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# PUERTO RICO NUCLEAR CENTER

THE RAINFOREST PROJECT

A Renewal Proposal for
Fiscal Year 1967-1968.

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PUERTO RICO NUCLEAR CENTER
UNIVERSITY OF PUERTO RICO
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Submitted by

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TABLE OF CONTENTS

## 3) ABSTRACT

This is a renewal proposal for the rainforest project which covers two major areas of work. Part one concerns documentation of the recovery of vegetation in the area which was previously irradiated with $^{137}Cs$. In this part we will propose to continue mapping the new vegetation as it appears, to continue the biological productivity measurements, and to continue such indices of recovery as leaf area index measurements and optical density measurements. Other studies to be carried out include the continuation of photographic records in the area, the initiation of optical spectral measurements, the initiation of new species diversity measurements and the continuation of measurements on new shoots from old trees.

Part two emphasizes continuation and amplification of the mineral cycling objectives of the project and includes proposals for further work in fallout radionuclide distribution, and biological residence time measurements which includes the use of tritiated water to study the flow of water in soils and plants. These as well as other studies are designed to provide a relatively complete picture of mineral cycling processes in the tropical ecosystem including rates and quantities of mineral flow in these cycles and the measurement of amounts and rates of input and escape from these cycles.

Other phases of the proposal provide for the continuation of soil contamination experiments, for metabolism measurements and for continuation of El Verde field station including the recording of certain selected weather variables.

## 4) SCIENTIFIC BACKGROUND

The Rainforest Project has been in effect since 1963. In the first three years of the project a section of the lower montain rainforest in the Luquillo mountains of Eastern Puerto Rico was irradiated with 10,000 curies of $^{137}Cs$ for a three month period. The irradiation of the forest was preceeded by about one year of general ecological survey studies of the plants and animals of the area and was followed up after the irradiation with similar studies where relevant in order to measure radiation effects. Many of these studies were carried out by visiting investigators from other institutions who came to Puerto Rico to contribute to the project within the area of their own specialties. This phase of the work is at present being organized into a volume entitled A Tropical Rainforest by H.T. Odum former director of the project.

The important results of this work are two fold. Firstly, the damaging effects of gamma radiation on a tropical ecosystem have been directly observed and will serve as a tropical basis for comparisons with other similar studies in temperate zones which have been carried by AEC and should provide an objective basis for the prediction of effects of other types of radiation exposures which may occur in the tropics. Secondly an extraordinarily extensive ecological survey of the environment of Eastern Puerto Rico involving 70 or more scientific specialties has been accomplished. This survey is similar in approach and scope to that demonstrated in the volume edited by Wilimovsky and Wolfe* and demonstrates again the efficacy of this method in obtaining environmental data.

* Wilimovsky N.J. ed., Wolfe, J.N. assoc. ed. Environment of the Cape Thompson Region, Alaska. USAEC Div. Tech. Inf. (PNE-481) 1966, 1250 pp.

In the present project the ecological surveys are no longer an important objective. It is intended rather to select certain restricted study areas which were shown to be potentially productive in the previous surveys for intensive work. Two areas of major importance which have been selected are the study and documentation of the recovery and succession in the irradiated area, and the study of mineral cycling in the tropical forest. These form the major basis for this proposal and are discussed more fully in the Scientific Scope section.

## 5) SCIENTIFIC SCOPE, WORK PHASES

### Introduction

The AEC rain forest project is a study of irradiation effects, and mineral cycling in a section of lower montane rain forest located at 1500 feet elevation on El Yunque mountain of Eastern Puerto Rico. The originally stated objectives of the project were:

(1) To measure the effects of irradiation, direct and indirect, on the ecological system and its components.

(2) To determine the quantitative nature of the biogeochemical cycles within the forest through tracer and fallout studies so that movements and fates of radionuclides may be predicted in rain forests.

(3) To determine the general structure and processes of the rain forest system as part of the general quest for principles which will permit an understanding of radiation effects and isotopic movements in this and other ecological systems.

These objectives continue to be the central motivation for the Project. The experimental emphasis however shifts as demanded by circumstance. The present proposal for example is strongly oriented towards observations leading to the complete description of the recovery of the forest system with only minor effort directed to continued damaging effects. The specific objective of these studies is to determine whether the recovery is related to the source of damage. Thus many of the proposed studies include observations on

other plots in the rainforest which have sustained damage from other sources than radiation.

The recovery of the irradiated center will undoubtedly require many decades. It is anticipated however that the intensive recovery studies may be completed in a relatively short time. In a matter of only two or three years we expect to be able to show the extent to which the recovery of the irradiated center resembles recovery elsewhere in the forest. There after the recovery studies will decline with regard to overall project effort with perhaps only annual orbiannual measurements of selected indices being required. Correspondingly the staff will be increasingly available for other projects, same of which are presented for preliminary discussion in this proposal.

The mineral cycling aspects of the Project are expected to increase. Extensive new laboratory space in the PRNC building has been tentatively allocated to the Project contingent upon construction of a new building wing. Thus at about the same time that recovery studies begin to decline the project will be in a position to propose a fully diversified and extensive program in mineral cycling.

The present proposal is written in two major sections covering the recovery and succession studies, and the mineral cycling studies. In addition these are several proposals for relatively minor effort in other areas. These do not necessarily imply that the subject areas are of minor importance but only that with present staffing we are unable to make well developed proposals.

As an example we propose only to maintain continuity in the accumulation of weather records while fully realizing that there is stong potential for highly relevant micrometeorological research in the forest. The existence on site of a functional weather station, and of a giant cylinder, and recent successful efforts in the use of tritiated water in the forest combine to make an unparalleled opportunity for systematic research in gaseous diffusion for example.

Other ideas are presented at various points in the proposal to serve as a basis for future discussions of Project activities. The specific funding proposal for the next fiscal year is given in the following pages.

## ECOLOGICAL STUDIES: RECOVERY AND SUCCESSION IN THE IRRADIATED AREA; GENERAL ECOLOGY; WEATHER RECORDS

### Recovery and Succession

Radiation center map. The radiation center has been laid out in 900 individual 1 meter square grids for the purpose of mapping the individual plants as they emerge in the radiation center. One survey was completed in 1966 and we will continue to make one such detailed map each year so that a record of the rate of change of populations in the irradiated center can be obtained. The map to be made in September of 1967 will show all plants then existing in each grid by species. Comparisons with that made in the previous year will show changes which have taken place during the interval.

Net productivity calculation. The survey of the radiation center grids will also include the taking of stem diameters, tree heights, and in the case of grassy plants areas of coverage. Since we have already shown that these data are reasonably well correlated with the individual biomasses of the plants, we will use them to calculate the total net biological production in the radiation center. Data for this calculation are already available for 1966 and another identical survey and calculation will be made in 1967.

The PRNC computer is not adequate for this task and the services section of the budget will reflect costs for programming and computer time to complete the calculations.

Comparison of radiation recovery with that from other types of damage. Several areas on El Yunque mountain have sustained catastrophic damage from various

sources. These include the irradiated center, the cut center which was established as a control for the irradiation experiment, and several areas which were damaged by herbicides as part of another project. Many of the herbicides areas are in the approximate same stage of recovery as the irradiation center. The Project will make two surveys of an herbicide damaged area and the cut center for the purpose of comparing the recovery and succession in these areas with that of the radiation damaged area. The surveys will consist of several optical density transects and several leaf area index transects of the damaged areas. Both measurement series will take place at six month intervals starting in September of 1967.

Both types of transects are taken on a line running from undamaged forest through the area of maximum damage and continue to the undamaged forest on the opposite side. The data obtained yield curves which are an index of the amount of vegetation in the area. The change in the curves through time are related to the rate of regeneration of the damaged areas. Transects of the type described will also be run in the radiated center in an identical manner. The data obtained will enable us to determine whether the rate or character of the recovery in the irradiated area is in any way unique or different due to the fact that the original source of damage was radiation rather than chemicals or mechanical clearing.

At the time that the data are collected in the areas of mechanical and chemical damage series of color photographs will also be taken of each area to provide a visual record of the recovery. These photos will be used along with the more extensive record taken in the radiation center to give a visual comparison series for recovery from various types of damage.

Photographic Records. The project has accumulated a series of color slides of the radiation center which were taken monthly from the walk up tower in the giant cylinder site. This series provides a useful record of the further changes which take place in the radiation center. We will expose at least 20 frames of 35 mm Ecktachrome monthly from the walkup tower to show the changes which continue to occur in the irradiated center.

The project now has a tower erected in the radiation center at the border line of radiation damage. This tower provides an excellent platform for viewing the succession of new plants in the area. A monthly series of both color and black and white photos will be taken from the tower to show the rapid changes which are taking place in new growth.

A monthly series of color and black and white photos will be taken of the radiation center from ground level to provide another perspective in the recovery.

Another series of aerial photographs of the radiation center will be taken during the summer of 1967.

Leaf Age Experiments. Evidence from tracer experiments, from the recent injection of Chinese debris, and from leaf scrapping experiments indicates that tropical forest leaves are efficient collectors of radionuclides by surface interception from air or rain. Biological half life measurements in the El Verde forest show long nuclide residence times. Data collected from leaf fall collection stations however imply that leaf ages in this forest might be relatively short. It is not possible to reconcile these two points of view. We therefore need a direct measure of leaf age in this forest in order to gain insight into the mechanism of radionuclide retention.

Several hundred leaves from tree species which can be reached from project walk up tower will be tagged with light aluminum tags around the petiols. The tags will counted bimonthly until a reliable measure of age has been obtained.

The radiation center may still be dying back from radiation damage however it is not possible to observe this informally any longer because the dieback if it exists is extremely slow. Since the new radiation center tower has been placed at the current border of radiation damage we are able to make objective measurements of canopy recession. These measurements will be made by tagging individual leaves from each of several species which can be reached from the tower and counting at bimonthly intervals for at least one year. Comparison of die off curves with those obtained from the walk up tower will give an objective measure of further canopy dieback if it exists.

The leaf age measurements are of importance not only in the El Verde Forest but in others as well. It is of particular interest to estimate this quantity in the Elfin forest atop El Yunque because of the large amounts of fallout radionuclide present in the vegetation there. As part of the general leaf age project we will tag in excess of 200 leaves on each of 5 dominant tree species in this forest and will observe them bimonthly until a reliable die off curve has been obtained.

Species diversity index. Species diversity is presently in a rapid period of change in the radiation center and the cut center. Initially the areas were invaded by only one species while presently both areas have several species of plants. It is of basic ecological interest and of specific

interest to the radiation recovery program to know the pattern of diversity change through time. The rate of change data when obtained will be of value in determining the rationship between the achievement of full forest diversity and full forest maturity, and will provide a test of the hypothesis that diversity may be achieved considerably in advance of final maturity. These curves will also be of value in comparison with the current measures of net production since current energy budget theory would predict that energy spent in diversification would not be available for biomass production.

The curves will also have a considerable empirical value in comparing the recovery of the irradiated area with the cut area and should help in providing a basis for determining whether the character of recovery is in any way influenced by the original source of damage when such damage occurs as an essentially single catastrophic event.

In the area between 10 and 15 meters from the old source position in the radiation center we will obtain a diversity index by counting the number of species encountered per 1000 individuals, in a circular manner around the center. This will be done at 6 month intervals subject to modification according to rate of change observed until a reliable diversity increase function has been obtained. The procedure as described will also be carried out in an identical manner in the cut center.

Sprouts. An important factor in the regeneration of the radiation center is sprouting from the base of old apparently dead trees. We have already verified that in a large percentage of cases the points of sprouting occur in positions which had line of sight protection from the radiation source. This indicates

that even though the main stems of trees were killed by the irradiation, local shielding of the predominantly surface roots in this forest may have been an important survival factor.

Existing basal sprouts in the radiation center will be tagged and the center will be surveyed at 6 month intervals for the occurrence of new sprouts. These sprouts will be counted and tabulated according to whether they had line of site protection from the radiation. Tagging of the new sprouts as they are surveyed will give a method for determining the rate of emergence of new sprouts as a function of time.

Spectral studies. Using the project spectroradiometer we will take spectral transects of the forest across the irradiated center and running at least 100 meters from the center. The purpose of these transects is to look for possible lomg distance radiation effects which have not been previously observed. Qualitative evidence from a series of aerial photographs recently obtained indicates that such long range effects might be present although this proposal represents the first attempt to objectively measure them.

A minimum of 4 transects will be made in a transect series and at least two such series will be done during the year. Each transect will start at the radiation center and will proceed along one of the cardinal compass directions for at least 100 meters. A complete light spectrum in the visible region will be obtained along these transects at 10 to 15 meter intervals, at the forest floor.

## General Ecology

Tree Growth. The 260 trees which were previously taped with vernier tapes will continue to be observed at monthly intervals as in the past.

Phenology of higher plants. The higher plant phenology records will to be taken in order to provide a more reliable record of fruit and flowering in the forest. The measurements to be made monthly in a manner identical to the methods used in previous years will be done as follows:

a) Count of fruit and flower fall on ground quadrats for 5 tree species.

b) Weights of fruit and flower fall in the leaf fall baskets

c) Counts of fruits and flower stalks on 50 selected palms and at 100 basket stations.

Insects. Dr. Elizabeth McMahan (Univ. of North Carolina) will return to the project during the summer of 1967 to continue her detailed studies of termites in the El Verde area. The objectives of this visit are to carry out field studies on the survival of termite nests which were originally exposed to radiation during the forest irradiation project, and to carry out controlled radiation exposures of termites using the PRNC Cobalt-60 source.

Field and laboratory studies to be carried out are listed as follows:

1) Identification and mapping of termite nests which have survived and those which have been abandoned during the year since they were last observed.

2) Measurements of the behaviour and distribution of castes in surviving nests.

3) Measurement of population vigor in the field as indexed by tendency to repair controlled damage to nests.

4) Measurement of $CO_2$ metabolism in irradiated versus unirradiated nests.

5) Attempt to measure LD50 of various species of termites and castes by making systematic exposures of known populations in the PRNC $Co^{60}$ source.

Dr. McMahan will visit the project for a minimum of 60 days during the summer of 1967. Application has been made to carry out this project under an Oak Ridge Summer Research participant grant. If this is not obtained for any reason the project will provide financial aid in the form of a per diem and travel expenses, with no salary or consultant fee included.

Another insect diversity index should be measured in the radiation center to provide information on changing populations as the center fills in with vegetation. This will be carried out under the supervision of Dr. McMahan who will select a graduate student to come to Puerto Rico for a short stay. The project will pay for travel and a small per diem.

The student will sample the insect population in the radiation, control and cut centers using sweep nets until at least 1000 individuals have been gathered in each place. Collections will be done at least once during daylight hours and once during night time hours for each center. The insects will be separated by species, and the number of species per thousand individuals will be reported as the insect diversity index.

## Weather Records

The weather station at El Verde is a temporarily rigged, unconventionally designed system which was built for the purpose of giving a short term description of the major weather variables in the area.

It fulfilled this purpose during the early years of the project but would now seem to have exhausted its usefullness in its present state. Principle objections to the station in its present condition are related to data recording on Rustrack recorders which do not permit ready retreival of large amounts of information, and lack of personell specifically asigned to equipment maintenance, calibration.

The operation of a functional reliable weather station is of benefit to our programs in recovery and succession, phenology, tree growth tritium experiments, and metabolism. In addition the station will provide a long term meteorological record in the vicinity of Eastern Puerto Rico and could provide the basis for future proposals for research in microclimatology in the tropical forest.

We therefore propose to create a meteorological data acquisition system by modifying the existing El Verde system in the following ways:

1) Obtain the services of an electronic technician who is familiar with meteorological equipment and who can see to the constant calibration and functioning of all apparatus.

2) Obtain at least the consulting services of a recognized scientist microclimatologist who can recommend and initiate investigations relevant to biology and to diffusion problems in the tropical forest.

3) Discard Rustrak data recording and convert to digital recording entirely. Overhaul digital data logging system including replacement of present nonfunctional and inadequate digital millivolt meter. Replace with digital voltmeter and external amplifier designed for continuous service.

4) Process all data through modern commercially available computers with high speed paper tape reading capabilities.

5) Replace certain field sensing equipment such as wind speed and direction indicators, and pyranometers and restring data and power cables to meet approved standards of industrial safety.

After the above modifications have been completed we will record twenty channels of digital information as shown in the following table.

| VARIABLE | CHANNELS | VARIABLE | CHANNELS |
|---|---|---|---|
| Temperature | 3 | Solar Radiation | 1 |
| Rainfall | 2 | Optical Density | 2 |
| Wind Speed (hot wire) | 2 | Surface water runoff | 1 |
| Wind Speed (Cup) | 1 | River Stage record | 1 |
| Wind direction | 1 | Trunk rundown | 1 |
| Relative Humidity | 1 | Lysimeter water conductivity | 1 |
| Voltage check | 1 | Lysimeter water volume | 2 |

The data will be recorded at hourly intervals on a 24 hour per day schedule. Computer summaries including diurnal variations and averages, daily averages, weekly averages and monthly averages will be for all data where appropriate, at six month intervals. The data will be available to all project scientists and consultants and will be summarized in the annual report to AEC.

Costs directly related to the outlined improvement of the station are itemized and not included as line items in the overall project budget.

| Item | | Cost |
|---|---|---|
| Salaries. | Including overhead and fringe benefits for a technician, and fees for programming and consultation. | 10,000 |
| Services. | Estimated 20 hours per year of computer time at 80 dollars per hour. | 1,600 |
| Materials | | 500 |
| Total Operation | | 12,100 |
| Equipment (See appendix B) | | 8,200 |

## CHEMISTRY OF THE FOREST

The objectives of the forest chemistry program are: 1) Measure the amounts of fallout radionuclides, the amounts of corresponding stable chemical elements, and the amounts of possible neutron activation products now existing in several components of the forest system. 2) Identify for the same elements pathways of movements and measure rates of movements along these pathways. 3) Generate a testable predictive model for the retention and movement of these elements within a rainforest system.

Work phases in this section represent a continued effort with our last years proposal. We will continue the work started in trace element characterization of the rain forest with emphasis on thermal neutron activation products in forest materials and further exploratory work with Cd shielded neutron activation, and $Li^6D$ activations. We propose new effort in the trace element characterization of successional vegetation of the radiation center. The work concerned with distribution and retention of fallout radionuclides will continue with new effort directed to island wide geographical distribution as related to forest type and elevation. The interforest comparison work will be deemphasized although we will continue to take samples in the Elfin Forest of El Yunque in order to more fully characterize biological half lives of nuclides in this area.

We will propose major new effort in our program to evaluate the dynamics of element movement in this forest. This program will be based as before on the use of radioactive tracers as well as stable element analysis. We have already installed more than 30 lysimeters of the type developed by Dr. Jordan

in the soils of El Verde station. Permission has been secured to use tritium as well as nuclides of Cs, Sr and others in experiments. We are therefore in a position to propose the measurement of both water and elemental movement in soils of the area, in addition to further studies on the behaviour of nuclides in plants.

## Trace Element Composition of the Forest

Neutron activation products. We have shown in soils of El Verde and other points in Puerto Rico as well as for soils from Panama that the primary neutron activation products which can be measured instrumentally after the decay of interfering $^{24}Na$ and $^{56}Mn$ are $^{46}Sc$ and $^{59}Fe$. This is consistent with J.R. Kline's previous world wide surveys of soils. Tropical soils of Puerto Rico and Panama appear to be relatively depleted in La and Co. Further work is desirable in the instrumental neutron activation characterization of plant materials in the tropical forest.

Instrumental neutron activation analysis will be carried out on at least 5 samples each of ashed tree leaves, epiphyllese scraped from leaves, and epiphytic plants to include bromeliads, ferns, and mosses. The resulting gamma ray spectra will be used to identify trace elements in these materials which can be measured by this method and to make quantitative determinations where possible.

Cadium Clad Activations. At present it is not known whether plants and soils have characteristic gamma ray spectra when irradiated with neutrons of higher than thermal energies. Exploratory reactor irradiations of at least 5 soil samples from Puerto Rico and 5 ashed plant samples will be carried out with

the samples enclosed in specially designed Cadmium cups. The resulting gamma ray spectra will be used to identify elements in these materials and to make quantitative determinations where possible.

Further development in the technique of using $Li^6D$ to produce 14 Mev neutrons is required. We have designed a Cadmium cup which allows access of thermal neutrons to a $Li^6D$ source while at the same time protecting the sample within from these neutrons. Further work is needed to develop convenient handling and packaging techniques for $Li^6D$ which is a hazardous material when exposed to the open air. Upon solution of this problem we will carry out irradiations of at least 5 soils and plants using $Li^6D$ as a converter of thermal neutrons to fast neutrons. Gamma ray emmitting radionuclides which are produced in these irradiations will be identified and measured quantitatively where possible.

Chemistry of Successional Vegetation. The vegetation now invading the radiation center is in a vigorous state of growth. This implies that the essential mineral nutrients required to support this growth are both present and chemically available. In order to characterized patterns of mineral nutrient uptake in a successional area samples of leaves and stems will be collected from plants in the area at the time of the annual mapping and biomass survey for chemical analysis. The samples will be analyzed for K, Ca, Fe, and Cu by flame spectrophotometric or atomic absorbtion analysis. The results will be combined with the biomass calculations to give standing state of these elements. Annual repetition of the survey and analysis will reveal patterns of nutrient uptake as compared with biomass production. At least 50 samples of plant materials will be analysed during the first year of the project.

Concurrently with the vegetation analysis soils will be obtained from the area and subject to analysis for the same elements. These elements will be determined primarily o aqueous extracts from the soils which are thought to be indices of chemical availability. Such extracts may consist of neutral ammonium acetate solutions or dilute mineral acid solutions. At least 5 soil samples will be thus analyzed the first year of the survey.

## Distribution and Retention of Fallout Radionuclides

Retention Time. Biological retention time for the nuclides $^{95}Zr$, $^{54}Mn$, and $^{144}Ce$ have been estimated in the forest at El Verde. It was found during a period of exceptionally low fallout that the forest plants bind these nuclides very tightly and that the major factor in the decline of radioactivity was the physical decay of the nuclides themselves. An estimate for the environmental half life of $^{137}Cs$ was obtained which indicated that this quantity was about nine years for this nuclide. The result was not statistically reliable because of the short time interval of measurement as compared with the apparent long environmental half life. These measurements were complicated by the fact that the area received a fresh input of radionuclides within 20 days after the Chinese nuclear test of May 9, 1966.

We now intend to continue the monthly sampling program at the El Verde station in order to characterized the behaviour and immediate distribition of nuclides after a fresh injection. The nuclide which is most readily discernable from this injection is $^{95}Zr$-$^{95}Nb$.

The Chinese injection of nuclides did not appear to alter the forest concentrations of $^{137}Cs$ or $^{54}Mn$. Thus the opportunity still exists to obtain a reliable environmental half life for both nuclides. An apparently anomalous result was obtained for $^{54}Mn$ in our previous measurements in that the environmental half life was longer than the physical half life. While this is a possible result further measurements are needed to verify its reality.

We will continue as before to collect monthly samples from 5 canopy and 5 understory trees along with samples of lotter and soil, for analysis by gamma ray spectrometry. The data will be used to provide more reliable estimates for nuclide residence times in the El Verde Forest.

Residence Times; Elfin Forest. While radionuclide levels in the Elfin forest on East Peak in the Luquillo Mountains are now firmly established in comparison to those at El Verde the reason for the difference is not yet clear. The data from past measurements is not yet sufficient reliable statistically to determine whether retention or accumulation are factors in this increased burden.

We will continue to sample the leaves of two species of trees, mosses, ferns and ground litters on a bimonthly basis for at least another year for gamma ray spectrum analysis. The data for $^{137}Cs$ and $^{54}Mn$ will continue to be used to estimate environmental half lives for these nuclides. The data for $^{144}Ce$ and $^{95}Zr$-$^{95}Nb$ will give some indication of the immediate behaviour of fresh injections of radionuclides in this forest.

Geographical Distribution of Nuclides. Preliminary evidence indicates that there may be a geographical gradient of radionuclides on the island runnining from a high in the east to a low in the west. This gradient if it exists could be caused by effective precipitation scavanging of the prevailing easterly trade winds as they strike the Luquillo Mountains of Eastern Puerto Rico.

In order to confirm or reject the presence of these possible gradients the vegetation will be sampled on the island in a series of adjacent transects which run from the north to the south coasts. Four such transects will be done. The first will done on the eastern edge of the island in the mountainous area. The second will be done parallel to the first but 30 miles further west. The third will be done 30 miles west of the second, and the fourth will be done near the west coast in the mountains near Maricao Puerto Rico.

Each transect will have 5 sampling locations. These locations will consist of the northerly sea level foothills, the northerly middle montane region the peak region, the southerly middle montane region, and the southerly sea level foothills. At each station 5 to 10 samples of vegetation will be taken. These will consist of leaves from prominant trees of the area, prominant epiphytes such as ferns mosses, and bromeliads, leaf litters, and samples of surface soil.

All samples will be dried and counted nondestructively by gamma scintillation spectrometry. The complex spectra will be resolved using our existing computer solution and the resulting data for $^{95}Zr$-$^{95}Nb$, $^{144}Ce$, $^{137}Cs$, and $^{54}Mn$ will be plotted over a map of Puerto Rico to illustrate any differences found.

Strontium-90 Retention. A procedure for the determination of $^{90}Sr$ has been successfully adapted to the analysis of tropical foliage. Samples which were counted nondestructively for gamma emiting nuclides have been retained. We are thus in a position to measure the environmental half life of $^{90}Sr$ in the El Verde and Elfin forest regions. Approximately 100 plant samples from the collection will be ashed in a furnace and analyzed radiochemically for $^{90}Sr$. The samples will be selected from various dates over a period from 1964 to 1966 from both the El Verde and Elfin forests. The results will be plotted on a semilogarithmic scale as a function of time and will be subject to regression analysis in an effort to establish the environmental half life for this nuclide.

## Pathways of Movement Within the Forest

Tracer Experiment. Plant growth phases of the tracer experiment described in last years proposal have been completed and the plants growing in the area have been harvested. The uptake of nuclides was slow and much of the original contamination remains where it was placed. The presently barren radioactive plots offer the opportunity to study uptake of $^{134}Cs$ and $^{54}Mn$ by successional vegetation.

The plot area will be cleared of surrounding trees to produce a small sunlit open area. This area will be allowed to reestablish plant growth naturally. When all plots have sufficient plant growth, samples will be taken for radioactive counting. The course of nuclide uptake will be followed by periodic sampling for at least one year or until a reliable description of uptake patterns has been obtained.

The radioactive soil in this plot has been subject to natural weathering for more than one year. The radionuclide in the soil should now be in an equilibrium state. Small amounts of this soil will be removed from the plot for laboratory studies. These studies will consist of chemical extractions of soils from each of the four plots as follows:

1) Replicated extractions of field moist soils from 4 plots with solutions of neutral normal ammonioum acetate. The soils will be counted before and after the extraction to determine extractability of $^{134}Cs$ and $^{54}Mn$.

2) Replicated extractions of soils from 4 plots with solutions of dilute mineral acid. Determinations will again be made by the method of before and after counting.

3) Samples of the field moist soils will be subject to three wetting drying cycles and will then be extracted according to the method in (1) above to give an indication of the fixing power of the soils for Cs and incidently Mn.

Tracer Experiment 2; Behaviour of Epiphylleae. An area of the El Verde forest has been set aside exclusively for low level tracer experiments involving leaves and plants. This area has been fenced, warning signs have been erected, and Health Physics Division approval has been obtained. The area consist of approximately 500 square feet and was selected because of the high abundance of plants supporting epiphytic growth.

Epiphyleae have been previously implicated in the interception and retention of radionuclides and mineral elements form air and rain. They have been shown to absorb nuclides rapidly from solutions in the laboratory. It remains unknown whether minerals thus captured by these surface plants can be transferred to the supporting leaf and thereby form a source of supply of essential nutrients to the higher plants which is outside of the normal routes involving root uptake and translocation.

The following experiment will be done to aid in answering this question:

1) Thirty leaves of understory plants showing vigorous epiphytic growth will be contaminated on the surface with near neutral solutions containing microcurie levels of $^{85}Sr$ and $^{134}Cs$.

2) After a brief uptake period the leaves will be rinsed in distilled water and cut into sections of approximately 4 square centimeters each.

3) Thirty of these sections will be placed on the surface of thirty intact growing leaves in the field and held in place with a rubberband. Fifteen of the intact leaves will have vigorous epiphytic growth and fifteen will have no visible growth. The overlays will remain in position for 24 hours, and will then be removed and discarded.

4) The growing leaves will be harvested in groups of ten at the end of 3,6 and 10 days after labeling. Five clean and 5 epiphytic leaves will be taken in each group. Each leaf will be sectioned into three parts which will consist of regions below the overlay, the overlay region, and the region above the overlay.

5) Each leaf section will be counted on the project single channel analyzer, first in the $^{85}Sr$ energy region and then in the $^{134}Cs$ energy region. The complex spectra will be resolved using data from standards counted in the same way and the movement of nuclides from epiphylleae into leaves will be determined.

Epiphylleae have been shown previously to be accumulators of fallout radionuclides. It has also been shown that environmental residence times for these nuclides is long. It would seem then that these plants might be involved in the mechanisms which result in long retention times. We will study this point in the following experiment:

1) Both epiphyte covered and clean leaves will be labeled with neutral solutions containing carrier free $^{134}Cs$ and $^{85}Sr$ using a micropipet to deliver exact volumes to each leaf surface. The solutions will be allowed to evaporate to dryness. Each leaf will be marked for later identification.

2) Leaf samples will be harvested immediately after the isotope solution has dried to serve as a set of counting standards. Other harvests will be made first 2 weeks after application, and then at longer intervals until at least 6 harvest covering at least one year after application will have been made.

3) The leaf samples will be counted nondestructively in the project single channel analyzer, first for $^{85}Sr$ and then for $^{137}Cs$. The resulting data will be plotted as a function of time for epiphytic and clean leaves. The results are expected to show whether surface retention is an important factor in observed long biological residence times for fall-out, and whether epiphytes are involved in this retention as is now thought.

Tracer Experiment 3; Water movement in soils and plants. Using one of the lysimeter installations of Dr. Jordan an attempt will be made to measure some aspects of the water balance in the forest. Several water balance plots have been constructed in connection with these installations. Such a plot consists of an enclosed section of soil surface of one to 2 square meters which lies directly above one or more of the lysimeters. The plot terminates at the edge of a pit on the downhill side and at this terminus is a trough. At each plot is a specially designed raingauge for measuring under canopy rainfall. Water falling on the plot through soils is intercepted be the lysimeter and that which runs off is caught in the terminal trough and directed to a container where it can be measured.

One such installation has been fenced and equiped with warning signs for radioactive experiments. Health Physics Division approval has been obtained to use tritiated water in this area. Under Health Physics surveillance we will apply a known amount of tritiated water to a known surface area above the buried lysimeters. Water flowing from the lysimeter and the run off collecter will be captured at periodic intervals and brought to the laboratory for liquid scintillation counting. The resulting data will be used to calculate the proportions of applied water which ran off the plots and the proportions which moved into soil. This experiment is exploratory and will undoubtedly form the basis for other future experiments which cannot be rigorously defined at present.

Within the same security area another tritiated water experiment will be carried out to measure the uptake and translocation of water by a canopy tree. Approximately one curie of tritium will be diluted with 2 liters of water and the solution will be applied to the soil at the base of the tree. At 2 to 3 hours intervals thereafter leaves will be harvested from the tree, placed in plastic bags, and frozen. The frozen leaves will be returned to our PRNC laboratory where the unbound waters will be removed by passing a stream of dry air over the leaves in a heated chamber and into a standard liquid nitrogen cold trap. The volume of the condensed waters will be measured and they will be transferred to a vessel for liquid scintillation counting. The specific activity of the waters extracted from leaves as compared to that of the waters originally applied will give an indication of the dilution with environmental water which has occurred and will enable a rough calculation of the total water moving into the tree per unit time. The time of tritium persistence in the tree will enable a rough calculation of the total water which has passed through the tree during the interval of measurement.

While this experiment is in progress approximately 24 flasks fitted with an aluminum pipe and containing liquid nitrogen will be exposed to the atmosphere at varying distances from the site of the experiment. The pipes will condense atmospheric water on their surfaces until the liquid nitrogen has been completely evaporated whereupon the pipes will warm and allow the condensed water to flow into the flasks. These were developed by the Health Physics Division to moniter safety aspects of the experiment. By placing them in a systematic grid around the experiment the may yield some information on the diffusion patterns of water in the atmosphere of the forest.

Tracer Experiment 4; Radionuclide Movement in Soils. Water balance plots which include lysimeters at various depths in the soil and water runoff collectors have been prepared for radionuclide experiments. In one such plot millicurie levels of both $^{134}Cs$ and $^{85}Sr$ will be applied to the soil surface in a carrier free aqueous solution. At weekly intervals thereafter the total volume of input water, the volume of lysimeter waters, and the volume of runoff water will be measured. Composite subsamples from lysimeters at the same depths will be taken for gamma ray counting. Samples for counting will be taken at first at weekly intervals until patterns of nuclide movement have been established. After evaluation of these patterns we may find it feasible to count monthly composites of the water. This plot will be monitered for at least one year after the application of nuclides, at which time a decision will be made of whether or not it should be continued. It is expected that this plot will show the relative proportions of nuclides moving through soils, and the proportions of nuclides which have been immobilized by soil chemical reactions.

Lysimeters Experiments; Ion and Water Movement in Soils. Approximately 36 lysimeters have been installed in various soils of the El Verde area. These areas include well drained soils, poorly drained soils, soils on ridge tops and soils on hillsides. Most installations have been made at a depth of 5 inches, and each location has been replicated in quadruplicate. At each location a specially designed raingauge which is two inches wide by 5 feet long is set up to give an integrated measure of rainfall penetrating the canopy.

These installations will be used to obtain at least one year of water balance records under the indicated variations of soil drainage conditions. These records consist of weekly recording of the under canopy rainfall at each site and weekly recording of volumes of lysimeter collected water. Using performance data from the tritium experiment an effective collection area for the lysimeters will be calculated, and this will enable the calculation of percolating waters through the various soils. The difference between volumes per unit area of percolating waters and total input will be ascribed to runoff and evapotranspiration. At some later date when more experience has been gained in the construction and reliability of runoff plots we expect to be able to propose the measurement of evapotranspiration by difference when all of the mass flow variables are measured directly.

# NITROGEN FIXATION

It is of key importance to the general understanding of mineral cycling in the tropical forest to have specific information on the possibly unique nitrogen cycles. There are two reasons for this: 1) There no significant geochemical source of biologically available nitrogen 2) Environmental conditions favor the rapid nitrification of biologically released nitrogen which may then be rapidly lost from the ecosystem due to its anionic chemical form and to the high rainfall of the area. Nitrogen which is lost in large quantities must be replaced in like quantities from any of several sources if the forest is to maintain its steady state. Possible sources of nitrogen include symbiotic fixation, non symbiotic fixation, epiphyleae, and lightning strokes.

Edmisten (Univ. of Ga.) has previously examined root nodules of leguminous plants of the area and found them to be apparently active and enriched in nitrogen content. We will initiate a preliminary study in cooperation with Dr. Edmisten to determine the possible roll of epiphyleae in the nitrogen cycles and fixation mechanisms in the forest. Dr. Edmisten will make at least three trips to the El Verde forest for the purpose of on site study of epiphyleae and for specimen collections. The specimens will be returned to Dr. Edmisten's laboratory where attempts will be made to culture the leaf surface organisms in artificial media. Organisms which are successfully cultured will be examined for nitrogen fixing capability. Nitrogen will be measured in epiphyleae and leaves to determine any existing patterns of relative nitrogen enrichment.

The Project will provide costs of transportation and per diem for Dr. Edmisten, but will not provide a consultant fee. Culturing and analysis of samples will be carried on primarily as graduate student projects under Dr. Edmisten's supervision at no cost to the project. Data resulting from this study will be equally available to the University of Georgia, and PRNC for use in annual reports and progress reports. Any resulting open literature publications will be under joint authorship from both institutions.

## BIOLOGICAL FUNCTIONS

One of the stated primary objectives of the Terrestrial Ecology Project is to study those aspects of biological function in the rain forest which could give theoretical interpretation and perspective to much of the empirical data already collected in the areas of mineral cycling and radiation recovery. This remains an important one and is an area of research which could provide a unifying framework within which all other project activities are carried out. Because of staff obligations in the areas of mineral cycling and radiation recovery however we are unable to make major research proposals in the area of energy circuitry and biological function. The studies which we intend to carry out are restricted to those which require a minimum of man-power and expense and are listed as follows:

1) Respiration and Photosynthesis will be measured on individual leaves of plants filling the radiation center. This will be done on a few of the major species now present including Phytolaca, Cecropia, Psychotria, and Palicourea. The results will be converted to net production and will be used as an independent check on the proposed direct method to determine the reliability of this method. Elsewhere in this proposal

we indicate that H.T. Odum will make 4 consultant visits to the project during the year. We expect to have his consultantship and participation in the metabolism work.

2) As indicated in the section of dust experiments we will measure the metabolism of individual plants in the root covering experiment along with controls to determine whether covering the roots has any detectable metabolic effect.

3) The metabolism apparatus will be carried to the Elfin forest on El Yunque where metabolism will be measured on several plants including tree leaves, ferns, and mosses. These measurements will provide the first indices of the differences in energy utilization between this forest and the one at El Verde.

4) As time and resources permit we will continue performance testing of the giant cylinder and attempt to obtain usable respiration and photosynthesis data.

The performance tests of the cylinder will consist of the attempt to measure recovery of controlled metered releases of pure $CO_2$ in the middle of the cylinder, while the fan is running. These releases will be made from ground level and at 20 foot increments up the tower until the final release is made above the forest canopy. The data will indicate levels in which losses of metabolic gasses are occurring out the top of the cylinder and should provide a correction factor which can be applied to all previous data taken from the cylinder and allow a rigorous calculation of the metabolic activity within.

Concurrently with the performance tests the cylinder will be run for at least one day and night without $CO_2$ releases in an attempt to measure the natural metabolic processes.

## EFFECT OF SURFACE DUST ON TROPICAL PLANTS

Consistent with the previous years project proposal we have investigated in some small scale experiments the effects of dust contamination in the tropical forest. The purely mechanical experiments show little of interest at least on the small scale experimental level and have been discontinued. In the biological effects experiments however preliminary results suggest that there may definite detrimental results from relatively small inputs of soil. When the well of bromeliads were closed by small applications of soil preliminary data show that the rate of new leaf production may have been slowed. Palms with similar treatment have thus far remained uneffected. Metabolism and photosynthesis of soil covered leaves is variable. In some cases we have seen apparent increases in metabolism by as much as ten percent. In others a decrease of the same magnatude was found.

The most interesting experiment involves covering the surface roots of plants in this forest with soil. In this plot we have clearly produced accelerated leaf fall and death of some small trees by covering the roots with six inches of soil. The effects however are chronic rather than acute and the plot should be observed for a considerably longer time, to establish the effects reliably.

The exploratory experiments do not justify an attempt at this time to carry out a major forest prism contamination experiment. While such an experiment may become desirable in the future more data from the small scale experiments is needed to demonstrate the need.

We will continue the small scale experiments as follows:

1) Bromeliads: The soil treated bromeliads will be observed monthly along with their matched control plants for the production of new leaves and for the death of old leaves.

2) Palms: The soil treated palms will continue to be observed monthly for leaf production, stem growth, and leaf death. The same measurements will be made also on the matched control plants.

3) Metabolism: Respiration and photosynthesis will continue to be measured on soil covered leaves until a reliable effect has been demonstrated or until it has been shown that such treatment has no effect.

4) Soil plots: The soil covered plot will be observed monthly along with matched control plants and the following variables will be measured on all plants. 1) stem growth, 2) leaf fall, 3) leaves on ground, 4) death of plants. The soil covering will also be checked periodically to determine whether there is any tendency for the plants to send their new roots back to the surface. If time and manpower permit we will attempt to make metabolism measurements on the plants in the plot as compared with the control plants.

## NORTH CAROLINA PARTICIPATION

In addition to the consultant services of H.T. Odum of the University of North Carolina the Project will continue to participate in the completion of a project being carried out by him in North Carolina. This is the publication of the book A Tropical Rainforest.

The principle project support required for the book publication involves secretarial services for final manuscript preparation. The project will provide a secretary for this purpose to be employed at the University of North Carolina for 6 months, starting July 1, 1967. This is arranged as in the previous year by purchase order to the University for the amount of actual salary with no overhead charges included. The services section of the budget includes an item for $2,400 for this purpose.

## EL VERDE FIELD STATION

The physical facilities of the El Verde field station have been described in some detail in previous proposals and annual reports. At present the station continues to be fully utilized for project activities. This utilization includes, data recording in the Project instrument room, drying and grinding of field specimen for chemical and radiochemical analyses, final preparation and adjustment of field apparatus, preparation of low radioactivity specimens from tracer experiments for counting, counting of such specimens, housing for project herbarium, housing of project insect collections and office space for project personnel.

Experience from several years of operation of the field site now shows that such operation corresponds to a hazardous industrial situation. In order to continue operating the site it will be necessary to make investments leading to improved safety in the area.

In particular, the site electrical system must be completely re-evaluated and rebuilt or else abandoned. There now exists 110 volts power cables lying haphazardly on the ground. These have been in place for more than three years and could deliver a lethal electric shock to any person inadvertently touching them. Cables must be replaced where necessary, they must be encased in approved conduit, and the entire system must be provided with appropriate electrical safety devices to minimize shock hazard. Rebuilding of this system will take place under the closest supervision of PRNC Health Physics Division. Existing trails must be rebuilt with concrete steps and cable hand rails installed at particularly steep portions; the

trail to the upper parking lot which is frequently used for official visitor access must be completely gravelled with steps and hand rails installed in hazardous regions. The upper river crossing must be rebuilt. Fences, gates and signs must be installed to exclude unofficial project visitors and tourists from the research area. Guards must be erected around the giant cylinder fan and engine.

The cost of operating the El Verde Station including installation of required safety provisions is detailed as follows.

| Item | | Cost |
|---|---|---|
| Salaries. | 1 man year for maintenance, driving, and special safety provisions, including overhead and fringe benefits. | 6,000 |
| Services. | Vehicle | 500 |
| | Power | 4,200 |
| Materials. | Gravel, wire, fencing, cable, cement, for routine and special safety applications. | 1,000 |
| | Total | 11,700 |

## CESIUM SOURCE; A PRELIMINARY PROPOSAL

Definite plans have not yet been formulated for future use of the $^{137}Cs$ source. Possibilities for its use as detailed in previous proposals include. 1) Loan to Canada for Chalk River spruce forest irradiation, 2) Reef irradiation, 3) Elfin forest irradiation. Alternative (1) is no longer being considered while (2) and (3) are still possibilities.

A fourth and highly feasible possibility is now presented. As was suggested by Dr. Howard Andrews (Assistant Director for Health Physics PRNC) the source could be placed in the center of the giant cylinder for an anticipated short term irradiation with the objective of measuring the effects of irradiation on photosynthesis, respiration and transpiration. Under this plan it would not be necessary to irradiate until lethal effects became visible in the plants. Irradiation until definite patterns of alteration in these biological functions had been established would be sufficient.

At least one year lead time would be required before this experiment could be carried out. This time is required to establish patterns of variation of these functions in the undisturbed forest, and to do further reliability and performance testing of the giant cylinder itself with the hope of improving its performance or establishing correction factors for the known air losses which occur. Final decision to do the radiation experiment would be deferred until project scientists were confident that the giant cylinder was functioning properly.

The experiment as outlined seems attractive for several reasons. 1) It would be the first attempt to measure the effects of radiation on

biological functions at the system level in the tropics. 2) It could be carried out on the existing project site with many of the facilities and staff involved with the first radiation experiment still intact. 3) It could be done at less total cost than any of the other alternatives so far discussed.

The proposed experiment could be carried out under Terrestrial Ecology Administration. Extensive ecological surveys carried out prior to the first radiation experiment would not be required and the proposed experiment could be handled internally with the addition of one professional level investigator and one or two field workers to the staff. Outside consultant's would be required only for special measurements such as dosimetry.

The experiment could be done without jeopardizing other project programs in mineral cycling or radiation recovery since the source may be exposed only 2 to 3 weeks. While the experiment would result in irradiation of the first radiation center the effects would be slight since no effects were found in the giant cylinder site from the first exposure and since the proposed exposure is for only 1/3 the duration of the first.

This is not a funding proposal for this experiment. This outline is offered as a basis for future informal discussion only. In the event these discussions lead to a decision to do the experiment a formal propsal will be submitted.

## 6) SCIENTIFIC PERSONNEL

1) Jerry R. Kline, Ph.D. Chief Scientist I and Director, Terrestrial Ecology Project. Experience in plant-soil relationships in agricultural crops; radiochemical and instrumental investigations of thermal neutron irradiated soils and plants; investigations of fallout radionuclides in the environment utilizing gamma-ray spectrometry and radiochemical separations. Formal training in Soil Chemistry and Analytical Chemistry. Full Time.

2) Carl F. Jordan, Ph.D. Associate Scientist I, Terrestrial Ecology Project. Experience and formal training in Plant Ecology and Soil Science. Previous work and publication in effects of fire on old field vegetation in New Jersey. Developer of simple lysimeter system for the measurement of water and ion flux through soil profiles. Full Time.

3) George E. Drewry, MS (Ph.D pending 1967). Associate Scientist I, Terrestrial Ecology Project. Experience and formal training in biology and zoology with special interest in animal behaviour. Previous work and publications on behaviour of fishes and aural behaviour of Puerto Rican Coqui. Self taught electronics expert with circuit design capability. Full Time.

## 7) OTHER PERSONNEL

Henri Watson. Research Associate I. Project Field Botanist. Present status doubtful due to serious injury on Project. If recovery permits is employable despite possible physical handicap due to specialized botanical knowledge.

| Name | Title | % Time |
|---|---|---|
| Nelson Mercado Burgos | Res. Assistant II | 100% |
| Elpdia Rivera Santiago | " " I | " |
| Alejo Estrada Pinto | " " I | " |
| Jaime Ruíz Reyes | " " I | " |
| Charles Robert Venator (Grad) | " " I | 50% |
| Abel Rossy | " Technician | 100% |
| Gilberto Cintrón | " " | 25% |
| Ana Josefina Correa | Adm. Secretary II | 100% |
| Hilda Rosa Escobales | Tech. Assistant | 100% |
| Moisés Parrilla Rosario | Maintenance Foreman | 100% |
| Juan Martínez Maisonet | Field Worker in Terrestrial Ecology I | 100% |
| Doroteo Martínez García | Field Worker in Terrestrial Ecology I | 100% |

## 7A) Project Visitors

The Project makes less use of technical consultants than in the past due to the fact that our increasingly detailed studies cannot be exploited effectively by these persons in short term trips. These are however certain areas where consultant relationships are advantageous. Consultant contracts will be entered into with the following persons to enable them to make site visits.

Dr. Howard T. Odum. Professor of Ecology. University of North Carolina, Chapel Hill. Site visits to permit organization of Rainforest book publication and to serve as consultant in metabolism and energy budget measurements.

Dr. Elizabeth McMahan. Associate Professor. University of North Carolina, Chapel Hill. Summer visit for detailed study of termite populations and behaviour in radiation center and for experimental determination of radiosensitivity of termites.

Dr. Joe Edmisten. Associate Professor. University of Georgia. Initiation of preliminary studies on possible role of epiphyleae in nitrogen fixation.

## 8) OTHER FINANCIAL ASSISTANCE

The project is ordinarilly funded entirely from the single AEC grant. During the past fiscal year an appropriation of $10,000 was received through AEC channels from Battelle Memorial Institute to permit fallout radionuclide studies in Panama and various on site experiments in Puerto Rico. Project obligations resulting from this appropriation were fully discharged by the submission to Battelle of two progress reports covering the work performed. No similar arrangement has been negotiated for the forthcoming fiscal year.

The project is subsidized to a certain extent by the participation of consulting scientists since it does not usually cover the full cost of research performed. In the usual arrangement the project covers the costs of transportation and a nominal per diem for the participant while the home institution continues to pay his salary and costs of continued effort relating to the research outside of Puerto Rico.

## 9) PREMISES, FACILITIES, EQUIPMENT, AND MATERIALS TO BE FURNISHED BY CONTRACTOR

The main facility, the forest area and the El Verde field station, including a house for visiting personnel are furnished through a 5 year interagency agreement between the U.S. Department of Agriculture administering the Luquillo forest area and the Atomic Energy Commission. Another residence house, Cienaga Alta house, 5 miles from the El Verde station and also on Rt. 186 is available by an interagency agreement between PRNC and U.S. Dept. of Agriculture. The Institute of Tropical Forestry furnishes a room in Rio Piedras and loan of some specialized equipment. Some utilities of Forestry Building are paid by PRNC.

A laboratory building, 800 square feet, at El Verde; an office and two laboratory rooms in the Biomedical Building at Rio Piedras; and considerable equipment previously bought on this project are furnished according to the provisions of the general operating contract between AEC and the University of Puerto Rico for the Puerto Rico Nuclear Center.

10) BUDGET

| | FY-68 | FY-69 |
|---|---|---|
| Salaries (Itemized in Appendix A) | 98,000 | 100,600 |
| Travel | 5,000 | 6,000 |
| Material and Supplies | 10,000 | 12,900 |
| Services | 11,000 | 14,000 |
| Overhead (65% of Salaries) | 60,000 | 60,000 |
| Total Operating cost | 184,00 | 193,000 |
| Equipment (Itemized in Appendix B) | 12,000 | 10,000 |
| Total Project Cost | 196,000 | 203,000 |

Appendix A

Salary Budget

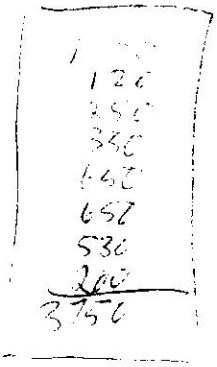
| 1) Salaries | Annual |
|---|---|
| Jerry R. Kline, Chief Scientist I<br>$1,250/mo, full time | 15,000 |
| Carl F. Jordan, Associate Scientist I<br>$916.66/mo, full time | 11,000 |
| George E. Drewry, Associate Scientist I<br>$791.66/mo, full time | 9,500 |
| Henri W. Watson, Res. Associate I<br>$566.66/mo, full time | 6,800 |
| Nelson Mercado Burgos, Res. Assist. II<br>$416.66/mo, full time | 5,000 |
| Atomic Absorbtion Analyst, Full time | 5,300 |
| Charles R. Venator, Res. Assist. I<br>$175.00/mo. 50% time, graduated student | 2,100 |
| Alejo Estrada Pinto, Res. Assist. I<br>$302.50/mo, full time | 3,630 |
| Elpidia River Santiago, Res. Assist. I<br>$302.50/mo, full time | 3,630 |
| Hilda Rosa Escobales, Res. Assist. I<br>$230.00/mo, full time | 2,760 |
| Jaime Ruíz Reyes, Res. Assist. I.<br>$250.00/mo, full time | 3,000 |
| Gilberto Cintrón Molero, Res. Technician<br>$1.75/hr. Approx. $140.00/mo, Grad. | 1,680 |
| Abel Rossy, Res. Technician<br>$300.00/mo, full time | 3,600 |
| Ana Josefina Correa López, Adm. Secretary II<br>$302.50/mo, full time | 3,630 |

| | |
|---|---|
| Moisés Parrilla Rosario, Maint. Foreman<br>$300.00/mo, full time | 3,600 |
| Juan Martínez Maisonet, Field Worker<br>$208.33/mo, full time | 2,500 |
| Doroteo Martínez García, Field Worker<br>$208.33/mo, full time | 2,500 |
| Total Salaries | 85,230 |
| Fringe Benefits (9.3%) | 7,870 |
| Lump sum for raises, and summer assistant | 4,900 |
| Total | 98,000 |

# Appendix B

## Equipment

| | |
|---|---|
| Digital Voltmeter | 4,000 |
| 4 Amplifier | 800 |
| 3 Power Supplies | 450 |
| Epply Pyranometer | 1,500 |
| Wind Speed Indicator | 450 |
| ~~3 Typing bucket Raingauges~~ | 1,000 |
| Rustrak Event Recorder | 120 |
| YSI Temperature Indicator | 200 |
| ~~Telephoto lense for 35 mm Camera~~ | 250 |
| Laboratory Shaker | 350 |
| Combustion Furnace | 650 |
| Hollow Cathode lamps (5) | 650 |
| Conductivity Cells (5) | 530 |
| Twenty five liter Dewers for liquid N (2) | 250 |
| Two tier Ball Mill | 300 |
| Wiley Cutting Mill | 300 |
| Barnstead Still for distilled water | 200 |
| Total | 12,000 |



## 12) AUTHENTICATION

| | |
|---|---|
| Signature | Title |
| Signature | Title |
| Signature | Title |
| Signature | Title |