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CRC

A SURVEY FOR THE USE OF REMOTE SENSING IN THE CHESAPEAKE BAY REGION

June 1974

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FOREWARD

I have written this report with four potential reader audiences in mind.

First and foremost are the administrators and investigators at National Aeronautics and Space Administration, Wallops Station who commissioned this survey. The recommendations herein have been addressed primarily to encouraging the most efficient and complete application of NASA's capabilities to the problems of the Bay.

Secondly, this information is intended to serve the leaders and participants of the Chesapeake Research Consortium as a background upon which to plan a coordinated program of Bay-related research which employs remote sensing as one of its data-gathering tools.

Narrative descriptions of the various problem areas have been kept brief and free of detail to provide the general NASA community with a glance into the nature of the Bay's environmental difficulties. In talking with my colleagues at NASA I have often found that the pressures of their technical tasks leave little time for any independent survey of the Bay's problems. They are, however, extremely capable investigators, and are usually quite enthusiastic when a new possible application for their work is revealed to them.

On the other side of the communications barrier sits a multitude of citizens who are actively involved in seeking resolutions to the political, economic, and ecological conflicts involving the Chesapeake Bay area. Many of them, like myself, have viewed remote sensing research as being no more than an investigator who pores over aerial photos and counts stumps on the ground. This kind of work is important, but it is only one facet of a whole realm of data-gathering tools. Hopefully, a display of what is being accomplished on the Bay will lead more investigators to turn to the full potential of remote sensing to help meet their data needs.

It should be obvious from this report that at least one man-year is necessary to cover the subject matter adequately. Of necessity, the present report was completed in two months. Obviously, the results reflect the compressed effort. I have drawn from only two sources in completing this work--the series of interviews, and my own general knowledge of Bay problems. My apologies are extended to any reader whose name and area of interest have been missed.

The obverse of the law of diminishing returns says that one reaps substantial returns for one's initial effort. I hope the reader will feel that this survey is a case-in-point. The possibilities for new applications are many. I have tried to single out a few in the form of recommendations. Hopefully, others will occur to those who read this report in its entirety.

I wish to acknowledge the thorough reviews given this document by Mr. Don Davis, of NASA, Langley, and Dr. Charlie Freer, of Washington Technological Associates. In several instances, additions suggested by these reviewers were incorporated verbatim into the final text.

I also appreciate several helpful comments from Dr. Peter E. Wagner, Dr. L. Eugene Cronin, Dr. Robert Krieger, Mr. Abe Spinak, Mr. Gil Trafford, and Lt. Scott Sollers. Thanks also to Mr. Hunter F. Dyer for editing the original draft, and Ms. Margaret Roper for typing the manuscript.

The encouragement of Drs. Theodore Chamberlain, Peter Wagner and L. Eugene Cronin, given to me at times when the task seemed insurmountable, is gratefully acknowledged.

Robert Ulanowicz
Research Assistant Professor
University of Maryland
February 5, 1974

Note Added at Press Time

Since my completion of this report in early February, a great deal of effort on the part of several CRC personnel has gone into editing and reviewing the text. As I alluded to in my forword, the compressed period of time which my other commitments allowed for this survey predetermined that this document would be incomplete in several respects.

Most of the deficiencies stem from the necessary short-cut of relying solely upon selected interviews. It was simply impossible to interview all potential users in two months. I therefore began by contacting those investigators personally known to me, and the subsequent chain of referrals reflected their interests and contacts. After the review procedure it is evident that some glaring omissions were made. For example, my investigation into the nutrient problem included no input from the Maryland Department of Health and Mental Hygiene, the Maryland Environmental Services, the Maryland Water Resources Administration, the Virginia Water Control Board, the various counties, etc. Similar important omissions can be cited for each of the other problem areas.

Also, the problem statements leave much to be desired for the informed reader. Looking back, it is clear that I should not have attempted to write all the problem statements from my own personal knowledge--I am simply not an expert in all (if any) of the problem areas. It was never my intention, however, to compile a state-of-the-Bay report, and the brief expositions were included only for the sake of those readers with virtually no familiarity with the problems. They serve only to whet such a reader's interest to pursue the problem further and should never be construed as _the_ authoritative word on the subject.

Time and further work would easily correct these deficiencies. Other commitments, however, preclude my return to the survey trail at this time. Also, six months have passed since the completion of the text. Time has already eroded some of the impact of the report--the institutions, personnel, technology, even the problems have changed in interim.

I feel strongly, however, that the report bears relevance to the activities of the remote sensing community. Lest these recommendations be lost, I reluctantly give my _imprimatur_ to the report in its present form in the hope that it will be received by an indulgent readership that shares with me a willingness to listen to any ideas which might improve our ability to meet the challenge of improving our Chesapeake Bay environment.

R. E. U.

August 13, 1974

ABSTRACT

Twelve environmental problem areas concerning the Chesapeake Bay Region are reviewed along with ongoing remote sensing programs pertaining to these problems. Forty-three recommendations are presented to help fill lacunae in present research and to utilize the remote sensing capabilities of NASA to their fullest. A list of interested organizations and individuals is presented for each category.

Among the recommendations are the development of technologies to monitor dissolved nutrients in Bay waters, the initiation of a census of the disappearing rooted aquatic plants in the littoral zones, and the mapping of natural building constraints in the growth regions of the states of Maryland and Virginia.

INTRODUCTION

In December 1972, as the National Aeronautics and Space Administration was beginning to place greater emphasis upon earth resources problems, the Director of the NASA Wallops Station, Dr. Robert Krieger, consulted the Chesapeake Research Consortium to determine how NASA could better utilize its facilities in solving problems facing the Chesapeake Bay and its community. The Consortium appointed an ad hoc committee of CRC investigators, NASA personnel, and other interested parties, to formulate a report citing lacunae in the coverage of ongoing remote sensing programs.

This task proved to be intractable for a full committee to execute, and the task fell to the chairman, Dr. Robert Ulanowicz.

During December 1973 and January 1974, Dr. Ulanowicz conducted interviews with users of remote sensing data in the Chesapeake Bay area. This report is a synopsis of the responses of those persons interviewed, in regard to work in progress on twelve problem areas defined by the Chesapeake Bay Remote Sensing Committee. The material in each of the twelve problem areas is arranged according to the following format:

1. a brief narrative of the nature of the problem;
2. a summary of remote sensing work underway on the topic;
3. a set of recommendations by the author for possible future action; and
4. a list of personnel and organizations interested in the problem who may be contacted for further negotiations.

The author rated the recommendations according to the following scale:

A. a matter demanding urgent action to be implemented immediately, using any available resources;
B. an action of very high priority, to be considered for earliest possible funding;
C. an item which should enter into long-range operational plans;
D. a course of action to be undertaken as the opportunity arises (or a recommendation of a highly speculative nature).

For the sake of those readers who are unfamiliar with remote sensing technologies, there are three basic tools.

1. Multispectral scanning (MSS) is presently one of the most effective tools for developing a "signature" of any object or area on the ground. Roughly speaking, light from an area on the ground is consecutively scanned through several different band filters. The reflectance of each spot in the scan (pictal)

in each band is recorded digitally and, in the case of a satellite, radioed to earth. Each pictal in the scan thus has a set of reflectances associated with it. The ratios between the various received intensities from a point comprise a signature in the spectrographic sense. Such signatures have been used to categorize an enormous variety of ground phenomena. It is obvious that much ground truth data is required to develop a signature which can be applied with high confidence.

2. Data collection platforms (DCP's) have been a popular feature of the ERTS programs. Basically, they are long-range telemetry which uses the satellite as an active relay. Any data which can be sensed in situ and transduced into a 0- to 5-v dc signal serves as input to a magnetic tape buffer set upon a platform, along with a transceiver and antenna. Upon command from the satellite passing overhead, the accumulated data is transmitted to the spacecraft and relayed to an earth station.

3. Another system just out of the developmental stage is Laser Induced Detection and Ranging (LIDAR). In this technique, a coherent beam of light is directed from above into the water. A return signal caused by either reflection or backscatter of the original light, or flourescence induced in some substance in the water column, is detected through a telescope mounted near the emitter. The return signal can carry information on a number of variables. For example, the reflected signals from the water surface and bottom (when visible) yield a depth sounding. Backscattered light has been used to estimate a turbidity profile, and the flourescence from chlorophyll yields a measure of the surface concentration. The laser technology is quite suitable for in situ measurements where a depth profile is required and, of course, can be interfaced with a DCP.

Taken as a whole, these and other more familiar methods may be viewed as the components of a macroscope whose function is to extend the senses of man in space and time, as he views his world from above.

THE CHESAPEAKE BAY REMOTE SENSING COMMITTEE

Robert Alexander	U. S. Geological Survey
Theodore Chamberlain	Chesapeake Research Consortium
Phillip J. Cressy, Jr.	National Aeronautics and Space Administration Goddard Space Flight Center
Don D. Davis, Jr.	National Aeronautics and Space Administration Langley Research Center
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Louis S. Walter	National Aeronautics and Space Administration Goddard Space Flight Center

*Chairman

PARTIES INTERVIEWED

I wish to express my gratitude to the following individuals for donating their time and knowledge to the interviews upon which this report is based.

Mr. Keith Adams	U. S. Army Corps of Engineers
Dr. Robert Alexander	U. S. Geological Survey
Mr. John Antonucci	Maryland Department of State Planning
Mr. Earl Bradley	Maryland Department of Natural Resources
Mr. Keith Buttleman	Virginia Office of Environmental Resources
Mr. Robert Butts	Bayshore, Inc.
Mr. Peter Buzzannell	U. S. Geological Survey
Dr. Robert Byrne	Virginia Institute of Marine Science
Dr. John Cairns	Virginia Polytechnic Institute
Mr. Joseph Davis	Virginia Office of Environmental Resources
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Dr. Robert Dolan	University of Virginia
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Dr. John Frazier	The Johns Hopkins University
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Mr. William Nickel	The Nature Conservancy
Dr. William Odum	The University of Virginia
Dr. David Pettry	Virginia Polytechnic Institute
Mr. John Pleasants	Virginia Institute of Marine Science
Mr. Frank Pine	The Johns Hopkins University
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Mr. Carlton Rutledge	Westinghouse Oceanics
Mr. Turbit Slaughter	Maryland Geological Survey
Mr. Robert Slocum	Virginia Office of Environmental Resources
Lt. Scott Sollers	U. S. Army Corps of Engineers
Mr. Craig Ten Broeck	Maryland Department of Natural Resources
Mr. Edwin Thomas	Maryland Department of State Planning
Dr. Kenneth Warsh	The Johns Hopkins University
Mr. Donald Wilson	Westinghouse Ocean Research Laboratories
Dr. Jay Zeeman	University of Virginia

I. NUTRIENT LOADING

The Nature of the Problem

The number one threat to the continued health of the Chesapeake Bay, according to Dr. Donald Lear, of Environmental Protection Agency, Dr. Donald Pritchard, of the Chesapeake Bay Institute, and Dr. L. Eugene Cronin, of the Chesapeake Biological Laboratory is excess nutrient additions from domestic sewage and other related sources.

Even before the advent of large human populations, the Chesapeake Bay was the receptor of large nutrient runoff from the surrounding drainage basins. Over the ages, a flora and fauna have evolved to effectively cycle these nutrients so that they yield an abundance of useful organisms for which these "naturally eutrophic" waters are so famous.

Problems occur, however, when these natural systems are suddenly pulsed with large quantities of nutrients from domestic waste, etc. The inputs can be too large for the natural cycles to bear, and the web of mass and energy flows is "short-circuited" in favor of a few species less useful to man. Such disturbed systems may be observed in the Upper Potomac Estuary (large mats of floating blue-green algae), Baltimore Harbor, Little Creek Basin, and the Sassafras River.

From the human viewpoint, a second difficulty is brought about. The possible presence of pathogenic bacteria and viruses makes waters potentially unsafe for drinking or contact, and the fish and shellfish in the area unsafe for consumption.

Nutrient overload can occur in several different ways: (A) from municipal sewage plant effluents; (B) from agricultural practices; (C) from hard-pan soils with poor percolation; (D) from the use of shipboard versus dockside sanitary facilities; (E) from improper land disposal of sewage sludge; (F) from miscellaneous runoff; and (G) from ocean dumping. A discussion of each of these seven ways follows.

A. The outstanding source of nutrients is from <u>municipal sewage plant</u> effluents. Usually, bacterial contamination is eliminated by aeration and chlorination, but rarely is more than 80% of the nutrient removed. Often feeder overloads or plant malfunctions send raw sewage into the receiving waters.

   Areas of concern include the Upper Potomac, site of the Blue Plains treatment plant, and proposed plants on Piscattaway Creek, Belmont Bay, Occoquan Bay, and Dunston Creek. Treatment plants adjacent to shellfish beds are being proposed further down the Estuary at Cabin John Creek, Cobb Island, and Kitts Point. Both Back River and the Patapsco Estuary receive effluent from the Baltimore Metropolitan Area, with the Patapsco receiving water that has been used in the pickling process at the Bethlehem Steel Plant. During recent times of flooding, the Upper James River has received substantial loadings of raw sewage. In the Portsmouth-Little Creek area EPA reports agglomerated fecal material in some of their water samples. The Upper Patuxent Estuary has received ever-increasing loading from the District of Columbia suburban area, which has led to the closing of numerous shellfish beds. A similar problem has occurred in the Choptank River, presumably by sanitary effluent from Cambridge. The newest sites for studies sponsored by CRC-RANN on preoperative and postoperative effects of sewage treatment facilities are at Sandy Point near Annapolis, and on the Elizabeth River at Norfolk.

B. Metropolitan areas are not alone in causing nutrient overloads. Recent changes in <u>agricultural practices</u> have exacerbated nutrient runoff. The shift from the use of dilute organic fertilizers to concentrated chemicals was accompanied by heavy nutrient losses to groundwater and erosion (whence the Bay).

A change in the methods of animal husbandry has likewise resulted in increased runoff from feedlots, in that the same amount of animal waste is now distributed over a much smaller area.

Swine operations in the area of the Wicomico on the Potomac received national publicity when the feedlot runoff contaminated shellfish beds in the area. A similar problem exists throughout the coastal areas of Virginia, especially along the tributaries of the James River.

Farther up the Bay, the Sassafras, Elk, and Northeast Rivers are subject to blue-green algae blooms which, in the case of the Sassafras, can be traced directly to fertilizer runoff.

C. A significant fraction of the soils of the Coastal Plain adjacent to the Bay is unsuitable for septic tank disposal of domestic waste due either to water tables near the surface or hard-pan soils with <u>poor percolation</u> characteristics. Hence, flow from septic tanks in these areas finds its way into the tributaries of the Bay. Such sources are distributed throughout the Bay region, and they constitute a major diffuse source of bacteria and nutrients. Areas which have received publicity due to beach closings, building moratoriums, and similar prohibitions include the Baltimore County shoreline, the Mayo District of Anne Arundel County, and York County.

D. Neither Maryland nor Virginia presently requires holding tanks for human waste aboard commercial or recreational vessels. Up to the present, there has been no particular problem incurred by release of wastes upon open waters. In areas dense with marinas, however, there is often severe pollution as a consequence of boaters' preference for shipboard toilets over dockside facilities, civil prohibitions notwithstanding. Impacted areas include the Deltaville, Reedville, Yorktown, and Newport News-Hampton areas in Virginia and the St. Michaels, Solomons, and Annapolis areas in Maryland.

E. To abate the nutrient overload problem, land disposal of sewage sludge and liquid effluent is being investigated. Pilot projects on the spray disposal of liquid sewage effluent on marshland and fastland are underway in Easton and Edgewater, Maryland (Smithsonian CBC), and Lancaster County, Virginia.

F. The bulk of the remaining nutrient loads comes from diffuse sources, and may be lumped as miscellaneous runoff. The most important of these is probably the municipal street runoff which occurs after periods of high rainfall. In Washington, Richmond, Cambridge, and Newport News this runoff is incorporated into the domestic waste lines, and accounts for the pulses which pass too quickly through the sewage plants for treatment to be effective. In Chicago, the street runoff after rainfall was estimated to be greater than the domestic sewage output, and it is reasonable to assume that Baltimore and Norfolk deposit similar quantities of runoff into the Bay.

Of course, there remains the background runoff from uncultivated forest and fields, and the fauna associated with them. Along these lines, this writer has noticed the strong smell of ammonia and murky waters which accompanies the large flocks of waterfowl which winter on the Eastern Shore marshes and tributaries. Other parties interviewed corroborated this observation, and they pointed out that Hog Island on the Atlantic Coast and the Pamunkey River are similar densely populated waterfowl areas.

G. Since the Delmarva Atlantic Shore should also be included in any inventory of problem areas, the issue of ocean dumping should be mentioned in passing. Thus far, only two areas which have merited notices are the Philadelphia Sanitary District dumping grounds off the Delaware shore, and the Virginia Beach sewage outfalls.

Remote Sensing Work

The group most concerned with nutrient loads in the Chesapeake Bay is the EPA in Washington, Las Vegas, and Annapolis. Drs. Robert Holmes, S. Harvey Melfi, and Donald Lear are already directing strong remote sensing programs in cooperation with NASA. In discussing the methods currently being used to monitor nutrient problems, it became clear that there is no remote sensing technique for the direct quantitative measurement of nutrients.

Present methods include qualitative detection of nutrient pollution using false-color IR, microwave thermal scans, and color.

Consequences of nutrient pollution such as phytoplankton blooms can be quantitatively assessed by measuring the associated chlorophyll, either with remote multispectral mapping of chlorophyll concentrations from solar reflectance, or by measuring laser-induced flourescence of the chlorophyll molecule (LIDAR or in situ Laser techniques). Progress is being made by the NASA, Langley group on identifying genera of phytoplankton using the signature from the flourescence excited by a 4-channel dye laser.

A breakthrough in the quantitative remote sensing of such nutrient species as NO_3, NH_3, PO_4, etc. would not only be a great asset to pollution monitoring and control, but would tremendously boost efforts at gathering data on nutrient concentrations to be used in developing a model of the rates of primary productivity. (See XII, B. 6.) Recent efforts by Dr. Charles Freer of the Washington Technical Associates in applying Laser Raman techniques to in situ aqueous trace constituent monitoring indicate that there is a strong possibility that nutrient monitoring can be accomplished using this technique.

Laser-induced Raman Spectroscopy conducted under laboratory conditions has detected some of these nutrient species for very high concentrations; however, the tests indicate that direct, remote quantitative measurement of the nutrient ions (NO_3, NH_3, PO_4, etc.) at concentrations experienced in marine waters is well beyond the present state of the art. The possibility of inferring nutrient loading from LIDAR measurements of phytoplankton concentrations is feasible, and should be actively pursued.

In situ-ion specific enzyme electrodes to monitor dissolved nutrient species are under development at the University of Maryland's Chemical Engineering Department by Drs. Randy Hatch and Theodore Cadman. If fully developed, these electrodes could be applied in remote monitoring schemes such as the ERTS Data Collection Platform system.

The in situ Laser and electrode techniques have the advantage that sub-surface concentrations can also be measured.

The Chesapeake Research Consortium, in cooperation with the Research Applications Directorate of NSF, is conducting a program on the fate and effect of wastewater in the estuarine environment. It is most probable that this program would be benefited by the inclusion of remote sensing data.

With regard to sewage plant siting, the only person interviewed who has used remote sensing to help determine a site was Dr. David Pettry of VPI. He and Dr. W. J. Edmonds used color IR to evaluate soil conditions and to predict lateral movement of sewage leaching through the soil from holding ponds. NASA, Wallops Station is monitoring a small sewage outfall on their base to develop appropriate aerial sewage sensing techniques.

Dr. Pettry is also using low altitude (2500-3500 feet) color IR to amass data for a generalized soil model which will be used to predict runoff from agricultural areas and urban development sites.

Septic tank seepage has been monitored from the air by Dr. William J. Meyer of the Center of Environmental Studies at VPI, and by Messrs. Spencer Franklin of the Anne Arundel County Department of Health, and James Chocamatz of NASA, Langley.

The problem of nutrient loading from boats has been studied by Nancy Dimsdale and Spencer Franklin, of the Chesapeake Bay Foundation. They relied upon thermal scans of the South River area to pinpoint natural runoff outfalls. Ground truth data on the intensities of these outfalls lead them to estimate that boat pollution was secondary to natural and suburban runoff in causing eutrophication in the South River.

Dr. Maurice Lynch of VIMS and Mr. Craig Ten Broeck of the Maryland Department of Natural Resources made requests for weekend flights at 10,000 feet to determine an accurate instantaneous estimate of the number of vessels on the Bay and selected tributaries. Such boat census data are also in demand by the Virginia Department of Recreation and Parks.

The changes in vegetation that spray disposal of sewage effluents causes in marshlands has been monitored remotely by Ms. Susan Weck of the Smithsonian's Chesapeake Bay Center on the Rhode River as part of the CRC-RANN program.

Dr. William J. Meyer, who has remote sensing experience in other fields, is studying how spray disposal affects soil composition, structure, and heavy metal accumulations.

The only projects underway using remote sensing to monitor runoff were the above study by Ms. Nancy Dimsdale and the ERTS investigation of the Patuxent River hydrology by Mr. Vince Salmonson of NASA, Goddard.

According to Dr. Donald Lear, reasonable models for metropolitan and rural runoff are in existence. Very few data exist on the important problem of suburban hydrology. He felt it was a problem well suited to exploration through remote sensing.

Dr. Pettry's group in the Agronomy Department of VPI is actively studying the predevelopment soil structure of large-scale building projects to ascertain how development will affect runoff and aquifer recharge. Also, a before-and-after study of the hydrology of clear-cut forest areas is being undertaken.

This same soil science group has used black and white, color, and color IR low-altitude photography to delineate oceanside sewage outfalls in the Hampton Roads area.

Dr. Donald Lear points out that the trace from the Philadelphia Sanitary District's ocean sludge dumping is very apparent on Channel 4 ERTS imagery, although no formal remote sensing project to monitor this problem is yet underway. (See also XI, A.)

Recommendation 1

Investigation should proceed posthaste on the development of remote sensing technologies to gather data on nutrient concentrations. Laser induced flourescence (single or multiple frequency) and multispectral mapping seem to hold some promise. The enzyme-specific electrodes in combination with telemetry systems such as the ERTS-DCP package offer another possibility, as do the in situ Laser techniques. [A]

Recommendation 2

The chlorophyll measuring technologies in operation at NASA, Wallops and Langley seem excellently suited to gathering ground truth data for the modeling of the fate and effects of sewage effluents and should be coordinated with the CRC-RANN program.

Recommendation 3

Models for suburban runoff are urgently needed by EPA. Remote sensing offers perhaps the most cost-effective way of gathering ground truth data for the development of such models, and the implementation of such a program should be pursued. [B]

Recommendation 4

Remote sensing in the form of aerial photography should be utilized for synoptic censuses of boats on the Bay and tributaries. [C]

Interested Parties

The Environmental Protection Agency, Washington, D. C.

Mr. Donald Holmes
Mr. John Koutsandreas
Dr. Donald Lear (Annapolis)
Mr. Art Dybdahl (Denver)
Dr. S. Harvey Melfi (Las Vegas)

The Chesapeake Research Consortium, Baltimore, Maryland

Dr. Theodore Chamberlain
Dr. Melvin Nolan
Dr. Donald Pritchard

The Chesapeake Bay Foundation, Annapolis, Maryland

Ms. Nancy Dimsdale
Mr. Spencer Franklin

The Smithsonian Chesapeake Bay Center, Edgewater, Maryland

Dr. Robert Ballantine
Dr. Susan Weck

The Department of Natural Resources, Annapolis, Maryland

Mr. Craig Ten Broeck (boating)
Mr. Vernon Stotts (waterfowl)

The Potomac River Fisheries Commission

Mr. Robert Lewis

Hampton Roads Sanitary Committee, Hampton, Virginia

Mr. Robert S. De Mauri

The Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Maurice Lynch (boating)
Dr. Robert Huggett

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry
Dr. William J. Edmonds
Dr. William J. Meyer

The University of Maryland, College Park, Maryland

Dr. Theodore Cadman
Dr. Randy Hatch

The Washington Technological Associates, Rockville, Maryland

Dr. Charles Freer
Mr. Robert Shepard

National Aeronautics and Space Administration, Wallops Island, Va.

Mr. Al Holland

II. THERMAL LOADING

The Nature of the Problem

A. The conversion of various fuels to electrical energy is performed at an efficiency of about 30%. The bulk of the wasted heat finds its way back into the environment via flue emission, condenser cooling water, or cooling towers.

1. Presently, the least expensive way for a utility company to dispose of condenser heat is to flow the condenser cooling water (which was obtained from a natural body of water) directly back into the cooling water source. The heat introduced by the above process can have a number of possible effects upon the aquatic biology. First, the planktonic organisms entrained in the cooling waters or exposed to the heated effluents can be directly killed by the thermal shock. Organisms gradually acclimate themselves to the prevailing seasonal temperatures, and a sudden thermal shock could be lethal at any time of the year. Direct kill is most acute, however, during the summer when ambient surface temperatures may naturally reach the upper tolerances of various organisms.

There are several other possible ecosystems effects which are more subtle in nature. The power plant may be viewed as a giant predator which is selectively cropping certain species, thereby changing the species-population makeup of the community. The same end result may also be obtained through the nonuniform effect which a rise in temperature might have on the various species' parameters of feeding, respiration, assimilation, etc.

Most temperate organisms possess a "thermal clock" which regulates their seasonal activity. Triggering the thermal clock out of season could invoke behavior which is deleterious to the species concerned.

There is a good deal of concern that a large thermal source at a point in an estuary could serve as a "thermal dam" to the spawning stock, or larvae of certain anadromous fishes.

Besides the thermal shock which an entrained planktonic organism must endure, there are the added mechanical stresses of shear, acceleration, and pressure change effected by the cooling water circulation system.

Estuarine waters support planktonic forms which will attach to surfaces and continue to grow in the sessile form. Barnacles and oysters are perhaps the better known representatives of this class of organism. Condenser tubes must be periodically cleaned of such marine growth, usually with the aid of a biocide such as chlorine. The fate and effect of chlorine, chloramines (the reaction product of free chlorine with amino acids of organisms), and other biocides is of obvious concern.

2. Depending upon the fuel used, the combustion conditions, and the amount of air pollution control equipment employed, the stack gases will often contain oxides of sulfur and nitrogen as well as particulate fly-ash. The dispersion and eventual fate of these pollutants is an area of much activity.

3. Not only the aquatic regime, but also the surrounding landscape can suffer from the activity of power plants.

The health of flora (not to mention humans!) in the areas where stack emission plumes touch ground is often impaired.

In an attempt to reduce the impact of generating plants upon the aquatic environment, the cooling water is circulated in a closed or semi-closed cycle, and cooled by natural or forced convection cooling towers. Such systems are not without their impact upon the land, however. Salt-water-fed evaporative-type cooling towers can deposit concentrated salt solution upon the surrounding flora and farm crops. Endemic ground fogs may result from the large amounts of moisture given off by the evaporative towers. Even in the closed cycle cooling tower system, the makeup water required can put substantial drains on groundwater supplies.

B. Certain of the large industrial operations such as the Bethlehem Steel mills at Sparrows Point reject large amounts of energy, and can act as thermal sources to the aquatic environment.

C. The asphalt-macadam complexes such as Baltimore, Washington, and Norfolk serve to heat up runoff waters, and thus act as distributed thermal sources. Even on a smaller scale, a large macadam shopping center parking lot could serve as a significant thermal input to a nearby small stream.

Remote Sensing Work

Presently there seems to be little application of remote sensing technology to problems of thermal loading. However, there is a great deal of enthusiasm and technical expertise on the part of users in the problem area, making it one of the most promising fields for extending the capabilities of remote sensing.

There is no organized approach by the State of Virginia to the power plant siting question although there is talk within government circles about moving along this front. At VIMS, Dr. Frank Fong is attempting to develop a mathematical model of thermal loading in the James River Estuary. Thermal scans of the James River are being viewed against a background of ground truth data collected under a concurrent AEC contract. Mr. Haydon Gordon is developing an algorithm for correcting the geometric distortions incurred with the thermal scanner. Presently, the program seems to be handicapped by a lack of calibrated thermal scan data. Three geographical sites in Virginia are currently receiving prime attention--the Yorktown plant, the Surry Point plant at Hog Island on the James River, and the proposed North Anna plant near Richmond.

At the Virginia Polytechnic Institute, Dr. D. C. Martens is modeling the thermal shock that ground surface heat has upon water percolating into it, and Dr. D. C. Irch is studying the buildup of radioactive materials in soils.

The State of Maryland has established a Power Plant Siting Committee to advise on the site location and acquisition, monitoring, and general research on present and proposed sites in the state. Research in these fields is guided by the Committee and funded by an environmental surcharge on electrical power sold within the state.

Drs. Milton Moon, Kenneth Warsh, and Lawrence Kohlenstein were quite enthusiastic about remote sensing possibilities when interviewed at the Applied Physics Laboratory of the Johns Hopkins University (under contract to the PPSC).

Foremost, they would like to see a series of calibrated thermal scans of the Potomac River (eventually to become the most impacted river) from its mouth up to the West Virginia line. The scans should be run under a variety of different surface air temperatures, different loadings from the power plants, and various stages of the tidal cycle. If possible, such a program of scans should be extended to (a) the Patuxent River, (b) the C and D Canal, (c) the western edge of the Bay from the Bush River down to Cove Point, and (d) the Susquehanna well into Pennsylvania.

Optimally, the salinity should be simultaneously monitored perhaps, by passive microwave, providing this technology proves to be sufficiently accurate in the oligohaline regions of these scans. Ground truth could be provided by standard DCP probes or in situ Laser techniques.

Such a program of flights would yield information on thermal inputs from metropolitan runoff and sewage outfalls which could be helpful in assessing the associated nutrient loads.

Also, and simultaneous data which might be acquired on surface oil contamination either from LIDAR-fluorescence microwave, or multispectral scanning would be most helpful since surface oil has quite an important effect upon the air-water energy exchange rate.

Dr. Moon is a pilot and reveals that, from the air, outfalls from most power plants are usually slightly different in color from the receiving waters, thus making a host of remote sensing technologies potentially applicable.

Dr. Warsh commented that the behavior of certain small planktonic species such as copepoda and fish larvae in tidal estuaries is of immediate concern to power plant siting. He speculated on the possibility of creating a small, tagged probe which would simulate the behavior of these species and could be dispersed and monitored from the air.

Leaving the aquatic regime, the monitoring of airborne contaminants via remote sensing has potentials. Dr. Warsh spoke of the difficulties involved in retrieving quantitative data on stack plumes from a single overflight. He suggested an initial flight at low altitude (2, 000 feet ?) to map a surface background, followed by (or simultaneous to) a second flight at 10, 000 feet to observe the plume. The bracketed layer of air containing the stack plume would then be subject to quantitative analysis by difference.

Dr. Moon pointed out that reasonably good models exist for predicting the fate of plumes up to a distance of about 10 miles from the point of origin. Beyond that distance the models begin to fail. The possibility of interacting plumes whose origins are 20 to 50 miles apart has not been made for providing the missing data. Dr. Earl Kindle of Old Dominion University has been studying ERTS imagery of the Hampton Roads area for plumes. Dr. Moon suggested the possible addition of sodium, barium, and cesium tracers to the stack gases, like those used in the Wallops rockets, to facilitate following the plume.

There was discussion of the possibility of mounting some of these remote sensing packages on high towers to monitor the plumes broadside. The important contaminants, i.e., the oxides of nitrogen and sulfur, can be detected from Raman scattering, and the use of the LIDAR package is an exciting possibility. A mobile research LIDAR system has successfully demonstrated the detection and tracking of such compounds in power plant plumes.

Mr. Joseph R. Jahoda of Bayshore, Inc. has been experimenting with millimeter radar resonance techniques, and feels they hold some promise for detecting various gaseous species in the atmosphere, particularly the oxides of sulfur and nitrogen in stack plumes.

Recommendation 5

A program of thermal and salinity scans of the Potomac, James, Patuxent, and other impacted rivers should be initiated to provide data for monitoring and siting power plants. [B]

Recommendation 6

The present and proposed power plant sites in Maryland and Virginia should be intensively observed with a whole array of remote sensing methods (black and white, color, color IR, multispectral scanning, thermal scans) to provide a library of data for decision makers. The adjacent terrestrial and aquatic regions should be included. [C]

Recommendation 7

Multilevel flights focused upon providing data on stack gas emissions and plume dispersions, especially in the far field (> 10 miles), should be initiated. [C]

Recommendation 8

The applicability of the LIDAR package and/or millimeter radar resonance techniques (in either the fixed or airborne mode) to the measurement of stack gases should be pressed into an operational mode. [B]

Interested Parties

State of Maryland, Power Plant Siting

Mr. Lee Zeni, Head
Dr. Peter E. Wagner, Research
Dr. Steven Long, Monitoring
Dr. Paul Massicott, Siting
Mr. Joseph Gerath

State of Virginia, Office of Environmental Resources

Mr. Robert S. De Mauri

Martin Marietta Laboratories, Baltimore, Maryland

Dr. Leonard Bongers
Dr. Tibor Polgar
Ms. Alice J. Lippson

Chesapeake Biological Laboratory, Solomons, Maryland

Dr. Joseph A. Mihursky
Dr. J. Albert Sherk

The Johns Hopkins University, Baltimore, Maryland

Dr. Alan Eliott
Mr. Harry Carter
Dr. Grace S. Brush
Dr. Jerome Gavis
Dr. Jerome Schubel
Dr. Loren Jensen

Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Robert Byrne
Dr. Frank Fong
Dr. Haydon Gordon

Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry
Dr. D. C. Martens
Dr. D. C. Irch
Dr. Joseph Schetz
Dr. John Skelley

Old Dominion University, Norfolk, Virginia

Dr. Earl C. Kindle

Bayshore, Inc., Alexandria, Virginia

Mr. Joseph Jahoda

Washington Technological Associates, Rockville, Maryland

Dr. Charles Freer

III. INDUSTRIAL EFFLUENTS

The Nature of the Problem

Other than nutrients, a variety of other man-made introductions to the Bay waters are causing widespread problems.

A. Perhaps the most heavily researched of these introductions is the loading of heavy metals. Through evolution, ecosystems have evolved to tolerate, and in many cases to depend upon, natural levels of heavy metals (Fe, Cu, Zn, Pb, Hg, etc.) present in the ecosphere. The activities of civilized man almost unanimously tend to greatly accelerate the rate at which heavy metals are made available to the aquatic environment. The effect of such localized imbalance is usually to decrease the stocks of useful biological species either by decreasing the natural productivity of these populations or by making the organisms unfit for consumption by direct contamination.

Practically all abnormally high concentrations of heavy metals in the Chesapeake Bay can be associated with point sources due to man's activity. Impacted areas range from the agglomerated sources found near the metropolitan areas of Baltimore, Richmond, Norfolk, and Washington, to the large but remote sources such as power plants, sewage plants, and isolated factories, to the small-scale, localized contaminations found around marinas and duck blinds.

While no accute crisis of the order of the Minamata (methyl-mercury poisoning) tragedy in Japan, or the popularized Hg contamination of tuna and swordfish, has hit the Chesapeake Bay, there is still widespread concern that elevated levels of heavy metals from the impacted areas might be related to chronic health problems.

B. While heavy metals are of particular concern because of their persistence in the environment, a whole host of other materials are causing local and/or temporary pollution problems.

The effluents of both power plants and sewage treatment sites contain at times toxic doses of chlorine which were used in the plant as a biocide. Fish kills due to chlorine have been noted near the Newport News James River sewage plant outfall.

A level of 25 ppm of cyanide has been detected in the effluent of the Sparrows Point steel mill.

Acids, used in such quantities in industry, often find their way into the waterways. EPA has been monitoring Celanese in Fredericksburg as well as the West Point paper mill for acid leakage. In addition to industrial point sources, the streams of the Alleghenies are often unfit for life because of acid drainage from old mining operations.

While oil spills due to unloading and transfer operations has come under tighter control in recent years, there are still a large number of vessels which continue to pump their bilges while within the confines of the Bay.

A controversy still exists as to whether radioactive traces in the cooling water effluent are a possible threat to human health. While actual concentrations are quite small, there seems to remain a concern that biological concentrating processes might render them dangerous.

I uncovered no definitive projects concerned with the introduction of radionucleides associated with nuclear power plant operation. One such plant is already operating on the Bay and three are in operation on the Susquehanna River. More plants are being planned for the near future. Other sources of radionucleide disposal include medical facilities and various industrial users. Localized effects resulting from these releases are, in general, very small, studies of potential long-term consequences of long-lived radionucleides such as Cs_{137}, Sr_{90}, and tritium are highly desirable. Although remote sensing instrumentation does not, at present, have the capability to monitor present Bay concentrations of the important radionucleides, knowledge of the source inputs could be coupled with the Bay's dispersion properties to predict any future impacts of long-term buildup and life-chain selective concentration.

Possible Remote Sensing Applications

Research on the industrial effluents problem may be conveniently divided into two sections for the purposes of this report.

First, there is the problem of determining the distribution and transport of the various metal species, which affect bioavailability. This task involves not only the delimitation of the sources referred to above, but also an adequate description of diffuse sources (natural weathering and erosion, agricultural runoff, the flushing or urban areas by rain, and aerial fallout). The goal of those working on the bioavailability problem is a model that will predict the space-time dynamics of the bioavailability of heavy metals in the Bay. To this end, the physical cycling of heavy metals in the system by means of dilution, current dispersion, turbulent diffusion, and sedimentation are relatively well understood. Processes such as absorption, ion exchange, complex formation, chelation, flocculation, and coprecipitation are poorly understood. In the Bay these processes are principally associated with the regions of heavy suspended sediments and dissolved organic compounds so that remote sensing of these variables as described in Sections I. F, VI. A, and XII. A. 6 could have eventual applications here. Most notably lacking in the bioavailability model are data which will help formulate the rates of introduction of heavy metals into the aquatic environment. These introductions originate fron both point sources and diffused land-based sources. Here the input of remote sensing can be enormous, scanning practically all the other problem areas. Thus, the input of heavy metals of a given watershed will depend upon the areas of forest, fallow fields, cultivated land, residential use, and rock outcroppings, as well as the identifiable point sources mentioned above. Already Dr. John M. Frazier is studying the inputs of five subwatersheds of the Rhode River, each with a distinct pattern of development, to correlate them with remote sensing data characterizing the watershed.

Concentrations of metals in the water column are usually below the present capability for direct remote sensing. Progress is being made, however, on the development of an in situ polarographic monitor of metals. Like most other in situ devices, this one would be interfaced with a DCP.

Heavy metals are usually detected from a sample by atomic spectroscopy. A Dr. Aceto from the College of William and Mary has measured metals levels much quicker by electrically exciting a sample with the aid of a Van Der Graff generator and scanning the X-ray emission spectrum for heavy metals.

The other line of research involves the effects upon organisms incurred by an available amount of heavy metals. This area can be further broken down into acute kills, chronic pathology, and indirect food chain effects. Practically all this biological research involves the laboratory analysis of organism tissue, thus making possible remote sensing application remote. There is, however, the possibility that remote sensing monitoring of populations in areas of known contamination would be helpful. (See XII. B.)

Some other outfalls of exotics can usually be traced with black and white, color, and color IR photography, or with thermal scans. Knowledge of the source is usually required, as no known signature exists for many pollutants. Quantitative information likewise is hard to obtain from the remote sensing results.

Messrs. David Giana and Allin Pearson of NASA, Langley are presently involved in a joint program with EPA to determine the applicability of remote sensing techniques for monitoring the effects of acid drainage from mining operations on vegetation and as a pollutant in the North Branch of the Potomac River.

Surprisingly, most researchers interviewed expressed interest in only heavy metal effluents. An exception was Dr. John Cairns, who has developed a system to monitor industrial effluents by continuously measuring the activity and respiration of fish contained in an instrumented chamber with flowing diluted effluent. Mr. Robert Butts proposed to monitor chlorine concentrations in holding ponds by tagging and accoustically tracking the activity and physiological behavior of fish released into the ponds. Dr. Charles Freer would like to monitor chlorine and chloramines using in situ Laser techniques. All of these systems could be interfaced with DCP-like telemetry links.

On the other hand, agencies with enforcement duties (DNR, OER), were quite alert to the possibilities afforded by NASA remote sensing. These organizations would benefit by learning to use some of NASA's less costly technologies.

An excellent map of all the sewage and industrial outfalls in the State of Virginia is included in a report on "The Location of Oyster Beds in Virginia," which may be obtained from the State Water Control Board, P. O. Box 11143, Richmond, Virginia 23230.

Recommendation 9

Remote sensing data on areas having heavy metals concentrations should be made available to interested researchers to provide background data for their models of heavy metals inputs. [C]

Recommendation 10

Unlike many other states, Maryland has not extensively used remote sensing for a survey of its strip mining activities and acid mine drainage fields. Any available remote sensing data on this topic should be sent to the Department of Natural Resources. [C]

Recommendation 11

The aquatic enforcement arms of Maryland and Virginia would benefit from learning remote sensing techniques, and should take advantage of NASA technology and advances in this area. [B]

Interested Parties

School of Public Health and Hygiene
Johns Hopkins University, Baltimore, Maryland

Dr. John M. Frazier

Virginia Institute of Marine Science, Gloucester Point, Virginia

Mr. Robert Huggett
Dr. Michael Bender

Environmental Protection Agency, Annapolis, Maryland

Dr. Donald Lear
Dr. Thomas Pheiffer

Westinghouse Ocean Research Laboratory, Annapolis, Maryland

Mr. Hal Palmer

Chesapeake Biological Laboratory, Solomons, Maryland

Mr. Klaus Drobeck

Maryland Water Resources Administration, Annapolis, Maryland

Mr. Anthony Abar
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The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. Keith Furr
Dr. John Cairns
Mr. Gary Westlake

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Mr. Craig Ten Broeck

Office of Environmental Resources, Richmond, Virginia

Mr. Robert S. De Mauri

National Aeronautics and Space Administration, Langley, Virginia

Mr. A. O. Pearson
Mr. David Giana

Washington Technological Associates

Dr. Charles Freer

College of William and Mary, Williamsburg, Virginia

Dr. Aceto

IV. PESTICIDES

The Nature of the Problem

The deleterious side effects of persistent pesticides have received wide publicity in the last five years. Briefly, (1) The poisons eliminate species other than those intended, including predatory insects, bees, birds, fish, and oftentimes mammals; and in certain accidental cases, humans. (2) The concentrations of pesticides normally absorbed by the environment are often amplified as they are transferred along the food chain, resulting in dangerous concentrations in the higher trophic species. (3) Chronic exposure to sublethal concentrations is suspected as being carcinogenic to humans. (4) The ecosystem as modified in (1) could possess a lower yield to man rather than the intended benefit due to the elimination of biological controls and the creation of resistant pests. And finally; (5) It is thought that pesticide residues in the soil contribute to physical breakdown of the soil structure and preclude a healthy microorganism community.

Pesticides generally are applied to agricultural land as a distributed source. They enter the aquatic regime attached to sediment runoff or incorporated into detrital particles. Their concentrations in sediments and organisms tend to be quite low, and detection thus far has been limited to laboratory concentration followed by gas chromatography.

In comparison with other impacted estuaries, the Chesapeake Bay has not been the focus of any acute pesticide episodes. In fact, the Westinghouse Laboratories in Annapolis cite in their Chester River Study that the Susquehanna River input is the major source of pesticides to the Upper Bay. They found that the bulk of the pesticide-bearing sediments at the mouth of the Chester River could geologically be identified as coming from the Susquehanna drainage basin. Constant surveillance and more data are required, however.

In cooperation with the Maryland Department of Natural Resources, the Westinghouse Laboratories, CBI and UM are embarking upon an Upper Bay Study in which they will (1) make a baseline survey of pesticides (and closely associated polychlorobiphenyls (PCBs) and bacteria in the Upper Bay; (2) determine whether the pesticide problem is serious; and (3) model how pesticides and bacteria will vary as the sources are changed.

Another suspected area of pesticide runoff is into the Wicomico tributary of the Potomac River. Stream channelization in the area has exacerbated agricultural runoff of all sorts. (See I. B.)

Dr. David Pettry of VPI has studied the dynamics of pesticide buildup in soils and the erosion of soils into adjacent waterways.

Remote Sensing Work

Because of the very low concentrations of pesticides and PCBs, there are no reported sensings of these toxins by any passive or active remote sensing techniques.

There are, however, possible remote sensing applications in gathering data for the proposed models of pesticide dispersion in the Bay waters. In particular, the Westinghouse Laboratories are constructing a three-dimensional hydrodynamic model of pesticide dynamics. Any data which remote sensing could contribute on tidal heights, currents, temperature, salinity, and sediment load would be welcomed. (See also XII. A.) Data is required as a function of depth, thus causing complications for remote sensing work; however, Mr. Wilson has designed an instrumented tower package for obtaining depth profiles of the needed variables. This data is generally buffered and read remotely. Also, any information which remote sensing technologies could supply about suspended sediment size distribution would be of great value to the modeling effort.

Williamson and Fraban at the Waterways Experiment station have ground truth particle size distributions for several ERTS images and are attempting to define a signature which can be correlated with various distributions. Of course, in situ scattering and/or turbidity probes could always be coupled to DCPs.

Recommendation 12

A cooperative program should be considered to provide a more complete data base for the proposed pesticide transport model. [C]

Recommendation 13

The various remote sensing technologies should be reviewed for possible application to the determination of particle size distributions of suspended sediment loads. [C]

Interested Parties

Maryland Department of Natural Resources, Annapolis, Maryland

Mr. Lee Zeni
Mr. Craig Ten Broeck

Westinghouse Laboratories, Annapolis, Maryland

Capt. Deke Ela
Mr. Carlton Rutledge
Mr. Donald Wilson
Mr. Hal Palmer
Dr. Kent Tsou

Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry

Environmental Protection Agency, Annapolis, Maryland

Dr. Donald Lear

Chesapeake Biological Laboratory, Solomons, Maryland

Mr. Charles K. Rawls

The Washington Technological Associates

Dr. Charles Freer

V. INDUSTRIAL PLANT SITING

Siting of sewage treatment and electrical generating plants has been covered in other sections (I and II) of this report. Mention is made here of the problems attendant to the siting of large-scale industrial operations outside the public domain.

From the developer's point of view, a proposed building site must be close to transportation, have adequate supplies of water and energy, be close to services of skilled and unskilled labor, be a suitable base for the construction of large structures, preferably be close to markets and sources of raw materials, and be relatively safe from damage by natural calamity caused by earthquake, floods, high winds, etc.

The public in whose neighborhood the project is to be located must be aware of the positive and negative impacts upon their local community and its environment. They must know how the operation will change the local population density and what the consequent needs will be for housing, schools, roads, fire protection, hospitals, libraries, cultural opportunities, electrical power, and taxes. How will the aesthetics of the area change in regard to scenic value, noise, and smell? The interest that the broader community has in the environmental displacements should be given proper venue by providing information on the possible degradation of the aquatic community from effluents and runoff, the floral and faunal displacements, the introduction of airborne toxins and particulate fallout, and the destruction of historical or archeological sites.

The proposed developers are usually possessed with the means for funding the research necessary to meet their own interests. Fortunately for the public, the EPA now requires that the developers also file an environmental impact statement on the external diseconomies of the project. Local planning groups are now beginning to have access to remote sensing data through state organizations, the U. S. Geological Survey at Sioux Falls, and NOAA at Greenbelt. That leaves the general public and such groups as ad hoc citizens action committees as the only groups without ready access to such remote sensing data, if they should wish to make use of this information.

Major projects in the Maryland Bay region eliciting some degree of controversy at the present time include proposed refineries at Marley Neck in Anne Arundel County and at Piney Point in St. Mary's County; a proposed industrial park on the proposed Hart-Miller Island fill area; and numerous public utilities discussed elsewhere in this report.

In Virginia, there are three regions of proposed intense industrial growth. Plans are being advanced for large parks in Portsmouth, and in the Nansemond-Suffolk City regions. A great deal of new activity is being proposed for the southwestern shore of the lower York River where major alterations or additions are being proposed to the existing refinery and electrical generating facility. The construction of a huge sewage plant is being proposed, and the Cheatham Naval Annex is scheduled for conversion to an oil reprocessing plant.

Mr. John Antonucci of the Maryland Department of State Planning says that there is some form of pressure to develop into an industrial site virtually every undeveloped tract of land greater than 200 acres having deep-water access.

Recommendation 14

A photobank of color and color IR imagery of all undeveloped holdings in the Bay Region of more than 200 acres with deep-water access should be developed so as to be available for local planning and citizens action groups as the need for such information arises. With careful planning these surveys can be piggy-backed onto existing reconnaissance missions at token additional cost. [B]

Interested Parties

Maryland Department of State Planning, Baltimore, Maryland

Mr. Edwin Thomas
Mr. John Antonucci

Virginia Office of Environmental Resources, Richmond, Virginia

Mr. Robert S. De Mauri

VI. SHORELINE EROSION AND COASTAL PROCESSES

The nature of Coastal Zone problems and remote sensing data needs have been neatly summarized previously for NASA by Dr. John C. Munday, Jr. (Applied Marine Science and Ocean Engineering, Sept. 1970). This writer, therefore, will only briefly mention the concerns with emphasis on Bay-related problems, and will catalog some of the newer efforts in this area.

The Chesapeake Bay is a drowned valley of the Susquehanna River bed. As the water level rises over geological time, there is a tendency for the soft, sedimentary edges to erode quickly in a lateral direction, giving form to the wide, shallow expanse which characterizes many coastal plain estuaries. A number of climatologists and geologists claim the ocean levels are still on the rise. This would tend to destabilize any natural equilibrium configurations which would normally arise to slow erosion (grass beds, vegetated spits, etc.).

With prevailing northwesterly winds, the low-lying areas of the Eastern Shore are particularly hard-hit. Poplar Island, once an estate of 1,000 or more acres, has shrunk to 1/10 of its earlier recorded size and has a projected lifetime of a very few decades. Sharps Island has become a shoal, and the newspapers of Maryland and Virginia are full of accounts of small islands, now used principally for recreation, eroding rapidly away.

Nor is the Western Shore immune from its problems. The Calvert Cliffs are subject to several mudslides every year which, geologically speaking, is a fantastic rate of erosion. Geologists in the Chester River Study lay part of the blame for such bluff erosion on groundwater flows out of the face of the cliff.

Along the Atlantic Coast, storms, waves, and meteorological and astronomical high tides often combine to breach the barrier island, often changing the morphology permanently.

Not all changes result in more water surface, however. In the upper reaches of the Bay and tributaries, the deposition of sediments from upland drainage is filling in the upper estuaries. Colonial records indicated that ocean-going vessels called at the port of Upper Marlboro on the Patuxent, now well removed from the reach of many moderate draft vessels. Intense development in the Gunpowder River basin has caused the marshes at the mouth of the river to expand. Hurricane Agnes left behind several islands in the Susquehanna Flats area.

Application of Remote Sensing

Three separate efforts are underway to inventory the morphology of the shoreline in the Bay and along the Coast. Mr. Craig Ten Broeck of DNR has used oblique photography to map shoreline characteristics. He is eager to see if the slight penetrating ability of the side-scan radar frequencies would enable him to further characterize the density of the shoreline soils. He is also quite eager to have data on the effects of storms on the Maryland Barrier Islands.

The VIMS flying club is likewise using low-level, oblique photography to classify shorelines as to physiography, artificial structure, use, etc. Mr. Daniel Bliley, a student of Dr. David Pettry at VPI, is completing a similar task.

While the New Jersey and North Carolina Atlantic shores are receiving attention form the ERTS program, the Delmarva coastline is conspicuously being overlooked. However, Drs. Robert Dolan and John Fisher do have a program with NASA, Wallops to catalog the effects of storms along Assateague Island.

Also at University of Virginia, Dr. Bruce Hayden is developing an evolutionary model of coastlines and is desirous of time-series photography of the Delmarva Atlantic Coastline. His colleague, Dr. Grant Goodell, is using LIDAR bathymetry to map possible landing sites along the Atlantic shore for the Office of Naval Research.

Dr. Norriss Powell of VPI has been regarding coastline erosion problem from the standpoint of the stability of various coastal soils.

A VIMS project has been using black and white, color, and color IR photos, along with radar transponding drogues, to map out the circulation patterns around the Virginia Barrier Islands.

The Bay, and especially the Maryland section of the Bay, has received relatively scant attention in regard to coastal processes. The one active group in this area is the Maryland Geological Survey branch of the Department of Natural Resources. There, Messrs. Turbit Slaughter, Randy Kehrin, and Barry McMullan have a program in which they apply color and color IR photography to near-shore, littoral processes. Particular areas of study include James Island State Park near Crisfield, Kent Island, and the Calvert County shoreline (with particular emphasis on the Long Beach Flag Ponds, the Scientists Cliffs groin field, and the North Beach-Chesapeake Beach piers and bulkheads). They are particularly interested in any penetrating technique for evaluating the littoral bottom contours

(> 10 m) on a time-lapse basis. Supporting data taken in these areas include a thorough geological survey, artificial structure analysis, wind, waves, tides, and tidal currents, and shore-induced currents (long shore current).

A hoped-for result of this project will be a technique for evaluating the feasibility of man-made structures to retard erosion. The aim is not only to identify areas where these structures might be built, but also to indicate where these expensive projects would prove to be futile. A proposed groin field north of Point Lookout is currently under examination.

The erosion of eastern shore marshes is covered in Section VII.

Recommendation 15

Here, as elsewhere in this report, remote sensing work is not nearly as intense in the northern end of the Bay as to the south. An entire coordinated program could be built upon the initial endeavors of the Maryland Geological Survey, and Environmental Concern, Inc. Such a program could well be coordinated by CRC. [B]

Recommendation 16

The Maryland Geological Survey has need for littoral bathymetric data which may be possible to obtain using LIDAR. LIDAR bathymetry is normally of little use in the turbid waters of the Chesapeake Bay; however, there are usually a few calm days in November when water visibility is six meters or more. Flight coverage of a few key study areas should provide the Maryland Geological Survey with most of the data they require. [B] Such a cooperative venture should be pursued.

Recommendation 17

Although a very small amount of research is being done on the Delmarva coastline, it is nowhere near commensurate with its regional importance. NASA should endeavor to solicit research to bring the focus upon this area up to the level of that upon the Jersey and Carolina coasts.

Interested Parties

Maryland Geological Survey, Baltimore, Maryland

Mr. Turbit Slaughter
Mr. Randy Kehrin
Mr. Barry McMullan

Department of Natural Resources, Annapolis, Maryland

Mr. Earl Bradley
Mr. Craig Ten Broeck
Mr. Raymond Schwartz

U. S. Army Corps of Engineers, Washington, D. C.

Mr. John Housley
Mr. Keith Adams
Lt. Scott Sollers
Mr. James DeSista
Mr. Warren Braban (WES)

The Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Robert Byrne
Dr. John Zeigler
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Dr. Larry Haas
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The Johns Hopkins University, Baltimore, Maryland

Dr. Jerome Schubel

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry
Mr. Daniel Bliley
Dr. Norriss Powell

The University of Virginia, Charlottesville, Virginia

Dr. Bruce Hayden
Dr. Robert Dolan
Dr. John Fisher
Dr. Jay Zeeman
Dr. William Odum
Dr. Grant Goodell

VII. WETLANDS

The Nature of the Problem

For the sake of this presentation, the term "wetlands" will be defined as an area that is permanently or very frequently inundated, supporting vegetation with generally submerged roots, but with emergent structure that is mostly above the water surface (so-called emergent vegetation). The actual legal definition of the term was the subject of much controversy, and if a more precise definition is desired, refer to the Wetlands Protection Act of the State of Maryland or Virginia. Most of the wetlands referred to here are saltwater or brackish marshes. However, Maryland and Virginia possess a very substantial acreage of freshwater wetlands. The estuarine marshes vary in character with the salinity of the waters flushing them--anywhere from the freshwater Typha-dominated marshes to those characterized by the marine forms of Spartina.

Marshes are important as ecosystems because they are more capable of producing the highest level of biomass and energy fixation than any other natural system. This is caused by an abundance of nutrients, efficient recycling mechanisms, and a relative freedom from limiting factors which diminish the productivity of other terrestrial or aquatic climax communities. Possessing such high rates of primary production, the marshes are capable of supporting an intense web of higher life forms. They serve as an important nursery area for young finfish, and support heavy populations of furbearers (muskrat, nutria, raccoon and otter), as well as birds.

Rather than simply being the result of a fortuitous environment, the marshes also seem possessed of an ability to absorb and buffer some perturbations acting upon them. Tidal range decreases markedly in the landward direction through the marsh. More importantly, some marsh seems capable of assimilating large amounts of nutrients without losing its fundamental structure and diversity. There are those who believe that the key factor in the survival of the Patuxent River estuary in the face of an onslaught of nutrient loading comparable in intensity to that flooding the Potomac is the large "filter" of oligohaline marshes in the upper reaches of the estuary.

In earlier times, marshes were regarded as unhealthy to man. Even after the conquest of yellow fever and other marsh-related diseases, the areas were still looked upon as wasteland to be reclaimed for other uses. Large segments of freshwater marsh were channeled and drained to be used as agricultural land. Salt marshes were often the repository for spoil from dredging operations to create new real estate. During the 1950's, the creation of real estate from marshland became an end in itself, giving rise to a number of Venice-like "waterfront communities." Just when such developments threatened to engulf the remaining marshes, wetlands biologists were able to educate the public on the value of this resource. The result has been legislation in various states, including Maryland and Virginia, to control the dredging and filling of wetlands.

Impacted areas of wetlands are spread throughout the Bay area, but pressures are perhaps most intense on the western side of the island at Ocean City, the Isle of Wight, and along the Sinepuxent.

Remote Sensing Work

Practically all academic research organizations in the Bay area have ongoing programs in marsh systems, and many make use of some form of remote sensing.

Dr. Richard Anderson of American University is using ERTS multispectral scanning data in an effort to delineate and differentiate various marshes in the Bay area.

The Chesapeake Research Consortium has an entire program devoted to wetlands research. Dr. William Queen, program director, and Dr. John Stevenson are presently trying to model the energy flows through marsh systems, and are gathering much of their background data from past aerial surveys. The bulk of CRC's funded efforts is going towards the investigation of the nutrient assimilation capacities of various marshes. The CBC study (see Section I) on the fate of nutrients in sewage effluents sprayed upon the marshes is utilizing remote sensing to monitor changes in the marsh itself. CBC and VIMS have similar studies underway to identify unique spectral signatures from marsh-dominant vegetation. Such a signature (or series of signatures) will, hopefully, give positive identification regardless of time of day, atmospheric conditions, season, etc.

Ms. Ruth Whitman at NASA, Langley is working with VIMS to identify unique photographic texture of marsh vegetation. Helicopter flights were made over saltwater and freshwater marshes. Photographs of specific communities were taken at different altitudes and with different focal length cameras. Photographic texture found in a high resolution photograph can be used to identify tone or color in a lower-resolution, conventional mapping photograph. Texture can thus be used as a calibration technique for remotely sensed data.

Drs. Kenneth Webb and Larry Haas of VIMS are attempting to define more accurately the exchange between the marsh and the barrier island circulation currents. They are trying to detect chlorophyll, sediment, and detrital patterns which originate in the marsh.

Another group which is endeavoring to quantify the marsh-open-water exchange consists of Donald Heinle, David Flemer, and Charles Rawls of CBL. Drs. Heinle and Flemer have chosen a blind gut in the oligohaline marshes of the Upper Patuxent, and are directly measuring fluxes at the mouth of the gut over a full tidal cycle. Along with Mr. Rawls, they have used color IR and black and white stereo to determine the drainage area of the gut, and to estimate the standing crop of emergent vegetation within this area.

Drs. Flemer and Heinle are also using color photos of the Parker Creek Marsh to census vegetation and muskrat dwellings. Parker Creek Marsh begins near Prince Frederick at the site of a newly built sewage treatment plant, and runs easterly a few miles to the Bay. It is a before-and-after study to assess the effects the effluent and marsh have on one another.

At VPI Dr. Pettry, the head of the Soil Science Center, is using remote sensing to develop a wetlands soil classification scheme which he claims will eventually obviate many of the messy legal technicalities in defining wetlands.

At the University of Virginia, Drs. Robert Dolan and John Fisher have plans for using side-scan radar to look at the coastal wetland areas. They, like Dr. Maynard Nichols of VIMS, are interested in interpretation of the grey-tones from SLAR.

Dr. Edgar Garbisch, Jr., president of Environmental Concern, Inc., has been trying to establish artificial new wetland areas with some degree of success. He theorizes that the acceleration of erosion of the marshes is caused by large populations of geese destroying the rooted aquatic beds at the foot of a marsh. The grass beds serve as a wave buffer to the marsh edge. (See XII. B. 10.) He presently plans to use aerial photographs of certain areas of marshes to document the rate of erosion and to see if this rate can be correlated with the rise of the geese population in the area.

The State of Maryland has contracted a private firm to execute aerial photography of all of Maryland's tidal wetlands. There is a need for better than one-shot coverage, however, and much of the updating that state records require could be made from cost-effective high- or medium-altitude reconnaissance.

Recommendation 18

A time schedule of flights at regular seasonal intervals should be set up to cover the tidal wetlands of the Chesapeake Bay and Atlantic coast. Medium-altitude flights are recommended as a compromise between expense and necessary detail. The exact data to be taken should be worked out with the multiple users this project is intended to serve (CRC, DNR, Environmental Concern, etc.). [B]

Recommendation 19

An attempt should be made to characterize the various grey-tones observed on the marsh with side-looking radar. [C]

Interested Parties

The Chesapeake Research Consortium, Baltimore, Maryland

Dr. William Queen
Dr. John Stevenson

The Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Michael Bender
Dr. Robert Byrne
Dr. John Zeigler
Dr. Michael Penney
Dr. John Boone
Dr. Christopher Welch
Dr. Kenneth Webb
Dr. Larry Haas
Dr. Eugene Silberhorn

The Chesapeake Biological Laboratory, Solomons, Maryland

Dr. Donald R. Heinle
Dr. David A. Flemer
Mr. Charles K. Rawls

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry

The University of Virginia, Charlottesville, Virginia

Dr. Robert Dolan
Dr. John Fisher
Dr. Jay Zeeman
Dr. William Odum

The American University, Washington, D. C.

Dr. Richard Anderson

The Smithsonian Chesapeake Bay Center, Edgewater, Maryland

Dr. Susan Weck

Maryland Department of Natural Resources, Annapolis, Maryland

Mr. Roger Kanerva
Mr. Lester Levine
Mr. William Sipple
Mr. Earl Bradley

Environmental Concern, Inc., St. Michaels, Maryland

Dr. Edgar Garbisch, Jr.

National Aeronautics and Space Administration,
Langley Research Center, Langley, Virginia

Ms. Ruth Whitman

VIII. NAVIGATIONAL CHANNELS

The Nature of the Problem

Oftentimes the bottom topography of a body of water is inadequate to accommodate the shipping vital to an economic region. The requisite dredging of channels and displacement of the spoil is wrought with problems, physical and biological.

A.1 First, the channel cannot be chosen haphazardly. All channels will have a finite lifetime unless maintained. The art is to choose a channel according to local sediment flows to minimize the subsequent maintenance dredging. Of course, a certain amount of benthic (bottom-dwelling) life is displaced in the initial dredging of a channel but, more importantly, the flushing characteristics of the estuary are significantly altered. This is particularly true in a vertically stratified estuary where mean tidal velocities are driven by density differences. Thus, the Baltimore channel in the Patapsco gives rise to a novel three-layer net tidal flow.

Sometimes consequences could be far reaching, as in the case of the widening and deepening of the C and D Canal. This project will result in a greater diversion of freshwater from the Bay head into the Delaware Bay, possibly increasing salinities along the longitudinal axis of the Chesapeake Bay. Consequent possible biological changes range from a shift of the striped bass spawning grounds to an encroachment of more high-salinity dependent oyster predators upon the Maryland beds.

A.2 Dredging or maintaining a channel generates copious amounts of displaced material, or spoil. Where to place the spoil is often the greatest problem incurred in any dredging operation. As the true value of marshes has become clear, possibilities for land disposal have dwindled. Overburden usually destroys what bottom life it covers without soon providing a new viable bottom surface. The new bottom surface, not being in equilibrium with the prevailing currents, tends to erode, spreading a burden of silt over the nearby bottom areas and disturbing nearby crabs and finfish; and perhaps even smothering shellfish beds in the fallout area.

The bottom sediments serve as a sink for a number of pollutants and nutrients. Resuspension of these sediments due to dredging and spoilbank erosion tends to release these materials to the water column once more. Of course, heavy metals, pesticides, and nutrients are most abundant in populated areas where dredging is needed, so the problem is worsened by destabilizing feedback.

A. 3 The navigational lanes must also be kept free of dangerous flotsam, natural or man-made. The Corps of Engineers, as part of its normal operations, tries to keep the waterways free of dangerous debris. According to Dr. Kenneth Warsh, such debris also poses hazards to certain industrial intakes such as those of power-generating stations.

B. There has, of late, been interest in the location of old borrow pits as possible spoil disposal sites.

Remote Sensing Work

Most of the remote sensing work presently underway on the main navigational channels is confined to the lower Bay. Dr. Maynard Nichols is using visible range (black and white, and color) photography to delimitate sediment flows connected with the James River shipping channel, Craney Island fill area, and the enlargement of the Hampton Roads channel. New spoil disposal sites are urgently needed, and an enlargement of Craney Island and back filling of the James River borrow pits is under consideration. Dr. Nichols stressed the need for subsurface vertical profiles of sediment and time-series data.

At the Waterways Experiment Station in Vicksburg, Mississippi Dr. Albert M. Williamson is using ERTS imagery to identify a spectral signature for sediment flows, and is concentrating on the Choptank and the Wicomico Rivers of the Eastern Shore of Maryland, and the York and Rappahannock Rivers in Virginia. Dr. Jack Ludwick of Old Dominion University, and Dr. David Bowker of NASA, Langley are also using ERTS-1 and Skylab imagery to determine sediment transport of the Lower Chesapeake Bay, with emphasis on the Hampton Roads area.

Drs. Jay Zeeman and William Odum of the Department of Environmental Sciences of the University of Virginia are developing models of plant succession on dredged spoil islands in the York River area. They are presently using vertical color photography taken at 4,000 feet over a time-series to determine the temporal sequence of vegetation on the islands. They would like to try side-scan radar to see if it can be used to evaluate vegetational patterns. They are interested in any low-level photography with which vegetational species can be identified (see also IX. A. 4), particularly in the York River area.

Dr. David Pettry of VPI has used black and white and color IR to assess the soil quality and soil evolution on spoil islands. He is also evaluating the temporal succession of vegetation and how to stabilize spoil banks with planted flora. His work has centered around the spoil islands along the intercoastal waterway.

Mr. Will Bornbush of the Waterways Experiment Station in Vicksburg has used color IR to assess the fate and grain size of tailings from mining operations. His work could be applied at a number of points in the Bay, notably along the Potomac River sand and gravel operations.

Mr. Douglas Pirie of the Corps of Engineers San Francisco Bay District is using remote sensing to study the frequency of shoaling of the mouths of channels in the Bay District.

Recommendation 20

Practically all remote sensing work on the Bay pertaining to navigational channels has been in the southern end. There are urgent problems in the northern end which also demand attention. Notable among these are the widening and deepening of the Baltimore Harbor Channel, and the use of the spoil to enlarge the Miller-Hart Islands, the widening and deepening of the C and D Canal, and the Potomac River sand and gravel operations. CRC and NASA should work out a cooperative program. [B]

Recommendation 21

The Power Plant Siting Committee of the State of Maryland and NASA should create a program for monitoring flotsam in the neighborhood of present and proposed power plants to identify sources of such debris. [C]

Interested Parties

U. S. Army Corps of Engineers
Chiefs Office, Washington, D. C.

Lt. Scott Sollers
Mr. John Housley
Mr. Keith Adams
Mr. James De Sista
Col. Ludwig
Mr. Milton Milard

Baltimore District, Baltimore, Maryland

Ms. Noel Beagle
Mr. John O'Hagen
Mr. John Gercalk

Waterways Experiment Station, Vicksburg, Mississippi

Dr. Albert M. Williamson
Dr. Warren Grabau
Mr. Will Bornbush

San Francisco District, San Francisco, California

Mr. Douglas Pirie

Department of Natural Resources, Annapolis, Maryland

Mr. Earl Bradley
Mr. Craig Ten Broeck

Chesapeake Biological Laboratory, Solomons, Maryland

Dr. Albert Sherk (biological effects of sediments)
Mr. Charles K. Rawls (borrow pits)
Dr. T. S. Y. Koo (finfish)

Chesapeake Bay Institute, Baltimore, Maryland

Dr. Donald W. Pritchard (hydrographical change)
Dr. Jerome Schubel (sediment transport)

Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Maynard Nichols (sediment transport)

University of Virginia, Charlottesville, Virginia

Dr. William Odum) (spoil island stabilization)
Dr. Jay Zeeman)

Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry (spoil soil analysis)

Johns Hopkins University
Applied Physics Laboratory, Howard County, Maryland

Dr. Milton Moon) (flotsam)
Dr. Kenneth Warsh)

National Aeronautics and Space Administration
Langley Research Center, Langley, Virginia

Dr. David Bowker) (signature determination)
Mr. Walter Bressette)

IX. LAND USE

The focus of this report is upon aquatic-related problems. One cannot ignore, of course, the related terrestrial topics. Because of the nature of the satellite sensors, the active ERTS program has focused upon land-based resources. Whole libraries of information on the nature of land-use problems have been generated, and most NASA researchers are well acquainted with these issues. For this reason, the usual narrative on the nature of the problem will be omitted.

The bulk of this section will be a brief description of the land-use projects underway in the Chesapeake area which involve remote sensing, with particular emphasis placed upon areas where researchers have indicated a need for additional complementary remote sensing data.

Land-use planning is regional in nature, and a good place to begin the survey is with mapping efforts that are state-wide in scope.

At the Federal level, the Geographic Applications Program of the U. S. Geological Survey is preparing a land-use map of the Central Atlantic Regional Environmental Test Site (CARETS) which includes the Chesapeake system. Multispectral scanning data from ERTS serve as the bulk of the data used in this study. The major object is to develop a national land-use inventory system. Many states are at various stages in the development of statewide land-use maps. Such mapping efforts are generally executed on a rectangular grid basis with the size of such grids varying in the different states.

Using remote sensing data, Dr. Robert Alexander of USGS has devised a "polygonal" format for creating land-use maps. A set of software programs will process the multispectral spanning tapes of an area so that the various land-use categories will be shown on the map in a polygonal form which closely approximates the actual observed area. A great deal of information on the actual land area is thereby created and stored. Additional programs have been created to convert these polygonal outputs to an arbitrary lower resolution grid scale. Hence, Alexander's polygonal maps can be quickly converted to yield output on, say, the 25-acre grid scale used by VPI's Bob Giles, or the 90-acre grid scale used by John Antonucci. Land-use categories are presently identified under a two-digit scheme with occasional three-digit subclassifications. Besides ERTS data, USGS is using color, color IR, black and white stereo, and APQ97 side-scan radar in this mapping effort.

In the state of Maryland the Department of State Planning is preparing a map of land use in the state on a grid scale of some 27,000 quadrants of

90 acres each. Accompanying the map will be an inventory of soil structure, underlying geology, flora, fauna, man-made buildings, commerce, and historic sites present in each quadrant. They are cooperating with Dr. Alexander's group, and have extended the CARETS region to include Western Maryland for the sake of their efforts. Mr. Thomas of DPS related that side-scan radar data on topographic structures would provide useful data yet needed in this survey. An effort with similar goals is underway at the Virginia Polytechnic Institute under the supervision of Dr. Robert Giles of the Center for Environmental studies. Dr. Giles hopes to map land use in the state on a 25-acre grid scale. He is presently not using remote sensing data directly, but rather is reducing data from USGS 7.5-minute maps. Since his project seems to be the only comprehensive mapping effort in the state, it seems imperative that his project be linked with the remote sensing capabilities of NASA and the data bank of USGS. Dr. Giles has looked at certain ERTS imagery, but he finds the data of insufficient resolution to be useful. His 25-acre grid requires more in the way of lower level observation.

In VPI's Soil Science Center Dr. David Pettry is at work creating a map of soil types in the state of Virginia, using his wide experience in remote sensing.

State-wide vegetational maps seem surprisingly deficient. Dr. Grace S. Brush of the Department of Earth and Planetary Sciences of the Johns Hopkins University is under contract to the state Power Plant Siting Committee, to construct an arboreal map of the state. Dr. Brush's effort lays particular stress upon certain vegetational associations which she claims can only be observed by the lowest-level remote sensing flights. For this reason, the study is based on a windshield-survey routine. While this data will provide excellent ground truth data for later remote sensing endeavors, this writer feels that NASA's aerospace experience may make low-level, cost-effective aerial surveys available to investigators needing very high resolution data (see below, and Section VII) through the use of NASA, Wallops balloon technology, to create a one- or two-man balloon craft which can compete with an automobile windshield survey.

A map of critical areas in the Chesapeake region marked for possible preservation has been created by The Nature Conservancy. Areas to be marked for protection are also of concern to the Maryland Departments of Natural Resources and State Planning, and to the Virginia Office of Economic Resources. Remote sensing can be useful in delineating land types that should be considered for preservation, but Dr. Robert Jenkins of The Nature Conservancy relates that decisions on which particular parcels are to be earmarked for preservation need "microscopic" examination to determine the presence of rare and endangered species, as well as flora and fauna which are existing on the fringes of their natural ranges.

On a more local scale, the Maryland Department of State Planning is regarding those areas of rapid development in detail. They are scrutinizing the vicinities of Deep Creek Lake in Western Maryland, and Chincoteague Bay near the Atlantic Coast, as well as Kent Island on the Chesapeake. The suburban areas of Baltimore County, Laurel, Bowie, Columbia, and lower Harford County are being monitored for changes by comparing the 1972 and 1973 ERTS imagery. They are also analyzing the grey-tones on the multi-spectral scanning tapes from the Baltimore-Washington Corridor to create a three-digit heirarchy of urban and suburban land-use classifications.

In Maryland, DSP is acting as a cover organization for all the county planning groups and is passing along processed remote sensing data as it pertains to the various counties.

Likewise, USGS is regarding several local areas in greater detail, such as the Portsmouth-Norfolk Area, the Baltimore Harbor, and the Baltimore-Washington Corridor.

The Environmental Geology Department of the Maryland Geological Survey in conjunction with USGS is creating a file of 7.5-minute overlay maps which plot out the geology, mineral resources, constraints to construction, septic tank constraints, and groundwater potential for the whole state of Maryland. They have just finished the Baltimore-Washington Corridor and will move on to Charles County, and eventually to other developing areas of the state. They have found ERTS data is of minimal help in their efforts and are anxious to obtain color IR coverage from 10,000 feet to speed their efforts along.

Of prime concern in the Baltimore Harbor Area is the land-air heat transfer, which gives rise to thermal advection patterns or "heat islands." USGS feels the technology they are developing will eventually be applicable to air-sea heat exchange. (See also Section II.) Dr. Alexander states that one problem incurred in projects involving thermal scans has been the dearth of well-calibrated data where the grey-tones can be quantitatively evaluated. Dr. Alexander also suggested that a contemporaneous rocket thermal scan be made along with the aerial survey to gather three-dimensional thermal data of the area.

The Portsmouth-Norfolk area was the pilot area on which the data-processing routines were developed to yield the polygonal land-use maps. Dr. Alexander's group is experimenting with assigning "loading factors" to the various land-use categories to develop a rapid method of censusing and to derive background data for models. For example, Mr. Peter Buzzanell is endeavoring to assign energy storage and use factors to each land-use category so that natural and man-made energy flows of a region can be rapidly assessed and eventually applied to an energetics model.

Other regions of secondary concern to USGS are the RADCO District around Fredericksburg, the North Virginia Planning District of Fairfax County, and the Virginia Coastal Barrier Islands.

Dr. Alexander felt that a missing gear in the machinery of satellite and high-altitude remote sensing is a statistical study of the averaging that goes into one pictle of information. Information from a given area on the ground is spatially averaged by the resolution limits of sensors, and a systematic confusion is superimposed by the movement of the platform relative to the ground. This is a frequent reason for disagreement between remote and in-situ data. Obviously, more than one ground truth measurement is necessary to arrive at a value to assign to the measurement recorded by the sensor. A separate study to obtain the optimal design of ground truth data acquisition will do a great deal to put remote sensing on a more substantial scientific footing.

Mr. Craig Ten Broeck of Maryland's Department of Natural Resources is laboring over remote sensing photography to identify potential recreational access to the Bay and its tributaries. Public access to the Bay is poor, and any tool which will aid in making this public resource more public is welcomed by DNR.

The siting of utilities corridors is a raw issue in several sections of the Bay Region. Dr. Robert Giles of VPI is using his 25-acre land-use map of Virginia to supply the data base for an optimization routine which will map out the least destructive, least expensive route for a power line to follow from point A to point B.

In the pedagogical realm, Dr. Robert Giles is developing a management strategy game to train prospective environmental decision makers. The game is effective as a resource base computer model which is run in the input mode so that the participant can make decisions (increase hunting pressure so much, build so many houses, etc.) and immediately see the effects on the stocks being managed. Resource base data from remote sensing are welcomed by Dr. Giles.

There was an interest on the part of several parties for flood plain mapping, including both state agencies, the Corps of Engineers, and the Virginia Water Control Board.

Recommendation 22

Statewide land-use mapping projects to supplement the CARETS program should be undertaken. The most expedient course of action along these lines would be to expand the mapping program of Dr. Robert Giles of VPI to include remote sensing data. [B]

Recommendation 23

Additional knowledge about how high-altitude sensors average data is needed. An experiment should be designed to determine the optimal program of ground truth sampling so that confidence limits can be set for signatures of remote sensing data. [A]

Recommendation 24

NASA should look into the development of balloons or sounding rockets to provide economical low-level reconnaissance needed in a number of surveys. [D]

Recommendation 25

The NASA facilities in Virginia should make contingency flight plans for the Chesapeake Bay Region for comprehensive coverage of flooding after major rainstorms. The data should be forwarded to the state planning agencies in Maryland and Virginia. [C]

Recommendation 26

The usefulness of side-scan radar data for topographic studies by state planners should be investigated. [C]

Recommendation 27

Routine meteorological data of the type obtained from tracked radiosonde balloons of the area above Baltimore Harbor should be made synoptic with the USGS thermal scans of the area in order to provide adequate three-dimensional thermal mapping of the atmosphere. [B]

Recommendation 28

Contact should be made with the Department of Environmental Geology of the Maryland Geological Survey to see if a mutual program for color IR coverage of the developing areas of the State can be arranged to speed the mapping of building constraints throughout the state. [A]

Interested Parties

United States Geological Survey, Reston, Virginia

Geographical Applications Branch

Dr. James Anderson, Director
Dr. Robert Alexander
Mr. Peter Buzzanell

Regional Hydrology Branch

Mr. Patrick Hollyday
Mr. Edward Plukowski

Maryland Department of State Planning, Baltimore, Maryland

Mr. Edwin Thomas
Mr. John Antonucci
Mr. Richard Hooper (Regional Planning)
Mr. Scrib Schaeffer (Regional Planning)
Mr. Arthur Benjamin (Research Branch)
Mr. James Jordan (Research Branch)

Maryland Department of Natural Resources, Annapolis, Maryland

Mr. Craig Ten Broeck
Mr. Earl Bradley

Office of Environmental Resources, Richmond, Virginia

Mr. Robert De Mauri
Mr. Keith Buttlemann

Virginia Water Control Board, Richmond, Virginia

Mr. Donald Richwine

The Johns Hopkins University, Baltimore, Maryland

Dr. Grace S. Brush

The University of Virginia, Charlottesville, Virginia

Dr. Grant Goodell
Dr. Robert Dolan
Dr. John Fisher
Dr. Dexter Hinkley

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. Robert Giles
Dr. David Pettry

Old Dominion University, Norfolk, Virginia

Dr. Chopra

Washington Council of Governments, Washington, D. C.

M. Harry Mallon

U. S. Army Corps of Engineers, Washington, D. C.

Lt. Scott Sollers

Maryland Geological Survey, Baltimore, Maryland

Mr. Turbit Slaughter

X. METEOROLOGY

Due to the short tenure of this survey, the field of meteorology was not adequately researched.

Most mention of meteorological problems was made in connection with stack emissions from power plants--a subject covered in Section II.

In the mountainous regions of Virginia there are several areas with chronic inversion problems caused by local topography.

Both LIDAR and millimeter radar techniques have been mentioned elsewhere in connection with sensing stack emissions (Section II).

<u>Interested Parties</u>

The Johns Hopkins University, Baltimore, Maryland

Dr. Owen Phillips

The University of Maryland, College Park, Maryland

Dr. Alan J. Faller
Dr. Thomas Wilkerson
Dr. William Benesch
Dr. Thomas McIlrath
Dr. David Koopman

The University of Virginia, Charlottesville, Virginia

Dr. Grant Goodell
Dr. Michael Garstong
Dr. Carl Aspliden
Dr. Joanne Simpson
Dr. Robert Simpson

State Air Pollution Control Board, Richmond, Virginia

Mr. George Haggerman

XI. SOLID WASTE DISPOSAL

The ocean has always appeared to be an infinite reservoir in which to dump the wastes of modern society. All too often, however, there are aquatic side-effects of the wastes in the water, and in some instances the waste will find its way shoreward to haunt the disposers. Sludge dumped in the New York Bight area has drifted shoreward along the bottom and is encroaching upon the beaches of Long Island. Towards the center of the site the sediments are pathologically devoid of any higher life forms.

While the situation has not degraded to such a point in these latitudes, there has been significant dumping off the Delaware-Maryland coastline and the situation there should be monitored and controlled.

Disposal on land has some very obvious aesthetic drawbacks. In addition, many dumps in rural areas are not properly managed so that fires which break out pose a threat to the nearby landscape and add a good deal of smog to the air. Even well-managed dumps can pollute nearby streams and groundwater through runoff and leaching.

Possibility of Applying Remote Sensing

The surface traces of the dumping off the Delaware-Maryland coast show up vividly on ERTS band 4 of the multispectral scanner. Presently, according to EPA, the Dupont Company is releasing acidic material (pH 1.1) while in the same general area Sun Oil is discharging alkaline (pH 14+) materials. The city of Philadelphia has been contributing sewage sludge to the mix. Apparently, no one is analyzing the dumping areas from the air. Dr. Lear of EPA says that the height of the thermocline is an important parameter because the materials seem to sink down to this point and then disperse rapidly in a lateral direction.

The Westinghouse Laboratories have tried tracking the dumped materials by releasing a host of density adjusted "frisbee-like" discs at the site. When a tag is washed ashore, anyone finding it is instructed to place the smelly disc into the mail to be returned to Westinghouse. Captain Ela suggested that these probes might be actively tagged and tracked either from the air or via a telemetry buoy.

At VPI, Dr. David Pettry and Mr. Ellwood Black have been consulting for the Virginia Health Department on the nature and dispersion of leachate from solid waste, using remotely sensed data, and this work is funded by EPA, Cincinnati.

Quite possibly, a number of fires in sanitary landfills could be prevented by thermal scanning of such dumps prior to spontaneous combustion.

Recommendation 29

The possibility of using active tags to follow the dispersion of ocean dumped material should be explored. [C]

Interested Parties

U. S. Army Corps of Engineers, Washington, D. C.

Mr. James De Sista

The Environmental Protection Agency, Annapolis, Maryland

Dr. Donald Lear

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry
Mr. Ellwood Black

Westinghouse Oceanics, Inc., Annapolis, Maryland

Capt. Deke Ela

XII. GENERAL RESEARCH

There is a host of investigative problems for which remote sensing is needed, being developed or being applied, which either are not immediately applicable to a "brushfire" problem or cannot easily be classified in one of the previous problem areas. These areas have been grouped together into this section and labelled "General Research." Actually, every topic covered herein is only one link away from, and necessary input to, the urgent problem areas covered previously; each topic should therefore be accorded equal importance. Some topics (rooted aquatics, for instrance) are well on their way to becoming to m or r o w's headaches. The topics fall into two categories, "A", physical investigations, and "B", biological research.

A. 1 Tidal Heights

The level of the surface of an estuary varies with the lunar annual frequencies and meteorological events. Precise measurement of the absolute height of the water surface is extremely expensive, requiring first-order surveying methods. Usually, the relative height of the water is measured either by the mean pressure recorded on a submerged pressure sensor or by the level of a float within a stilling well. Either of these measurements can be converted into an analog or digital voltage format, and telemetered by a DCP.

Dr. Robert Byrne of VIMS used black and white photography of tidal marsh ponds taken at high and low water, respectively, to determine the change in water surface of the embayment. This area estimate was then used in conjunction with a ground-sensed tidal amplitude to calculate the volume of the tidal prism; hence, the flushing rate of the pond.

A. 2 Tidal Currents

The tidal currents in an estuary may be sensed in a variety of ways and telemetered to a data collection center. More apropos, however, are a number of efforts to assess surface currents from the air.

The most qualitative of these methods involves the location on remote sensing photography of material streamlines which indicate the general pattern of surface flows. The material may be sediments, chlorophyll or any other identifiable substance. The method has severe limitations in that it is not quantitative, and often fails in cleaner waters. Crude quantitative measures of current speed and direction can be made by time-lapse photography of an induced dye tracer.

An ingenious modification of this latter method was used by Mr. James White of Photoscience, Inc., when he was frustrated by smog and air traffic from surveying currents in Baltimore Harbor. He put Hibachi stoves on styrofoam floats and made time-lapse IR photographs of the float positions by night.

In the same vein, Drs. Kenneth Webb and Larry Haas of VIMS, working with Mr. John McFall of NASA, Langley, have employed the sophisticated radar of NASA, Wallops to follow responder drogues up to five miles off the coast and around Newport News Point in Hampton Roads.

Dr. Maynard Nichols of VIMS has tried measuring currents in the lower York River from a stereoscopic displacement technique developed by researchers in Canada. Unfortunately, the photos were made at 60,000 feet and the current-induced displacement was practically unobservable. The method should be attempted again at lower altitude, perhaps from a near-stationary platform such as a balloon stationed over an appropriate uncongested area.

A.3 Salinity

The change in concentration of dissolved inorganic salts is the defining feature of an estuary. It is normally measured in-situ with a conductivity or induction probe, either of which may ideally be interfaced with a DCP network.

The characteristic association of plants in a region of an estuary is usually a function of the mean annual salinity. Therefore, determining the species composition of submerged and emergent vegetation from the ground or from the air will by association give a rough indication of salinities in the area. Mr. Bressette of NASA, Langley has detected different spectral characteristics of phytoplankton across the salt wedge of the Potomac using aerial filtered photography.

Radiation is emitted at all electromagnetic wavelengths due to thermal vibrations of water molecules; however, only in the lower microwave region is the radiation a function of both salinity and temperature. By obtaining data over at least two widely spaced points in the microwave spectrum, precision microwave radiometers can measure salinity to 1 ppt for salinities greater than 5 ppt.

The Westinghouse Oceanics Division is developing a cheap, expendable STD probe for use off the coast. The idea here is that an aircraft could drop these probes and monitor the salinity-temperature profile over several points in the ocean for an overall cost which would be competitive with a seaborne mission.

A.4 Temperature

Microwave radiometers have obtained measurements of water temperature to an accuracy of 1^{o} K. This represents an absolute measurement which can be obtained under all weather conditions; however, spectral scans of the microwave radiations are necessary to separate other parameters, such as salinity, from the measurement.

Often a given water column will be sharply stratified into two layers caused by temperature-induced density differences. The presence and location of these thermoclines provide valuable data to assess the fate of ocean-dumped wastes. The EPA is very interested in any remote sensing methodology which might allow for rapid determination of thermoclines and haloclines. LIDAR and acoustic techniques are likely candidates although in-situ DCPs might be more expedient.

A. 5 Bathymetry

Sensing the depth of the water has always been a problem for remote sensing in that water is relatively impenetrable to short wavelength electromagnetic radiation. In regions where the water is not excessively deep or turbid, the surface and bottom reflections of a laser beam will readily indicate the depth of water and possibly a turbidity profile. While this method shows much promise, it may be impractical to use over a great deal of the turbid Chesapeake.

Mr. John Housely's group in the Corps of Engineers is quite desirous of having any bathymetric data which NASA may be accumulating.

A. 6 Sediment Load

There are several problems associated with sediment in estuarine waters. How did it get there, how much is in suspension, how fast is it sedimenting out, and what is the rate of resuspension from the bottom?

The soil model which Dr. Pettry and coworkers at VPI are developing will hopefully shed light on the first question. A good deal of remote sensing background data is going into this endeavor.

Material in suspension will have its own signature which allows for quantitative analysis via multispectral-scanning techniques. Dr. Warren Grabau of the Waterways Experiment Station, Vicksburg, is using ERTS multispectral-scanning data to map sediment in four areas of the Bay.

Dr. Walter Bressette of NASA, Langley is investigating suspended material in the Potomac River by analysis of selected broad-band black and white photography taken at an altitude of 10, 000 feet. The theoretical approach is that suspended particles in water backscatter sunlight as a function of both quantity and size. When the spacing between the suspended particles is greater than the particle size, then the particle size becomes important relative to the wavelength of light. The backscatter of the small particles will be greatest in the blue region of the solar spectrum, while the backscattering of the large particles will be greatest in the yellow and red regions. The photography is being correlated with river flow and in situ measurements of suspended sediment quantity and particle size.

When a laser beam is directed into the water there is not only a reflection from the surface and the bottom, but also backscatter from suspended particles in the water. This backscatter can be related to the profile of suspended sediment concentrations, and Sparcom, Inc. has had reasonable success in measuring suspended material concentrations in moderately turbid waters in the laboratory.

A. 7 Sea State

Wave height and length are currently being monitored by submerged pressure probes in some operating DCP installations.

Direct sensing of surface conditions is available with the aid of microwave radar. These units can be mounted on a tower or in an aircraft.

Mr. John Housley of the Corps of Engineers is eager to correlate a time-series study of sea-state conditions and meteorological data with morphological boundary conditions to model shoreline erosion and silt deposition. Westinghouse Oceanics has prior experience in tower-mounted microwave radar monitoring of sea-state conditions, and NASA, Wallops possesses an airborne package as well as a sophisticated tower near the Chesapeake light near the mouth of the Bay.

A. 8 Ice

Being a temperate estuary, the Chesapeake is subject to occasional short periods of icing-over, especially in the northerly, less saline regions of the Bay. Dr. Maynard Nichols has made a study of the nature and effects of icing on the Rappahannock River. Ice flows can be particularly destructive to piers and pilings.

The extent of ice coverage is easily measured by any photographic method. Quantitative information on its makeup and thickness is much harder to come by, however. Mr. Joseph Jahoda of Bayshore, Inc. has preliminary designs for an acoustic probe which could be tethered just below the surface before icing occurs, and then interrogated periodically when ice is present. In this manner, time-series data on thickness and density profile of the ice could be accumulated. Mr. Jahoda says that the interrogator could be airborne. The same data can be obtained using radio-sounding techniques.

Ice, snow, and frost on the land are important factors in the erosion of the soil, and remote sensing has been used by Dr. Pettry's group in constructing their model for soils and soil erosion.

A. 9 Hydrology

NASA, Goddard has an active ERTS project under the direction of Dr. Vincent Salmonson to develop a model of the Patuxent River watershed hydrology.

The Maryland Department of Natural Resources is especially eager to map aquifer recharge areas and groundwater supplies in Western Maryland, particularly in the area of the Albert Powell Hatchery in Washington County.

A. 10 Oxygen

The abiotic factor which is most often limiting to estuarine waters is the supply of dissolved oxygen. It is the lack of oxygen induced by the biological oxygen demand of detritus and added nutrients which is responsible for most of the finfish, shellfish, and crab kills that have been reported. Dr. Donald Lear of EPA, Annapolis, identifies the development of the ability to monitor dissolved oxygen as having the very highest priority. Unfortunately for remote sensing, most critical oxygen levels occur in the lower region of the water column and are difficult to sense remotely.

Mr. Joseph Jahoda reports that initial experimentation with millimeter wavelength radar indicates that dissolved gases in the water exhibit pronounced absorption spectra. Whether oxygen in the parts-per-million range would cause an identifiable absorption should by all means be investigated.

B. 1 Finfish

The estuaries are the nursery area for the greater number of temperate fishes and also serve as a major feeding arena for the adults of numerous others.

Commercial fisheries such as the menhaden industry employ light aircraft to spot schools of these filter-feeding surface fish. Other species of finfish are not as easy to spot from the air, and require other methods.

A number of acoustic and radio tags are available to monitor the position and depth of an individual fish. Some tags are also capable of transmitting physiological information such as body temperature, heartbeat, respiration rate, etc. Such active tags are not easily linked with aircraft operations, however, unless the information is sensed in the water, buffered on tape storage, and transmitted on command to an overhead receptor, DCP style.

In addition to tracking an individual fish, a control volume of water could be staked out and the number of fish passing through it could be logged. This is feasible (and operational) according to Mr. Joseph Jahoda of Bayshore, Inc., whose firm has developed a sonar system which periodically samples the control volume on a number of acoustic frequencies. The resonance of certain frequencies with the swim bladders of passing fish provides data on total number of fish and size-frequency distribution. Again, linkage with aircraft would, perforce, be via a DCP-type hookup.

Mr. John McFall and Mr. Ray Lovelady of NASA, Langley are developing the capability to track sonar-tagged fish in an open estuary to explore the effects of powerplant thermal plumes on migratory species.

The Environmental Protection Agency gives high priority to any system which could monitor and forecast fish kills in an area.

B. 2 Shellfish

The bottom-dwelling oysters and clams of the Chesapeake are of prime commercial importance. Clams generally live a few inches below the surface of soft bottoms. The oyster, on the other hand, attaches itself to a hard surface and grows outward into the water. Both organisms are usually found in water less than 25-feet in depth due to a lack of oxygen in deeper waters during the warm weather periods.

The characteristic bottom habitats make the identification of oyster and clam beds a straightforward, if sometimes difficult, task. VIMS is eager to attempt a survey of Virginia oyster beds by using remote sensing.

Aside from natural predators and parasites, oyster mortality has been traced to chronic low salinity, high temperature, heavy siltation, and lack of oxygen; or any combination of the above. A particularly bad combination of factors culminating in heavy mortalities is caused by lack of oxygen brought on by heavy rainfall, little wind, and high temperatures over several weeks. Any monitoring system which would forecast these conditions would be valuable.

B. 3 Crabs

As with shellfish, there seems to be little remote sensing application to research in this field. Like shellfish, crabs are subject to large mortalities due to oxygen deprivation, except that crabs are pelagic and able to escape the low oxygen area, within limits. The so-called "crab wars" where thousands of crabs appear near the shore are the result of mass migrations to avoid suffocating waters. Again, at this time the value of remote sensing to the crab biologist is largely in providing supporting environmental data, although tag tracking experiments remain a possibility.

B.4 Phytoplankton

The small microscopic plant life floating freely in the waters of the Bay provides the majority of the energy which fuels the biological activity of the aquatic regime. (Other sources include rooted aquatics and detrital material.) The agent which fixes the solar energy is the chlorophyll molecule. Since it engages in a photosynthetic reaction, the chlorophyll molecule leaves a number of optical clues as to its presence and exact nature, thus making it an ideal candidate for remote sensing.

It is possible to sense chlorophyll passively or actively. In the passive sense, one identifies a rough spectral signature of a particular chlorophyll molecule and picks this combination out of a multispectral scan.

Mr. Walter Bressette of NASA, Langley has successfully mapped blue-green phytoplankton in the upper reach of the Potomac River using the near-infrared reflectance of the chlorophyll molecule. However, only phytoplankton growth that results in chlorophyll a concentrations above approximately 40 micrograms per liter (bloom conditions) can be mapped. This is because of the strong absorption of sunlight by water beyond the wavelength of 0.70 micrometers. Mr. Bressette is now investigating the first scattering peak of chlorophyll a, around 0.55 micrometers, where the water absorption is much less, for mapping phytoplankton when chlorophyll a concentrations are below 40 micrograms per liter. The success of mapping phytoplankton using the first scattering peak of chlorophyll a is also contingent upon successfully mapping suspended sediment, because both organic and inorganic suspensoids contribute to the backscattering of sunlight at 0.55 micrometers. EPA, Annapolis, and the Chesapeake Biological Laboratory have provided the ground truth data for these studies. VIMS is presently doing the same sort of work under a Skylab contract.

Another way of sensing the chlorophyll is to excite it into fluorescence with a particular frequency of collimated light, laser-induced fluorescence, or Laser technology. Drs. Kim of NASA, Wallops and Hickman of Sparcom, Inc. have pioneered the development of chlorophyll measurement by this technique.

The four major color groups of phytoplankton each contain different mixes of chlorophyll a, b, c and d. Based on this, Messrs. O. L. Jarrett and C. A. Brown of NASA, Langley employed a four-channel dye-laser to obtain fluorescence response which should permit quantitative determination of the amount of each type of phytoplankton present.

Dr. John Cairns of VPI is developing a sophisticated in situ method for counting diatoms which attach to a glass plate placed in the environment. The plate is scanned with 3-D laser holography, and the interference patterns sensed are described as a 3-D fourier series and compared with the key set of components from a known species. A match will trigger a count. Dr. Cairns hopes that it will eventually be possible to perform a census of all species on the plates. Presently, it appears that overall counts and diversity indicies are possible. As with many before, this method shows possibilities for remote sensing only through a DCP link.

The Environmental Protection Agency gives highest priority to any method which will accurately sense or predict red tide (properly referred to as mahogany tide) outbreaks in the Chesapeake Bay.

B.5 Zooplankton

The herbivorous species which feed upon the plankton (i.e., the second trophic level) are dominated in the Chesapeake estuary by the copepoda (or copepods), tiny crustacea (0.1 mm) which swim freely about, filtering the water for food. Not only do the higher organisms depend upon this second link in the food chain, but there is reason to believe that the estuarine ecosystem dynamics are most sensitive to changes in this particular functional group.

Being almost colorless and more rarified than the phytoplankton, they do not lend themselves readily to remote sensing. The present method of estimating populations is to concentrate the organisms with a plankton net and laboriously count the number of individuals with a microscope.

A proposed scheme for obviating this slow procedure is being proposed for development by Mr. Joseph R. Jahoda of Bayshore, Inc., and Dr. Donald R. Heinle of the Chesapeake Biological Laboratory. They have designs for passing a flow of sampled water through an acoustic cell wherein the organisms of particular size and composition, i.e., the copepods, will resonate with a chosen frequency. The counter could be monitored live onboard ship, or designed as a package to interface with a DCP or other telemetry link.

B.6 Nutrients

(See Section I)

B.7 Waterfowl

The Chesapeake Bay is a major stopover point along the Atlantic flyway and in the last few decades has seen an amazing increase in the number of waterfowl (particularly Canadian Geese) which overwinter in the region.

That the populations are beginning to strain their food supply is the topic discussed below in B.10. Their minor role in nutrient loading is mentioned in Section I.F.

Censusing the birds in the area is no mean task. It is presently done by leaning out of a small aircraft and counting. A census of the whole Bay is time-consuming, and the uncertainty of the result is compounded by migrations of flocks within the span of several flights. A method of high-altitude censusing would be welcomed by Mr. Vernon Stotts of DNR, and Dr. William Sladen of JHU.

B. 8 Upland Habitat

According to Mr. Craig Ten Broeck of DNR the censusing of deer in the state of Maryland can be accomplished with a fair degree of accuracy by knowing the acreage of various forest communities (oak-hickory, oak-beech, etc.) in the state. Each community has its own "loading factor" of deer. The similar censusing of other game (rabbit, quail, pheasant, grouse, etc.) has not been as successful; but then neither has it been investigated vigorously.

The monitoring of the spread of pest epidemics in forest communities is ideally suited to remote sensing. Dr. Cal Morriss has followed the spread of the pine bark beetle on the Eastern Shore of Virginia, and has plans for a similar study of the invasion of the gypsy moth into the Maryland-Virginia area.

Drs. Jack Heikennen and Robert Giles of VPI theorize that the southern pine beetle will attack only trees which are already disturbed due to sub-optimal environmental conditions. Accordingly, they are eager to map out the optimal areas for various sylvicultural operations to take place, and they welcome any assistance from those involved in remote sensing techniques.

B. 9 Sea Nettles

The mesohaline regions of the Chesapeake Bay have been subject to chronically high populations of a single species of coelenerate (jellyfish) Chrysaora quinquecirrha which is a menace to bathers because of its painful sting. While there is debate as to whether efforts should be made to eliminate the sea nettle, there is universal agreement that their populations should be monitored. Population sampling is still done by towing nets and counting the captured jellyfish.

Observation of large populations in the field has led this writer to the speculation that a characteristic color of water is associated with high densities of the nettle. If this is true, it could provide for more effective population estimation by multispectral scanning or other remote sensing techniques.

A number of coelenterata and ctenophores (comb jellies) phosphoresce and most probably fluoresce. This poses the question of whether a laser fluorescence technique might be applied to censusing these organisms.

B. 10 Rooted Aquatics

The littoral zones of the Chesapeake Bay have always sheltered macroscopic plant life which is rooted into the bottom but never grows above the surface of the water. Such vegetation is termed "rooted aquatics" to distinguish it from the emergent vegetation of the marshes, and includes such genera as Zostrea and Ulva in the high salinity areas; Ruppia and Zannichellia in the mesohaline regions; and Vallisneria and Potamogeton in the fresher regions of the Bay.

The rooted aquatics are acutely important as sources of food to the waterfowl of the region. While the layman may think the geese, swans and other waterfowl can subsist on a diet of corn, the fact is that rooted aquatics are a necessary supplement to their diets.

Presently there is a crisis because the number of waterfowl which overwinter in the Bay is increasing, while the beds of rooted aquatics are diminishing.

Besides serving as food for the waterfowl, the grass beds serve the ecological function of providing a refuge for repopulation of various species. Fish fry and shedding crabs seek such shelter. Clams are known to endure stress better when in association with aquatic grasses.

As the grasses disappear, the primary productivity of the littoral zones shifts to the phytoplankton. This raises the issue: Is the observed shift a result of declining water quality, and as such, is it of relatively permanent duration? Or are we simply observing a long-period oscillation of grasses-phytoplankton-grasses, as has been observed on a shorter time-scale in some of the freshwater lakes of Central Florida? The Environmental Protection Agency is concerned lest the former possibility proves to be the case.

The submerged beds also serve as a buffer against wave action, thus retarding shoreline erosion (as covered in Section VI).

Information is desperately needed on the bed location, the standing crop of aquatic vegetation, the species make-up of each bed and how the stocks vary temporally.

Research on aquatic vegetation in the Bay, using remote sensing, is practically without precedent and holds much promise. Dr. Robert Orth and Mr. Frank Pine both report enthusiastically that aquatic beds can be censused from 10, 000 feet, using false-color IR.

The grasses themselves contain concentrated amounts of chlorophyll. This immediately suggests the use of multispectral scanning signatures and LIDAR techniques. As in terrestrial vegetation, the various species of grass have characteristic chlorophyll a/chlorophyll b ratios so that the species identification by remote sensing is a likelihood.

There is also the possibility that through their influence on the local hydrodynamics the grass beds can give rise to thermal pools (or cool pools) which can be sensed by thermal scanning.

Recommendation 30

A remote sensing program to inventory the rooted aquatics in the littoral regions of Chesapeake Bay should commence as soon as possible. Development of possible remote sensing techniques for assessing the density of the grass beds, their species make-up and the temporal variation of vegetative stocks should proceed apace. Ancilliary ground truth data should also include a thorough investigation of the accompanying faunal community. [A]

Recommendation 31

The possibility of employing millimeter radar techniques to quantify surface concentrations of dissolved oxygen should be explored. [B]

Recommendation 32

The feasability of using multispectral-scanning techniques and laser-induced fluorescence to quantify sea nettle populations in the Chesapeake Bay and its tributaries should be researched. [C]

Recommendation 33

Remote sensing of the watershed area around the Albert Powell hatchery to determine the location of aquifer recharge areas feeding the hatchery is urged. This mission should be coordinated with Maryland Geological Survey and the Fish and Wildlife sections of the Department of Natural Resources of the State of Maryland. [C]

Recommendation 34

NASA expertise is requested to suggest a method of high-latitude remote sensing of waterfowl populations to improve upon the present censusing techniques. [B]

Recommendation 35

A possible cooperative venture between NASA and the Corps of Engineers to acquire time-series data on sea-state, climatology and long-shore processes should be considered. [C]

Recommendation 36

Any suggestions on remote sensing of the thermocline in coastal waters should be forwarded to EPA, Annapolis, for consideration as a joint program. [B]

Recommendation 37

NASA should offer its expertise in any appropriate manner to aid in the development of a rapid zooplankton sampling technique. [C]

Recommendation 38

A test of the Cameron stereoscopic method for measuring currents in the Chesapeake Bay should be made at low altitude. [C]

Interested Parties

Environmental Protection Agency, Annapolis, Maryland

Dr. Donald Lear (A.4, 10; B.1, 4, 10)

U. S. Army Corps of Engineers, Washington, D. C.

Mr. John Hensly (A.5)
Mr. Warren Braban (A.6) (WES)

National Aeronautics and Space Administration

Langley Research Center, Hampton, Virginia

Mr. O. L. Jarrett
Mr. Walter Bressette (A.6, 10; B.4)

Goddard Space Flight Center, Greenbelt, Maryland

Dr. Vincent Salmonson (A. 9)
Dr. Phillip Cressie (A. 6)

Wallops Test Facility, Wallops Island, Virginia

Dr. H. H. Kim (B. 4)

Maryland Department of Natural Resources, Annapolis, Maryland

Mr. Craig Ten Broeck (A. 9; B. 10)
Mr. Turbit Slaughter (A. 9)
Mr. Vernon Stotts (B. 7)

Virginia Office of Environmental Resources, Richmond, Virginia

Mr. Joseph Davis (B. 8)
Mr. Robert Slocum (B. 8)

Division of Game and Inland Fish, Richmond, Virginia

Mr. Chester Phelps (B. 8)
Mr. James MacIntyre (B. 8)

Division of Forests, Richmond, Virginia

Mr. W. F. Custard (B. 8)

Marine Resources Commission, Richmond, Virginia

Mr. James Douglas (B.1, 2, 3)

Soil and Water Commission, Richmond, Virginia

Mr. Arthur Hart (A. 6, 10)
Mr. Joseph Wilson (A. 6, 10)

University of Maryland, College Park, Maryland

Dr. Robert Orth (B.10)
Dr. John Foss (A.6)
Dr. Vagn Flyger (B.8)

The Johns Hopkins University, Baltimore, Maryland

Dr. William Sladen (B.7, 10)
Dr. Donald Pritchard (A.1-8)
Dr. James McCarthy (B.6)
Mr. Frank Pine (B.10) (SPHH)

The University of Virginia, Charlottesville, Virginia

Dr. Dexter Hinkley (B.8)

The Virginia Polytechnic Institute, Blacksburg, Virginia

Dr. David Pettry (A.6, 8)
Dr. John Cairns (B.4)
Dr. Calvin Morriss (B.8)
Dr. Robert Giles (B.8)

The Chesapeake Biological Laboratory, Solomons, Maryland

Dr. L. Eugene Cronin (B.1, 2, 3)
Dr. T. S. Y. Koo (B.1)
Mr. David G. Cargo (B.9)
Dr. Donald R. Heinle (B.5)
Mr. Charles K. Rawls (B.7, 10)
Dr. Shirley Van Valkenburg (B.4)
Dr. David A. Flemer (B.4, 6)
Mr. Elgin A. Dunnington (B.2)
Dr. Stephen Sulkin (B.3)

Virginia Institute of Marine Science, Gloucester Point, Virginia

Dr. Robert Byrne (A.1)
Dr. Maynard Nichols (A.2, 3, 8)
Dr. Kenneth Webb (A.2)

Dr. Larry Haas (A. 2)
Dr. Larry Engels (B. 3)
Dr. John Dupuys (A. 6, B. 4)

Photoscience, Inc., Rockville, Maryland

Mr. James White (A. 2)

Bayshore, Inc., Arlington, Virginia

Mr. Joseph R. Jahoda (A. 8, 10; B. 1, 5)

Westinghouse, Inc., Annapolis, Maryland

Capt. Deke Ela (A. 3)
Mr. Carlton Rutledge (A. 7)

Sparcom, Inc., Rockville, Maryland

Dr. Daniel Hickman (A. 5, 6; B. 4)

Washington Technological Associates

Dr. Charles Freer (A. 6, 10)

MISCELLANEOUS REMARKS

In the course of the interviews, several comments were made concerning NASA, Wallops, and remote sensing in general which bear on no one Bay-related problem in particular.

Several of those who were interviewed commented on the desirability of time-series remote sensing. There are, of course, economic constraints on what can be accomplished in this area. ERTS 18-day multispectral-scanning data is a step in this direction. There are many instances cited that lend themselves to present DCP technology. There is, however, no general vehicle for collection of the basic data over a wide range of position and time. If CRC or NASA were to provide a dispersed buoy system to serve as the vehicle for various investigators, then projects of individual researchers could be promoted through such an effort. The expense would then be for only the particular sensor system to be added for whatever appropriate length of time desired by the experimenter, provided onboard space and power schedules permit. The power of the ERTS DCP capability could then be brought to local focus on the Bay without the development of increased satellite capability. Unfortunately the resolution and time interval of ERTS data are inconvenient for many projects. Lower altitude remote sensing could become cost-effective if there were enough overlap in resolution and time-interval specifications among several projects.

Several parties, including some with working programs with NASA, Wallops, indicated a desire to be informed of Wallops' monthly flight schedules (preferably beforehand) so that remote sensing investigators might be aware of recent data taken elsewhere.

In at least two instances there was displeasure voiced between the civilian and military remote sensing reconnaissance. It was felt that certain techniques could be made available for civilian use without endangering national security.

One of the main reasons why the use of remote sensing is not more widespread is the seeming lack of a single, simplified handbook on remote sensing methods. (If such a text exists, it hasn't found wide use.) Several faculty at VPI mentioned that they would welcome more guest lectures, or perhaps an entire course, on remote sensing as applied to environmental problems.

With all the activity described in this report focused on a finite area, it is obvious that there is bound to be a good deal of geographic overlap, i.e., any given flight is bound to yield data of value to others besides the principal investigator. To maximize resources, this writer would suggest the creation of a large atlas of the Chesapeake Bay with all the geographic sites connected with the problem areas covered in this report marked on the map and coded by number. An inventory of all the problem areas on a planned flight path could be quickly made, and the parties concerned with each area (as recorded on a file under the site code numbers) could be notified before the flight. Thus, the data taken would see maximum use, and in many instances additional requested data could be taken at nominal extra expense. Of course, some equitable expense-sharing scheme would have to be worked out.

There was some concern voiced among those interviewed that the recent necessary shift of emphasis from basic to applied research seems to have gone to an extreme. Thus, with the ERTS program, the emphasis has been on using the "macroscope" like a big microscope. (Certain geological programs are exceptions to this generality.) In the opinions of this writer, the field of remote sensing would be significantly helped by soliciting such macroscopic thinkers as L. E. Slobodkin or H. T. Odum to search the spectral emissions as sensed by satellite and high altitude aircraft for phenomenological relationships on an expanded time and space scale.

Recommendation 39

The remote sensing user community should be polled to see if there is enough geographical overlap among those investigators requiring time-series data to institute a routine series of flights to create such information. [B]

Recommendation 40

NASA, Langley and Wallops should experiment with a monthly flight bulletin to see if such advanced flight information might stimulate more intensive use of remote sensing data. [C]

Recommendation 41

An up-to-date atlas of problem sites in the Chesapeake Bay, cross referenced with interested investigators, should be assembled so that the maximum possible use could be gained from remote sensing data on a given flight path. [B]

Recommendation 42

There is still widespread lack of knowledge about the environmental capabilities of remote sensing. Efforts should be made to disseminate information on the application of remote sensing technologies to the Chesapeake Bay problems. [B]

Recommendation 43

Some percentage of remote sensing research funds should be earmarked for basic research on the use of high-altitude remote sensing data for formulating phonomenological laws on a macroscopic time and space scale. [B]

LIST OF RECOMMENDATIONS

Recommendation 1

Investigation should proceed posthaste on the development of remote sensing technologies to gather data on nutrient concentrations. Laser induced fluorescence (single or multiple frequency) and multispectral mapping seem to hold some promise. The enzyme-specific electrodes in combination with telemetry systems such as the ERTS-DCP package offer another possibility, as do the *in situ* Laser techniques. [A]

Recommendation 2

The chlorophyll measuring technologies in operation at NASA, Wallops and Langley seem excellently suited to gathering ground truth data for the modeling of the fate and effects of sewage effluents and should be coordinated with the CRC-RANN program.

Recommendation 3

Models for suburban runoff are urgently needed by EPA. Remote sensing offers perhaps the most cost-effective way of gathering ground truth data for the development of such models, and the implementation of such a program should be pursued. [B]

Recommendation 4

There is a desire on the part of at least two parties interviewed for synoptic censuses of boats on the Bay and tributaries. Remote sensing in the form of aerial photography offers perhaps the best solution to such a need and should be applied to the problem. [C]

Recommendation 5

A program of thermal and salinity scans of the Potomac, James, Patuxent, and other impacted rivers should be initiated to provide data for monitoring and siting power plants. [B]

Recommendation 6

The present and proposed power plant sites in Maryland and Virginia should be intensively observed with a whole array of remote sensing methods (black and white, color, color IR, multispectral scanning, thermal scans) to provide a library of data for decision makers. The adjacent terrestrial and aquatic regions should be included. [C]

Recommendation 7

Multilevel flights focused upon providing data on stack gas emissions and plume dispersions, especially in the far field ($>$ 10 miles), should be initiated. [C]

Recommendation 8

The applicability of the LIDAR package and/or millimeter radar resonance techniques (in either the fixed or airborne mode) to the measurement of stack gases should be pressed into an operational mode. [B]

Recommendation 9

Remote sensing data on areas having heavy metals concentrations should be made available to interested researchers to provide background data for their models of heavy metals inputs. [C]

Recommendation 10

Unlike many other states, Maryland has not extensively used remote sensing for a survey of its strip mining activities and acid mine drainage fields. Any available remote sensing data on this topic should be sent to the Department of Natural Resources. [C]

Recommendation 11

The aquatic enforcement arms of Maryland and Virginia would benefit from learning remote sensing techniques, and should take advantage of NASA technology and advances in this area. [B]

Recommendation 12

A cooperative program should be considered to provide a more complete data base for the proposed pesticide transport model. [C]

Recommendation 13

The various remote sensing technologies should be reviewed for possible application to the determination of particle size distributions of suspended sediment loads. [C]

Recommendation 14

A photobank of color and color IR imagery of all undeveloped holdings in the Bay Region of more than 200 acres with deep-water access should be developed so as to be available for local planning and citizens action groups as the need for such information arises. With careful planning these surveys can be piggy-backed onto existing reconnaissance missions at token additional cost. [B]

Recommendation 15

Here, as elsewhere in this report, remote sensing work is not nearly as intense in the northern end of the Bay as to the south. An entire coordinated program should be built upon the initial endeavors of the Maryland Geological Survey, and Environmental Concern, Inc. Such a program could well be coordinated by CRC. [B]

Recommendation 16

The Maryland Geological Survey has need for littoral bathymetric data which may be possible to obtain using LIDAR. LIDAR bathymetry is normally of little use in the turbid waters of the Chesapeake Bay; however, there are usually a few calm days in November when water visibility is six meters or more. Flight coverage of a few key study areas should provide the Maryland Geological Survey with most of the data they require. [B] Such a cooperative venture should be pursued.

Recommendation 17

Although a very small amount of research is being done on the Delmarva coastline, it is nowhere near commensurate with its regional importance. NASA should endeavor to solicit research to bring the focus upon this area up to the level of that upon the Jersey and Carolina coasts. [B]

Recommendation 18

A time schedule of flights at regular seasonal intervals should be set up to cover the tidal wetlands of the Chesapeake Bay and Atlantic coast. Medium-altitude flights are recommended as a compromise between expense and necessary detail. The exact data to be taken should be worked out with the multiple users this project is intended to serve (CRC, DNR, Environmental Concern, etc.). [B]

Recommendation 19

An attempt should be made to characterize the various grey-tones observed on the marsh with side-looking radar. [C]

Recommendation 20

Practically all remote sensing work on the Bay pertaining to navigational channels has been in the southern end. There are urgent problems in the northern end which also demand attention. Notable among these are the widening and deepening of the Baltimore Harbor Channel, and the use of the spoil to enlarge the Miller-Hart Islands, the widening and deepening of the C and D Canal, and the Potomac River sand and gravel operations. CRC and NASA should work out a cooperative program. [B]

Recommendation 21

The Power Plant Siting Committee of the State of Maryland and NASA should create a program for monitoring flotsam in the neighborhood of present and proposed power plants to identify sources of such debris. [C]

Recommendation 22

Statewide land-use mapping projects to supplement the CARETS program should be undertaken. The most expedient course of action along these lines would be to expand the mapping program of Dr. Robert Giles of VPI to include remote sensing data. [B]

Recommendation 23

Additional knowledge about how high-altitude sensors average data is needed. An experiment should be designed to determine the optimal program of ground truth sampling so that confidence limits can be set for signatures of remote sensing data. [A]

Recommendation 24

NASA should look into the development of balloons or sounding rockets to provide economical low-level reconnaissance needed in a number of surveys. [D]

Recommendation 25

The NASA facilities in Virginia should make contingency flight plans for the Chesapeake Bay Region to comprehensively cover flooding after major rainstorms. The data should be forwarded to the state planning agencies in Maryland and Virginia. [C]

Recommendation 26

The usefulness of side-scan radar data for topographic studies by state planners should be investigated. [C]

Recommendation 27

Routine meteorological data of the type obtained from tracked radiosonde balloons of the area above Baltimore Harbor should be made synoptic with the USGS thermal scans of the area in order to provide adequate three-dimensional thermal mapping of the atmosphere. [B]

Recommendation 28

Contact should be made with the Department of Environmental Geology of the Maryland Geological Survey to see if a mutual program for color IR coverage of the developing areas of the State can be arranged to speed the mapping of building constraints throughout the state. [A]

Recommendation 29

The possibility of using active tags to follow the dispersion of ocean dumped material should be explored. [C]

Recommendation 30

A remote sensing program to inventory the rooted aquatics in the littoral regions of Chesapeake Bay should commence as soon as possible. Development of possible remote sensing techniques for assessing the density of the grass beds, their species make-up and the temporal variation of vegetative stocks should proceed apace. Ancilliary ground truth data should also include a thorough investigation of the accompanying faunal community. [A]

Recommendation 31

The possibility of employing millimeter radar techniques to quantify surface concentrations of dissolved oxygen should be explored. [B]

Recommendation 32

The feasibility of using multispectral-scanning techniques and laser-induced fluorescence to quantify sea nettle populations in the Chesapeake Bay and its tributaries should be researched. [C]

Recommendation 33

Remote sensing of the watershed area around the Albert Powell hatchery to determine the location of aquifer recharge areas feeding the hatchery is urged. This mission should be coordinated with Maryland Geological Survey and the Fish and Wildlife sections of the Department of Natural Resources of the State of Maryland. [C]

Recommendation 34

NASA expertise is requested to suggest a method of high-altitude remote sensing of waterfowl populations to improve upon the present censusing techniques. [B]

Recommendation 35

A possible cooperative venture between NASA and the Corps of Engineers to acquire time-series data on sea-state, climatology and long-shore processes should be considered. [C]

Recommendation 36

Any suggestions on remote sensing of the thermocline in coastal waters should be forwarded to EPA, Annapolis, for consideration as a joint program. [B]

Recommendation 37

NASA should offer its expertise in any appropriate manner to aid in the development of a rapid zooplankton sampling technique. [C]

Recommendation 38

A test of the Cameron stereoscopic method for measuring currents in the Chesapeake Bay should be made at low altitude. [C]

Recommendation 39

The remote-sensing user community should be polled to see if there is enough geographical overlap among those investigators requiring time-series data to institute a routine series of flights to create such information. [B]

Recommendation 40

NASA, Langley and Wallops should experiment with a monthly flight bulletin to see if such advanced flight information might stimulate more intensive use of remote sensing data. [C]

Recommendation 41

An up-to-date atlas of problem sites in the Chesapeake Bay, cross referenced with interested investigators, should be assembled so that the maximum possible use could be gained from remote sensing data on a given flight path. [B]

Recommendation 42

There is still widespread lack of knowledge about the environmental capabilities of remote sensing. Efforts should be made to disseminate information on the application of remote sensing technologies to the Chesapeake Bay problems. [B]

Recommendation 43

Some percentage of remote sensing research funds should be earmarked for basic research on the use of high-altitude remote sensing data for formulating phenomenological laws on a macroscopic time and space scale. [B]

User Agency		Application Problem	Technology	Recommended Action*
NSF/RANN EPA Md. Va.	Nutrient Loading	Nutrient concentrations	MSS; Laser induced fluorescence; Enzyme specific electrodes on DCP	A
NSF/RANN	Nutrient Loading	Chlorophyll concentrations	MSS; Laser induced fluorescence	B
CBF EPA NSF/RANN	Nutrient Loading	Suburban runoff	Thermal scanning	B
Md. DNR VIMS	Nutrient Loading	Boat census	B&W, color underflights	C
Va. AEC Utility companies	Thermal Loading	Thermal and salinity determination in tributaries	Passive microwave DCP's	B
Va. AEC DNR Utility companies	Thermal Loading	Library of remote data at Power Plant sites	B&W, color, color IR MSS Thermal scans	C

*See page 4 for ratings of Recommended Actions

User Agency	Category	Application Problem	Technology	Recommended Action
Md. Bureau of Air Quality Control DNR (PPSP) Industry EPA	Thermal Loading	Stack Gases	RAMAN scattering Millimeter RADAR	B
EPA OER (Office of Environmental Resources, Va.) DNR EHA	Industrial Effluents	Outfall measurements for heavy metal determination	Visible imagery Thermal scans Color IR Polarographic monitor on DCP	C
DNR OER	Industrial Effluents	Acid mine drainage	Color IR B&W, color Thermal scans	C
DNR OER	Industrial Effluents	Enforcement of outfall regulations	All	B
DNR EPA Westinghouse Potomac River Fisheries Commission	Pollutants	Pesticides transport	Technologies on tidal heights, currents, temperature, salinity, sediment load	C

User Agency		Application Problem	Technology	Recommended Action
USACOE U. S. Bur. of Sport Fisheries	Pollutants	Particle size distribution--suspended sediment	Visible imagery, in-situ turbidimeter, or laser - DCP	C
DSP (Md.) EPA NOAA OER Local planning groups through USGS	Pollutants	Census of potential industrial holdings on deep water (non-power plant, non-sewage plant)	Visible imagery; Color IR	B
Md. GS VIMS DNR Environmental Concern, Inc.	Coastal Processes	Shoreline mapping and coastal processes analysis	Visible imagery; Side scanning RADAR Color IR	B
Md. GS DNR	Coastal Processes	Littoral bathymetry	LIDAR underflights	B

	User Agency	Application Problem	Technology	Recommended Action
Wetlands	DNR Environmental Concern, Inc.	Wetlands mapping	Visual imagery; Medium altitude underflights	B
Wetlands	DNR Environmental Concern, Inc. VIMS	Wetland characterization	Side-scanning RADAR?	C
Navigation	USACOE DNR City of Baltimore	General studies of dredge and spoil effects	Visual imagery (ERTS); Side-scanning RADAR?; Low-level photography; Color IR; LIDAR	B
Navigation	USACOE Md. PPSP Industries using cooling water	Identify sources of flotsam around power plants	Low level visible imagery	C

Land Use

User Agency	Application Problem	Technology	Recommended Action
N. Va. Planning Dist. DSP (Md.) CBCES Nature Conservancy Va. OER Md. GS USGS	Mapping	Visible imagery Color IR MSS	B
NASA	Optimization of "signatures"	MSS	A
USGS PPSP VIMS	Development of balloons and sounding rockets	All	D
DSP (Md.) OER (Va.) USACOE Local planning groups	Floodplain mapping	Color IR	C
DSP (Md.)	Topographic studies	Side-scanning RADAR	C
USGS	Vertical thermal profiles in Balto. Harbor	Radiosonde balloons	B

User Agency		Application Problem	Technology	Recommended Action
Md. GS DSP	Land Use	Mapping of building constraints	Color IR	A
EPA Westing-house	Solid Waste Disposal	Fate of ocean-dumped materials	To be developed	C
EPA DNR Environ-mental Concern, Inc.	General Research	Inventory of rooted aquatics	Color IR; MSS	A
NA	General Research	Quantification of dissolved oxygen	Millimeter RADAR	B
DNR CBL VIMS	General Research	Sea nettle census	Laser techniques; MSS	C
DNR Md. GS	General Research	Delineation of Albert Powell watershed	Color IR;	C
DNR Dept. of Interior	General Research	Censusing of waterfowl	High altitude flights to be developed	B

User Agency		Application Problem	Technology	Recommended Action
USACOE CBI VIMS NOAA	General Research	Sea-state and coastal processes	Microwave RADAR	C
EPA	General Research	Thermoeline sensing	To be developed	B
CBL VIMS	General Research	Zooplankton census	Acoustic device - DCP to be developed	C
CBI VIMS NOS	General Research	Current measurement	Stereoscopic photo	C
All	Misc. Recommendations	Flight coordination	All	B
All	Misc. Recommendations	Flight bulletin	All	C
ALL	Misc. Recommendations	Problem site atlas	All	B
All	Misc. Recommendations	RS education	All	B
JHU UM UVA	Misc. Recommendations	Basic research	All	B