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Application of Remote Sensing to the Chesapeake Bay Region Volume 1 - Executive Summary

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Application of Remote Sensing to the Chesapeake Bay Region

Volume 1 - Executive Summary

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PREFACE

The Conference on the Application of Remote Sensing to the Chesapeake Bay Region was held at the Coolfont Conference Center, Berkeley Springs, West Virginia, April 12-15, 1977. Sponsored jointly by the National Aeronautics and Space Administration, the Environmental Protection Agency, and the University of Maryland, the Conference served as a forum for discussing the complex technical and management issues surrounding the application of remote sensing to the Chesapeake Bay area.

Experts in the scientific and engineering community, as well as managers of the Bay's resources and representatives of the Bay community itself, were assembled to focus attention on the value of remote sensing techniques involving a variety of Bay problems associated with land-use development, resources, and pollution. Pre-Conference questionnaires, planning meetings, working groups, open sessions, and summary reports were all utilized to assess the Bay's problems, to examine issues of primary concern, to air conflicts, and to relate the technology of remote sensing to the improvement and maintenance of health and beauty of the entire Bay area.

This Executive Summary (Volume 1) contains the recommendations that resulted from this Conference, in addition to brief summaries of written papers and reports of the working groups. The complete papers, detailed discussions of some of the sessions, and the complete reports of the working groups are found in the Conference Proceedings, Volume 2, as are a listing of the open session presentations, supporting resource material, and Appendixes. The headings used throughout the Executive Summary are identical to those used on the Conference papers and working groups given in Volume 2. The reader can refer to the individual papers for subject details.

The immediate Conference accomplishments according to the post-Conference questionnaires were the new contacts developed within the remote sensing and natural resources communities, and the update that the conferees received on current sensor capability and data processing. Their greatest concerns are whether action will be taken on the Conference recommendations.

That, too, is a concern of the Conference coordinators. Their hope is that these two volumes will supply the impetus and documentation needed for informal groups begun during the Conference to secure the needed human, budgetary, and organizational resources to implement the Conference recommendations in a formal way.

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INTRODUCTION

Conference presentations, discussions, and reports document the availability of suitable remote sensing monitoring techniques for diagnosing, prescribing, and forecasting the conditions of the Chesapeake Bay. The pressing need revealed by the Conference is for a mechanism through which federal, state, and private agencies can coordinate their stewardship of the Bay.

The Chesapeake Bay, about 288 kilometers long, from 8 to 48 kilometers wide, and averaging 6.5 meters deep, is the largest estuary in the United States. It is widely known for its seafood industry and recreational opportunities. Among the eight million persons who live within the Chesapeake Bay watershed, however, there are many who fear for the Bay's future. Dredging to maintain Bay navigability threatens bottom and shore life. Thermal pollution from discharges of heated water from power plants can inhibit or prevent plant growth and, consequently, animal life in the area. Deadly chemicals poison Bay tributaries, and wetlands are being filled.

Remote sensing allows experts to monitor these problems over the whole Bay area. Changes in large areas from urbanization, cessation of farming, land filling, tree cutting, shoreline development, utility installations, and other activities are very noticeable. And chemical and physical changes in air and water quality are easily detected and quantified.

Remote sensing of the Bay began in 1971 when the National Aeronautics and Space Administration (NASA) Wallops Chesapeake Bay Ecological Program was launched. About 65 agencies have used or now use remote sensing data in Bay projects. Resources for processing and plotting remotely sensed Bay data include the U.S. Geological Survey, Maryland Geological Survey, University of Maryland, and U.S. Corps of Engineers (Baltimore District). But none has a formal, definitive program underway.

Meanwhile, remote sensing equipment and techniques continue to proliferate with rapid increases in sensitivity, range, and capability. Also, in addition to these advances in detection, there is improvement in processing and analysis of data collected. Processing and analysis of data are especially difficult because of the changing relationship between measurements and ecological evolution of the Bay. Model building is the most widely used analytical tool in which the determinants of such aspects as temperature, turbidity, color, and salinity of the Bay are sought among drainage, surface materials, geology, soils, vegetation, transportation, cultural features, and land use.

These matrices require much expertise for their development and interpretation, demanding continuing and extensive educational and training programs, advances in data processing technology, and, in particular, the economic management of the growing commitment of human and scientific resources to Bay monitoring problems.

Management responsibility for the environmental quality of the Chesapeake Bay must be defined; principal factors having an impact on the Bay must be assessed, and a comprehensive monitoring technique must be used. But most of all, there must be an honest and open cooperative effort among all those concerned with the Bay's future. It is the facilitating of this management responsibility through remote sensing—assessment, monitoring, and cooperative effort—that is the concern of the Conference.

CONFERENCE RECOMMENDATIONS

The Conference recommendations are summarized under the following headings:

- Intergroup cooperation/organization/coordination
- Environmental quality
- Geophysical and environmental surveys
- Standards
- Advanced sensor development
- Funding

They reflect the recommendations made during presentations of papers, informal discussions, and summaries of the working-group sessions. The page numbers associated with each recommendation refer to the pages in Volume 2 on which the recommendation is detailed.

INTERGROUP COOPERATION/ORGANIZATION/COORDINATION

- A central planning organization be structured and funded to develop an overall approach and management plan for investigating the Bay. This group should incorporate the efforts of all parties involved in the Bay into a single coordinated program, which could take the form of a commission under Title II of the Water Resources Planning Act of 1965. This organization could be very important in making results of decision-oriented impact assessment available to all concerned (pages 10, 11, 224, 320, and 326).
- People interested in carrying forth the work of this Symposium form a task force and attempt to obtain the support of their agencies in matters such as release time, the use of specific equipment, and possibly funding (pages 99, 100, 324, and 329).
- A citizens' committee be formed to maintain a continuous dialogue with users of the Bay, and a strong public-participation program be instituted in conjunction with the committee. New surveys should be made to determine and enhance the public awareness of the Bay environment and its manmade changes (pages 12 and 325).

- A Center for Remote Sensing be established at the University of Maryland for service, research, and education in remote sensing (page 55).
- A reference center or information "clearinghouse" on remote sensing be formed. This center could be available for users to quickly determine the status of remote sensing data on any given Bay problem (page 313).
- Federal research and development laboratories be encouraged to work more closely with instrument production and marketing industries to transfer remote sensing devices into a form that can be economically produced, sold, and widely used (page 309).
- A better interface be established to coordinate user needs with the National Aeronautics and Space Administration (NASA)/Wallops Flight Center (WFC) remote sensing activities (page 109).
- Short-term projects, such as the demonstration of the application of Landsat data to generating environmental impact assessment statements for major facility sitings, be brought to the attention of the NASA Regional Applications Training Centers, such as the Goddard Space Flight Center (GSFC) (page 309).
- Cooperative efforts be established between federal agencies and planning groups in local government to develop computerized environmental information systems for meeting the needs of local planners. For instance, NASA should carry through with making Landsat data available to the states. The states would then be responsible for making a serious commitment to the program's utilizations (pages 309, 334, and 343).
- A circulation atlas oriented toward users in consulting engineering firms and local governmental agencies be produced in a single, easily accessible document (page 346).
- The environmental sampling data now being collected on the Bay be examined, and a continued capability be established for collecting, storing, analyzing, and disseminating the data (page 11).

ENVIRONMENTAL QUALITY

- Remote sensing of water quality and shellfish sanitation could be extremely valuable if it could be shown to produce, with a minimum of ground corroboration, information on bacteriological, physical, and chemical aspects of water quality, and on hydrology and point/nonpoint sources of pollution.

One method of investigation is that of low-altitude vegetation photography combined with selected ground truth (pages 267, 268, 273, and 280).

- A hierarchical remote sensing technique be used that makes use of a combination of data to classify watersheds with regard to severity of potential pollution (pages 279 and 312).
- Environmental monitoring of plant operations be conducted aggressively because of federally mandated compliance schedules (page 223).
- The principal factors that have an adverse impact on the environmental quality of the Bay be assessed, and research and abatement programs to address these factors be developed and implemented (page 11).
- Remote sensing, particularly from satellites, can play an immediate role in documenting living resources in the Bay by assessing population distribution and fluctuations of aquatic plants. Projects in these areas should be undertaken as soon as possible (pages 300 and 301).
- Good data on nutrient enrichment of the Bay and its estuaries could be obtained by using *in situ* sensors that are remotely interrogated for rapid summation of the condition of the environment over a large area (page 272).

GEOPHYSICAL AND ENVIRONMENTAL SURVEYS

- Arrangements be made to routinely document and monitor episodic events in the Bay and shoreline using existing remote sensing techniques (page 321).
- A deep seismic reflection profile be surveyed along the spine of the Bay. Assistance should be sought from the Marine Geology Division of the U.S. Geological Survey for this work. The profile would provide invaluable data on the geometry of freshwater aquifers, on depths to basement rocks, and possibly on faulting in basement rock and coastal-plain sediments (page 321).
- A complete bathymetric survey of the Bay be scheduled at an early date by the National Ocean Survey of the National Oceanic and Atmospheric Administration (NOAA). Such a survey is needed for delineating the bathymetry of the entire Bay within a short timeframe, and can be used for a multitude of purposes (e.g., shoal areas, rates of sedimentation, dredging applications, and channel migration) (page 321).

STANDARDS

- Standards be established so that data collected by different agencies on different parts of the Bay can be integrated into a meaningful study of the Bay as a total system (page 51).

ADVANCED SENSOR DEVELOPMENT

- A sequence of research and development steps be proposed that is designed to lead to a complete evaluation of the detection of underwater pollution by means of submersible vehicles carrying nuclear probes (page 219).
- Comprehensive field trials be used for the full validation of "conventional" remote sensing techniques such as aerial photography (page 207).
- Side-scan sonar and deep seismic profiling be considered as remote sensing techniques that may add significantly to the geologic baseline data of the Bay (page 40).
- The use of laser (lidar) techniques for both water and air application be routinely considered as part of the approach to environmental problems. Ongoing demonstrations (experimental and numerical-simulation) and tests should be held to delineate the usefulness of these techniques (pages 207, 249, and 250-254).
- Measurement programs involving the use of many *in situ* and remote sensing techniques in concert will yield far more benefits than could be obtained by using only a few favored methods (pages 207 and 280).
- Integrated observation networks consisting of both satellite sensors and sensors and probes mounted on platforms at the surface of the Earth be used to provide an integrated data set (page 156).
- Landsat imagery be recognized as a major initial step in the evolution of remote sensing technological developments that can build awareness of the environment and its changes (page 324).

FUNDING

- Congress and the states actively support continuation of the Landsat Program with its proposed (follow-on) improvements, such as greater area resolution and better capabilities for vegetation discrimination (pages 334 and 339).

- NASA's Chesapeake Bay Ecological Program be given additional support and emphasis, including the addition of an instructional program in remote sensing (page 109).
- Additional employment positions be created for the Environmental Protection Agency (EPA) Chesapeake Bay Program (page 13).
- Funding agencies be aware of the necessity for duplicate data acquisition during the development of new standards (page 309).

SUMMARY OF WRITTEN PAPERS AND PRESENTATIONS

OPENING SESSION

The Honorable Charles Mc.Mathias, Jr., U.S. Senator, Maryland, the keynote speaker of the Conference, opened the Conference. He stated that:

“The Chesapeake Bay, our nation’s largest estuary, could, within our lifetime, become a dead sea. There is no time left to grope for solutions. With every year that passes, the Bay is diminished. Some day, unless we intercede, the wear and tear will become terminal. We must join together to ensure the health of the Chesapeake Bay as our legacy to the future.”

Senator Mathias believes that the Chesapeake Bay, the nation’s largest estuary, could in time, become a dead sea. Insufficiently treated sewage and deadly chemicals are being dumped into the Bay and its tributaries. Wetlands are being filled, and existing and proposed nuclear power plants threaten the quality of the Bay’s waters.

Despite the punishment the Bay has taken, it is surprisingly healthy, and recent developments hold out some encouragement. National, state, and local laws exist to protect the Bay and its resources against increasing damage, and important research efforts are being directed toward environmental and biological benefits. Yet these federal, state, and local programs are not coordinated. If the Chesapeake Bay is to survive, it must be addressed as an entity, as a total system, for if one part is damaged, all parts are affected.

The remedy for these uncoordinated efforts is the establishment of a commission under Title II of the Water Resources Planning Act of 1965. Legal authority for bringing Maryland and Virginia into a partnership for management of the Bay exists, and a Title II commission, in which the two states and Federal agencies combine their efforts, will preserve the Bay.

Following Senator Mathias’ presentation, Leonard Mangiaracina described the objectives of the Environmental Protection Agency’s Chesapeake Bay program and the opportunities for the use of remote sensing. The great size of the Bay and the conflicting jurisdictions that have control over it make any monitoring program difficult. By using remote sensing techniques, especially through the use of satellites and aircraft, the Bay could be viewed as a unified system.

ROLE OF REMOTE SENSING IN LAND-USE PLANNING IN THE CHESAPEAKE BAY WATERSHED

The planning and management of the land and water resources of the Chesapeake Bay system must reconcile a complex array of conflicting demands. Decision-makers working in this field must use every available aid as they anticipate the consequences of their actions. A very important phase of this decision-making process involves the determination of land-use distributions surrounding the Chesapeake Bay and its tributary watersheds. Without this land-use information, a thorough understanding of the Chesapeake Bay system is not possible.

Models developed for simulating population dynamics, water quality, economics, and hydrology have become important tools to the decision-maker. The most flexible models require land-use distributions as one of the primary inputs. For example, a number of land-use based hydrologic models have been developed for simulating the behavior of the stream flows or water-quality parameters in terms of land cover. The advantage of such a model is that it can be calibrated to reflect the present hydrologic or water-quality consequences of the existing land-cover pattern. When the decision-maker is satisfied that the model adequately represents his system, he has a tool that permits him to experiment and to evaluate the impact of changes that he may consider. In this context, he can also use the model to locate areas that may be disproportionately impacted by a particular problem.

Unfortunately, estimating model parameters in terms of land cover is a very difficult and time-consuming task when areas larger than several square kilometers are involved. Without remote sensing, definition of land cover in an area as vast as the Chesapeake Bay region would be next to impossible.

Present Status of Landsat Remote Sensing

The status of Landsat remote sensing technology can be characterized as experimentally successful with tremendous potential for future applications. The present Landsats (-1 and -2) are the most recent and sophisticated in a series of remote sensing satellites. This technology development was largely the result of NASA's investment through universities, and government and private research organizations.

Although some of this type of support must be maintained, a noticeable shift to applications is now underway. The prime example is the Landsat-2 Principal Investigator Program, which requires involvement of user organizations. Other federal agencies—Corps of Engineers, Environmental Protection Agency, and Departments of the Interior, Agriculture, and Commerce—are investigating the practical uses of remote sensing for their needs.

**ORIGINAL PAGE IS
OF POOR QUALITY**

This focus on practicality brings with it new responsibilities. The technologist must develop working relationships with the user to better understand the user's information needs and to help the user master a new technology. The potential users of remote sensing must also contribute to these relationships. They must often work with scientists who are unfamiliar with resource planning and management. Conflicts between users and technologists can impede remote sensing projects, or they can become opportunities for professional growth and the development of new concepts of monitoring and decision-making.

Landsat data are available through the U.S. Geological Survey's (USGS) Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota. The data handling process, from NASA through EROS to the public, was never intended to support operational requirements on turnaround time. The frequency of satellite overpasses is inadequate for monitoring some dynamic phenomena. However, the most important aspect of data availability impeding progress toward operational utilization is the lack of a long-term commitment to an operational Earth-observation program.

Recent NASA initiatives are aimed at addressing these issues in regional facilities at Ames Research Center, California; Earth Resources Laboratory, Mississippi; and, particularly appropriate to the Chesapeake Bay Region, the Goddard Space Flight Center, Maryland. In a variety of settings, potential users are being given the opportunity to work with remote sensing experts and to test the application of remote sensing to their information needs. The purpose of these programs is to enable potential users to discover for themselves the value of remote sensing and the processes by which they can use these data routinely. The programs are successful to the extent that the experiences of the customers lead them to become independent users of the technology. Remote sensing will make great progress toward operational status as these "adopters" become "change agents," influencing and assisting other potential users to integrate remote sensing technology into their operations.

Forums such as this workshop are needed as a mechanism to review where applications efforts are today and where they might be tested in the future. The interactions of technologists, potential users, and change agents provide the opportunity to match technology with issues and to explore options for the transfer of remote sensing applications to operational use.

Activities of the U.S. Geological Survey in Applications of Remote Sensing in the Chesapeake Bay Region

Two developmental remote sensing projects were jointly sponsored by NASA and the Department of the Interior EROS Program. These experiments focused on land use, land-cover inventory, and change detection, using remotely sensed data from aircraft, Landsats-1 and -2, and Skylab missions. One of these projects involved the Central Atlantic Regional Ecological Test Sites (CARETS). The other project is entitled the "Census Cities Experiment in Urban Change Detection."

The present major program deals with the data analysis of an operational land-use and land-cover system, including a supporting geographical information system. It relies heavily, but not completely, on remotely sensed data. Now in its third year, this program is nationwide and will therefore provide coverage of the Chesapeake Bay region. Even with the participation of cooperating state agencies, it will take another 5 years to complete first-time national coverage. An update of selected areas mapped earlier is expected to begin in 1979.

Recent developments in machine interpretation of multispectral digital data from Landsat show promise for data-analysis programs. The development of a semiautomated regional information system involves a sequence of five integrated steps:

- Initial land-cover inventory
- Intermediate map-like product
- Area analysis by likely jurisdictional statistical areas
- Preparation of separation plates for publishing a thematic land-cover map
- Detection of land-cover change and update of regional information

Products, applications, and related user experiences from demonstrations in the San Francisco Bay and Puget Sound regions provide perspectives on the problems and needs of user agencies in the Chesapeake Bay region and on the extent to which evolving tools and techniques promise to help.

Operational Programs in Forest Management and Priority in the Utilization of Remote Sensing

The Forest Service of the U.S. Department of Agriculture has the federal responsibility for national leadership in forestry, including participation in setting national priorities, formulating programs, and establishing federal policies that relate to man and his natural environment. In addition to managing the lands in the National Forest System, the Forest Service performs research at 80 stations throughout the United States and assists state governments and private industry in managing 2554 million km² (631 million acres) of nonfederal forest and rangeland.

The magnitude of the problem faced by the Forest Service in assessing renewable resources for 6.5 billion km² (1.6 billion acres) of land, for making management decisions, or for giving technical assistance dictates some application of remote sensing.

Although most operational programs of the Forest Service employ some form of aerial photography, none are Landsat-based. The present 80-meter resolution of Landsat-1 and -2 is a major limitation to widespread use of these satellites for the Forest Service.

Increased quality and kinds of film emulsions have led to the use of true color and color infrared film and to the application of small-scale photography that includes large land areas within one frame. Resource photography is taken over all national forests on a 5-year average cycle. Airborne and tower thermal-scanner sensor systems are used by the Forest Service and states to detect and map forest fires; however, these have been used mainly as research tools.

Present plans do not include thermal or multispectral scanners as part of the Forest Service's operational systems. The Forest Service, several states, the Bureau of Land Management, the forest industry, and NASA are working both together and independently to develop the required methodology and to transfer it to the user.

The Forest Applications Program, a joint effort between the Forest Service and NASA, is committed to developing the remote sensing methodology for: (1) large-area forest and rangeland inventory, (2) insect and disease impacts on forests, and (3) monitoring of environmental effects of manmade activities.

Landsat and Other Sensor Data for Land-Use Planning in the Baltimore Area

In early 1976, the Regional Planning Council of Baltimore realized that their 208 Water Quality Planning Grant required a detailed, up-to-date knowledge of the land cover and use for the nonpoint source runoff models, in addition to knowledge of soil type, slope, etc. Investigations of the then current uses of the Landsat data revealed that there were no successful uses of Landsat data in identifying specific urban uses (other than densities of residential use, paved areas, and roof tops). It was therefore decided to combine the information on developed land uses from the aerial photographic interpretation and the land-cover data from the Landsat sensors. A number of systems available for processing Landsat and other sensor data were evaluated to determine how well they could meet the needs and goals of the 208 Project. This exercise had the added value of raising the level of local government expertise in data collection procedures, modeling, etc.

The preliminary output of the Landsat project at the Regional Planning Council has already spurred investigations into other types of studies that might be helped by using Landsat sensor data such as: (1) change detection (suburbanization, farm conversions, tree cuts, and land filling); (2) pollution monitoring (air, water); (3) weather effects (Hurricane Agnes, etc.); and (4) tree cover by species.

Remote Sensing, Geology, and Land Use

The term "remote sensing" is now frequently associated with aircraft and satellites using sophisticated sensors to map various features of the Earth's surface. On the other hand, remote sensing in the Earth sciences disciplines is an old concept. The use of seismometers to measure earthquakes has been known for centuries. Seismic methods using explosives or other acoustic sources have been used for about 50 years. Similarly, measurements of radioactive, magnetic, and electrical properties and of the Earth's gravity have been conducted for many years, both on the ground and from aircraft sensors. All of these remote sensing methods are perceived by the geologist as tools that provide additional insight into the structure, composition, and spatial relationships of the Earth's subsurface.

The remote sensing methods that have the most immediate application to the Earth sciences aspects of the Chesapeake Bay region are seismic, magnetic, and various down-hole geophysical logging methods and aircraft and satellite imagery. Gravity and radioactivity measurements are also helpful as supplementary methods.

The Maryland Geological Survey is currently conducting shallow seismic reflection profiling in the Chesapeake Bay. These methods give valuable data on the location, depth, and orientation of paleochannels beneath the bottom of the Bay and will give important insights into the geologic history of the Chesapeake Bay.

Digital data processing of Landsat computer-compatible tapes has been used to map mining activities in Maryland. This method has been used for mapping disturbed areas related to coal mining and is equally good for mapping other activities, such as sand and gravel extraction in the Chesapeake Bay region.

Maryland Automated Geographic Information System

The Department of State Planning established the Maryland Automated Geographic Information (MAGI) system in April 1974. MAGI is a computer-based information system designed to store geographic data in a consistent and coordinated manner. The stored information can be displayed by means of digital maps in a manner similar to standard map graphics. Through access to the Univac 1108 system at the University of Maryland, the data bank contains the following information useful for performing land-use analyses:

- Natural soil groups
- Geology
- Mineral resources
- Water and sewer service areas
- Transportation facilities
- Public properties

- Slope
- Aquifers
- Surface-water quality
- Natural features
- Vegetation
- Historic sites
- Existing land use
- Watersheds
- Electoral districts
- County-comprehensive plans

The capabilities of the MAGI system for rapid data retrieval and analysis permit the system to serve many of the information needs of local, regional, and state agencies. According to the U.S. Department of Interior, Office of Land Use and Water Planning, the MAGI system has the most comprehensive capability for the storage, retrieval, manipulation, and display of geographic data of any current statewide system.

The Maryland Department of State Planning became a "principal investigator" in the NASA/Earth Resources Technology Satellite (ERTS) program and, in 1975, published a document entitled "Investigation of Application of ERTS-1 Data to Integrated State Planning Maryland" that describes the potential for interfacing remotely sensed data with the MAGI system. This report also documents hardware improvements that are required for effectively using the satellite data for state planning purposes. Maryland tested the use of Landsat computer-compatible tapes for monitoring bare ground as an indicator of land development, as well as a host of related physical and environmental factors. Greater resolution capabilities would greatly improve the accuracy of such a routine.

Mission of a Remote Sensing Center

A University of Maryland faculty group suggested setting up a "Center for Remote Sensing" at the University to provide service, research, and education in the various disciplines comprising remote sensing. One of the objectives is to expose students to the possibilities inherent in remote sensing so that they are more aware of new techniques for detection and identification and the applications to a variety of environmental problems. This work will generate new research programs, many of which would be difficult to undertake by conventional techniques. In addition, the Center would provide state and local governmental agencies with training and services in the field of remote sensing.

The service function would emphasize the maintenance of current data bases and provide assistance on problem-solving by remote sensing. The Center would maintain current high-altitude and conventional aerial photography files for the state. In rapidly changing urban areas, the information on these photographs would be digitized annually and made available

to users in the form of computer maps, statistical files, cards, or magnetic tapes. The Center would also maintain a set of current, geometrically corrected Landsat tapes providing seasonal coverage of the state or region. The Center would respond to special request projects from state and local governments needing remote sensing technology for environmental, water-resource, land-use, transportation, or general planning decisions.

Though Landsat and other remote sensing platforms have been shown to have important applications to environmental problems facing state and local governments, acceptance of the technology has been slow. A major problem continues to be a lack of understanding and of opportunities for training in the user community; therefore, a Center should provide short courses designed for a community of users. Undergraduate courses would introduce students from resource-related fields to the potential offered by remote sensing. Graduate courses would be given both on- and off-campus to attract practitioners in the field.

The Center would function as an international service and training facility. In this capacity, the Center would offer academic courses at the Master's level for foreign students pursuing degree programs and would develop short courses designed especially for foreign personnel. These short courses would be suitable for presentation at foreign universities or in major governmental offices. The Center would also aid foreign governments in setting up remote sensing interpretation systems and professional teams.

Application of a Computerized Environmental Information System to Master and Sector Planning

The Maryland-National Capital Park and Planning Commission has worked with the USGS to develop a computerized environmental information system to meet the needs of a local planning program. Montgomery County, Maryland, was well-suited as a study area for this cooperative project because of the potential for urban expansion into environmentally sensitive areas and the availability of recently published, planning-oriented geologic information.

As part of the general plan adopted for the Maryland-Washington regional district, a sector plan was developed for the Shady Grove area because of the special impact anticipated from a projected major transit station. The Shady Grove planning sector was used as a test site to evaluate the computerized environmental information system described here.

The resulting Montgomery County Composite Mapping System (MCCMS) was designed to provide economical and efficient storage and retrieval of environmental information for planning, primarily in map form, and to provide for combining several types of mapping information to produce synthesis or composite computer maps. No familiarity with automatic data processing is required for working with the MCCMS because all planner interaction with the computer is accomplished through a series of formatted questionnaires.

Specifications set by the user control the computer mapping and analysis program in processing the stored source maps to retrieve, combine, and analyze the information they contain. The product of this process is a computer-generated map that may show only one factor, such as distribution of surface water, or a combination of several factors.

The overall environmental issues associated with the development of Shady Grove were addressed by means of the composite map and master-plan transparency at a workshop held by the Community Planning North Division to discuss the inputs of the Transportation, Research, and Environmental Planning Divisions of Montgomery County. Although the composite map provided a good method for discussing environmental problems associated with general urbanization, it was felt that the environmental analysis of Shady Grove could be expedited by the development of optimization printout maps for various types of specific land uses. Suitable criteria for three major types of land use were then established after testing various alternatives. Computer printouts were produced for each of the three land-use categories, and these composite maps contributed to the development of the Shady Grove Sector Plan.

It was concluded that the MCCMS provides a readily accessible geographic data base and a method for compositing and analyzing the mapped information it contains. The purpose of the MCCMS is to provide a rapid and reliable method for analyzing the environmental issues associated with the development of planning areas. This system provides a convenient tool for planning the effective utilization and conservation of natural resources.

The development of the MCCMS and the analysis of the Shady Grove sector afforded the opportunity for a unique cooperative effort to develop methods for including environmental considerations in the planning process.

RESOURCES OF THE BAY REGION

Only by treating the Chesapeake Bay as a "complete" system will its full resource potential be realized. Remote sensing provides the necessary tools for obtaining extensive synoptic coverage of the Bay. Such coverage will provide time-history that is not possible without remote sensing.

A wide variety of remote sensors now operates from boats, aircraft, and satellites. It is obvious that emphasis should be placed on how best to use the data from the sensors that are currently operational and those that are scheduled for flight on the new satellites (Seasat, Landsat-C and -D, and Nimbus-G), which are to be placed in operation during the next few years. The most important single area of concern is eutrophication in the Bay. The general consensus is that, in this area, remote sensing can be extremely valuable. Some of the sensors to be flown on the new satellites have been especially designed with spectral bands that are optimized for water penetration studies.

A new "remote sensing" tool that is now available to the Bay community is the physical hydraulic model of the Chesapeake Bay located at Mattapeake on Kent Island. A real challenge exists for Bay scientists and managers to "tie in" the capability of this facility for understanding Bay problems with remote sensing techniques using boats, aircraft, and satellites. The physical model could help guide remote sensing experiments toward a better understanding of the total Bay system.

On Measuring the State of the Bay

The three questions that were addressed are: What entities should be measured in a comprehensive data base? How close together should measurements be made in space and time? What should be done with the data? A brief discussion of the requirements of a Bay information system follows.

To be useful with existing scientific knowledge, the entities to be chronicled must include at least those items that have been measured and computed in the past. Salient parameters to be measured include temperature, salinity, dissolved oxygen, pH, turbidity, chlorophyll, alkalinity, suspended solids, current-vector field, ambient light, abundance of adult and juvenile stages and various species, trace toxins, nutrients, oxygen demand, and indicator bacteria.

The data must be compatible with an index or set of indexes that give a running numerical record of the overall condition of the Bay. Although there is no guarantee that a "Bay condition index" will ever be developed, it does impose requirements on the Bay data base, such as:

- Data should be numerical rather than descriptive.
- Data should be normalizable to a standard value set by a regulatory standard.
- Data should be as universally understandable and applicable as possible.
- Different items of data should cover the same time periods.
- Data should be capable of expansion or revision as dictated by improvement in data gathering technology or understanding of the ecosystem without loss of prior information.
- Data should be credible. (Both the measurement techniques, including validation and calibration procedures, and the error limits or uncertainties in data values should be entered as part of the data record.)

The spatial scale and temporal frequency must satisfy several criteria:

- Both global and focal spatial grids are necessary.
- Any spatial array of measurement points should be tailored to the spatial gradients in the quantity being measured.
- Similarly, time sequences should be fitted to the characteristic times for changes in the variables of interest.

Data gathering methods should exploit improvements in technology. Both acoustic and active optical devices should be exploited for sampling plankton distributions. Techniques used in routine practice appear to lag far behind what is technologically feasible. The underlying reason may be the unwillingness of any economic sector to subsidize the cost of developing new devices and measurement techniques.

After a data base has been designed and created, it must be used. Bay scientists and managers are not accustomed to having a centralized collection of data available to them because there never has been one. If and when a Chesapeake Bay data base becomes available, strong coercive measures, such as requiring its use as a condition of awarding grants or approving new regulations, should be invoked. The data program must contain built-in provisions to register extreme values. Water quality is often determined by extreme values, not averages. It is generally related to the effect of certain constituents in the water on one or more beneficial uses.

The following is a recommended approach to the design of a comprehensive data system. A working group would be assembled from the two principal factions involved with Chesapeake Bay information: (1) those who gather and study information, primarily scientists and agency field personnel; and (2) those who need information, chiefly governmental officials, but also personnel in industry, recreation, and commerce. This group would meet in a series of intensive planning sessions with the specific goal of answering the three questions previously addressed in this section.

The group should proceed by analyzing several actual Chesapeake Bay phenomena on a case-by-case basis to learn what kind of historical data would have been desirable for a working understanding of each phenomenon if these data had been on hand when the event occurred.

The following case studies are recommended for consideration:

- The steep decline and partial recovery in abundance of submerged aquatic grasses
- The recruitment failure of Bay spawning species

- The effect of the unusually cold winter of 1976-77 on fish, shellfish, and crabs
- The peculiar mortality patterns of benthic species in the Chester River
- The apparent eutrophication of the Bay
- Kepone in the James River
- The effects of very high pulsed freshwater flow from the Susquehanna River, such as that caused by Hurricane Agnes and spring "freshets"

Use of Remote Sensing Technology Provided by the NASA/WFC Chesapeake Bay Ecological Program

For a decade the NASA/WFC has been involved in the introduction of remote sensing to resource and environmental managers in the Chesapeake Bay region. In a symposium on remote sensing held at Wallops Island in 1971, the goals of NASA were outlined and included gathering environmental data and using the data obtained for prediction of future events and as a basis for taking action concerning environmental matters. The NASA/WFC Chesapeake Bay Ecological Program, a remote sensing program, was initiated in 1971 to further implement these goals.

In a 1975 study contracted through NASA/WFC, the Appalachian Environmental Laboratory of the Center for Environmental and Estuarine Studies assessed the use of remote sensing technology provided through the Program. The primary objective of the study was to determine the extent to which remote sensing technology was used by persons and agencies initially requesting it and by others to whom it was referred.

Personal interviews were conducted with representatives of the 65 regional managerial agencies that had requested the cooperation of NASA's remote sensing capability, including federal, state, county, and municipal agencies, universities, and private firms.

The user agencies employed remote sensing data in 136 different managerial projects with a wide range of implications, including environmental, socioeconomic, political-managerial, monetary, and legal. Of the completed projects (51 percent), approximately 89 percent were considered fully successful, and only 2.8 percent were considered unsuccessful. Remote sensing was believed to be a cost-effective technique for accomplishing the goals of the specific project. In addition, effective alternatives were not available, at any cost, for 30 percent of the project.

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Hydraulic Model of the Chesapeake Bay

The Chesapeake Bay is a complex estuarine system. The solutions to its problems involve complex analyses using analytical tools that reduce the Bay to a workable scale. One such tool is the hydraulic model of the Chesapeake Bay built by the Army Corps of Engineers at Mattapeake, Maryland—the largest estuarine model in the world (36-km² (9-acre)). The model represents the Bay proper, all of its tributaries up to the head of tidal effects, and the adjacent overbank areas to an elevation of 6.1 meters (20 feet) above mean sea level.

The model is a fixed bed, geometrically distorted type, with a horizontal scale of 1 to 1000 and a vertical scale of 1 to 100. This combination of scales provides the most economically sized model that will accurately reproduce the vertical and lateral distributions of current velocity, salinity, and tidal elevation. A 12-hour and 25-minute tidal cycle can be reproduced in approximately 7.5 minutes, or 1 year in 3.65 days.

Hydraulic studies of the model began in the spring of 1977, and the initial program of studies has been formulated, including

- The Low Freshwater Inflow Study to determine the effects on the salinity regime of significantly decreased freshwater inflows
- The Baltimore Harbor Channel Study to determine the effects of deepening the channels from 13 to 15 meters (42 to 50 feet)
- The Potomac Estuary Water-Supply Study to determine the ramifications of using the Potomac Estuary as a supplementary water supply for the Metropolitan Washington area

Landsat Sensors

Landsat-1, launched in July 1972, and Landsat-2, launched in January 1975, are equipped with similar complements of sensors. Each satellite has both a return-beam vidicon (RBV) camera system and a multispectral scanner (MSS). The RBV operates by shuttering three independent cameras simultaneously, each sensing a different spectral band in the range of 0.48 to 0.83 micrometers. The MSS is a line-scanning device that continuously scans the Earth's surface and records reflected radiation in each of four spectral bands from 0.5 to 1.1 micrometers.

On Landsat-C, to be launched in February or March 1978, both the RBV and MSS sensors have been improved. The new RBV system uses two panchromatic cameras that produce two nearly side-by-side images, and the effective resolution of the sensors has been increased

from 80 to 40 meters. The MSS has four visible spectral bands, plus a band in the thermal infrared. The thermal band enables the sensor to collect data during the nighttime portion of each orbit. The thermal data will be used for urban land-use identification, for visualizing temperature gradients in power-plant outfalls, and for detecting urban "heat islands." Resolution of the thermal band will be 240 meters.

Major changes have also been made to the NASA Image Processing Facility at the Goddard Space Flight Center in preparation for handling Landsat-C data. High-density digital tapes will replace film as the archival medium for all the data, which, in turn, will be available to users in the computer-compatible tape format.

Landsat-D, currently in the design and planning stage, will be equipped with a new sensor, the thematic mapper, with five bands in the 0.45- to 0.75-micrometer range, plus a thermal band in the 10.4- to 12.5-micrometer range. These bands have been chosen primarily to discriminate vegetation. Spatial resolution of the thematic mapper will be increased from the 80-meter instantaneous field of view (IFOV) now available with the MSS to a 30-meter IFOV, except for the thermal band, which will be 120 meters. Tracking and data-relay satellites will be used to gather data from the thematic mapper outside the range of real-time receiving stations, thus eliminating the need for onboard tape recorders.

Remote Sensing of Water Quality

Remote sensing from satellite or aircraft offers a method of observing a large area such as the Chesapeake Bay in a very short period of time. For example, a satellite such as Tiros or Nimbus can observe the entire Chesapeake Bay in less than 1 minute. Although high-altitude aircraft take somewhat longer, they can cover the Bay in about 2 hours. Aircraft sensors offer the advantage of much higher spatial resolutions with considerable lower cost instrumentation than can be obtained using spacecraft sensors.

Reasonably high-resolution sensing (80 by 80 meters) is accomplished from the Landsat series of satellites using the multispectral scanner, but such resolution is achieved at a considerable cost in sensor swath width (186 km) and infrequent coverage (once every 18 days, cloud cover permitting). In addition, the dynamic range of the Landsat sensor is optimized for land targets that reflect much more than water so that subtle changes in water color are more difficult to detect.

Water quality and content can best be remotely sensed by multichannel scanning radiometers, which provide much higher signal-to-noise ratios than photography, are more accurate quantitatively, and can operate in spectral regions not covered by film, such as the thermal infrared. The electrical signal generated by these sensors can be more readily processed for reduction of atmospheric effects and can be used for multispectral qualitative analysis. The disadvantages of scanner systems are that the scanners are expensive and data recording/processing equipment is more expensive and complex than that needed for photography.

For satellite and high-altitude aircraft sensing, however, the advantages far outweigh the disadvantages, and scanner systems predominate.

An extensive program in which NASA's multichannel ocean-color scanner was flown on a U-2 aircraft over the New York Bight off Sandy Hook proved to be fairly successful. Although the New York Bight results indicate that sensing of total suspended material is a promising area for remote sensing, it also showed that it will be very difficult to identify and quantify suspensoids in a system as complex as the Chesapeake Bay. An opportunity will be available in 1978 to conduct such investigations when Nimbus-G is launched carrying the coastal-zone color scanner. This sensor will provide color scanning in five spectral bands and thermal scanning in one band with 800-m resolution and 1500-km swath width for frequent coverage. Data from this scanner will be available at nominal cost from the NOAA Environmental Data Services in Suitland, Maryland.

Active Acoustic Remote Sensing of the Environment

Remote acoustic techniques are being developed at NOAA to measure environmental parameters. In addition to the uses of acoustics classified as sonar in bathymetry and target physics, new techniques are being developed to probe the atmosphere for thermal profiles and wind velocities and also to probe the water for current velocity profiles, turbulence and density profiles, wave spectra, and wave velocities.

The National Ocean Survey is concerned with developing a remote Doppler acoustic current sensor. Devices that incorporate such sensors will be used on ships or on bottom-mounted tripods for profiling water currents in depths up to 100 meters. A goal of this effort is to obtain profiles of currents with minimum vertical resolution cells of about 4 meters.

Work has begun at Catholic University in Washington, D.C., to model the acoustic scattering characteristics of the turbulence that should be expected in the water column* at frequencies of hundreds of kilohertz. Instrumentation that can identify and profile turbulence would be a valuable tool in the study of vertical mass and energy transport in the water column.

Conceptually, the application of active acoustic remote sensing to the Chesapeake Bay region might take the form of a number of devices with multiple acoustic sensor channels placed on the bottom at significant locations in the Bay. These devices would be hardwired to shore and would provide continuous monitoring of the various physical parameters, such as currents, tide, waves, and mixing turbulence. Atmospheric acoustic sensors could be installed either in the shore stations or on surface buoys to give data on winds and air temperature profiles. Such an integrated system of continuous marine and atmospheric monitoring of the Chesapeake Bay region would provide a valuable core of data that could be

*The water column is defined as a volume of water whose cross-sectional area is given by the field of view of the instrument, and extends from the instrument to its maximum range in the water.

used as a basis for a real-time predictive environmental alarm for the region. Applications for the data are almost unlimited, the most significant being verification of models describing the interchange of energy between the Bay and atmosphere.

Regional Energetic Coupling of Man and His Environment—Data Requirements

It is recognized that human and natural systems are coupled and can be interpreted, using a common base of energy-flow analysis. This analysis can be used to evaluate past, present, and future states of regional integrated systems in the coastal zone and to provide the capability for rational selection of alternative patterns of resource use. Energy flows (or flows of dollars or materials converted to energy equivalents) are believed to be the basic factor in the organizations of all types of systems. Therefore, if the energy basis of a system, such as the Chesapeake Bay region, can be estimated quantitatively, alternatives can be selected that will tend to enhance the value of that system's quality of life, as well as to permit comparisons with other systems of interest. Current remote sensing capabilities are permitting some analysis of an estuarine subsystem of the Chesapeake Bay, and regional data needs are given. It is suggested that the energetic concept described here may provide remote sensing specialists with challenges for employment or development of new sensing devices.

Relationship of Land Use to Water Quality in the Chesapeake Bay Region

Land use on the drainage basins of the Bay strongly affects the composition of runoff waters and thereby the water quality of the Bay. Both the proportions of the land-use categories present on each watershed and the local management practices affect the quality of runoff waters. This phenomenon is usually categorized as nonpoint or diffuse-source pollution. A research program designed to quantify diffuse-source pollution in the Chesapeake region was begun in 1973 by the Smithsonian Institution. Several small watersheds on the Rhode River (an arm of the Chesapeake Bay just south of Annapolis, Maryland) were instrumented to measure water discharge and to take volume-integrated water samples.

Several portable stations also operate on the Potomac River and move from basin to basin to collect data on seasonal discharges. Each basin is mapped with respect to land use by low-elevation aerial photography. All data are processed and stored in the Smithsonian Institution computer data bank. Average seasonal area-yield loadings from each land-use category for each parameter are then calculated. Categories under investigation include forest/old fields, pastureland, row crops, residential, upland swamps, and tidal marshes. These data are used to determine year-to-year variation in diffuse-source loading caused by weather variations and area-to-area differences attributable to topographic and geological differences and to predict long-term changes in diffuse-source loading caused by urbanization and other land-use shifts in a given area.

Permanent stations are under construction on the Choptank River at the University of Maryland's Horn Point Research Center. All stations will collect volume-integrated samples to be analyzed for nutrient, particulate, bacterial, herbicide, and heavy metal parameters.

Other studies are directed toward developing watershed models and determining the effects of altered land-use practices (e.g., the use of minimum-till or no-till practices in corn production). In these studies, intensive data are collected on land-use practices, weather, soil chemistry and physics, and vegetation.

NCSL Task Force Findings on Feasible State Uses of Landsat

The National Conference of State Legislatures (NCSL) appointed a Task Force to review state applications and limitations of NASA's current and proposed Landsat capabilities. The NCSL is a service organization that fosters interstate cooperation and increased effectiveness of state legislatures and works toward a strong state voice in the federal decision-making process.

Existing Landsat applications performed by state data users were presented to the NCSL Task Force in a survey of 136 state agencies now using satellite data. Format testimonies were also presented to the Task Force by a number of state program managers. The following key state programs emerged as having high demand for satellite remote sensing data:

- Land-use planning
- Wetlands management
- Coastal-zone management
- Flood-plain management
- Water-quality management
- Transportation planning
- Forestry management
- Water-resources planning
- Land reclamation
- Air-quality management
- Agriculture
- Fish and wildlife
- Solid-waste management
- Environmental impact statements

Particularly interesting examples occur in programs in Texas, Georgia, and the Pacific Northwest.

The Task Force concluded that the Congress and the states should actively support continuation of the Landsat Program with its proposed improvements (e.g., 30-m resolution and

better vegetation-analysis capabilities). They unanimously agreed that Landsat data can potentially fulfill many state information needs. However, implementation of the highly technical Landsat capabilities as an information tool requires more than a satisfactory performance by the satellite. It became obvious to the Task Force that the real difficulties in the program are in building the states' capabilities for using the satellite technology.

Transfer of a new technology is not an easy process. The NCSL urges the states to establish effective in-state communications processes for a coordinated state approach. Awareness of the alternative approaches and their potentials and pitfalls is essential to the transfer process. Landsat technology offers tremendous potential for assisting states with their data requirements. The federal government should carry through with making it a reachable, operational program for the states. Each state will then be responsible for making a serious commitment to its utilization.

POLLUTION PROBLEMS OF THE CHESAPEAKE BAY REGION

Remote sensing portrays the Chesapeake Bay region in a much broader perspective than is usual in day-to-day operations of water-quality management. The Chesapeake Bay is much larger than the Charles River in Boston or the Delaware below Philadelphia, which are severely impacted with water pollution problems. Because the major development centers are on tributaries rather than on the Bay and because of its size, the Chesapeake Bay is less directly affected by human impacts. This means that more subtle effects are expected; by the same token, great difficulties may develop before they are recognized.

Remote sensing lends itself well to: (1) identification of the problem and problem areas, (2) monitoring and managing the aqueous environment and the subtending land areas that influence the aquatic habitat, and (3) long-term trend studies that are difficult to perform under present institutional structures and costs.

The application of remote sensing to environmental changes and problems is just beginning. New methods require testing time to become validated, and managers bemoan the fact that the hardware required for their immediate problems does not already exist. Many interesting parameters escape direct detection; a great need exists for developing inferential methods that will yield a desired result indirectly but reliably. For example, salinity that can be sensed reflects many known biological systems, and the variations of the salinity can be used as an indication of some biological responses. This concept must be greatly expanded, problems must be defined, and new hardware must be developed.

An Overview of Dredging Operations in the Chesapeake Bay

The Corps of Engineers maintains about 120 navigation projects in the Chesapeake Bay that support seafood-related commerce and recreational activities. These projects result in varied environmental effects on the ecosystem of the Bay.

Baltimore Harbor and Newport News/Norfolk Harbor are located on the Chesapeake Bay; the Chesapeake and Delaware Canal, which provides the port of Baltimore with a second access route to the shipping lanes of the world, is located at the head of the Bay. To dig and maintain these navigation projects, dredges are used for removing shoaled material. Dredged material is disposed of on land, in deep water, in lowland, or in shallow-water areas. This maintenance is a responsibility of the Corps of Engineers. The Baltimore District annually dredges 1.1 million cubic meters (1.4 million cubic yards) of material from the Chesapeake Bay and its tributaries.

New laws have affected the manner of dredging. Although these laws and regulations indicate some specific actions (such as the preparation of an Environmental Impact Statement, issuance of a Public Notice, or holding a Public Hearing), the intent is to require the Corps of Engineers and other agencies to consider a broad range of factors that may affect the public interest. This may result in deferral of a maintenance project or restrictions that make the project more expensive. Congress has enacted the Water Resources Development Act of 1976, which authorizes the expenditure of up to \$400,000 per project if wetland creation or restoration alternatives are employed. The two major factors in the delay or added expense of any given project are time constraints on the dredging activity and the use of upland, confined disposal sites rather than overboard, unconfined ones. These two factors arise from increased concerns about the effects that dredging and disposal have on seafood reproduction and growth by creating turbidity and by loss of benthic habitat.

Remote In-Situ Elemental Analysis Systems for Underwater Application

A group of investigators from the Energy Research and Development Administration (ERDA), NASA, NOAA, USGS, and the University of Maryland is now considering the application of remote elemental analysis systems to terrestrial problems. Of particular interest to the group is the problem of monitoring and mapping pollutants such as traces of heavy metals in the Chesapeake Bay region. The type of system being considered is a "free-flying" submersible vehicle that would operate underwater very much as an automated space satellite in orbit or on the Moon. Equipment on this vehicle would analyze metallic pollutants in sediment and perhaps in the surrounding water.

The experiments for remote underwater operation are strongly affected by low-power operations and the instrument survival requirements in a rather hostile environment. The developed system is made up of four parts: (1) the excitation source and detector instrument, (2) the data preprocessor section, (3) the data transmission system, and (4) the data analysis and interpretation portion. By separating the system this way, using distributed intelligence microprocessors and the developing interactive-analysis programs, the environmental, power, and data requirements can be achieved.

A neutron gamma-ray method is now being developed to demonstrate this system. The excitation source to be used is an accelerator using a deuterium/tritium reaction to produce

14-MeV neutrons. The neutrons excite characteristic gamma-ray emission from the irradiated surface. The discrete line emission produced can be used to infer both qualitative and quantitative elemental composition. The neutron die-away time can also be used to determine composition.

A data preprocessor developed at the Goddard Space Flight Center for space-flight application will be used to accumulate, digitize, store, format, and prepare the composition data for transmission. A major consideration in the development of the preprocessor hardware and software involves the development of programs that will accumulate the data without degrading the information content.

Data transmission through the data preprocessor can be accomplished by telephone, microwave, and, possibly, by satellite link from remote sites to central data processors. All three methods have been successfully demonstrated. The final link in these systems involves the use of large and small computers at a central data processing complex.

For application to the measurement of pollutants and their distributions in the Chesapeake Bay, a number of modifications to the system have to be made. For instance, the sensitivity of the neutron gamma-ray source-detector to the expected contaminant levels must be studied. The study program has begun, and sufficient work to demonstrate system feasibility should be completed by the end of 1977.

Thermal Discharges and Their Role in Pending Power-Plant Regulatory Decisions

Concern about thermal pollution by electrical power plants has prompted strong federal legislation and has caused the creation of many governmental and private groups to make assessments of aquatic impact. The present emphasis is on measurable, in-plant "cropping" of entrainable forms such as fish larvae, which tends to be specific to the power plant as well as to the site. The quantification of thermal stress and the response of aquatic biota is crucial for utility industries in deciding whether to backfit condenser cooling (artificial lakes, spray ponds, or cooling towers).

The 316a Variance Procedures under the National Pollution Discharge Elimination System require such a retrofit with offstream cooling by 1981 unless it can be demonstrated that this control of waste heat is more stringent than necessary for the protection and propagation of balanced indigenous populations. Power plants subject to these provisions are all major (> 500 MWe) steam/electric stations that began generating after January 1970 or older units failing to comply with state water-quality standards.

Decisions are much more pressing than the 1981 deadline, because cooling-tower construction requires lead times of 2 years. The focus of 316a is clearly on ecosystem yield and stability rather than water-quality parameters. The water plume from a power plant undergoes

successive dilution that changes its properties *vis-a-vis* excess temperature and exposure time. This modifies its stress upon biota and the ways it can best be monitored.

Numerous 316a issues can be settled by monitoring a power-plant plume from the cutfall location outward to the region where the plume has been diluted by a factor of about 10.

Traditional methods are adequate for monitoring within this dilution regime, but remote sensing promises to reduce costs and turnaround time. Thermistors, in towed strings or fixed arrays, obtain thermal maps for desired depths, tidal stages, and seasons. The time and space resolution of this approach is limited only by the number of boats and crew, and by the sponsor's ability to pay. Pumped sampling of fluorescent dyes is an equivalent method that is less hampered by ambient patchiness. Airborne photography of discharged dye integrates through the water column, so that detection and interpretation is limited. Infrared photography is helpful for flow and patchiness visualization, but is limited to a qualitative role unless extensive ground truth relates surface temperatures to what is beneath.

Overhead lidar (laser-radar) tuned to fluorescent dyes released in the discharge has the potential for giving a synoptic view of power-plant plume evolution. This technique will probably be cost-effective in its reduction of manpower for surface-based collections and data analysis.

Work on Power-Plant (Air) Plumes Involving Remote Sensing of SO₂

Since 1972, the Maryland Power-Plant Siting Program has been monitoring the air quality and meteorological data from four fossil-fuel power plants that lie on tributaries of the Chesapeake Bay.

A principal tool in the acquisition of air-quality data has been the Barringer remote sensing correlation spectrometer (COSPEC), a passive detector that uses selective absorption of atmospherically scattered sunlight to determine total overhead burdens of SO₂ and NO₂.

The COSPEC is incorporated into an Air-Quality Moving Laboratory in an upward-looking mode. Air-quality data related to the stack plumes of a power plant are obtained by making a series of traverses through the plume at several distances from the plant. The result of each traverse is a nearly instantaneous picture of the total overhead burden of SO₂ integrated vertically by the COSPEC; a complete set of six to eight traverses at a given radius gives a picture of both plume dynamics and average behavior over a period of 1 hour. The COSPEC can also be used to measure the rise of the plume.

The first application is the calculation of SO₂ mass flow, obtained by using the COSPEC burden data, together with simultaneous wind-profile data. The second is the refinement of plume-dispersion models in which the COSPEC data are used primarily to determine parameters of the plume's geometry.

Lidar: A Laser Technique for Remote Sensing

Lasers offer increasingly practical means for remote sensing of the environment. A laser-radar (lidar) instrument transmits a short, intense, and highly directional flash of light, whose backscatter or reradiation into a receiver telescope carries information about environmental conditions all along the line of sight. The variation of conditions with distance from the receiver is realized in the form of time variations in the received signal because of the finite velocity of light (300 meters/ μ). The practicality of lidar arises from the development of rugged stable lasers and electronic data systems that store and process the time-dependent lidar returns. Lidars can be installed on ships, aircraft, and satellites, as well as on ground stations.

In both air and water, the backscatter of light by small, suspended particles is the basis for various laser applications:

- Turbidity of coastal and estuarine waters is measured by airborne lidar.
- Aerosols are studied by lidar, including inversion layers in the air above industrial cities, cloud structure, stratospheric dust layers, and disposed plumes from power plants.
- Atmospheric gases are detected by combinations of lasers, one of which is tuned to absorption bands of the gases.

Bathymetry uses the time difference for the laser returns from the surface of the water and the bottom sediment. Rapid mapping of shifting depths in coastal and estuarine waters is an important application. In clear water, bottom types may be characterized by the bottom reflectivity deduced from lidar returns.

Oil and algae in the water can be detected and, to some extent, identified by means of their fluorescent response to lasers. Because of high sensitivity, airborne lidar is potentially very useful for the early detection of oil spills and for mapping the periphery of a spill as a function of time. Work is proceeding on airborne laser detection and identification of chlorophyll and various algal species.

Lidar stimulation of dye fluorescence is a promising extension of the "dye-drop" technique for mapping the flow of water. The potential exists for synoptic lidar mapping of dye concentrations over a large spatial grid, while simultaneously obtaining data on the depth variation of water currents.

Lidar should now be considered as part of the overall approach to a specific environmental problem, such as power-plant siting. Rapid coverage of air space and water area are

characteristic advantages to be weighed against the cost and expertise required for a lidar installation. The present status of lidar practice is one in which significant ongoing support is needed and readily justified for field instruments and testing.

Water Quality and Shellfish Sanitation

The Environmental Health Administration of the Maryland Department of Health and Mental Hygiene regulates the public health aspects of shellfish harvesting. This responsibility stems from the National Shellfish Sanitation Program (NSSP), a control procedure administered by the U.S. Food and Drug Administration.

The NSSP requires all shellfish-producing waters to be surveyed for their acceptability in meeting certain minimum standards. These surveys include: (1) evaluation of actual or potential pollution on the estuary and its tributaries and the distance of such sources from the growing areas; (2) effectiveness and reliability of sewage treatment plants; (3) the presence of industrial and agriculture wastes, pesticides, heavy metals, or radionuclides that would cause a public-health hazard to the consumer of the shellfish; and (4) the effect of wind, stream flow, and tidal currents in distributing pollutants over the growing areas.

The present monitoring program entails a monthly collection of bacteriological water samples and the determination of physical parameters at approximately 2200 stations located in the Bay and its tributaries. Shellstock is routinely collected for analysis from the growing areas. To identify and eliminate sources of pollution, survey crews conduct a property-by-property evaluation in all land areas adjacent to growing waters. There is also a sampling program on effluents from sewage treatment facilities.

The use of remote sensing techniques for collecting bacteriological, physical, and chemical water-quality data, locating point and nonpoint sources of pollution, and developing hydrological data could be extremely valuable to this program if it could produce the foregoing information effectively, rapidly, and with a minimum amount of ground truth.

Eutrophication in the Chesapeake Bay

According to a 1974 NASA/WFC preliminary survey of Chesapeake Bay problems, excessive nutrient additions pose the greatest danger to the continued well-being of the estuary.

Ecological consequences of heavy nutrient loads include high primary productivity, followed by increased oxygen demand for respirations. Historical data from the Patuxent River estuary exemplify the Bay-wide trend toward such eutrophication.

Uncertainties still remain concerning the mechanisms of stimulating bloom conditions in estuarine waters. Whether it is nitrogen or phosphorus removal that is the more effective in inhibiting eutrophication is a scientific question with management implications that may have multimillion dollar consequences.

Inferring Nutrient Loading of Estuarine Systems by Remote Sensing of Aquatic Vegetation

Nutrient loading and sediment cause water-quality problems in many estuarine systems, including the Chesapeake Bay and its tributaries. Several investigators have used remote sensing, including aerial photography, multispectral scanners, and thermal imagery, to qualitatively examine the water quality of estuarine systems. Recent research has centered around the use of remote sensing to quantitatively estimate the sediment and chlorophyll content of estuaries.

Major point sources of pollutants are known, and control measures have been instituted in some areas of the Bay. However, nonpoint sources are also considered to be a major factor in Bay pollution. These nonpoint sources are considerably more difficult to locate and control than point sources. Remote sensing appears to have great potential for identifying nonpoint sources of nutrients and sediments.

Experiments involving the use of remote sensing for inferring nutrient loading have been approached from two standpoints:

- Identification of nutrient loading sites through field investigation or low-altitude photography of sentinel aquatic plants; use of high-altitude photography to identify land use for the drainage basin; mapping potential nonpoint sources of nutrients; selective water sampling to quantify results; and recommending best management practices.
- Use of Landsat or high-altitude photography to develop land-use data base; inferring potential nonpoint sources from land-use and corollary data such as topography, these inferences being derived from visual interpretation or by fitting to a nonpoint sources model; low-altitude aircraft surveillance for vegetative indicators of nutrient loading; selective water sampling to quantify results; and best management practices.

Experiments have shown that remote sensing has potential for detecting and mapping surface manifestations of algal and vascular aquatic plant growths in estuarine waters. In most cases, it has not been possible to separate species. Excessive growths of some aquatic plants may be related to nutrient pollution. A remote sensing scheme has been proposed for classifying the watershed with regard to severity of potential pollution. Lower altitude photography of vegetation and selected ground sampling may be used to identify specific nonpoint sources of nutrients in tributaries of the watershed.

Progress Toward a Circulation Atlas for Application to Coastal Water Siting Problems

Circulation data needed to resolve coastal siting problems can be assembled from historical, hydrographic, and remote sensing studies in the form of a Circulation Atlas.

The siting of coastal facilities to utilize water resources requires assessment of local circulation. Circulation studies are needed with respect to siting sewage and industrial outfalls, municipal water-supply intakes, oil tanker and pipeline routes, tanker loading facilities, electric power generating stations, and harbor construction or modification projects. These needs can be met by either direct field study of circulation at the sites in question or use of numerical or physical hydrodynamic models. However, limitations in these approaches provide the stimulus for a continuing search for new or improved methods. Remote sensing cuts the time and expense of circulation studies and permits simultaneous study of alternate sites.

In compiling a Circulation Atlas for a given region, special efforts must be undertaken to evaluate earlier circulation studies and to uncover data gaps in terms of spatial, tidal, and wind-vector dimensions. The data sources include hydrographic studies, dye studies, and aerial and satellite remote sensing studies. This special effort is then the prelude to all future study of local circulation in that it defines which new studies must be performed to complete a sufficiently detailed picture of local circulation. The result is a uniform format for data emanating from studies using different methods. Empirical data are used rather than numerical model simulations to achieve fine resolution and to include fronts and convergence zones. Eulerian and Lagrangian data are collated, transformed, and combined into trajectory maps and current-vector maps as a function of tidal phase and wind vector.

For initial development of the Atlas concept, effort is being centered on circulation in the Elizabeth River, Hampton Roads, Virginia. This test area is a relatively small river basin with several river branches. It is heavily polluted and has not been the site of many circulation studies. Although only a portion of the data from earlier and recent Elizabeth River experiments has been reduced, progress has been made in developing the concept of a Circulation Atlas based on empirical data and in defining methods of data collation and synthesis.

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SUMMARY OF WORKING GROUP REPORTS AND CONFERENCE REFLECTIONS

A major emphasis of the Conference was on the six working group sessions that took place during the last half of the Conference. Topics for these working groups were based on the results of a questionnaire that was distributed to all conferees before the Conference. This section includes summaries of the working group sessions; their papers, which were complete after adjournment of the Conference, appear in the Conference Proceedings, Volume 2. The concluding summary of this section is a brief synopsis of the presentations entitled "Conference Reflections." All salient recommendations made during these working sessions appear in the "Conference Recommendations" section of this volume.

CONTRIBUTION OF REMOTE SENSING TO UNDERSTANDING THE BAY AS A SYSTEM

In considering a target as large and dynamic as the Chesapeake Bay, remote sensing from satellites possesses two indispensable attributes: (1) the synoptic view that can be achieved from space, and (2) the repetitive observations that are uniquely affordable from space.

Remote sensing from aircraft can provide much more detail than that from satellites. No regularly scheduled acquisition system exists for providing repetitive coverage for dynamic processes, and, even if there were, it is questionable if any agency could afford such a system. Metsats currently provide approximately 1/10-km resolution in the visible and ranges of 8/20- to 2-km in the thermal infrared for polar orbiters. Geosynchronous Metsats (Geostationary Operational Environmental Satellite) offer coarser spatial resolution (2 to 8 km) but much finer temporal resolution (30 minutes full-frame, -7.5 minutes zoom). It follows that the perspective of the problem is either very large, very dynamic, or both. Because these two attributes describe the Chesapeake Bay, it is appropriate to determine what this new technology can contribute to understanding the Bay.

The Chesapeake Bay is assumed to include the lithosphere, the hydrosphere, the atmosphere, and the biosphere (that is, the vertical profile encompassed by the systems and a two-dimensional plane defining the total watershed of the Bay from the headwaters of its tributaries to a distance in the ocean defined by ten tidal cycles). Also, the Chesapeake Bay system is assumed to be the ecosystem in the largest sense.

An information system concept was discussed that was designed specifically for use with remote sensing. It is a closed-loop model and is centrally oriented in that information flows to management while requirements for information flow from management.

If there is a unifying theme to the information system concept, it is expressed in the phrase "the convergence of evidence." These words describe both the method and philosophy of the approach. In merely stating the goal of the technology—to provide a current assessment of the status of the Chesapeake Bay—it is necessary to realize that one is trying to monitor and, in some cases, to predict the behavior and the interaction between three of our most dynamic environments—the atmosphere, the hydrosphere, and the biosphere. The convergence-of-evidence approach is in recognition that this is both a complex and dynamic problem and that the sources of input data vary in their precision and in their reliability. The concept implies that there are several input data sources, as indeed there are.

Studies on land systems have resulted in a methodology for partitioning the land into meaningful ecological units, representing land capability classes in terms of both natural processes and human activities. This ecological partitioning is designed to greatly improve the reliability and cost-effectiveness of all kinds of statistics related to productivity, land use, and natural resources.

ROLE OF REMOTE SENSING IN DOCUMENTING LIVING RESOURCES

The most immediate role that remote sensing, particularly from satellites, can play in documenting living resources in the Chesapeake Bay is in assessing population distribution and fluctuations of aquatic plants. It is strongly recommended that the following projects be undertaken as soon as possible:

- An investigation should be undertaken of the archival photography of the Chesapeake Bay to attempt an estimation of rooted aquatic population excursions over the last 30 to 40 years. To some extent, this recommendation is being carried out at the University of Maryland.
- There should be an investigation of satellite data to determine the sources, distribution, and fate of suspended particulate matter. We believe that the satellite data we now have, particularly Landsat, could give some indication of the dynamics of the suspended materials in the Chesapeake Bay.
- Possibly based on information generated from the projects outlined above, we believe that land use should be cataloged on a watershed or subbasin basis in the Chesapeake Bay Region watershed. We then could possibly infer organic and inorganic content of runoff on a watershed basis. Satellite data on land use have been valuable in recent years. The current Maryland geographical-based information system could be of definite value to this project.
- Field research is needed for obtaining a better data base in certain subject areas. A subsequent step should be the development of techniques and instrumentation

for gathering such data from remote platforms. Projects would include the assessment of the tolerances of important submerged grasses to salinity, temperature, pesticides, turbidity, heavy metals, and other factors. Also, more documentation and assessments are needed of the impact of submerged grass population excursions on important faunal components of the Bay.

USE OF REMOTE SENSING IN FACILITY SITING

Environmental studies related to the siting of major facilities, such as energy, industrial, and waste treatment, provide significant opportunities for the application of certain types of remote sensors. Although aerial photography, infrared scanning from satellites and aircraft, and side-looking radar are useful for site location surveys and surface geological studies, the remote sensing instruments most applicable to siting studies include special-purpose radars, lidar, radiometers, acoustic sounders, multispectral scanners, and special-purpose sonar. It is usually characteristic that these equipments provide a "data field" in the neighborhood of the site, rather than point sampling. Such instrumentation can be applied in both pre-construction studies and postconstruction monitoring.

A few remote sensing instruments are available in commercial form, but most are either "on the shelf" in government development laboratories or in earlier stages of active development. In neither of the latter two cases is the equipment easily available to user groups. NASA's program to transfer this technology to public use has moved very slowly because potential user groups have been unable to fund the development of the equipment to operational status.

The major problems that must be overcome if these equipments are to be used are:

- Proofing programs that will provide the validation of remote sensing data to the satisfaction of the legal system in adversary actions must be devised.
- Funding for the engineering required for commercial development must be provided.

ROLE OF REMOTE SENSING IN DOCUMENTING LAND USE AS IT AFFECTS THE BAY AND BAY USE AS IT AFFECTS THE LAND

This group discussed two problems: (1) the role of remote sensing in documenting land use as it affects the Bay, and (2) the need for a "clearinghouse" for all remotely sensed information that has been and will be acquired over the Bay and its drainage basin.

It was recognized that any comprehensive water-quality project should investigate the causal factors that affect the water quality. These factors may well result from improper land use (nonpoint pollution). The remote sensing technology required to locate, identify,

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and monitor these nonpoint pollution sources as available; it need only be applied. The mechanics of land-use surveys (nonpoint pollution source inventories) have been thoroughly investigated and are rather straightforward. They require a basic knowledge of image interpretation, experience in recognizing specific signatures (identifying features), and the ability to transfer image data to a map. Airborne remote sensors can provide pictures of the Earth's surface ranging from a 26,000-km (10,000-mi²) view that contains the entire Chesapeake Bay, down to a 9.3-m² (100-ft²) view.

A central location is needed for coordinating the collection and utilization of remotely sensed data. Remotely sensed data have been and are being collected by many organizations in support of water-quality projects concerning the Bay. At this time, there are no adequate means by which each organization knows what the other organizations are collecting. There is no coordination of collection and application requirements. This unawareness naturally leads to redundancy of effort, and redundancy is costly.

It was therefore recommended that:

- Remote sensing should be applied to locating, identifying, and monitoring non-point pollution sources as an integral phase of any comprehensive water-quality project concerning the Chesapeake Bay.
- A "clearinghouse" should be established to coordinate the collection and application requirements for remotely sensed data as applied to projects concerning the Bay. This clearinghouse would also function as a data reference point that could be queried as to the disposition of all remotely sensed data that have been collected.

ROLE OF REMOTE SENSING IN BAY MEASUREMENTS

Techniques and sensors for remote sensing of environmental quality from ships, aircraft, and satellites have been under development for many years. Only a few are now available as "off-the-shelf" hardware or are being used with sufficient regularity to provide synoptic coverage of the Chesapeake Bay. Although remote sensors cannot supply all the information that is needed to understand the Chesapeake Bay, they have proved to be very valuable in measuring a number of important parameters: water-surface temperature, suspended sediment gradients, chlorophyll, oil spills, changes in water level interface, wetland mapping, and various land-use phenomena and factors relating to climatology.

Application of remote sensing for operational monitoring of the Chesapeake Bay is not presently being contemplated by any specific organization. It is suggested that a central planning organization be structured to develop an overall approach for investigating the Bay. Many of the organizations now involved in remote sensing may be induced to perform repetitive measurements in the Bay area as part of their routine investigations.

Essentially the same situation exists in documenting and monitoring episodic events in the Bay region. Episodic events are those that result in unplanned step-function inputs of foreign substances into the system in short periods of time. These events include oil and hazardous-material spills, freshwater runoff from major storm systems, sediment and debris runoff from land-use practices, etc.

The ability to monitor episodic events in the Chesapeake Bay ranges from poor to nonexistent, not necessarily because of lack of technology, but generally because of a lack of clearly established responsibilities and commitment of resources by an appropriate organization.

It is recommended that institutional arrangements be developed so that existing remote sensing techniques (such as black and white, natural color, color infrared, and multispectral photography) be routinely used to document and monitor episodic events. Only after the contributions of existing techniques are fully understood and appreciated by the responsible parties can the improved monitoring capabilities of the advanced techniques be evaluated in the proper perspective. The U.S. Coast Guard (5th District) is now developing a contingency plan for response to episodes in waters under their jurisdiction for the 3rd Federal Region, which includes the Chesapeake Bay. It is recommended that a group (e.g., the steering committee for this Conference) influence the Coast Guard to provide airborne platforms and equipment, to initiate routine documentation, and to monitor episodic events using existing technology. The routine monitoring of the Bay by the Coast Guard could form the basis for a baseline monitoring program.

The following actions are recommended to address some problems discussed by this group:

- Episodic remote sensing (low-altitude aircraft) of Bay shorelines should be carried out after severe-storm events and on an annual basis to monitor shoreline erosion.
- A complete bathymetric survey of the Chesapeake Bay should be scheduled at an early date by the National Ocean Survey of NOAA. Such a survey is needed to delineate the bathymetry of the entire Bay within a short time-frame, and can be used for a multitude of purposes (e.g., shoal areas, rates of sedimentation, dredging applications, and channel migration).
- A deep seismic reflection profile should be obtained of the spine of the Bay. Assistance should be sought from the Marine Geology Division of the U.S. Geological Survey for this work. This type of profile would provide invaluable data on the geometry of freshwater aquifers, depths to basement rocks, and, possibly, on faulting in basement rock and coastal-plain sediments.

POSSIBLE ROLE OF REMOTE SENSING FOR INCREASING PUBLIC AWARENESS OF THE CHESAPEAKE BAY ENVIRONMENT

Many of the conferees suspect that the public is not sufficiently aware of environmental problems and that improved public information will lead to laws and policies for providing better protection of the environment. The basis of this idea is questioned by some, and a survey appears to be in order to settle the question and to see where the public information and concern have gaps or misconceptions. Therefore, the group recommended that:

- A survey be conducted to determine the degree and type of public awareness of the Chesapeake Bay environment and its manmade changes.

The participants believe that the public needs "an agency of trust" to develop an overall view of the regional environment and how it is affected by different influences. Public interest would be heightened by knowing that the commission's output would be relatively unbiased and taken seriously in establishing future environmental policy. Political difficulties are foreseen with existing commissions and conflicting state interests. Important aspects of any such commission's work would include: (1) an inventory of competing alternatives in the use of the Bay as a resource, and (2) a set of indexes describing the Bay's condition. It was recommended that:

- A coordinating regional institution be established, funded, and legally mandated to develop a management plan for the Chesapeake Bay.

The geographical overview afforded by Landsat imagery has proved to be very effective in stimulating awareness of environmental phenomena, in bodies of water, and in vegetated and arid areas. Detailed "ground truth" of conceivable Landsat projects is still being explored. Accomplishments to date suggest that this technique is an effective "environmental educator" and may evolve into a comprehensive method of surveying land and water environment. It was recommended that:

- Landsat imagery be recognized as a major initial step in the evolution of technological developments that can build awareness of the environment and its changes.

The group also recommended that a remote sensing task force be formed to further the appreciation and use of remote sensing in the Chesapeake Bay region. The following sub-tasks were proposed:

- Compile information on past demonstrations of remote sensing in the region. (This is partly underway at Goddard Space Flight Center.)

- Point out important gaps of technique and problem solving, and indicate how remote sensing might help.
- Fill some of these gaps with new demonstrations.
- Carry out the second and third subtasks so that there are also experiments in communications—the results of which will facilitate future work along the same lines.

Pictures of the Earth taken from orbit are particularly suitable for museum and library displays, presentations at congressional and other public hearings, information summaries being sent to state and federal science advisors, and magazine features (e.g., *National Geographic*, *Smithsonian*, etc.). In this region, we hope thereby to stimulate a sense of personal relation to the Chesapeake Bay system by helping interested people to locate themselves in the environment while visualizing the spatial connections to the people and areas around them. It was recommended that:

- The products of remote sensing technology, particularly satellite imagery, be systematically and increasingly employed for public information on the environment.

Environmental education has proven to be amenable to various techniques involving “new experiences” or “alternative” experiences in which exposure to the people in a region, the feel of the outdoor life, the interplay of the environment, customs art, poetry, and history all convey to the average citizen more of the importance of grasping the nature of one’s environment and its problems than is delivered by the basic sciences alone. In addition to its technical and objective aspects, remote sensing has a place in stimulating the student’s desire for wider understanding of his environment. It was recommended that:

- These educational implements (see foregoing recommendation) likewise be used in broader programs of environmental education in which the remote sensing outlook could be a valuable and innovative addition.

CONFERENCE REFLECTIONS

From the many agencies attending the Conference, two groups or communities emerge: (1) the remote sensing community, which sees its technology to be of direct use to Bay managers and users; and (2) the community of Bay managers and users who are seeking efficient means for maintaining the health of the Bay. The outlook of both was ably presented, and the beginning of mutual exchange did occur.

To continue this exchange and work of applying new technologies, especially information technologies, to Bay management, we must overcome language barriers and create a home in which the many agencies can learn each other's virtues. In such a place, the special technical languages can be learned, technology can be shared, and mutual needs can be made known.

The members of this workshop and people interested in continuing the work of this Symposium and in carrying out its recommendations, should form a task force, each member joining after obtaining the agreement of his home agency to do so. The task force activities should include: (1) setting goals and an approach to meeting those goals; (2) developing an experienced body through formation of working groups; (3) conducting a remote sensing survey of the Bay Region, beginning with shared resources; (4) assisting in site studies; and (5) reporting work to their agencies and to the Bay community.

The task force should look to a future role as a technical subcommission of the Title II Commission suggested by Senator Mathias. As a technical subcommission, the task force would have the experience of interagency cooperation in applying advanced technologies derived from many agencies to meet the urgent needs of the Chesapeake Bay for health, extended life, and continued joy for its users.

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