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Early Action on the Global Environmental Monitoring System

A report of the
INTERNATIONAL ENVIRONMENTAL PROGRAMS COMMITTEE

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Commission on Natural Resources
National Research Council

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Preface

Earthwatch was proposed at the United Nations Conference on the Human Environment in Stockholm in 1972 and is now part of the United Nations Environment Program (UNEP). The Global Environmental Monitoring System (GEMS) is one of four components of Earthwatch; the others are evaluation, research, and the exchange of information (Jensen 1975, UNEP 1975). The purpose of GEMS is to provide early warning of impending natural or man induced environmental changes or trends that threaten direct or indirect harm to human health or well being.

The Governing Council of UNEP agreed in May 1975 that high priority should be given to the development and improvement of Earthwatch, including a detailed progress report on accelerated development of GEMS in time for a thorough review at the Council's fourth session in April 1976. Refinement of the GEMS design is to be undertaken through a series of meetings of groups of government experts working on each of the seven program goals. In preparation for United States participation in those international meetings, a federal interagency committee under the leadership of the Department of State prepared a background paper entitled *Design Philosophy for the* GEMS (Department of State 1975).

In response to a request from the Department of State for an appraisal of possible United States positions concerning the development of the GEMS program, the International Environmental Programs Committee (IEPC) of the National Research Council joined with the Department of State in sponsoring a symposium on October 9 through 11, 1975 to review plans for GEMS. Participants came from government agencies and

Global Environmental Monitoring

Some alterations of the environment caused by man's activities, such as air pollution from urbanization and changes in the landscape from surface mining, are obvious. But the complex and long-term interactions of components of the global environment and long-distance transport of materials make the effects of other human activities less obvious and, for that reason, less tractable. Alterations of the chemical composition of the atmosphere, surface waters, oceans, and soils through introduction of anthropogenic and natural substances and their subsequent effects on living organisms point to the large-scale interconnectedness of environmental systems and to the possibility of effects ranging widely beyond sites of human activity. Unfortunately, only a partial picture exists of just how extensive these effects may be, and the need for filling in that picture is compelling. Among the activities adopted by UNEP, GEMS directly addresses the need for improved measurements of global environmental change (UNEP 1975).

Previous reports have described needs and outlined considerations that should enter into planning for global monitoring efforts (SCEP 1970, SCOPE 1971, NAS 1972, SCOPE 1973, Department of State 1975). Two of these reports, *Global Environmental Monitoring System* (SCOPE 1973) and *Design Philosophy for the* GEMS (Department of State 1975), were distributed as background documents for the symposium. They also serve as points of departure for this report.

The *Design Philosophy for the* GEMS identified a large number of actions which might be taken in support of global environmental monitoring, and the comments and suggestions made at the IEPC/Department of State symposium should contribute to the evolution of such support. The design should not be static but should continue to develop as United States participation in GEMS proceeds. The recommendations in this report are restricted to a core of immediate activities that would launch GEMS as a useful and productive program of world environmental cooperation.

We share the conviction of a growing number of scientists that another large and encompassing report is not needed (Goldberg 1975). Plans for environmental monitoring should consider what portion of the world's finite resources of scientists and funds it is appropriate to commit to monitoring efforts. In this report we concern ourselves with a concise group of programs for early action as a start in learning how to deal with the interactive global environment and how to produce results that will be of significance to the world community. Most of these programs are ongoing. The immediate need is to concentrate upon a few activities that promise substantial returns from the limited support in prospect.

The United Nations agencies and many national groups are involved in ongoing programs that serve GEMS goals. The specialized agencies play a crucial role in defining problems and providing scientific appraisal. UNEP can make a unique contribution to these activities by being alert to ways of coordinating ongoing and proposed projects throughout the world so that their results can be used to advance understanding of the global environment. GEMS itself should not, initially, make observations or collect data. It should help define problems and suggest modifications of ongoing activities or initiation of new programs. The integrative evaluations proposed here should be carried out within the specialized agencies or national groups, and UNEP should provide bases for such activities only when they are not appropriate to other groups.

An essential corollary of monitoring is assessment. The assessments envisioned in this report should be assigned to working scientists who have an understanding of the limitations and significance of the data. However, data can and must be used for multiple purposes, and there will be cases where other scientists are better equipped than the original investigators to make use of certain data. This does not in any way lessen the need for an appreciation of the significance and limitations of data on the part of those manipulating it.

The oversight and control of the activities recommended here should rest with the world community of scientists, both within and outside of government, through a system of advisory committees. Those committees, convened by UNEP, would determine the design, implementation, coordination, and assessment of activities identified for inclusion in

GEMS. The detailed design and management of the programs require scientists with first-hand knowledge of what the data represent and how they are to be used. A strong management office is needed to initiate and maintain the programs.

The programs will be carried out by nations cooperating throughout the world and will be dependent upon the support of the nations involved. Therefore, it is important that the advisory committees as well as the working teams of scientists be international in composition.

With these considerations in mind, we have made our recommendations for early actions with two aims: (1) they are to produce practical information on contemporary problems, such as desertification and contamination of food resources; (2) the resulting data are to be useful at the same time in advancing the basic scientific understanding of the world environmental system and its dynamics. Implicit in each of the recommendations is a conceptual model of the physical, biological, and social systems affected. It is impossible to construct any monitoring system in the absence of such a concept, and its evolution must be the primary goal of monitoring.

The recommendations are organized according to the seven GEMS categories adopted by UNEP:

- expanded warning system of threats to human health;
- assessment of global atmospheric pollution and its impact on climate;
- assessment of the extent and distribution of contaminants in biological systems, particularly food chains;
- improved system of international disaster warning;
- assessment of the state of ocean pollution and its impact on marine ecosystems;
- assessment of the response of terrestrial ecosystems to environmental stress; and
- assessment of critical problems arising from agricultural and land use practices.

All the recommendations are subject to general qualifications applying to quality control, sampling, and data storage and retrieval.

Data Collection, Validation, and Availability

The quality control of data to be used is critical to the success of the system. All data should have associated with them measures of accuracy and precision. The accuracy and precision appropriate to specific measurements should be governed by the natural variation of the variable. The preparation of standards for substances being measured and intercalibration of all laboratories are essential. This will cost time and money: perhaps 25 percent of total monitoring costs is a realistic estimate. Some cases (for example, the routine analysis of metals by automated equipment, such as one of several x-ray fluorescence systems) would not require as much intercalibration. In contrast, intercalibration expenses for plutonium determinations could easily exceed 25 percent of their monitoring costs. Whatever the range of costs, the data produced will be worthless without rigorous intercalibration (Goldberg 1972, Farrington et al. 1973, Holden 1973, Farrington et al. 1974, Medeiros and Farrington 1974).

Laboratories should be selected to serve as centers responsible for intercalibration on the basis of excellence in specific measurements as determined by scientists working in the field. Assignments to these laboratories should be for a limited time, 3 to 5 years, based on proposals solicited from qualified laboratories. Intercalibrations should be run periodically as appropriate to the observations in question. The results of all intercalibration exercises should be published promptly and results identified specifically with the laboratories that produced them.

To ensure that the data obtained in monitoring provide an unbiased estimate of the variations of the natural system, the sampling program must be statistically sound. We emphasize that this is a key factor in the success or failure of any monitoring effort. The design must include determination of both the component of variance that derives from differences among individual samples, and the component of variance that derives from the precision of the measurements. If good estimates of the variation among samples are available, samples may be pooled, eliminating the necessity for a series of costly, time- consuming analyses. Observations will be treated as a time series so that serial correlation will influence estimates of the error of the trend.

The data storage and retrieval arrangements for GEMS will have a significant impact on the success of the effort. The data files must be open and accessible to the world scientific community. Time requirements for reporting monitoring data and introducing them to the open files should be established and kept as short as possible. The data from different media must be compatible with respect to storage, access, and format. Measures of quality, such as the intercalibration results from the originating laboratory, must be included with all data.

Another important principle is the continuity of the data files over time. It is envisioned that the monitoring record will be continuous over decades, and that it will become more valuable as the data files increase. Intercalibration laboratories should be responsible for keeping up with analytical advances and, in concert with the advisory committees, for introducing new techniques in such a manner that the continuity of the data is maintained.

It is inevitable that information will become available that will call into question the data or interpretation of some of the monitoring suggested here. In anticipation of this it will be valuable to preserve samples for reexamination in clearing up uncertainties. Wherever practicable, appropriate samples from the various monitoring activities associated with GEMS should be preserved and cataloged. Methods of preservation and use of samples should be controlled by the advisory committees, and the repositories for these samples should be in permanent research institutions.

Any country can, in principle, develop the capability for making many of the measurements suggested here in a relatively short time (1 to 2 years). What is required is a commitment to doing the work conscientiously and carefully. For example, the effective use of a gas chromatograph is more a matter of knowing the machine extremely well than an ability to develop physical-chemical theory. However, some of the measurements, such as those for plutonium, require a level of expertise which may not be readily transferable. For these measurements, samples should be sent to established laboratories for analysis. Continual contact between laboratories participating in intercalibration exercises will provide a basis for establishing and maintaining the quality of the data. Once their capabilities are developed, the laboratories will become centers for dealing with local and regional problems, as well as components in a system of international exchange among scientific equals.

Recommended Activities

Building upon what we know about the environment, we have selected measurements which, if made on a regular basis, will satisfy the two goals stated earlier. The measurements will tell us something practical about the environment, such as the probability of modification in weather and climate patterns as a consequence of human induced changes in atmospheric composition, or the potential for anthropogenic contaminants rendering food or natural resources unfit for use. The measurements will also advance scientific understanding of dynamic natural processes by using specific compounds as tracers to yield information about the interchanges among the biosphere, lithosphere, atmosphere, and hydrosphere. These efforts should increase knowledge about what to measure, where to measure it, and what sort of forecasts can be made with confidence.

Measurements of portions of the global carbon cycle (carbon dioxide in the atmosphere, primary productivity and carbonate equilibria in the oceans, and the extent of tropical and deciduous forests) will provide data to advance world carbon models (Woodwell and Pecan 1973) and provide an overall measure of the health of the world ecosystem and its ability to support human activities.

The recommended monitoring of specific compounds in the atmosphere, oceans, terrestrial ecosystems, and human populations will provide data for mass flow estimates of these substances in the world environment. Such calculations will advance understanding of the dynamic interactions of the global environment and the ability to detect and possibly to predict areas of contaminant concentration that could endanger ecosystems or human health and welfare (Nisbet and Sarofim 1972; NAS 1975a, 1975d, 1975e, 1975f).

EXPANDED WARNING SYSTEM OF THREATS TO HUMAN HEALTH

The GEMS *efforts in this area should be coordinated closely with, and support, the ongoing activities of the World Health Organization (*WHO *1974). As part of its promotion of more effective vital statistics and international classification of diseases,* WHO *should be encouraged to expand its monitoring of the health status of populations with emphasis on the improvement of health data potentially related to environmental causes. For example, improved data should be gathered on cancer by organ site, on congenital defects, and on cardiopulmonary diseases.*

The examples cited above are of interest because they may be sensitive indicators of environmentally induced health disorders. Incidence of cancer as related to organ site has been shown to vary according to cultural setting, independent of ethnicity. This suggests that external factors in the cultural pattern, such as diet, may be major causative or contributing factors in cancer (Higginson 1974). At least 4 to 5 percent of congenital defects can now be definitely linked to external sources, chiefly chemicals (Wilson 1974). The 60 to 65 percent of congenital defects of unknown etiology may well be influenced by environmental factors. Since most mutagens are carcinogens and vice versa, there is good reason to believe that there may be cultural differences in mutation rates according to environmental factors. Use of cytogenetic indicators may be the most practical current technique for accumulating data on this problem.

Cardiopulmonary diseases have been sensitive indicators of inhaled toxic chemicals (Lee 1972). Continued monitoring holds promise for the detection of new environmental sources of disease.

The collection of morbidity and mortality data in accordance with accepted biostatistical procedures remains of primary importance, and our suggestions should not be taken to detract in any way from that effort or from studies of population segments, such as industrial workers exposed to higher levels of specific contaminants.

It would be valuable if the levels of contaminants identified in the ocean, terrestrial, and atmospheric sections of this report could be monitored in selected human populations as well. This would allow an assessment of the rate of delivery of the contaminants to humans, provide some verification for the mass flow estimates, and check for unexpected routes of delivery, both globally and regionally. As is true of the other activities, standardization, intercalibration, and uniform data systems are crucial to the usefulness of a system of warning of threats to human health.

ASSESSMENT OF GLOBAL ATMOSPHERIC POLLUTION AND ITS IMPACT ON CLIMATE

The highest priority should be placed on providing for standardization and intercalibration services for measurements of carbon dioxide, atmospheric turbidity, and precipitation chemistry currently underway or proposed by members of The World Meteorological Organization (WMO) and in national projects.

Measurements of carbon dioxide are of primary importance in advancing understanding of world environmental dynamics (Machta 1973; NAS 1975b, 1975c). Data on atmospheric turbidity and on atmospheric carbon dioxide concentrations are essential to an understanding of the earth's radiation balance and the driving forces behind weather and climate (NAS 1975c).

A current issue involving precipitation chemistry is that of the incidence of acid rain. The normal acidity of rainwater may be increased through the adsorption of sulfur and nitrogen oxides into cloud droplets that are subsequently oxidized, or through incorporation of suspended particulate sulfates and nitrates in raindrops (NAS 1974b, Nisbet 1975a). Quantitative prediction of these processes through modeling indicates that washout is both reversible and complex (Dana et al. 1975). Increases in the availability of compounds for this process have been attributed to the increased burning of fossil fuels in the northeastern United States (Altshuller 1973, NAS 1974b). Because of atmospheric mobility (NAS 1975b), the source of the pollutants may be separated from their effects by great distances. The international nature of the problem (Bolin 1971) and its potential effects on health and the environment (Nisbet 1972) demand international cooperation. Analyses of acid rain have been made for the United States, Canada, Sweden, and Norway (Nisbet 1975b). A cooperative study between Europe and North America has begun under the auspices of the Organization for Economic Cooperation and Development (OECD) (Nordø 1974, Garland 1975).

On July 1, 1972, a measurement program was initiated for the OECD Cooperative Technical Programme to Measure the Long-Range Transport of Air Pollutants (LRTAP) (OECD 1974). By April 5, 1975, the program had grown to 68 stations making daily air and precipitation measurements in Europe. Their documents indicate that sulfate ions in precipitation have been determined by the barium perchlorate-thorin method, and that strong acidity has been determined through titration. Standardized methods for sampling and analysis were instituted. No data were included to indicate the results of intercalibration or standardization (OECD 1974). Without the publication of such data, the usefulness of the results of the LRTAP program will remain limited.

It is important that GEMS help resolve the international environmental questions regarding the stratosphere. The subjects selected for measurement should include pollutants that may influence the ozone shield, such as the low-molecular-weight halogenated hydrocarbons and oxides of nitrogen (NAS 1975b, 1975d, 1975g).

Development by WMO and the Intergovernmental Oceanographic Commission (IOC) of methods such as the Integrated Global Ocean Station System (IGOSS) (Junghans and Zachariason 1974) for obtaining data regularly on sea-surface temperature and ocean currents from satellite or other sources should be encouraged. Additionally, estimates of past sea-surface temperature and salinity should be used to expand the data base available for global climate modeling (NAS 1975c). Although this effort could be classified as research rather than monitoring, it would provide a valuable extension of the monitoring data.

ASSESSMENT OF THE EXTENT AND DISTRIBUTION OF CONTAMINANTS IN BIOLOGICAL SYSTEMS, PARTICULARLY FOOD CHAINS

Measurements of important representative components of the atmosphere, oceans, terrestrial ecosystems, and human populations should be made so that mass flow estimates for those substances can be constructed (Nisbet and Sarofim 1972, NAS *1975a).*

Establishing a global environmental monitoring system for terrestrial ecosystems is exceedingly difficult because of the complexity and diversity of those systems. We were not able to identify a concise set of measurements that could be made on a global basis to fulfill this need. However, the data produced as a result of the activities recommended in the other sections of this report will make possible the construction of mass flow estimates for representative anthropogenic compounds. These estimates will provide an index of how much contaminant various biological systems are exposed to and thus represent a practical initial step in achieving the goal of this section.

Research directed toward establishing global environmental monitoring of biological systems should concentrate on selecting and sampling representative top carnivores (such as predatory birds) and cosmopolitan feeders (such as starlings) to serve as sentinel organisms for revealing the movement of anthropogenic contaminants in food chains.

IMPROVED SYSTEM OF INTERNATIONAL DISASTER WARNING

While clearly important to human welfare, this activity does not fit comfortably into our concept of a global environmental monitoring system. Regardless of where the efforts are made institutionally, the following basic steps should be taken to improve international disaster warning systems: (1) developing and extending existing systems to cover types of disasters (such as drought and flood) and geographical areas not already included, and (2) improving the capacity to react promptly and efficiently to warnings when they are issued.

Initially, disasters should be identified (such as tropical cyclones, storm flooding, earthquakes, tsunamis, and volcanic eruptions) for which significant capabilities exist for monitoring, forecasting, or collecting and disseminating information. Tropical cyclone and tsunami forecasts are relatively well organized for large areas. Earthquake reporting is already established on a global basis, and the international capability to analyze and forecast earthquakes is probably on the threshold of a major advance (NAS 1975h). Coordination of flood forecasting has been achieved in some international river basins, but we forsee no practical warning system for drought.

The agencies involved in existing activities should be encouraged to strengthen appropriate networks of centers of regional and worldwide information. Along with the formation and improvement of such networks, it is even more important to develop a simple system for collecting information about the social response to disaster warnings when they are issued. Such a system would improve the capacity for appropriate action by individuals, groups, and government agencies. It would be tragically misleading to extend and improve forecasting networks with the expectation that this alone would alleviate human suffering and limit property losses. Unless accompanied by other measures for preparedness and prevention, improved forecasting will not yield full benefits. In fact, the confidence generated by more reliable forecasting capacities could lead to even greater future catastrophes. Following each extreme natural event, the monitoring effort should accumulate basic information about what action, if any, followed the forecast, what actions could practically have been taken, and what the human consequences were.

ASSESSMENT OF THE STATE OF OCEAN POLLUTION AND ITS IMPACT ON MARINE ECOSYSTEMS

It is impractical to attempt to monitor all possible components of the marine system. The selective monitoring of a few highly important and representative substances in open ocean and coastal areas should be made on a yearly basis to determine the general extent of changes in ocean composition. The ultimate aim of these measurements, coupled with those recommended for atmospheric and terrestrial stations, will be the construction of mass flow estimates for the identified substances (Nisbet and Sarofim 1972, NAS *1975a).*

The location of open ocean stations should be representative of major ocean areas such as those identified in Figure 1 (Department of State 1975). Eight to twelve stations should be sufficient. Measurements at these stations should be made annually at a depth of 10 meters, and should include an indicator of petroleum contamination (such as polynuclear aromatic hydrocarbons), plutonium, americium, primary productivity (^{14}C), carbonate equilibria, nitrate, phosphate, and halogenated hydrocarbons. The latter should include both the low molecular weight halogenated hydrocarbons (NAS 1975b, 1975c, 1975g) and the higher molecular weight halogenated hydrocarbons that accumulate in food webs and are detected by the analytical procedures employed for DDT and PCB (Giam and Harvey 1976). The measurements will provide a broad index of human impact on the composition of the oceans as well as the effect of natural processes. The measurements could be made part of existing national and international research and monitoring efforts, such as IGOSS (Junghans and Zachariason 1974), with GEMS providing the necessary standardization, intercalibration, and assemblage of data where such steps are not already taken.

For coastal areas we endorse the mussel watch program suggested by Goldberg (1975). Mussels provide time-integrated samples in both their soft and hard parts, and for that reason they serve well as sentinels of coastal contamination (Noshkin et al. 1971, Lee et al. 1972, Holden 1973, DiSalvo et al. 1975). Measurements of contaminant levels in mussels should include metals (lead, cadmium, mercury, selenium, zinc, and copper), petroleum hydrocarbons (such as polynuclear aromatic hydrocarbons), plutonium, americium, and the halogenated hydrocarbons as indicated above. The sites selected for measurements should include areas affected by human impact as well as relatively unaffected areas of the world's coastlines. We estimate that annual measurements from a total of about 100 sites will be sufficient.

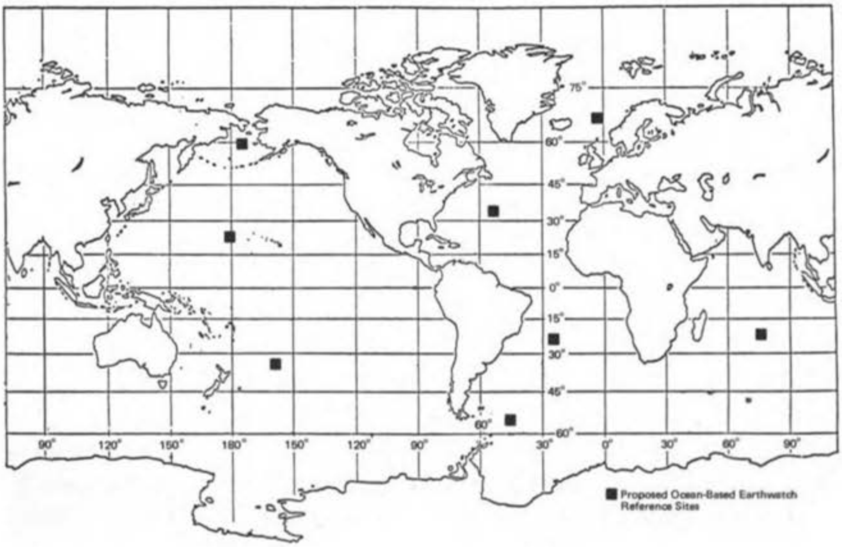

FIGURE 1 Open ocean areas suggested for surveillance by GEMS.

Sediment cores should be taken and determination made of the historical record of as many as practicable of the constituents being measured at each of the open ocean and coastal stations. At many places it may be possible to establish this from the published literature. In any case, the historical sediment determinations should be made only once.

It would be helpful if river stations identified for the World Registry of Rivers were monitored for the ocean contaminants we have just identified as well as for quantitative and qualitative analyses of suspended sediment. These stations should be in areas well mixed with coastal waters to take advantage of natural precipitation mechanisms of metals and other pollutants (Turekian 1971). The measurements should be taken just before maximum flood to provide the best index of total contamination of the drainage basin. Efforts beyond the scope of those outlined here may be necessary to yield statistically significant data on river transport. The coastal mussel stations recommended above, however, could provide time-integrated samples of the areas into which the rivers discharge and may, therefore, be adequate for present mass-flow estimate capabilities. A more detailed system of river monitoring has been suggested by the U.S. Geological Survey for later inclusion in GEMS (Department of State 1976).

Measures of fisheries and living marine resources are not recommended, because no suitable global index can yet be identified. Fisheries statistics can provide some indication of species distribution, but they are not usable in a quantitative sense because of uncertainties associated with efficiency and level of fishing effort. Yearly class recruitment analyses can provide information about population fluctuations. There is a need to develop effective indices of living marine resources. A portion of the research in this area should be directed toward selecting and sampling representative top carnivores to serve as sentinel organisms for the movement of anthropogenic contaminants in marine food chains.

ASSESSMENT OF THE RESPONSE OF TERRESTRIAL ECOSYSTEMS TO ENVIRONMENTAL STRESS

Three actions should be taken in this area. First, measurement of changes in the extent of tropical and deciduous forests should be accepted as priority goals within the program on agriculture and land use. Second, the identification and commitment of land and water areas to serve as reference and research sites for later development of a terrestrial monitoring system should proceed promptly. Third, measurements should be made of representative substances transported by the atmosphere to terrestrial ecosystems.

The periodic mapping of major land categories, as suggested in the agriculture and land use discussion, will provide a measure of the extent of change in terrestrial ecosystems that will be useful in managing land conversion and in assessing the gross status of terrestrial ecosystems. This program should identify areas of rapid change for closer monitoring and areas of gradual change for which the mapping interval could be extended.

Measurement of changes in the extent of tropical forests is recommended as a priority item because of reports of their rapid conversion to other uses (TIE 1972, Meggers et al. 1973, Farnworth and Golley 1974, Wagley 1974, Goodland and Irwin 1975). Determination of the extent of deciduous forests is significant because, along with the measurements of carbon dioxide in the atmosphere and carbonate equilibria in the ocean, it will provide data to advance current models of the world carbon cycle (Woodwell and Pecan 1973). This data will provide an indication of the status of the world's biological system and the impacts of human activities upon them.

Although there are differences of judgment about the nature of practicable baseline measurement and its usefulness, GEMS should strive for measurements that will detect changes over time, whether or not they can be directly associated with human activity. A global network of reference and research stations is essential in measuring globally significant trends in the terrestrial environment. The design and distribution of such a network has been the subject of numerous reports (SCOPE 1971, 1973; TIE 1976), but no consensus has yet been reached. Lack of consensus about the observations and methods that could be applied immediately and practically should not delay the commitment of land and water areas to this purpose. Such commitment is urgent because of the rapid reduction in the number of potentially suitable areas. GEMS should collaborate with appropriate bodies such as national governments and their agencies, UNESCO/MAB, and the International Union for Conservation of Nature and Natural Resources (IUCN) in securing commitment to areas of preservation. These areas will have increasing value as human influence over and modification of land continues to expand. They should also provide a home for various other monitoring activities suggested here as well as for other research activities. An example of an effort addressing this need is contained in *Experimental Ecological Reserves* (TIE 1976).

Immediate steps should be taken to establish one or more research efforts to develop, as speedily as practicable on a prototype basis, the protocols for a standard system of reference and research stations.

Substances released to the atmosphere tend to return to the earth's surface as dry fallout or in precipitation. This applies equally to natural releases and to those induced by man. Submicron particles and gases are capable of regional or truly global transport (Machta et al. 1956; Chamberlain 1966a, 1966b; Garland 1975). The ultimate composition and rate of removal of airborne particles at the earth's surface depends upon atmospheric mixing processes, distance, latitude, atmospheric chemical processes, and the roughness and wetness of the ground cover (Chamberlain 1960, 1966a, 1966b; USAEC 1970; Clough 1973; Garland 1975). Reliable data are needed on the rates at which aerosols are intercepted by soils, water bodies, and vegetation, and on the relationship of depositional changes to natural and human production rates. This information will provide data for regional and global transport models and aid in the development of a predictive capability for assessing risks to ecosystems and human populations.

A series of 9 to 12 measuring stations, on land separated by about 20 degrees of latitude and located roughly along a longitude, would be adequate to reflect any inherent circulation patterns (UNSCEAR 1964). These stations should be located so that interference from industry, mining, or towns would not be too great to prevent determination of the magnitude and variation of natural fluctuations. At each site the composition of the airborne particulates and total interception should be measured (Cawse and Peirson 1972, Goodman et al. 1975). As many as practicable of those substances identified in the section above on Ocean Pollution should be included among the analyses made. Samples should be carefully stored for historical reference particularly with a view to carrying out analyses for other substances.

Nations should be encouraged to establish additional stations in areas affected by human activities. These stations could be located at existing institutions. Related research projects would thereby benefit from participation in the standardization and intercalibration programs.

A significant potential for monitoring past and present transport of substances through the atmosphere exists in aquatic sediments (Anderson 1976) and snow (Murozuni et al. 1969). Methods for incorporating existing data from these sources and for encouraging further research in these areas should be investigated by GEMS.

ASSESSMENT OF CRITICAL PROBLEMS ARISING FROM AGRICULTURAL AND LAND USE PRACTICES

Periodic mapping should be undertaken to detect change in the following land classifications: (1) urban areas; (2) desertification areas; (3) deforestation and forestation areas, with emphasis on tropical deforestation and the extent of deciduous forests; (4) coastal zones; (5) irrigated and non-irrigated agricultural lands; (6) lands prone to hazard, such as flood plains and zones of geological instability; (7) permafrost areas; (8) upland wetlands; and (9) surface mined areas.

Urban areas can cause loss of land for agricultural use, create heat islands, and generate contaminated wastes. The impact of urban areas is disproportionate to their size because of their concentrations of population, energy production and energy consumption, and their large requirements of materials for support.

Desertification areas can indicate climatic change and reductions in agricultural areas. In addition, they cause changes in albedo that influence the atmospheric energy system which controls climate and weather (Idso et al. 1974, Charney and Stone 1975, Jackson et al. 1975, Charney et al. 1976).

Deforestation and forestation areas are important in assessments of albedo and nutrient cycling (Bormann et al. 1969, Bormann and Likens 1971, Bormann et al. 1974). In the latter regard, monitoring of the world's deciduous and non-deciduous forests coupled with measurements of carbon dioxide, carbonate equilibria, and primary productivity suggested in the other sections of this report will enable GEMS to provide data for advancing the capability to model the world carbon cycle (Woodwell and Pecan 1973). This is particularly significant in the assessment of potential world food production. Tropical forests and their currently perceived conversion to other uses (TIE 1972, Meggers et al. 1973, Farnworth and Golley 1974, Wagley 1974, Goodland and Irwin 1975) are important because of their impacts on the carbon cycle and their effects on biological and agricultural productivity.

The coastal zone should be examined because of the worldwide concentration of human activity in these areas and the many food chains of human importance based in them. In all parts of the world they will come under increased pressure for such conflicting uses as resource exploitation, transportation, food production, energy production, and recreation (Ketchum 1972).

The importance of agricultural land for world food production and human welfare is obvious. The balance of irrigated and non-irrigated land is significant to water management and its effects on the hydrologic cycle, the maintenance of soil profiles in the face of erosion and salinization, and other processes basic to soil productivity.

Consideration of areas prone to hazard plays a vital role in the prevention of human suffering as a result of natural disasters (White 1974). Zones can become hazard prone as a result of land use practices in other areas. For example, danger to flood plains can be increased by upstream development and channel modification.

Permafrost areas are indicators of climatic change (NAS 1975c). Upland wetlands are significant because of their characteristically high biological importance and their role as indicators of shifts in the hydrologic cycle. Surface mined areas are important to developing management and assessment programs as exploitation of natural resources expands.

The monitoring outlined in this section can be carried out principally by remote sensing, which, from satellite platforms, makes global data collection possible. LANDSAT, GEOS, and ITOS are examples of satellites now providing data that can contribute to better understanding of global environmental processes (NAS 1974a, NASA 1974). In terms of agriculture and land use information, LANDSAT offers particular promise (NAS 1974a). Two LANDSAT spacecraft are currently in near polar orbit. Each provides complete coverage of the cloud-free areas of the earth with an 18-day cycle at the equator. Because of limited on-board recording capacity, regional data read-out stations are required to collect all the available data from LANDSAT. Regional read-out stations are in operation in the

U.S., Canada, Brazil, and Italy. Additional stations are under construction in Zaire, Iran, Chile, and Canada. Other countries either planning construction of read-out facilities or expressing interest in them include Australia, Japan, India, and Indonesia. The four-channel multispectral scanner in the current LANDSAT sensor package provides data in four spectral bands from 0.5 to 1.1 micrometers for daylight observation (NASA 1972). Investigations have demonstrated that these data can be used to identify and inventory major vegetation types and, in some cases, to detect perturbations (NASA 1975). The analysis of sequential (multidate) coverage will assist in identifying ground cover types and some level of species diversity in forest stands as a result of differences in the phenology of various species (NASA 1975). Thus, satellite data can provide the overview of land use and agriculture which must form the basis for monitoring change in large areas.

Global maps of the distribution of the land use areas identified above can be prepared from LANDSAT data. Initially the land use maps should be reviewed at three-year intervals; the updating interval for specific areas should be adjusted in accordance with their rates of change. A unified classification scheme should be agreed upon internationally so that all nations can contribute to the compilation, review, and assessment of the maps.

In answering specific monitoring questions, especially those requiring images of high resolution (NASA 1972, 1973), it will be necessary to supplement satellite data in some cases with data from other sources. Aircraft radar systems (SLAR) can be used to collect data on certain surface features in areas obscured by cloud cover or heavy vegetation (NASA 1973).

The design, operation, and assessment of the remote sensing data collection methods will require close collaboration among all the nations affected. International collaboration among users and producers of the data and coordination of assessments will also be essential.

Literature Cited

Altshuller, A.P. (1973) Atmospheric sulfur dioxide and sulfate distribution of concentration at urban and non-urban sites in the United States. Environmental Science and Technology 7:709–712.

Anderson, R. (1976) Short-term sedimentation response in lakes in the Southeast U.S. as measured by remote sampling. Limnology and Oceanography: in press.

Bolin, B., Chairman (1971) Air pollution across national boundaries. The impact on the environment of sulfur in air and precipitation. Sweden's case study for the United Nations conference on the human environment. Stockholm: Ministry of Foreign Affairs and Ministry of Agriculture.

Bormann, F.H., G.E. Likens, and J.S. Eaton (1969) Biotic regulation of particulate and solution losses from a forest ecosystem. BioScience 19(7):600–610.

Bormann, F.H. and G.E. Likens (1971) The ecosystem concept and the rational management of natural resources. Yale Scientific Magazine XLV (7):2–8.

Bormann, F.H., G.E. Likens, T.G. Siccama, R.S. Pierce, and J.S. Eaton (1974) The export of nutrients and recovery of stable conditions following deforestation at Hubbard Brook. Ecological Monographs 4(3):255–277.

Cawse, P.A. and D.H. Peirson (1972) An analytical study of trace elements in the atmospheric environment. Atomic Energy Research Establishment 7134. London: Her Majesty's Stationery Office.

Chamberlain, A.C. (1960) Aspects of the deposition of radioactive and other gases and particles. International Journal of Air Pollution 3:63–88.

Chamberlain, A.C. (1966a) Transport of lycopodium spores and other small particles to rough surfaces. Proceedings of the Royal Society of London, Series A 296:45–70.

Chamberlain, A.C. (1966b) Transport of gases to and from grass and grass-like surfaces. Proceedings of the Royal Society of London, Series A 290:236–265.

Charney, J. and P.H. Stone (1975) Drought in the Sahara: a biogeophysical feedback mechanism. Science 187:434–435.

Charney, J., P.H. Stone, and W.J. Quirk (1976) Drought in the Sahara: insufficient biogeophysical feedback. Science 191:100–102.

Clough, W.S. (1973) Transport of particles to surfaces. Aerosol Science 4:227-234.

Dana, M.T., J.M. Hales, and M.A. Wolf (1975) Rain scavenging of SO2 and sulfate from power plant plumes. Journal of Geophysical Research 80:4119-4129.

Department of State (1975) Design Philosophy for the Global Environmental Monitoring System, prepared by Task Force II–Committee on International Environmental Affairs, September 16, 1975 draft. Washington, D.C.: U.S. Department of State.

Department of State (1976) Design Philosophy for the Global Environmental Monitoring System prepared by Task Force II–Committee on International Environmental Affairs, January 1976 draft. Washington, D.C.: U.S. Department of State.

DiSalvo, L.H., H.E. Guard, and L. Hunter (1975) Tissue hydrocarbon burden of mussels as potential monitor of environmental hydrocarbon insult. Environmental Science and Technology 9:247-251.

Farnworth, E.A. and F.B. Golley (1974) Fragile Ecosystems. New York: Springer-Verlag.

Farrington, J.W., J.M. Teal, J.G. Quinn, T. Wade, and K. Burns (1973) Intercalibration of analyses of recently biosynthesized hydrocarbons and petroleum hydrocarbons in marine lipids. Bulletin of Environmental Contamination and Toxicology 10:129-136.

Farrington, J.W., M.M. Teal, J.G. Quinn, P.L. Parker, J.K. Winters, T.L. Wade, and K. Burns (1974) Analyses of hydrocarbons in marine organisms: results of IDOE intercalibration exercises, pages 163-166. In Marine Pollution Monitoring (Petroleum), Special Publication 409. Washington, D.C.: National Bureau of Standards.

Garland, J.A. (1975) Dry deposition and the atmospheric cycle of sulphur dioxide, In Science, technology and environmental management. Richard D. Hey and D. Davies-Trevor, editors United Kingdom: Saxon House Studies, pp. 145-164.

Giam, C.S. and G.R. Harvey (1976) Polychlorodiphenyls and DDT compounds, In Strategies for marine pollution monitoring. E.D. Goldberg, editor. New York: Wiley-Interscience. in press.

Goldberg, E.D. (1972) Baseline studies of pollutants in the marine environment and research recommendations. International Decade of Ocean Exploration, National Science Foundation. Springfield, Virginia: National Technical Information Service.

Goldberg, E.D. (1975) The mussel watch–a first step in global marine monitoring. Marine Pollution Bulletin 6(7):111.

Goodland, R.J.A. and H.W. Irwin (1975) Amazon Jungle: Green Hell to Red Desert? Amsterdam: Elsevier-Scientific Publishing Co.

Goodman, G.T., S. Smith, and M.J. Inskip (1975) Report of a collaborative study on certain elements in air, soil, plants, animals, and humans in the Swansea/Neath Port Talbot area together with a report on a moss bag study of atmospheric pollution across South Wales. London: Welsh Office, Her Majesty's Stationery Office. chapters 7 & 8.

Higginson, J. (1974) Environment and Cancer. Practitioner 198:621-630.

Holden, A.V. (1973) International cooperative study of organochlorine and mercury residues in wildlife, 1969-1971. Pesticides Monitoring Journal 7(1):37-52.

Idso, S.B., R.D. Jackson, and R.J. Reginato (1974) Estimating evaporation: a technique adaptable to remote sensing. Science 189:991-992.

Jackson, R.D., S.B. Idso, and J. Otterman (1975) Surface albedo and desertification. Science 189:1012-1015.

Jensen, C.E., D.W. Brown, and J.A. Mirabito (1975) Earthwatch. Science 190:432-438.

Junghans, R. and R. Zachariason (1974) The integrated global ocean station system (IGOSS). Washington, D.C.: Environmental Data Service, National Oceanic and Atmospheric Administration.

Ketchum, B.H., editor. (1972) The water's edge: critical problems of the coastal zone. Cambridge, Mass.: The MIT Press.

Lee, D.H., editor (1972) Environmental factors in respiratory disease. New York: Academic Press.

Lee, R.F., R. Sauerheber, and A.A. Benson (1972) Petroleum hydrocarbons: uptake and discharge by the marine mussel *Mytilus edulis*. Science 177:344-346.

Machta, L., L.F. Hubert, and R.J. List (1956) Worldwide travel of atomic debris. Science 124:474-477.

Machta, L. (1973) Prediction of CO_2 in the Atmosphere. In Carbon and the Biosphere, G. Woodwell and I. Pean, eds. Springfield, Virginia: National Technical Information Service.

Martin, Brian and Francesco Sella (1976) Earthwatching on a macroscale. GEMS: The global environmental monitoring system of the United Nations aims to assess conditions on planet Earth. Environmental Science and Technology 10(3):230-233.

Medeiros, G. and J.W. Farrington (1974) IDOE-5 intercalibration sample: results after sixteen months storage, pages 167-169. In Marine Pollution Monitoring (Petroleum), Special Publication 409. Washington, D.C.: National Bureau of Standards.

Meggers, B.J., F.W. Ayensu, and W.D. Duckworth (1973) Tropical forest ecosystems in Africa and South America: a comparative review. Washington, D.C.: Smithsonian Institution Press.

Murozuni, M., T.J. Chow, and C. Patterson (1969) Chemical concentrations of pollutant lead aerosols, terrestrial dusts, and sea salts in Greenland and Antarctic snow strata. Geochimica et Cosmochimica Acta 33(10):1247-1294.

National Academy of Sciences (NAS) (1972) Institutional Arrangements for International Environmental Cooperation. International Environmental Programs Committee. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1974a) Remote Sensing for Resource and Environmental Surveys: A Progress Review. Committee on Remote Sensing Programs for Earth Resource Surveys. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1974b) Air Quality and Automobile Emission Control. Commission on Natural Resources. Volume 3. Washington, D.C.: U.S. Government Printing Office.

National Academy of Sciences (NAS) (1975a) Assessing Potential Ocean Pollutants. Ocean Affairs Board. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975b) Atmospheric Chemistry–Problems and Scope. Committee on Atmospheric Sciences. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975c) Understanding Climatic Change–A Program for Action. U.S. National Committee for the Global Atmospheric Research Program. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975d) Environmental Impact of Stratospheric Flight. Climatic Impact Committee. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975e) Principles for evaluating chemicals in the environment. Environmental Studies Board and the Committee on Toxicology. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975f) Decision making for regulating chemicals in the environment. Environmental Studies Board. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975g) Interim Report of the Panel on Atmospheric Chemistry. Climatic Impact Committee. Washington, D.C.: National Academy of Sciences.

National Academy of Sciences (NAS) (1975h) Earthquake prediction and public policy. Advisory Committee on Emergency Planning. Washington, D.C.: National Academy of Sciences.

National Aeronautics and Space Administration (NASA) (1972) Data Users Handbook. Houston, Texas: Goddard Space Flight Center. pages 2–8.

National Aeronautics and Space Administration (NASA) (1973) Symposium on Significant Results Obtained from the Earth Resources Technology Satellite–1, Volume I, Section A. Washington, D.C.: National Aeronautics and Space Administration.

National Aeronautics and Space Administration (NASA) (1974) The Space Applications Program. III–24, III–27, III–73. Washington, D.C.: National Aeronautics and Space Administration.

National Aeronautics and Space Administration (NASA) (1975) Earth Resources Survey Symposium Abstracts. Houston, Texas: National Aeronautics and Space Administration.

Nisbet, I.C.T. (1972) Environmental occurrence and human exposure. Environmental Research 5(3):287–307.

Nisbet, I.C.T. and A.F. Sarofim (1972) Rates and routes of transport of PCBs in the environment. Environmental Health Perspectives 1:21–38.

Nisbet, I.C.T. (1975a) Ecological effects, In Air Quality and Stationary Source Emission Control. Commission on Natural Resources, National Academy of Sciences. Washington, D.C.: U.S. Government Printing Office.

Nisbet, I.C.T. (1975b) Sulfates and acidity in precipitation, In Air Quality and Stationary Source Emission Control. Commission on Natural Resources, National Academy of Sciences. Washington, D.C.: U.S. Government Printing Office.

Nordø, J. (1974) Sulfur pollution arising from distant pollution sources. Manuscript. Kjeller, Norway: Norwegian Institute for air research.

Noshkin, V.E., V.T. Bowen, K.M. Wong, and J.C. Burke (1971) Plutonium in North Atlantic ocean organisms: ecological relationships, pages 681–688. In Radionuclides in Ecosystems Proceedings from the Third National Symposium on Radioecology, May 10–12, 1971, Oak Ridge, Tennessee. Oak Ridge, Tennessee: U.S. Atomic Energy Commission.

Organization for Economic Cooperation Development (OECD) (1974) Cooperative Technical Programme to Measure the Long Range Transport of Air Pollutants: Report on the First Measurement Phase. NR/ENV/74.7. Paris, France: Organization for Economic Cooperation and Development.

Scientific Committee on Problems of the Environment (SCOPE) (1971) Global Environmental Monitoring. Paris, France: SCOPE Secretariat.

Scientific Committee on Problems of the Environment (SCOPE) (1973) Global Environmental Monitoring System: Action Plan for Phase I. Paris, France: SCOPE Secretariat.

Study of Critical Environmental Problems (SCEP) (1970) Man's Impact on the Global Environment. Cambridge, Massachusetts: The MIT Press.

The Institute of Ecology (TIE) (1972) Man in the Living Environment. Madison, Wisconsin: The University of Wisconsin Press.

The Institute of Ecology (TIE) (1976) Experimental Ecological Reserves. Washington, D.C.: The Institute of Ecology. In press.

Turekian, K.K. (1971) Rivers, tributaries, and estuaries, pp. 9–73. In The Impingement of Man on the Oceans, D.W. Hood, editor. New York: Wiley-Interscience.

United Nations Environment Program/IG. 1/2. (UNEP) (November 15, 1975) Report of the Interagency Working Group on Monitoring on the Development of a Global Environmental Monitoring System (GEMS), paragraphs 5-7. Nairobi, Kenya: United Nations Environment Program.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (1964) Radionuclide Contamination of the Environment by Nuclear Tests. A/5814 General Assembly, Supplement 14. New York: United Nations Scientific Committee on the Effects of Atomic Radiation.

U.S. Atomic Energy Commission (USAEC) (1970) Precipitation scavenging. Division of Technical Information. Springfield, Virginia: National Technical Information Service.

Wagley, C. (1974) Man in the Amazon. Gainesville: University of Florida Press.

White, G.F., editor (1974) Natural Hazards: Local, National, Global. New York: Oxford University Press.

Wilson, J.G. (1974) Environment and Birth Defects. New York: Academic Press.

Woodwell, G. and E.V. Pecan, editors (1973) Carbon and the Biosphere. Proceedings of the 24th Brookhaven Symposium in Biology (May 16-18, 1972). Springfield, Virginia: National Technical Information Service.

World Health Organization (WHO) (1974) Report of a WHO Meeting. WHO Environmental Health Monitoring Program, EHE/75.1. Geneva: World Health Organization.

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