4. RENTALS, AND LEASES

JYAH STATE UNIVERSITY

PROGRAM SYNTHESIS
 PROPOSAL 2.4.1.
 FISCAL YEAR 1977

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
A. SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	0	0	\$0.00	\$0.00
SUBTOTAL			\$0.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
A. RESEARCH ASSOCIATES-POSTDOCTORAL				
OFF CAMPUS				
WARNER, JUDITH	0	0	\$15,350.00	\$0.00
SUBTOTAL	12	0	\$16,000.00	\$0.00
B. NON-FACULTY PROFESSIONALS				
CHENEY, DAWN ASST. EDITOR	12	0	\$13,700.00	\$0.00
RATTI, LESLIE	0	0	\$4,000.00	\$0.00
SUPER, SUSAN	8	0	\$7,250.00	\$0.00
SUBTOTAL	20	0	\$24,950.00	\$0.00
TOTAL SALARIES AND WAGES	32	0	\$40,950.00	\$0.00
B. FRINGE BENEFITS 11.00% OF A2C,A2D AND 20.00% OF REST OF A			\$11,260.00	\$0.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)			\$67,560.00	\$0.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES				
SUBTOTAL			\$3,500.00	\$0.00
F. TRAVEL				
1. DOMESTIC				
8 TRIP(S) @ \$250.00/TRIP			\$2,000.00	\$0.00
BIOME MEETINGS				
SUBTOTAL			\$2,000.00	\$0.00

SUBTOTAL	\$2,000.00	\$0.00
i. PUBLICATION COSTS		
SUBTOTAL	\$6,000.00	\$0.00
I. COMPUTER COSTS		
SUBTOTAL	\$2,000.00	\$0.00
I. OTHER COSTS *		
1. CONSULTANTS		
SUBTOTAL	\$8,000.00	\$0.00
J. TOTAL DIRECT COSTS (C THROUGH I)		
K. INDIRECT COSTS 50.00 % OF A		
.. TOTAL COSTS (J PLUS K)	\$122,840.00	\$0.00

* 1. CONSULTANTS OF A SPECIFIC NATURE. 2. SUBCONTRACTS PERTAINING TO THAT PARTICULAR PROJECT.
3. MAINTENANCE. 4. RENTALS, AND LEASES

JTAH STATE UNIVERSITY

CENTRAL OFFICE - CENTRAL OFFICE MANAGEMENT AND ADMINISTRATION
 PROPOSAL 2.1.01.
 FISCAL YEAR 1978

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
A. SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	6	0	\$7,675.00	\$0.00
B. FACULTY ASSOCIATES				
MACMAHON, JAMES A. ASST. DIRECTOR	0	5	\$3,020.00	\$0.00
NORTON, BRIEN E. ASST. DIRECTOR	9	0	\$7,250.00	\$0.00
SUBTOTAL			\$17,945.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
A. RESEARCH ASSOCIATES-POSTDOCTORAL				
ADMINISTRATIVE ASST.	0	0	\$1,562.00	\$0.00
E. SECRETARIAL-CLERICAL				
2 SECRETARIES			\$8,250.00	\$0.00
SUBTOTAL			\$27,757.00	\$0.00
TOTAL SALARIES AND WAGES				
B. FRINGE BENEFITS			\$5,571.00	\$0.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)			\$33,328.00	\$0.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES				
SUBTOTAL			\$4,000.00	\$0.00
F. TRAVEL				
1. DOMESTIC				
10 TRIP(S) @ \$270.00/TRIP			\$2,700.00	\$0.00
BIOME MEETINGS				
SUBTOTAL			\$2,700.00	\$0.00

SUBTOTAL	\$2,700.00	\$0.00
. PUBLICATION COSTS		
SUBTOTAL	\$5,000.00	\$0.00
. COMPUTER COSTS		
SUBTOTAL	\$300.00	\$0.00
I. TOTAL DIRECT COSTS (C THROUGH I)		
. INDIRECT COSTS 60.00 % OF A		
. TOTAL COSTS (J PLUS K)		
	\$45,328.00	\$0.00
	\$16,654.00	\$0.00
	\$61,982.00	\$0.00

TAH STATE UNIVERSITY

CENTRAL OFFICE - DATA PROCESSING AND RETRIEVAL
 PROPOSAL 2.1.2.
 FISCAL YEAR 1978

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
1. SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	0	0	\$0.00	\$0.00
B. FACULTY ASSOCIATES				
ROMESBURG, CHARLES OFFICER IN CHAR	5	0	\$5,580.00	\$0.00
SUBTOTAL			\$5,580.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
B. NON-FACULTY PROFESSIONALS				
MARSHALL, KIM A. SENIOR PROGRAMMER	5	0	\$5,750.00	\$0.00
TOTAL SALARIES AND WAGES			\$11,330.00	\$0.00
3. FRINGE BENEFITS 11.00% OF A2C+A20 AND 20.00% OF REST OF A			\$2,266.00	\$0.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)			\$13,596.00	\$0.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES				
SUBTOTAL			\$150.00	\$0.00
F. TRAVEL				
1. DOMESTIC				
2 TRIP(S) @ \$150.00/TRIP			\$300.00	\$0.00
BIOME MEETING				
SUBTOTAL			\$300.00	\$0.00

TAH STATE UNIVERSITY

CENTRAL OFFICE MODELLING
 PROPOSAL 2-1-3.
 FISCAL YEAR 1978

	MAN-MONTHS N.S.F.	CAL	ACAD	SUM	N.S.F.	GRANTEE
A. SALARIES AND WAGES						
1. SENIOR PERSONNEL						
A. PRINCIPAL INVESTIGATOR	0	0	0	0	\$0.00	\$0.00
WAGNER, FREDERIC H. BIOME DIRECTOR		440	26	4106		
B. FACULTY ASSOCIATES	2	0	0	0	\$1,775.00	\$0.00
INNIS, GEORGE S.		461	50	0816		\$0.00
SUBTOTAL					\$1,775.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)						
A. RESEARCH ASSOCIATES-POSTDOCTORAL	6	0	0	0	\$9,000.00	\$0.00
LUMMEN, PAUL		477	44	3820		
VALENTINE, WALTER	6	0	0	0	\$7,000.00	\$0.00
C. GRADUATE STUDENTS					\$2,000.00	\$0.00
WLOSINSKI, JOE		024	34	3903		\$0.00
TOTAL SALARIES AND WAGES					\$19,775.00	\$0.00
B. FRINGE BENEFITS						
					\$3,955.00	\$0.00
C. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)						
					\$23,730.00	\$0.00
E. EXPENDABLE EQUIPMENT AND SUPPLIES						
					\$1,000.00	\$0.00
					\$1,000.00	\$0.00
F. TRAVEL						
1. DOMESTIC					\$500.00	\$0.00
2 TRIP(S) BIOME MEETING					\$250.00/TRIP	
BUDGET 1977 1978 ATTACHMENT B						

SUBTOTAL	\$500.00	\$0.00
• COMPUTER COSTS		
SUBTOTAL	\$6,000.00	\$0.00
SUBTOTAL	\$6,000.00	\$0.00
• OTHER COSTS *		
4. OTHER ITEMS (RENTALS, ETC.)	\$2,300.00	\$0.00
COMMUNICATION COSTS	\$2,300.00	\$0.00
SUBTOTAL		
1. TOTAL DIRECT COSTS (C THROUGH I)	\$33,530.00	\$0.00
2. INDIRECT COSTS @ 7.00 % OF A	\$11,865.00	\$0.00
3. TOTAL COSTS (J PLUS K)	\$45,395.00	\$0.00

1. CONSULTANTS OF A SPECIFIC NATURE. 2. SUBCONTRACTS PERTAINING TO THAT PARTICULAR PROJECT.
 3. MAINTENANCE. 4. RENTALS, AND LEASES

ITAH STATE UNIVERSITY

PROGRAM SYNTHESIS
 PROPOSAL 2.4.1.
 FISCAL YEAR 1978

	MAN-MONTHS N.S.F.	CAL ACAD SUM	N.S.F.	GRANTEE
1. SALARIES AND WAGES				
1. SENIOR PERSONNEL				
A. PRINCIPAL INVESTIGATOR				
WAGNER, FREDERIC H. BIOME DIRECTOR	0	0	\$0.00	\$0.00
SUBTOTAL			\$0.00	\$0.00
2. OTHER PERSONNEL (NON-FACULTY)				
B. NON-FACULTY PROFESSIONALS				
CHENEY, DAWN ASST. EDITOR	5	0	\$7,000.00	\$0.00
TOTAL SALARIES AND WAGES			\$7,000.00	\$0.00
3. FRINGE BENEFITS 11.00% OF A2C,A2D AND 20.00% OF REST OF A			\$1,400.00	\$0.00
4. TOTAL SALARIES, WAGES, AND FRINGE BENEFITS (A+B)			\$8,400.00	\$0.00
5. EXPENDABLE EQUIPMENT AND SUPPLIES				
SUBTOTAL			\$1,700.00	\$0.00
6. TOTAL DIRECT COSTS (C THROUGH I)			\$10,100.00	\$0.00
7. INDIRECT COSTS 07.00 % OF A			\$4,200.00	\$0.00
8. TOTAL COSTS (J PLUS K)			\$14,300.00	\$0.00

TABLE OF CONTENTS BY PROJECTS

CENTRAL OFFICE - CENTRAL OFFICE MANAGEMENT AND ADMINISTRATION	
PROPOSAL 2.1.1.	1
FISCAL YEAR 1977	2
CENTRAL OFFICE - DATA PROCESSING AND RETRIEVAL	
PROPOSAL 2.1.2.	3
FISCAL YEAR 1977	4
CENTRAL OFFICE MODELLING	
PROPOSAL 2.1.3.	5
FISCAL YEAR 1977	6
PROGRAM SYNTHESIS	
PROPOSAL 2.4.1.	7
FISCAL YEAR 1977	8
CENTRAL OFFICE - CENTRAL OFFICE MANAGEMENT AND ADMINISTRATION	
PROPOSAL 2.1.1.	9
FISCAL YEAR 1978	10
CENTRAL OFFICE - DATA PROCESSING AND RETRIEVAL	
PROPOSAL 2.1.2.	11
FISCAL YEAR 1978	12
CENTRAL OFFICE MODELLING	
PROPOSAL 2.1.3.	13
FISCAL YEAR 1978	14
PROGRAM SYNTHESIS	
PROPOSAL 2.4.1.	15
FISCAL YEAR 1978	
	1

TABLE OF CONTENTS BY SUMMARIES

UTAH STATE UNIVERSITY	16	17
UTAH STATE UNIVERSITY	18	19
OVERALL SUMMARY	20	