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# REMOTE SENSING OF THE CHESAPEAKE BAY



A conference held at
WALLOPS STATION, VIRGINIA
April 5–7, 1971



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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*In cooperation with*

*State of Delaware*
*State of Maryland*
*Commonwealth of Virginia*
*Smithsonian Institution*
*National Aeronautics and Space Administration*

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# Preface

The objective of this Conference on Remote Sensing of the Chesapeake Bay is to identify the primary environmental problems of the Chesapeake Bay area and determine the extent to which remote sensing can contribute to the solution of these problems.

This volume and the conference it records will focus on ten major problem areas present in the Chesapeake Bay area. These areas include:

## ENVIRONMENTAL POLLUTION

### Pollution—Industrial Wastes

The petrochemical, metal, navigation, utility, and other industries are discharging increasing amounts of oil spills, exotic chemicals, and trace metals such as zinc, copper, cobalt, and mercury, as well as thermal pollution, all of which upset the ecology of the Bay and its estuaries. Also, sewage discharge from an increasing population increases nitrogen and phosphorus and decreases oxygen (eutrophication) in the water. This discharge stimulates obnoxious plant life and endangers fish life.

### Pollution—Air

Undesirable discharge of gas and particulates from increasing urbanization, industrialization, navigation, and auto traffic may affect health of people as well as health of biota in local waters. Air pollution changes oxygenation potential of the water.

### Pollution—Agricultural Sedimentation and Wastes

Agricultural activity increases rate of sediment runoff and introduces pesticide and animal wastes into the Bay. Also, sewage discharge from an increasing population increases nitrogen and phosphorus and decreases oxygen (eutrophication) in the water. This, again, stimulates obnoxious plant life and endangers fish life.

## ENVIRONMENTAL BALANCE

### Estuarine Turbidity, Flushing, Salinity, and Circulation

The physical properties of the Bay, including its ecosystem balance, need to be studied to determine their impact on the problems of the Bay. For example, the circulation pattern of the Bay affects many of the organisms.

## NATURAL RESOURCES

### Extractable Biological Resources

Oyster production has been decimated by excessive exploitation, and other species have been reduced by tributary dams and pollution. Nevertheless, large numbers of fish and shellfish are extracted from the Bay having an estimated value of 65 million dollars per year.

### Agriculture and Forestry—Identification, Vigor, and Disease

The Bay is a highly productive estuary. Well-managed grain, tobacco, and truck farms abound; hardwood and conifer trees are abundant; wildlife areas are plentiful. These are threatened by suburban encroachment.

### Recreational Uses

Boating, swimming, skiing, beaching, fishing, and hunting are all increasing rapidly. The outlook is for enormous and rapid increase in water-related recreation with attendant problems such as traffic jams, air pollution, and waste disposal.

## OTHER ECONOMIC ACTIVITY

### Engineering Changes

Dams, bridges, piers, and other installations tend to upset hydrology and nutrients of the system. There is a conflict of navigation demands and maintenance of an estuarine environment satisfactory for commercial and sport fisheries and for recreation. Deeper channels for navigation and disposal of dredge spoils change the hydrology of the system.

### Shoreline Activities

Problems of land use, urban growth, regulation of shoreline activities, coastal erosion, tidal marsh encroachment, and coastal zone stabilization all contribute to the character of the Bay. Also, conversion of wetlands at an increasing rate upsets the hydrology of the system and also can interrupt the estuarine ecology and life cycles with far-reaching effects on fish and shellfish and myriad other species.

### Urban Development and Growth

Urban development and growth on the shoreline of the Bay, along its tributaries, and in the headwaters of the Bay present some special problems with respect to the Bay.

Development rates and trends and land use should be studied for the purpose of policy-making and planning at the federal, regional, state, and local levels.

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# Keynote Address

THE HON. J. MILLARD TAWES
Secretary of Natural Resources
State of Maryland

Today as the keynote speaker for this significant conference, I would like to take care of a few pleasant duties. Governor Mandel has asked me to convey his greetings and he bids you a successful and productive conference. Recently at a cabinet meeting we discussed this conference and its potential significance to Maryland. Not only the Governor, but also the Secretaries of the Departments of Transportation, Economic and Community Development, State Planning, Health and Mental Hygiene, and others expressed their interest in what is to take place here in the next few days. Most of these departments are represented here. Their representatives will actively participate in the group discussions. Their presence, and the interest of their colleagues in Annapolis and Baltimore, reflect the central importance of the Chesapeake Bay to the state of Maryland. The reorganization of Maryland's Executive branch, which has created a cabinet form of administration, has brought sharp focus upon the overlapping interests in the Chesapeake Bay that are shared by the principal agencies and the public needs they support.

The Governor has asked for a full report of the results of this conference. He is pleased by the emphasis on real problems and the application of new technology to their solutions, and expects that this meeting will bear fruits.

I would also like to thank the many persons and institutions who participated in the planning of this conference, and, in particular, to thank our hosts here at the Wallops Island station of the National Aeronautics and Space Administration.

The phrase "remote sensing" is a relatively new one to me. When I asked a member of my staff for a definition, he pointed out that flying over the Bay and looking down on areas we usually see from the ground was an illustration of the kinds of new information we could get from remote sensing. I was immediately struck by the recollection that, when flying over the Bay, I am impressed by the size, complexity, and geographic variety of the Chesapeake Bay area. Also striking is the smallness of the Bay, as seen from the air. One gets the clear impression that Baltimore is very close to Crisfield; and yet it is difficult to realize what happens at the mouth of the Susquehanna River is likely to have some effect at Norfolk. I am also impressed and humbled by the many new things that can be learned about the Bay and the surrounding area when viewed from the air. As a life-long resident of Bay country, and as one who has devoted a good deal of time in public service to its protection and nurture, I find this mode of observation both sobering and thrilling.

There are some often-stated lessons in the perceptions of the Bay area that deserve continued re-statement. First, it is apparent from a bird's eye view that the Bay area, however complex and varied, must be viewed as a single system. The Bay is smaller than we tend to think, and it is shrinking all the time. Any one aspect of it, such as one of the problem areas that are the topics of this conference, must be set in the context of the whole system for that single topic to be well illuminated. These relationships between various aspects of the Bay require that planners, managers, and scientists gather and use information in such a way that the regional integrity of the Chesapeake Bay is highlighted, rather than obscured. A major challenge before this conference will be to see that the products of the separate work groups contribute to a better understanding of the Bay as a whole.

Second, the perception that the Bay area involves much more than any one person can observe in a lifetime suggests the need to be ever mindful of the variety of perspectives that must be brought together before general solutions can be achieved to the complex problems of management of the Bay. The system of which we are all speaking is one thing to a biological scientist who is attempting to develop a clear picture of marine life on the bottom of the Bay. It is quite another to the economist who is trying to portray the economic lines of force that influence and shape the oyster industry. Both of these points of view, as well as many others, must be involved in any meaningful discussion about problems of managing the Bay.

Equally important, although often ignored, is the variety of popular or non-technical perceptions of the Bay. In the last analysis it is what people think the Bay to be rather than what it is that will shape the management programs that we seek to improve. As long as marshes are considered waste areas of no value except to snakes, mosquitoes, and venom, the Wetlands Management Program in Maryland will be difficult to implement. If new residents of the Bay area have the notion that the Bay is unproductive or polluted, they might be slow to eat a Bay oyster or buy a sailboat. Each year in Annapolis and every two years in Richmond, groups of men and women from diverse backgrounds convene in their respective legislative halls to write the laws that are so vital to the proper management of the Bay. What they see to be the condition of the Bay is likely to be quite different from the view of the micro-biologist or the sanitary engineer or the regional planner. Yet their collective perception is the key to the translation of the scientists' and technicians' definition of problems translated into effective social actions leading to sound solutions—that is, toward sound management.

It is especially fitting, therefore, at a conference addressing itself to new and varied ways of seeing the Bay, to stress the importance of developing a composite view of the Bay. At a time when the whole nation is acquiring a growing understanding of how complex and interrelated our environmental problems have become, I think it is important to seek ways of making this complexity understandable. If my lay understanding of some of the prospects of remote sensing is correct, one of its principal values is in giving a series of pictures of a region that eliminates nonessentials and accentuates important interrelationships.

Just as my concept of the Bay is expanded each time I fly over the Bay, so might the concepts of all who have a hand in the Bay's future be enlarged and sharpened by information supplied by remote sensing.

I would urge, therefore, that while listening to the various speakers address specific problems, and while formulating comments on the application of remote sensing to solving these problems, you keep in mind the tremendous need for developing more effective communication between technicians, scientists, managers, elected officials, and general citizens regarding the myriad facets of the Chesapeake Bay, and that you make every effort to recommend ways that remote sensing can improve understanding of the Bay by all persons who have a stake in its future.

Now I would like to turn to a description of the environmental management problems in which we are involved for the Chesapeake Bay region. Many of you will have heard this description in some form or another before. But I understand that some of you have not had specific opportunity to work in the Chesapeake Bay region. My purpose, then, will be to give a brief overview of the topics you will be discussing in some depth throughout the conference.

Starting at the north end of the Bay, we note the inflow of the largest river in the eastern United States, the Susquehanna River. This river provides roughly 50 percent of the entire fresh water input to the Bay. Thus, the quality, quantity, and timing of river flow is of major significance to the Bay environment. As soon as we address ourselves to the influence of the Susquehanna, we realize that the Chesapeake Bay region is larger than the Bay and the immediate shoreline area. We must consider events throughout the Susquehanna watershed that extends into New York state if we are to take into account the important variables that affect the Bay proper.

When we examine the sources of demand for Susquehanna water for domestic and industrial use, we are also made aware that a physical-hydrological definition of the Bay region is too limited. For there is a real possibility that major interbasin exchanges of water might take place in the decades ahead. Even now there is active interest from the Wilmington, Delaware, metropolitan region in Susquehanna water for domestic use. Thus full consideration of the Bay region must take into account urban growth factors throughout the Philadelphia-to-Norfolk urban corridor.

Still referring to the northern end of the Bay, we now turn to the Chesapeake and Delaware Canal. This canal, which is being deepened from 27 to 35 feet to accommodate larger vessels, has been a central subject in the continuing examination of the interrelationships between commercial shipping and the biological productivity in the Bay. This examination has included questions of the effect of the canal on salinity in the upper Bay, the problem of dredged spoil disposal, the effect of major dredging on physical circulation, and the secondary effects of shipping on water quality. Basically the same questions are raised in the Baltimore and Norfolk-Hampton Roads port areas, with the additional question of disposal of contaminated spoil material.

Moving down the Bay to Baltimore we focus on the impacts of dense human populations and heavy industry on the

Bay. The problem of disposal of industrial and domestic wastes is accompanied by the less obvious problems of the effects of extensive construction activities in the various urban watersheds and on the Bay and tributary shorelines.

This urban area also represents a source of heavy latent and actual demand for recreational use of the Bay. As a public resource, the Bay can be considered a vast public park; yet, problems of getting people to this park, particularly in the metropolitan area, are considerable. The recreational potential of the Bay in the metropolitan area has gone relatively untapped.

Moving down to the Preston Lane Memorial Bridge, which is Maryland's "Bay Bridge," we find another tangible indication of the tremendous recreational and resort potential of the Bay region. A second span is now being built to accommodate the growing population of Mid-Atlantic residents who are headed for various DELMARVA recreation spots. These vacationers are placing more and more demand on the resource base of the Ocean and Bay waters and shorelines. Ironically, these people are seeking the very kind of environmental quality and aquatic bounty their presence tends to diminish. The management challenge is to fit this recreational demand into the existing environment with the least possible environmental effect.

Taking broader focus on the Bay we see throughout the region visible evidence of its biological productivity for both sport and commercial fishing and for waterfowl hunting. Some of you may not realize that Maryland leads the nation in the production of oysters, striped bass, and soft-shell clams and is second to Virginia in the production of blue crabs. Taking Virginia and Maryland together, the Bay yields an enormous commercial crop. Beyond this, the Bay contributes substantially to both sport and commercial fishing in the Atlantic Ocean and in other states. Furthermore, there is a very large, although poorly measured, take of fish and shellfish by sport fishermen. As the demand for sportfishing and hunting increases and as the commercial fisheries potential of the Bay continues to grow, the management challenge is to control and regulate production and harvest to achieve the optimum yields over time. Meeting this challenge involves collection and analysis of a large amount of information and a continuous process of improving our biological understanding of the system.

Virtually any section of tidal shoreline in Maryland shows some direct evidence of man's modification of that shoreline and of the near-shore bottom. Bulkheads, channels, jetties, filled areas, piers, and other structures abound. In just the last three months, there have been over 100 applications for licenses to dredge or fill areas of submerged tidal land in Maryland. We expect this figure to double as the requirements of the Maryland Wetlands Act become more generally known and as our enforcement and surveillance program improves. There is a growing concern about the cumulative effects of these modifications. This concern is manifest in the Maryland Wetlands Act and in our closer scrutiny of projects involving Corps of Engineers permits. Given the extensiveness of the Bay shoreline, our management information needs in this area are enormous.

Zeroing in lastly on a point along Maryland's famous Calvert Cliffs, I would like to mention briefly the management and environmental problems posed by large new industrial plants or plant complexes. In this case, the issue was and is over the siting of a nuclear electric power generating station. The Calvert Cliffs issue brought into public discussion a number of exceedingly difficult technical, scientific, and social questions that relate to the Bay environment. We have learned much in Maryland about the questions posed by such a plant.

Even now the Maryland General Assembly in considering a bill which would establish a substantial research fund and power-plant siting procedure for Maryland. This bill recognizes that questions of the environmental impact of late-twentieth-century technology must be addressed with the latest scientific and technical information and competence. If passed, the bill will reflect the intent of the General Assembly and the Governor to commit substantial funds to answering the difficult questions of power-plant siting. I think it appropriate to end my list of examples with this case because I think the subject of this conference is an attempt to apply a similar level of sophistication in new technology to the solution of environmental problems.

This list has not been all inclusive by any means. I have passed over the importance of the Potomac River and the major rivers in Virginia; I have neglected the significance of the metropolitan area of the District of Columbia; I have not mentioned agricultural drainage, stream channelization, sea nettles, or any number of other specific management problems that Maryland and other states are addressing daily. Most of what I have said can be extended to these other geographical and other problem areas.

I will close by simply repeating my sense of the importance of considering this resource as a whole, and my hope that remote sensing, as applied to the problems of the Chesapeake Bay, will do much to increase our understanding of this magnificant Bay region. I thank you very much for your attention and wish you every success in making this a productive and significant conference.

# Technical Keynote Address on Remote Sensing

**PRESENTED BY MARVIN R. HOLTER FOR ARCH B. PARK**
*National Aeronautics and Space Administration*

## INTRODUCTION

This paper will review briefly what remote sensing is, what it can do and problems presently being studied. Remote sensing refers primarily to sensors of electromagnetic radiation, i.e., the ultraviolet, visible, infrared and microwave regions. There are many other sensors that could be called remote sensors. But for one reason or another, usually very short range of operation or low geometric resolution, sensing from aircraft or spacecraft primarily means sensors of electromagnetic radiation. The time available does not permit explanation of all remote sensors; so most of the examples shown will be of ultraviolet, visible and infrared radiation, but the fact that radar pictures will not be included in this paper does not mean that they are not useful or important.

In environmental affairs there are three major classes of activity:

(1) Obtaining data on the environment

(2) Using the data to predict what is going to happen and to make recommendations for action on the environment

(3) Taking action on the environment based on (1) and (2)

Remote sensing is usually construed to be concerned with the first two of these activities. Also, for the most part, the activities of NASA are concerned with the data acquisition and the utiliziation of the data to reach certain conclusions and recommendations for action with regard to the environment. It is more often the responsibility of other agencies to actually take action with regard to the environment, so I will concentrate on the first two major classes of activities.

There is some tendency to regard remote sensing as being a matter of having a few new eyes, but remote sensing is far more. In fact, it is the joint effect of employing, with proper coordination, a variety of distinct technologies. Figure 1 is a representation of this definition of remote sensing.[1] Within the first sector (upper right) are a group of technologies concerned with obtaining data. This activity requires platforms, communications, navigation devices, and sensors. Within the next area (remainder of illustration) are a number of technologies concerned with utilizing the data to reach conclusions. It is a large activity and requires management of large programs. It is interesting that NASA is relatively strong in the technologies required for the two major classes of activities, with one exception. The construction of environmental models and knowledge of common practices are areas where, quite clearly, the relevent technical experience resides primarily in other places. But remote sensing is defined as the proper utilization of all of these technologies *in conjunction* with each other.

From the standpoint of NASA we regard our objectives in the remote sensing activity as contributing to man's ability to manage and use his terrestrial environment:

(1) By improving environmental data types, quality, and timeliness

(2) By improving systems for employing data to derive and communicate decisions for action (it is not a primary function of NASA Earth observations activities to improve the means of implementing the decisions for action beyond the informational - decision making aspects of the overall problem).

Figure 2 shows the Manned Spacecraft Center (MSC) at Houston. The technical activities that we engage in are given in the areas of data utilization and data acquisition. This organization is typical for any NASA center engaged in remote sensing activity.

[1]Copies of these and other charts and photographs are available upon request from Marvin R. Holter, Chief, Earth Observations Division, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas 77058.

Figures 3 and 4 show the component activities of data acquisition and data utilization, respectively. Data acquisition (fig. 3) involves development, implementation, and generation of sensors and data sources. Presently, we operate several aircraft that generate data. In about a year the ERTS satellite will go into operation and the Skylab satellite, equipped with sensors to obtain data, will follow a year later. Data utilization (fig. 4) requires:

(1) Data must be stored, indexed, and retrieved to make it available to users (We have such a research data facility at MSC and it seems certain that other centers of the agency will establish similar data operations as they become involved in remote sensing activities.)

(2) Data must be applied. (We are beginning to work very closely with user agencies in the Texas area to employ data we have obtained in real application to problems.)

## SYSTEM PROBLEM AREAS

Figure 5 illustrates some of the "pacing" problems in this business by following the life history of a piece of information. We begin by sensing some data. The next step is to translate the sensor outputs into reflectivities and emissivities of the objects under observation. Signatures and data processing represent an area of ignorance in which we must do some research. To proceed from the radiation properties to the identity of species or the condition of the species, whether the corn is deseased or not, for example, requires another transit through this circular area. It is an area of some considerable ignorance, a pacing technical problem if you will, on which we must do research. Having the identity of the species and the conditions, then the thing that is of most interest in this crop yield example is to make some predictions.

Whenever we attempt to make predictions with regard to the environment, we need environmental models. The people in NASA do not have the principal skills to develop such models. We must depend on other agencies, e.g., universities, the Departments of Agriculture and Interior, or certain international programs such as the International Biological Program or the International Hydrological Program.

Remote sensing techniques do not provide sufficient data on which to base recommendations for action on the environment. Rather, remotely sensed data must be used in conjunction with climatic data, knowledge of cropping processes, existing maps, planting records, political considerations such as acreage allotments, input from agricultural county agents and all sorts of other information. This necessity presents a technical systems problem, i.e., how to bring many disparate sources of data together so they can be applied to the same problem. Figure 6 illustrates this specific system problem. We must learn how to accept spacecraft data, aircraft data, data from ground instrumentation, weather data, verbal data from county agents, stored data and other different types of data and coordinate them for application to an environmental problem. Figure 7 gives an estimate of our progress in dealing with such system problems. We are learning to make observations. Ultimately, we hope to be able to monitor, understand, and modify the environment for our own purposes. Achieving this goal will be a matter of one or two decades.

Figure 8(A) shows a conventional aerial photograph. Examine this picture carefully and compare it with figure 8(B). It is the next picture on the same roll of film, made with the same camera, the same filter, and the same lens only 20 seconds later. The aircraft moved perhaps one mile. The appearance of this picture is radically different, not only in the middle but also in the appearance of the tones in the corner. I don't know why. I think I do, but I cannot yet prove it. I merely show it to illustrate that the question of signatures–what are the relationships between the materials on the surface that we want to observe and the radiation that we do observe–is something where we need a good deal more understanding, even with the oldest sensor that we have at the present time.

## REMOTE SENSING APPLICATIONS

Figure 9 shows the relationship of Earth observations to other national programs within the space agency. The Earth observations remote sensing program draws data from past space missions, from presently operating aircraft and from the projected ERTS and Skylab satellites. These data are channeled to workers in the remote sensing community by means of our research data facility. Finally, we work with a number of national and international agencies and universities.

I frequently get asked why we need to improve on aerial photography, the present classic means of doing surveys. Present survey techniques produce simultaneously too little information in one sense and too much information in another sense. Air photography, including color photography, does not produce very strong contrasts between some pairs of features that we would like to discriminate more exactly, while other kinds of sensors–ultraviolet sensors, infrared sensors or radar sensors–indicate strong differences. Thus the problem of too little information can be remedied by adding more wavelengths to the sensors.

The second problem with aerial photography is too much information. Any camera, if operated continuously, will produce more pictures than any reasonable number of human beings using ordinary methods can intensively interpret. This problem can be remedied by two means. First, sensors in other parts of the spectrum can be used to enhance the contrast between features so that human interpretation becomes easier and more rapid. The principal solution, however, centers around the attempt, already partially successful, to automate significant parts of the interpretation; i.e., to use computers to make certain classes of decisions. We will show some examples of those kinds of results later.

Figure 10 shows the aspects of the radiation that are remotely sensed that can be used to do the discrimination among the various materials and conditions of interest: The wavelength distribution or spectral discrimination, the shapes, spatial discrimination, polarization, and the prime effects that are really of two types, depending on speed of movement. If things are moving rapidly, Doppler shifts from the objects occur. The frequency of the radiation is changed. The only place outside of the Defense Department that Doppler radar is being used at the moment is for police radar used to determine whether cars are speeding. It has to my knowledge not yet been explored for environmental applications. The slow prime effect is that obtained with ordinary time-lapsed photography or time-lapsed observations with any sensor at intervals of hours, days, weeks, or months. With regard to automating the interpretation, we can today at least partially automate spectral discrimination based on wavelength. We are not in a very good position to automate shape or spatial discrimination, polarization, or Doppler effects at the present time. Therefore, the research work that goes on with regard to the last three here is an exploratory effort to develop methods. Much of the research in spectral discrimination is concerned with application since workable methods are available now.

Figure 11 shows a panchromatic mosaic of an agricultural area in California. This is ordinary photography. Some of the things that can be done with more modern instrumentation will now be illustrated.

Figure 12 shows 18 views of the same region. The view in the upper left is an ultraviolet image. The following 10 are narrow bands within the visible region and the remaining are reflected infrared except the last two. They are emitted infrared. Several interesting features of the imagery are shown here. Let us just consider one of them. Many people claim that there is no information in the ultraviolet that does not exist elsewhere in the optical spectrum. The ultraviolet photography shows marked difference between two fields that are the same crops: safflower. The marked difference shows up nowhere so strongly in any of the rest of the 18 bands in the visible and the ultraviolet and the infrared.

## Uses of Color

Plate 1 shows one of three uses of color as a display means. Color is used in the assignment of the color of the dye in the photograph to the wavelength used in the sensors. We have assigned a blue dye in the photograph to an ultraviolet sensor band, a green dye to a blue visible-region sensor band, and a red dye to a green visible band of the sensor. A difference between the two safflower fields shows because the ultraviolet information is sensed.

Plate 2 shows what the world looks like through infrared eyes. I have assigned the three dyes to three infrared wavelengths: the blue dye to the very near infrared; the green dye to a reflected infrared band at about 2.5 microns; the red dye to a thermally emitted infrared band. Note the two fields of the same crop: Rice at 10 centimeters tall of the same degree of health. They look quite different in this photograph only because the emitted infrared radiation band is present. The one field had been drained, and at 11:00 in the morning in the bright sunshine, the temperature in the field is much higher than in the other field which is still flooded with water. So here is another kind of information one can get and display in this fashion.

Plate 3 shows a different use of color. This is a single band in the sensor, the thermal band. It can be related directly to temperature and the colors have been assigned to temperature. In this case, the violet color is assigned to the highest temperature. The drained rice field is much higher in temperature than the flooded field and the other fields with more luxurious foliage. This is a second use of color that is different from the first one. The color here is assigned to amplitude of the signal within a single band rather than being assigned to wavelengths.

Figure 13 shows the result of having used a computer to decide what materials were present. A computer was asked in the uppermost strip to determine the 20-centimeter rice and nothing else. It did. In the second strip it printed out the 10-centimeter rice and nothing else, the process being sensitive enough to distinguish between the same crop at two different stages of growth. In the third instance it was asked to print out the safflower, and it did. In the fourth instance, the computer interpreted and printed out the bare soil.

Now it is not necessary to look at four photographs. Plate 4 shows exactly the same data; however, all are placed on the same chart with the third use of color. In this case, the colors have been assigned to the computer decision: red to 20-centimeter rice; blue, 10-centimeter rice; green, safflower; black, bare earth. That is an intriguing picture because it is my observation that most people who work with geographically distributed data very laboriously accummulate data, use many draftsmen to finally make, as the most useful output product, a chart or map with either cross hatching or coloring to code the different materials. What we have instead is a means of bypassing much of that labor. Almost directly from the sensor through a computer we produce a kind of a presentation which must be useful because so many people in so many groups who work with geographically distributed data spend much labor producing just this sort of display. One could carry the process at least one step further in the computer. The statistical recording service of the Department of Agriculture usually does not want to look at pictures at all. It wants tabulations.

Table 1 shows this kind of result. If the computer can recognize the materials, it is a fairly easy job to ask the computer to sum the areas, and this is what is done: The computer responds with totals– bare soil, 190 acres; safflower plants, 290 acres; etc. This is a typical sequence of the types of results that we are beginning to learn how to get in remote sensing applications.

TABLE 1.–Crop Acreage for Davis, Calif., Area Obtained by Digital Processing

| Crop | Symbol | Acres |
|---|---|---|
| Bare soil | • | 190 |
| Safflower | ( | 290 |
| Immature rice | ⊬ | 410 |
| Mature rice | X–X | 270 |
| Other | | 440 |

## Other Types of Results

Here are some sequences of other kinds of results. Figure 14 is a panchromatic photograph of all of that immoral oil out in the Santa Barbara Channel a couple of years ago. You can see the drill platform. Barely visible is a boat that is spreading detergent or some sort of dispersent. In this panchromatic photograph the oil slick is not visible.

Plate 5 shows an infrared photograph over an ultraviolet one. In this case, the thickness of the oil is such that it does not show in the infrared. In the ultraviolet it appears lighter in tone than does the surrounding water. But that is not all we have to do in this case because kelp beds in the area can be confused for oil. Recall the configuration here; oil shows nothing on infrared, shows light on the ultraviolet.

Plate 6 shows kelp which is brighter than the water in the infrared where the oil did not show at all. It is darker than the water in the ultraviolet where the oil was brighter than the water. So in this example we need no special data processing. All we need to do is look at a couple of special bands and we get an unequivocal distinction between the materials.

Plate 7 shows another kind of an example. This is an area of the Everglades. Colors represent the computer-assigned decisions with regard to the types of plant communities that are present in the area. Remote sensing has the obvious advantage that, in an area where it is difficult to gain access on foot, we can fly over the area with these multiband, multispectral sensors and reach decisions regarding the types of vegetation.

Figure 15 is an ordinary panchromatic photograph taken in Florida in an area characterized by subsurface voids, whose presence many times is not known. When houses, roads, and other structures get built over them at subsequent dates, subsidence occurs, as happened with this house.

Plate 8 shows an infrared photograph in which the intensity of the radiation, the apparent temperature, has been indicated by color. At the time the flight was made, this was a known area of crass feature. With a little imagination, a more or less concentric pattern of changing temperatures can be seen. At the time that flight was made there were no known crass features in the vicinity of the road junction. However, it was conjectured that there were subsurface voids there. Inspection was made on the surface, without any indication of voids. Drilling, however, indicated some voids down 40 to 60 feet. Four months later some subsidence began to occur here. I do not want to imply that we know how to do this every time. We don't yet. But, it is certainly intriguing that, in at least one place, we have demonstrated that we could get an indication of the subsurface void before any other obvious manifestations were present.

Plate 9 contains three photographs. Part (A) is an ordinary color photograph of the shoreline of Lake Michigan. Part(B) is another color photograph. Air pollution over the city is evident in the lower left. An effluent being discharged into the small body of water does not show up very clearly in the ordinary color photograph. In the infrared Ektachrome photograph, part (C), it shows up somewhat more clearly. That is the effluent from a paper mill. An infrared scanner photograph, plate 10, shows the signal levels coded in color where the red area is the discharge of warm water from an electric power generating plant into the lake; the orange area is the coastline of Lake Michigan; the blue area, the water. The highest temperature, in this case, is indicated by the red, and lower temperatures fade off into the yellow, the light blue and the dark blue. All is not simple, however; that is the flow pattern at just one time of the year.

Figure 16 shows, in black and white, the same area but at some different times of the year—the flow considerably varying seasonally. So it is not enough to get one look at where this hot water is going. It will shift, sometimes with the wind velocity, sometimes with the current, sometimes seasonally.

The upper part of plate 11 is an infrared photograph of Hilo, Hawaii. The dark strips are cooler fresh ground water seeping out into the bay. This water is of much interest in that region of volcanic soil where the water leaches through the soil very rapidly. The agriculture in the area is, in fact, limited pretty much by available water supply. Water wells suitably located could tap this valuable resource. The lower part of the illustration is the result of having done some density work on the upper part and coding the densities in color.

Plate 12 shows an urban problem. The black-and-white photograph is of a segment of Ann Arbor, Michigan. The question addressed here was as follows: As areas become urbanized, larger fractions of the surface become covered with materials through which the water cannot drain. The fraction of those materials present in the area determines how many, the size, and spacing of soil-water drain tiles. It is a laborious task to determine the fraction of the area that is impervious to water. Also shown is the result of having used a multiband sensor and a computer to very rapidly map the areas that will not leach water into the subsurface, the red area. The blue areas are those areas of soil where the water can leach. This demonstrates another kind of result we are getting from remote sensing. Table 2 shows, again in this application, where the computer was asked to just add the acreage because that is the relevent information with regard to the drain tiles.

Figure 17 is a chart of some crops in the Mesa area near Phoenix, Arizona. Shown along the bottom are several crops of hay grown each year. The light-green areas occur where it is cut, the dark-green areas where it is growing. Near the top, cereal grains are green in spring and ripen along about May (tan). They are harvested then, and only stubble remains (brown). This type of crop calendar is useful for making more intelligent choices about the frequency of observation, if one is interested in using what I would call time-distributed signature.

Plate 13 shows some infrared Ektachrome photographs at the major time intervals indicated in the crop calendar for March, April, May, and August. Note that the patterns of these fields change. The colors change from time to time. The pattern that they exhibit is a result of the variations in the plant growth and planting, cropping, and harvesting processes illustrated in the previous crop calendar.

TABLE 2.—Acreage Estimates of Impervious Materials from Digital Computer Recognition Map

| Category | Number of points | Acreage |
|---|---|---|
| Bare soil | 654 | 0.86 |
| Field | 1196 | 1.56 |
| Gravel | 7567 | 9.85 |
| Water | 6411 | 8.35 |
| Tree | 10246 | 13.34 |
| Lawn | 3503 | 4.57 |
| Light roof | 2055 | 3.13 |
| New roof | 1354 | 1.76 |
| Perpendicular roof | 231 | 0.30 |
| Parallel roof | 460 | 0.60 |
| Asphalt | 630 | 0.82 |
| Cement 1 | 507 | 0.66 |
| Not classified | 3241 | 4.22 |

Plate 14 shows another kind of an example. The fish and wildlife people are interested in the duck carrying capacities of certain regions in South Dakota where much duck breeding occurs. This is a function of the number of ponds, the length of the shoreline and shoreline convolution. There has been some preliminary success in surveying these regions with a multiband sensor and automatically determining the area of the ponds, the perimeter of the ponds, the degree of convoluting of the shorelines, and making estimates of the duck carrying capacities. Several kinds of results are indicated. Part (A) is an ordinary picture of the area. Part (B) is a photograph processed to show only the water, with all of the vegetation suppressed. Part (C) is processed to show the vegetation type with the water suppressed, showing it as black. Part (D) is a digital picture; I do not have the final computations but one can carry the process to the point where he can calculate the duck breeding capacities of the region.

Figure 18 shows two infrared photographs of interest to anyone concerned with aquatic affairs. This is part of the Tennessee Valley Authority's system 20 miles below Norris Dam and site of an electric-power generating plant. The dark tones are coal. An area can be seen in (A) where the warmer surface water has been skimmed off so only the cooler subsurface water is admitted to the turbines in the generator. The warmer water discharges from the other end of the turbines. At the time this photograph was made on September 3rd, the gates at Norris Dam, 20 miles upstream, were open and a slug of cold water was admitted to the stream. Just about 24 hours later on September 4th (we had been making observations in 2- or 3-hour intervals), we saw the slug of cold water advancing down the river and photographed it (B). Surprisingly, there was very little mixing at the interface after having been flowing down the river for 24 hours. Here is another kind of result with obvious applications to studying flow in streams. Figure 19 shows a densitometer trace across the river, indicating where the skimmer was at the input to the power plant at the main river. The hot plates and cold plates are calibration sources in the sensor.

## PLATFORMS

At the present time NASA has a number of aircraft (fig. 20) for the use of all the people involved in remote sensing. The Convair 240 has now been retired from the program, but we do have a P-3, a C-130, and an RB-57.[2]

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[2]Editorial Note: At the conference, it was announced that two instrumented U-2s, having higher altitude capability, will be scheduled for flights from Wallops Station, Virigina.

Figure 21 shows the various sensors aboard the C-130 aircraft and, very roughly, the areas they cover on the ground underneath the aircraft. Sensors include a 13.3 GHz scatterometer, a 24-channel multispectral scanner, a Reconofax 4 infrared scanner, six Hasselblad cameras, two RC-8 cameras, and the side-looking airborne radar that looks out considerably to the side of the aircraft. This is representative of the instrumentation aboard that aircraft.

Figure 22 shows instrument coverage of the P-3, with a similar set of instruments, that are not identical in ground coverage.

Figure 23 shows the high-altitude B-57 aircraft, with its compliment of sensors that change from time to time, as we do update them; if one wants to know for certain what the sensors are today, he should not rely entirely of this chart; note the various cameras, scanners, a calibrated radiometer with a very small field of view in the center, and a spectrometer.

Figure 24 shows the planned instrumentation and ground coverage for the Skylab Earth Resources Experiment Package. It is planned that in early 1973 this will be in orbit and, of course, in 1972 the ERTS Satellite will be in orbit.

We have covered the sorts of data sources that exist at the present time that NASA is using for the benefit of all the investigators in these programs. Figure 25 illustrates, in one sense, the scope of the activities that we believe are necessary in Earth observations: the theoretical analysis of various sorts; lab measurements we must have for signatures; *measurements in the field; aircraft at several altitudes; and spacecraft.*

I hope that this presentation informs you of the kinds of results available today and the kinds of instrumentation that are available in the remote sensing program.

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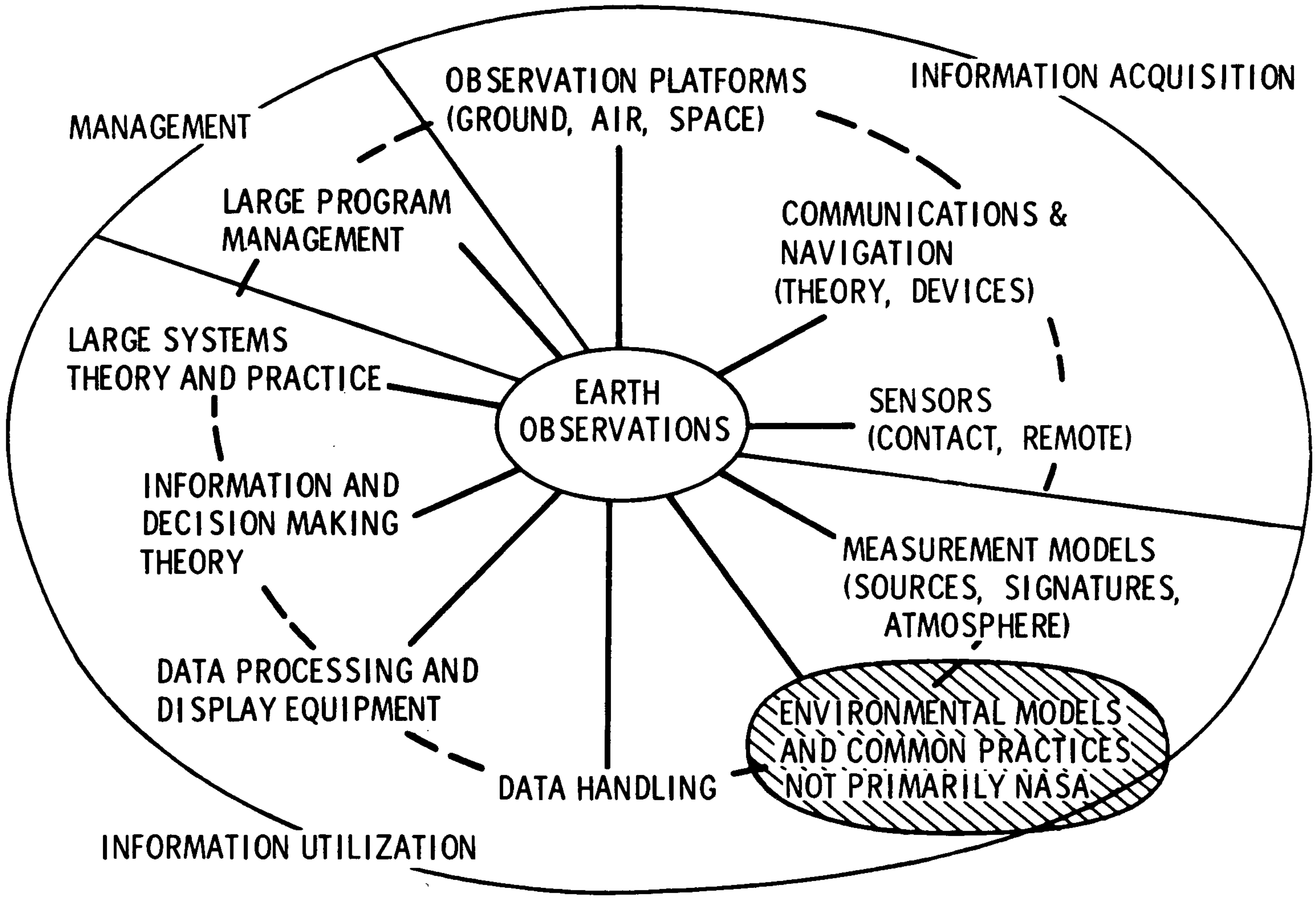



Figure 1.–Areas of NASA competence.

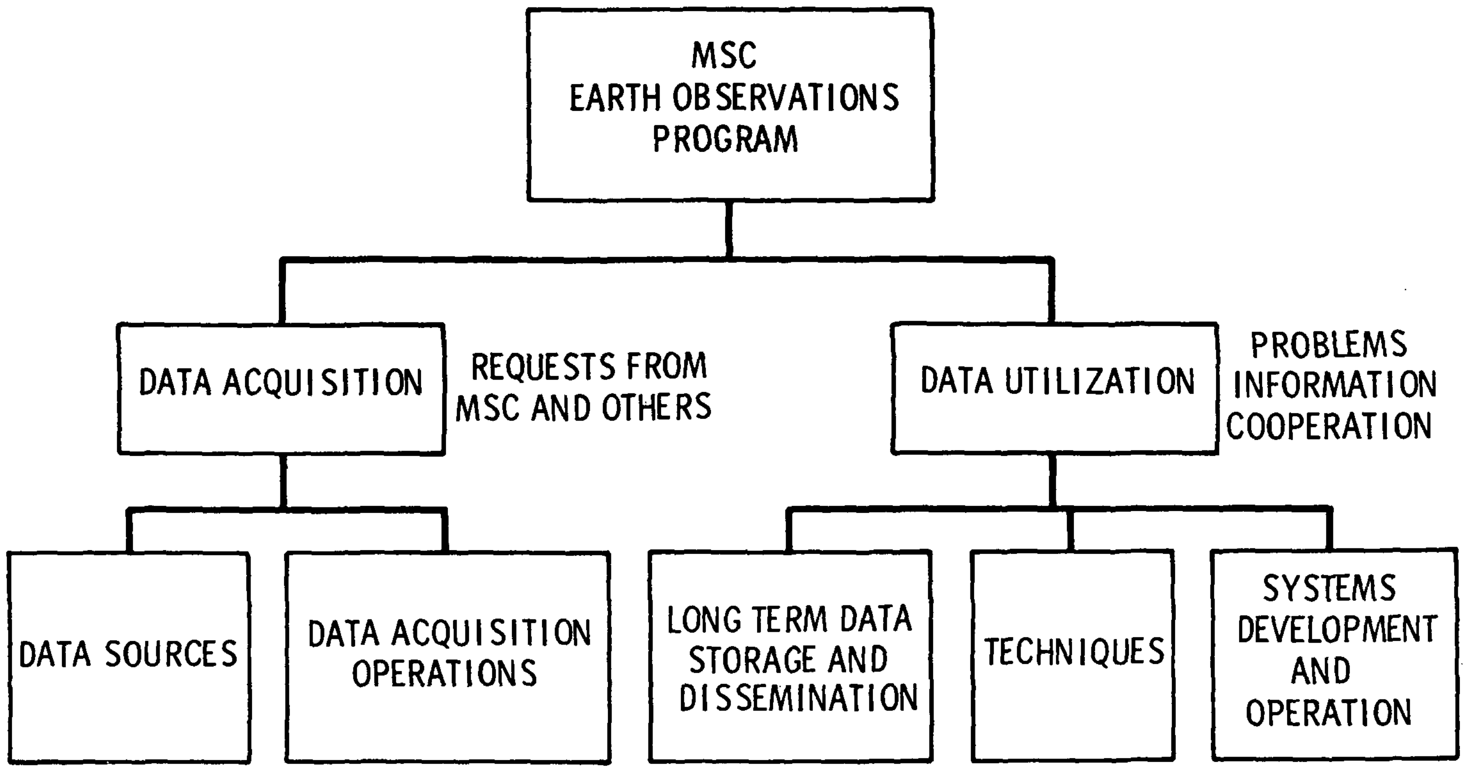



Figure 2.–Earth observations management responsibilities.

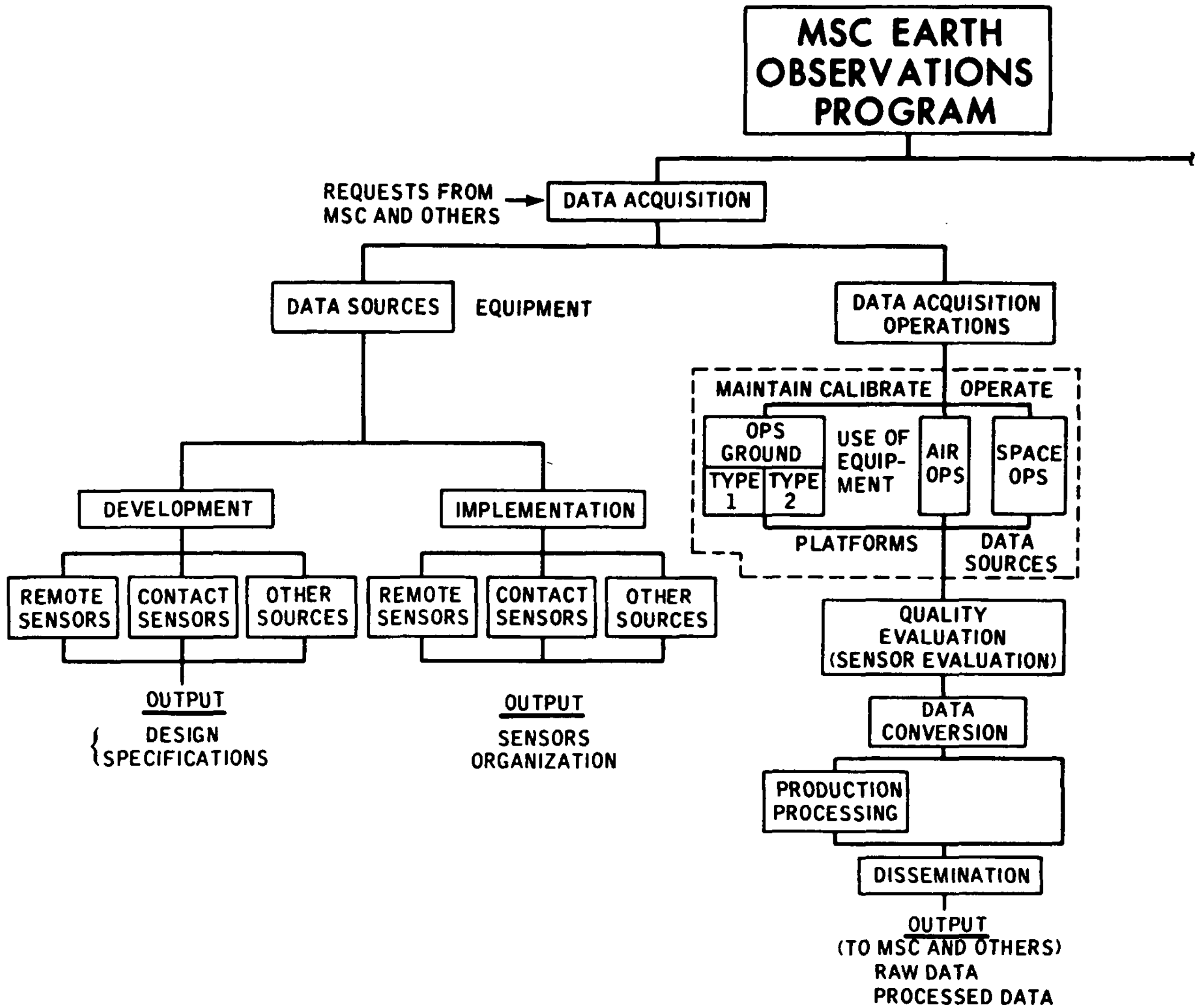



Figure 3.–Data acquisition activities.

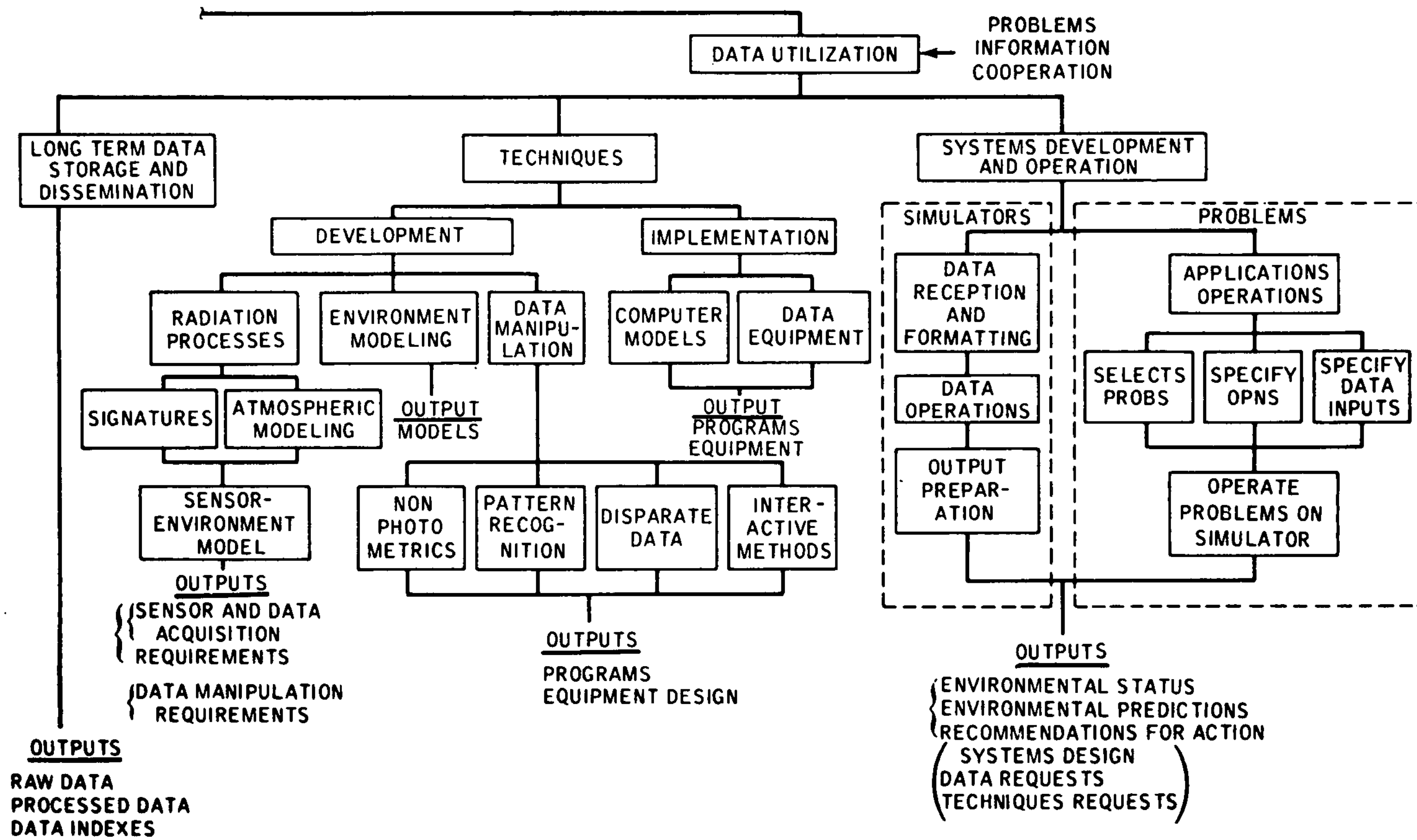



Figure 4.–Data utilization activities.

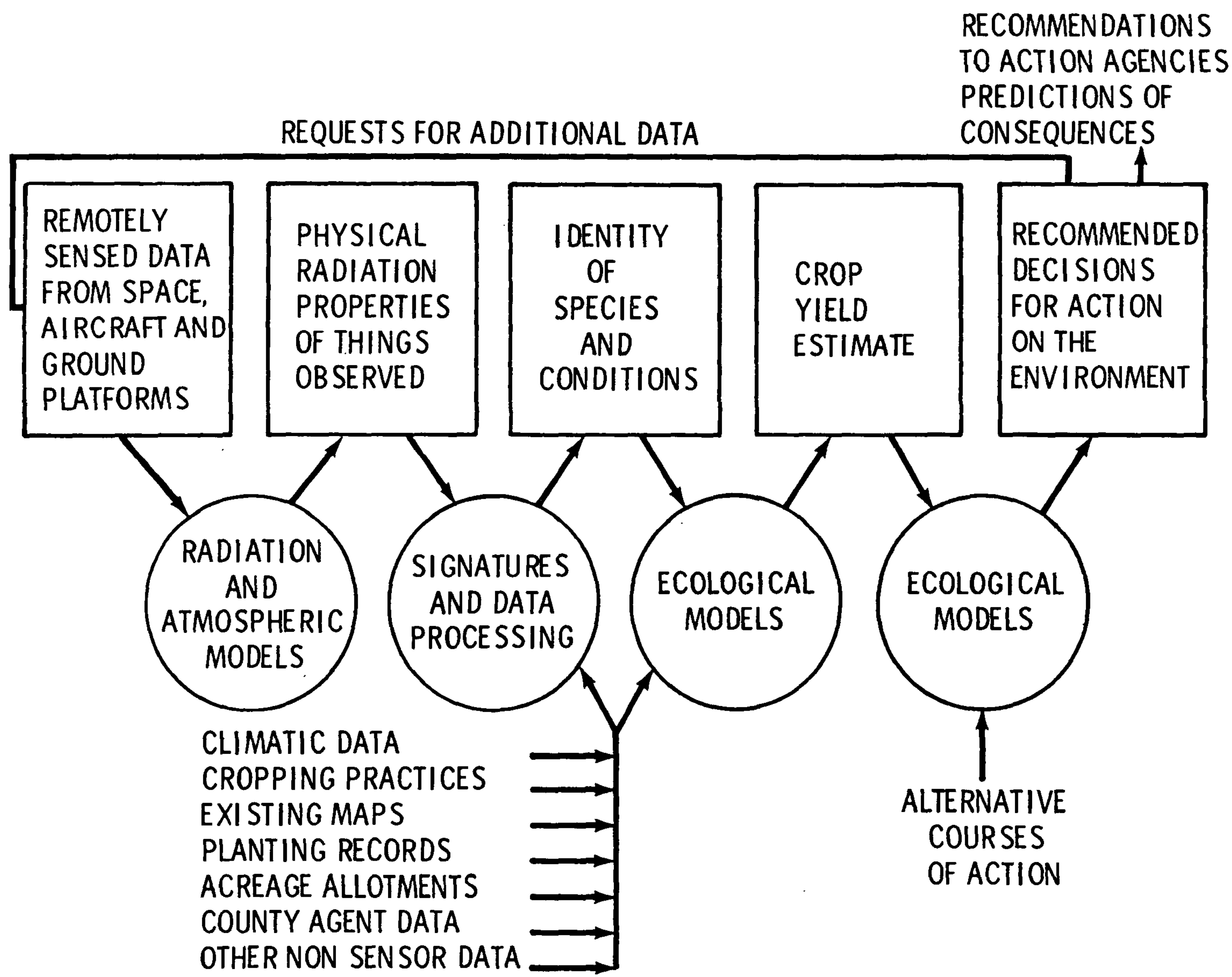



Figure 5.–Earth observations system (crop yield example).

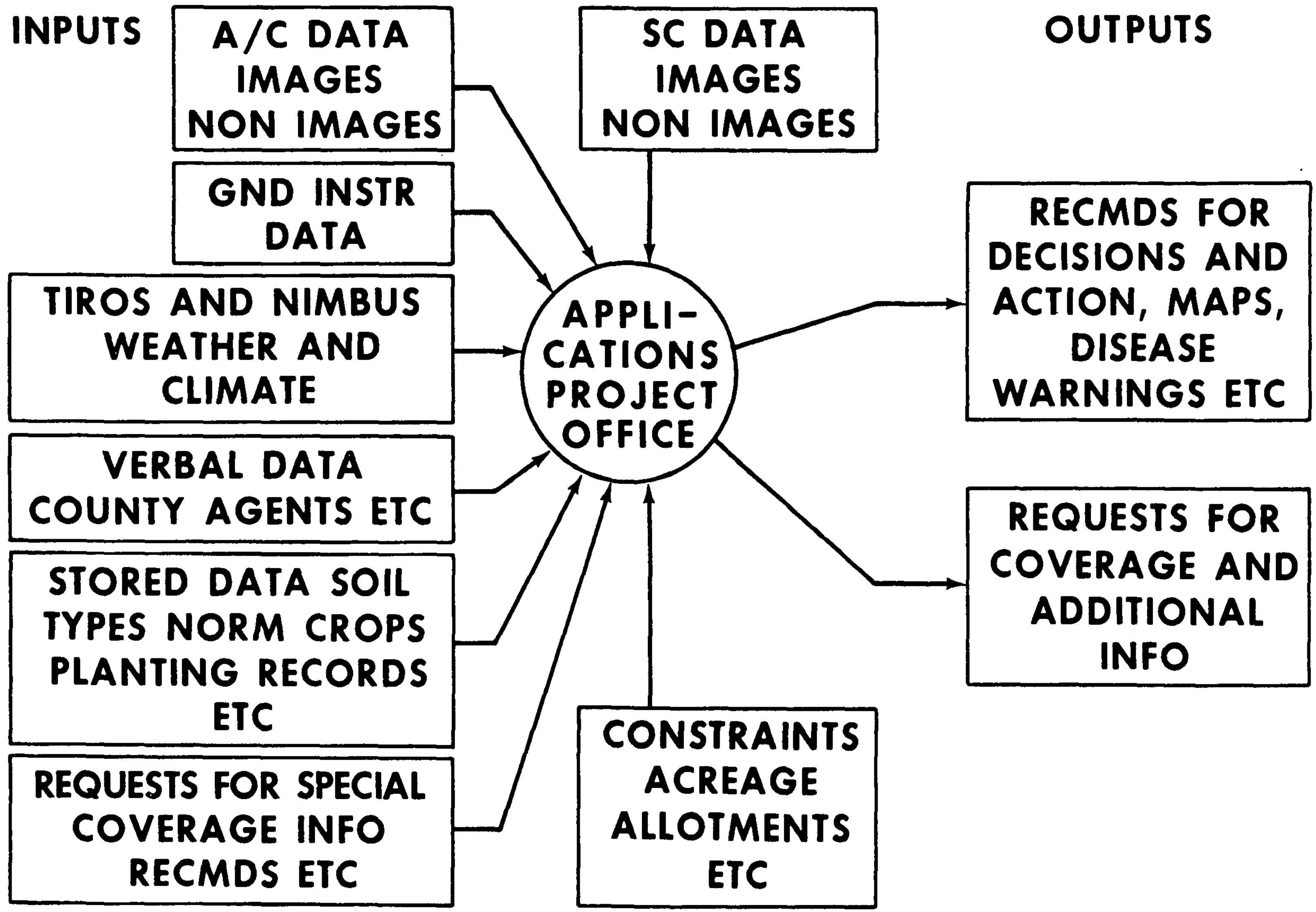



Figure 6.–Disparate sources must be coordinated for meaningful application.

| | SHORT RANGE | MID RANGE | LONG RANGE |
|---|---|---|---|
| OBSERVATION | THEMATIC MONITORING OF LAND AND SEA | | |
| ↓ UNDERSTANDING | IMPROVED WORLD REFERENCE SYSTEM | COMPREHENSIVE MODELS FOR ATMOSPHERE, DYNAMIC EARTH, OCEANS, AND LAND | |
| ↓ PREDICTION | | PREDICTIONS FOR FOOD PRODUCTION, POLLUTION, NATURAL DISASTERS, RESOURCES, AND TRANSPORTATION | |
| ↓ MANAGEMENT MODIFICATION | | REGIONAL EXPERIMENTS IN MANAGEMENT OF NATURAL RESOURCES SUCH AS WATER | EXPERIMENTS IN ENVIRONMENTAL MODIFICATION |

Figure 7.–Evolution of capability (typical examples.)

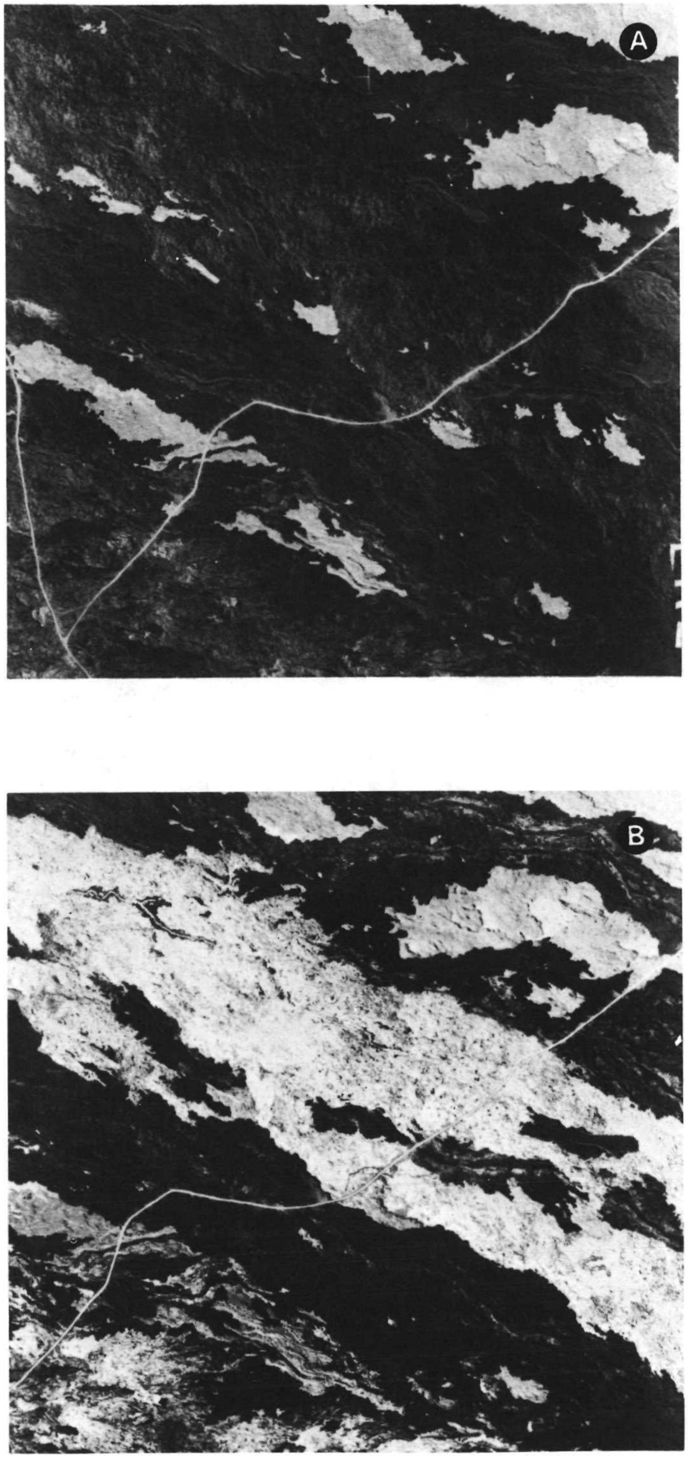



Figure 8.–Photographs (A) and (B) appear radically different even though they were taken 20 seconds apart under same conditions.

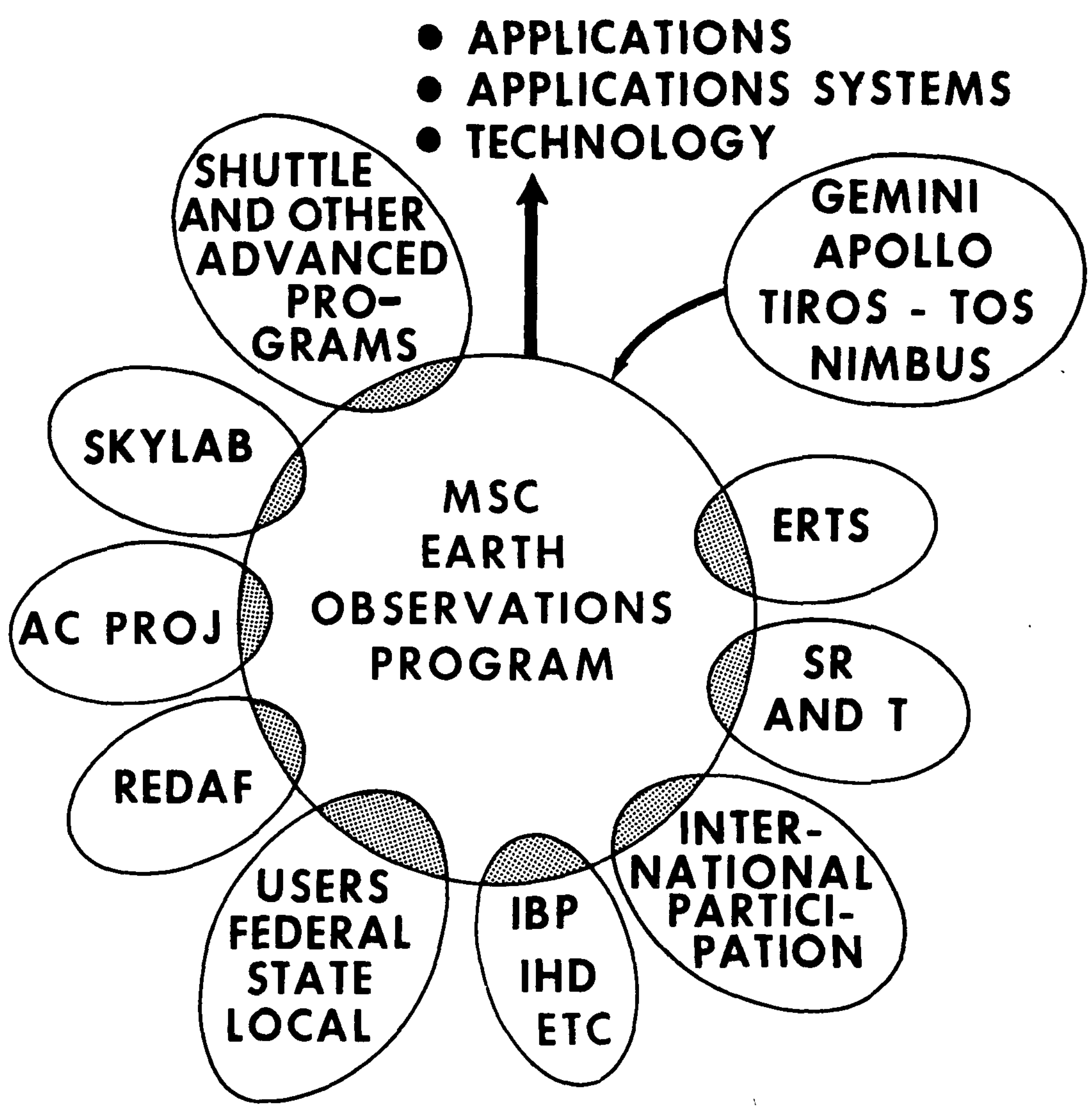



Figure 9.—Other programs impacted.

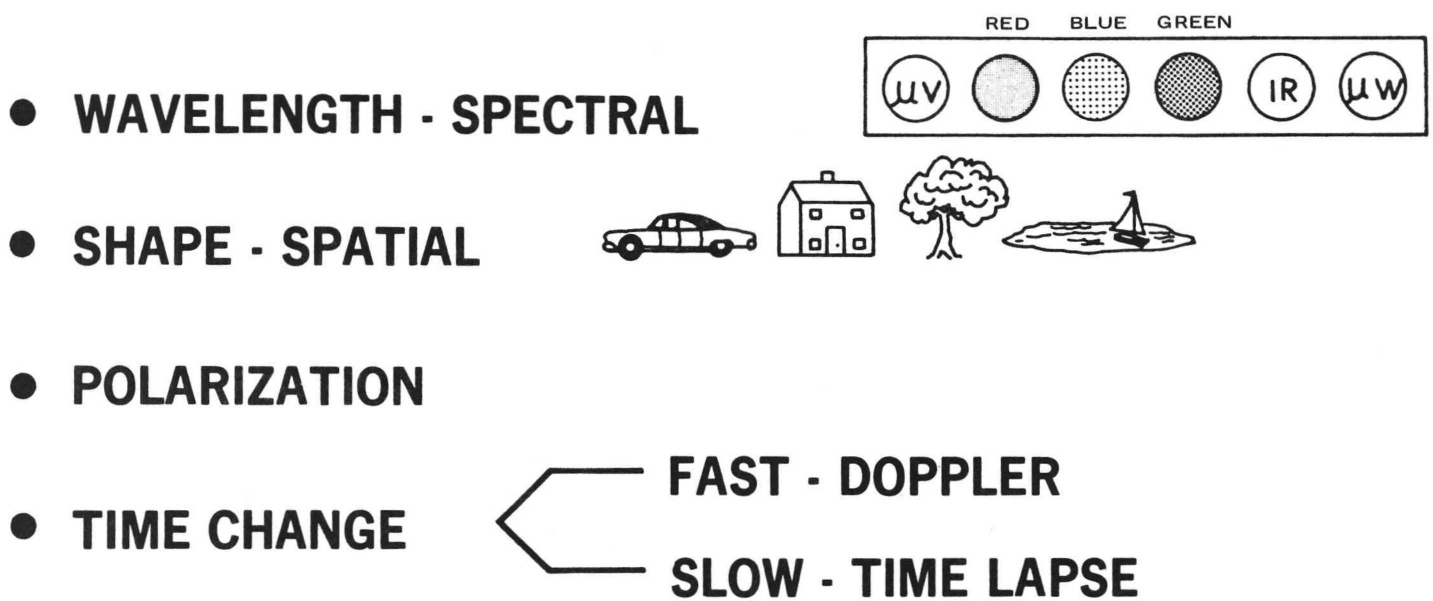



Figure 10.–Information in radiation.

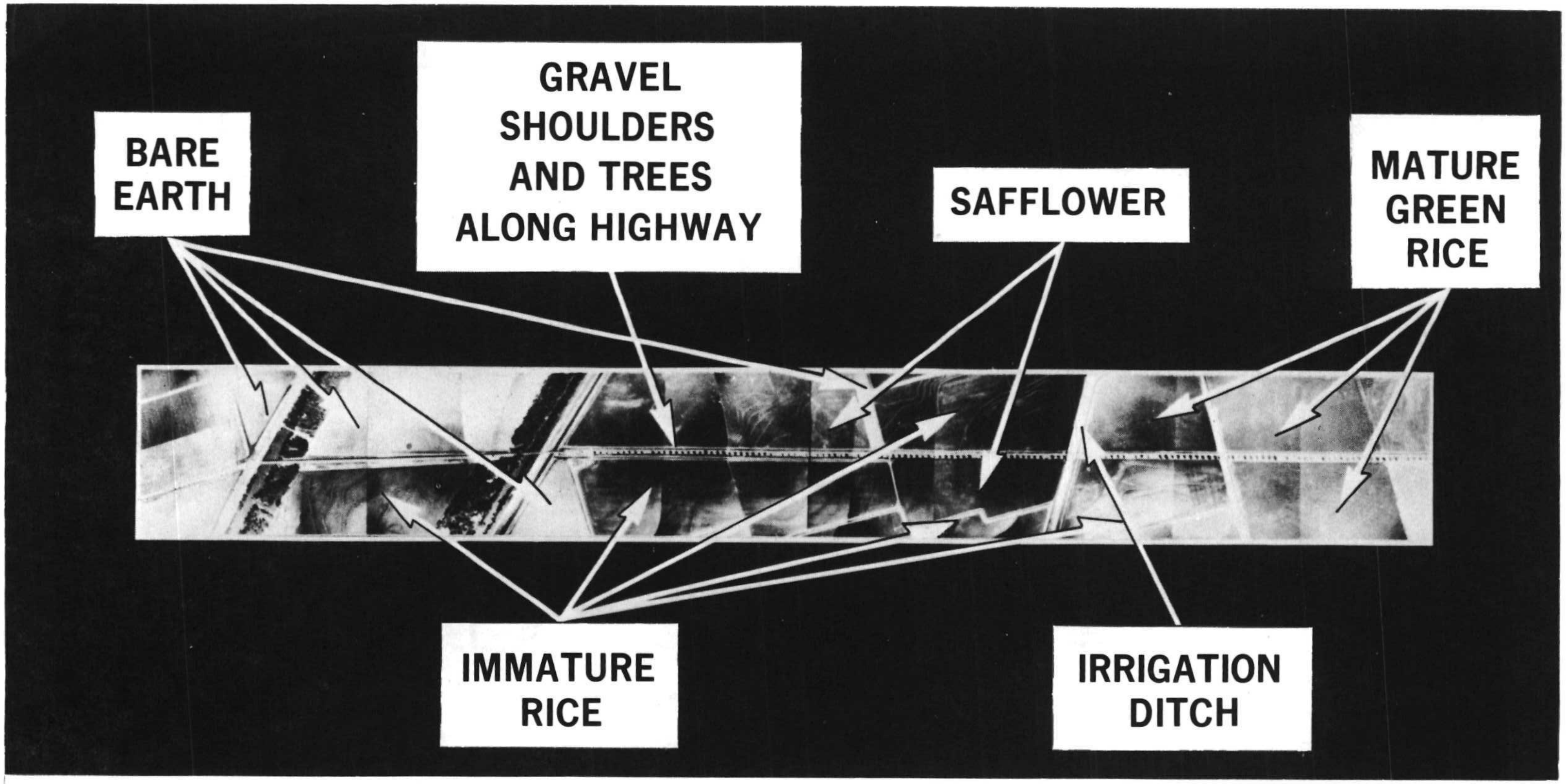



Figure 11.–Panchromatic mosaic of California farming area; May 26, 1966; 1600 hours; altitude, 2000 ft; sky condition, clear and bright, 10 percent cloud cover at 30 000 ft; surface temperature, 27° C; University of Michigan photograph.

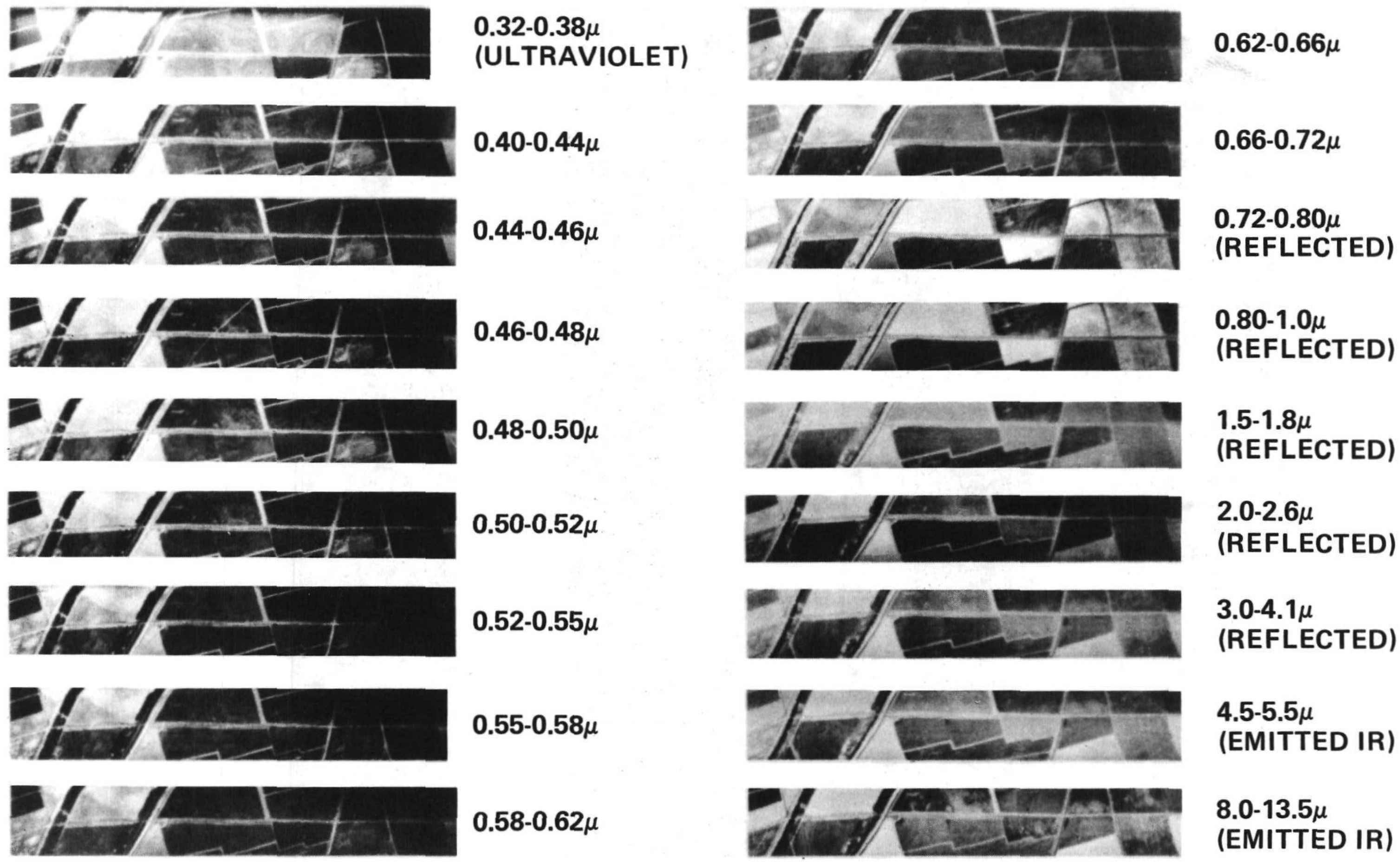
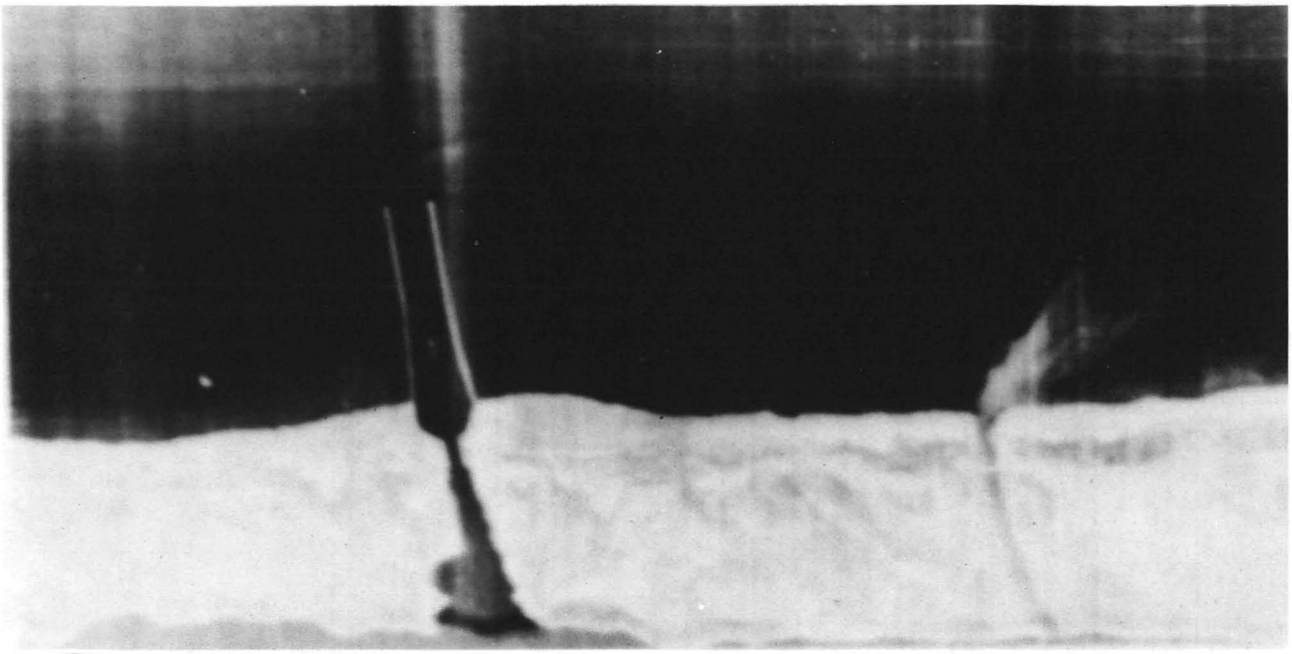



Figure 12.—Multispectral imagery of Davis, Calif., agricultural area. Same conditions as for figure 11.

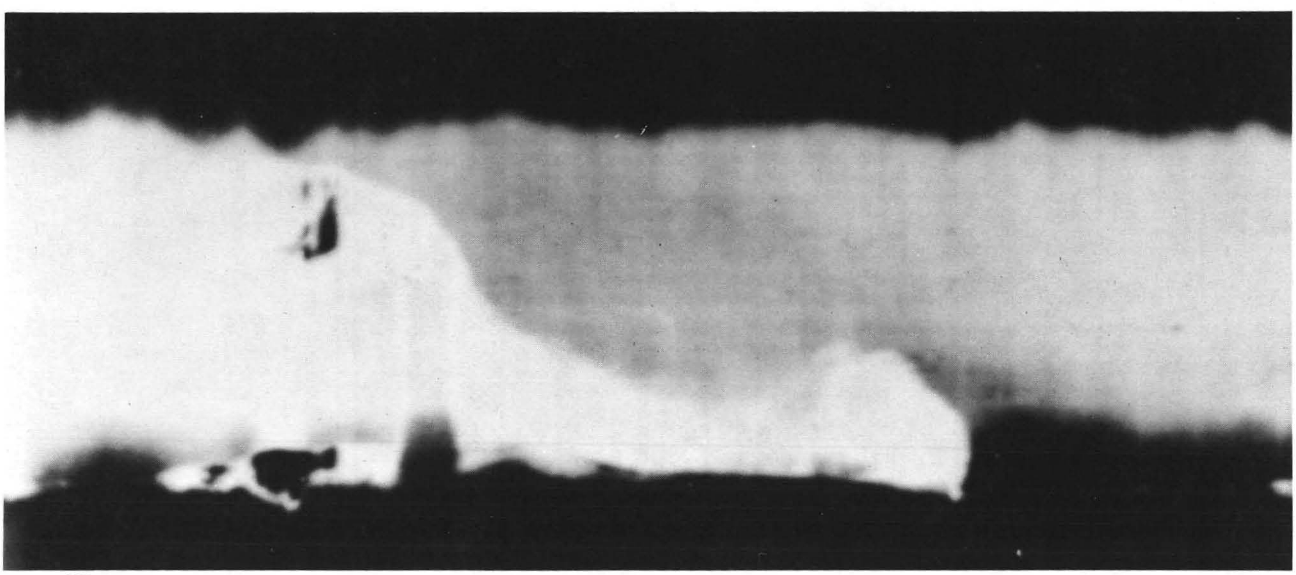

Figure 13.–Agricultural area, Davis, Calif., recognition pictures; (A) mature green rice, channels 0.46 to 0.48$\mu$ and 0.58 to 0.62$\mu$; (B) immature rice, channels 0.48 to 0.50$\mu$ and 0.62 to 0.66$\mu$; (C) safflower, channels 0.72 to 0.80 and 0.80 to 1.0; (D) bare soil, channels 0.46 to 0.48$\mu$ and 0.62 to 0.66$\mu$.

Figure 14.–Panchromatic photograph (K-2 filter) of Santa Barbara oil slick (University of Michigan photograph).

Figure 15.–Panchromatic photograph of area in Florida where subsurface voids led to subsidence.



(A)



(B)

Figure 16.–Seasonal current reversal detected in Lake Michigan via infrared imagery of warm water discharge. (A) Spring; (B) Autumn.

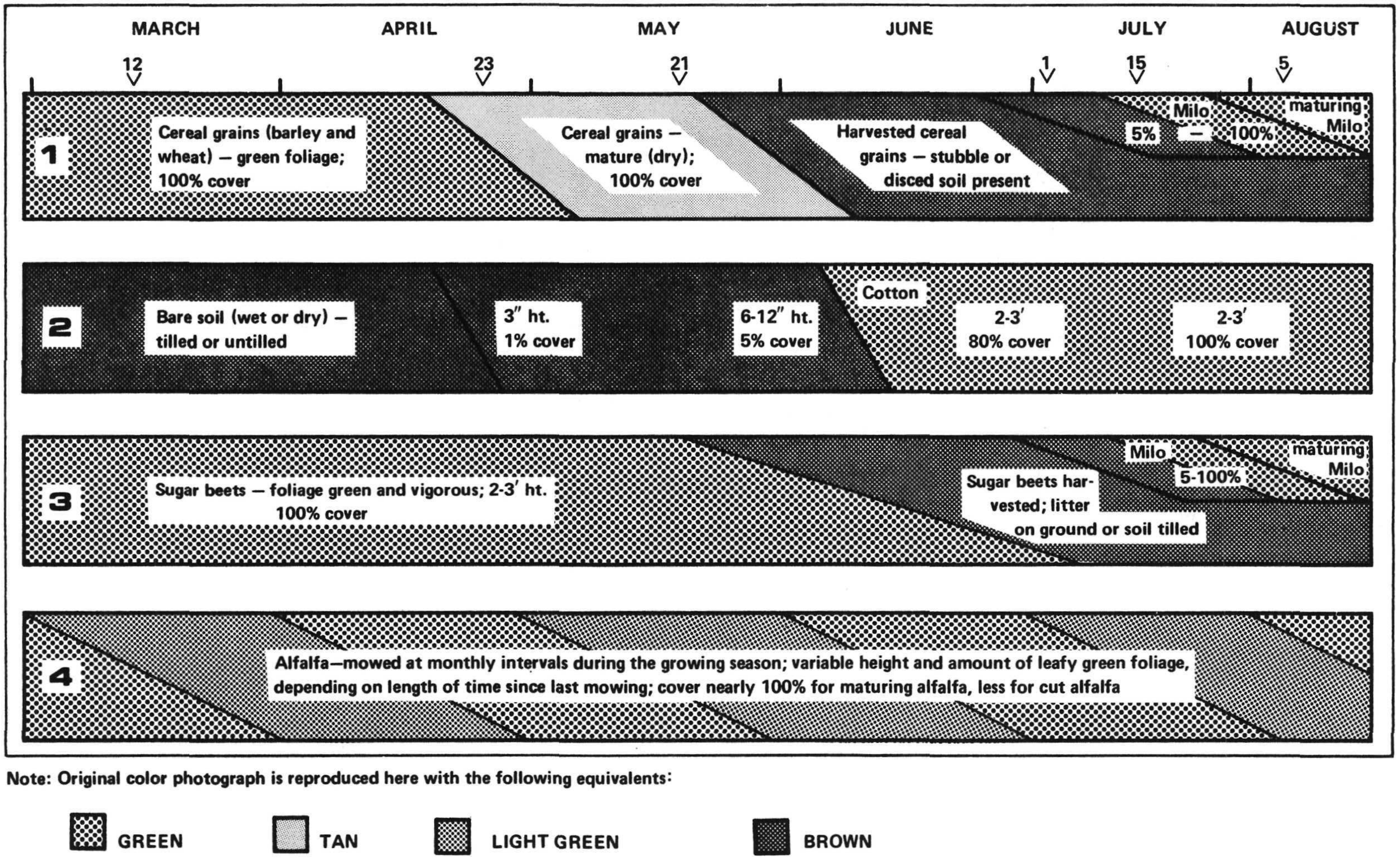



Figure 17.–Mesa test site crop calendar–1969 sequential shading.

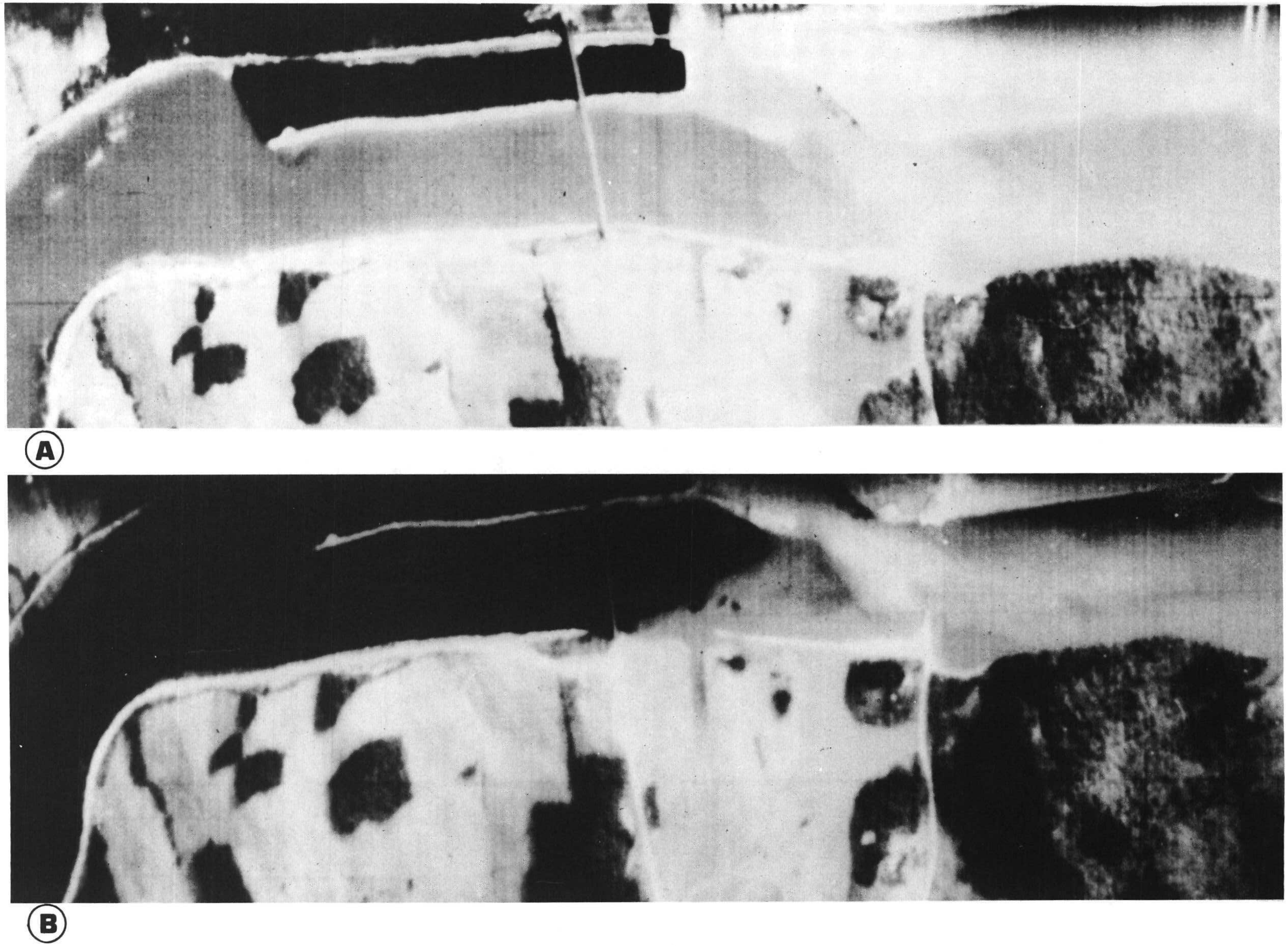



Figure 18.–Power plant site showing advance of upstream cold-water release into river. (A) Sept. 3, 11:15 a.m.; (B) Sept. 4, 10:18 a.m. (8 to 14$\mu$ imagery).

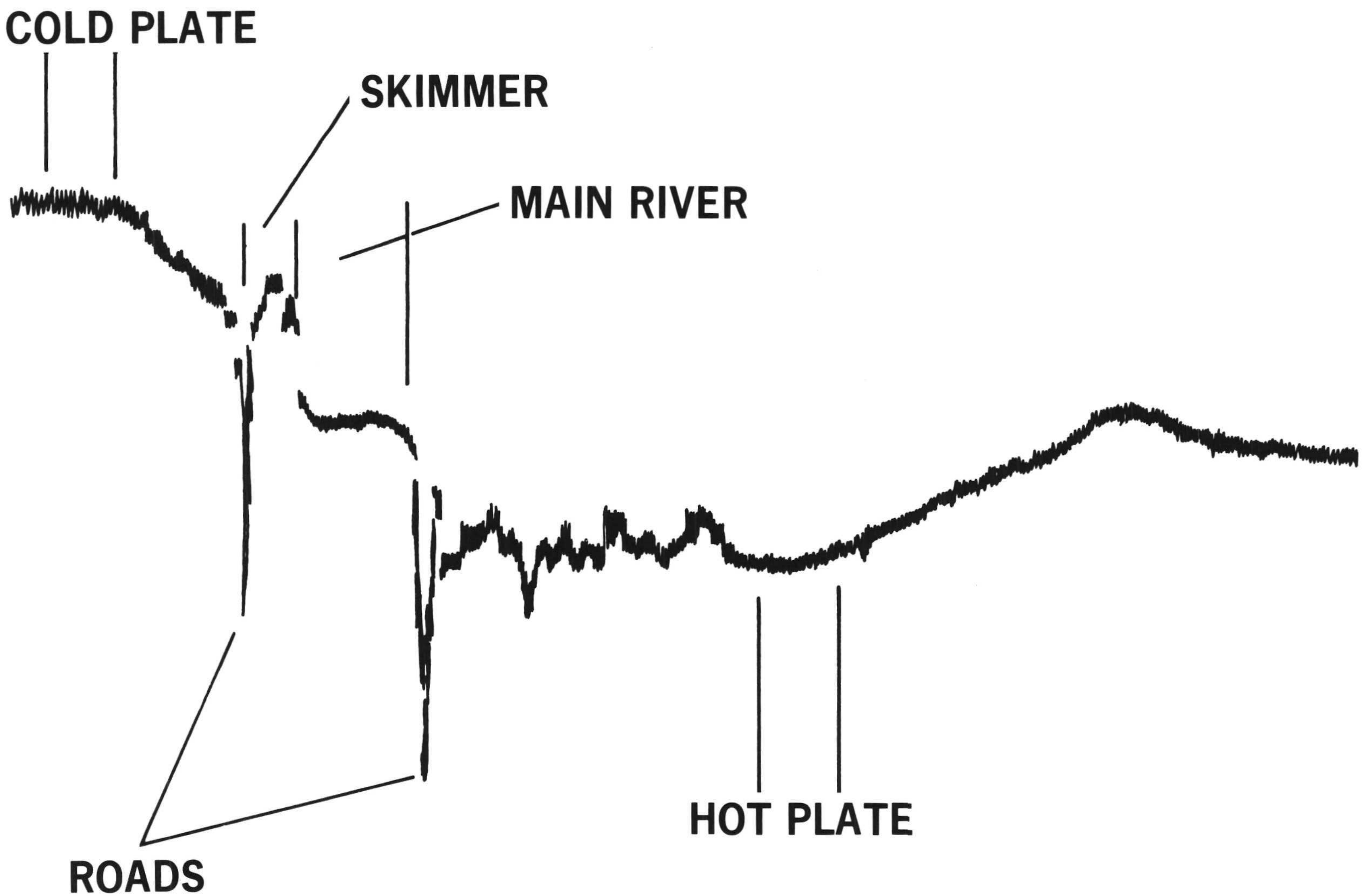



Figure 19.–Densitometer trace across river; see figure 18.

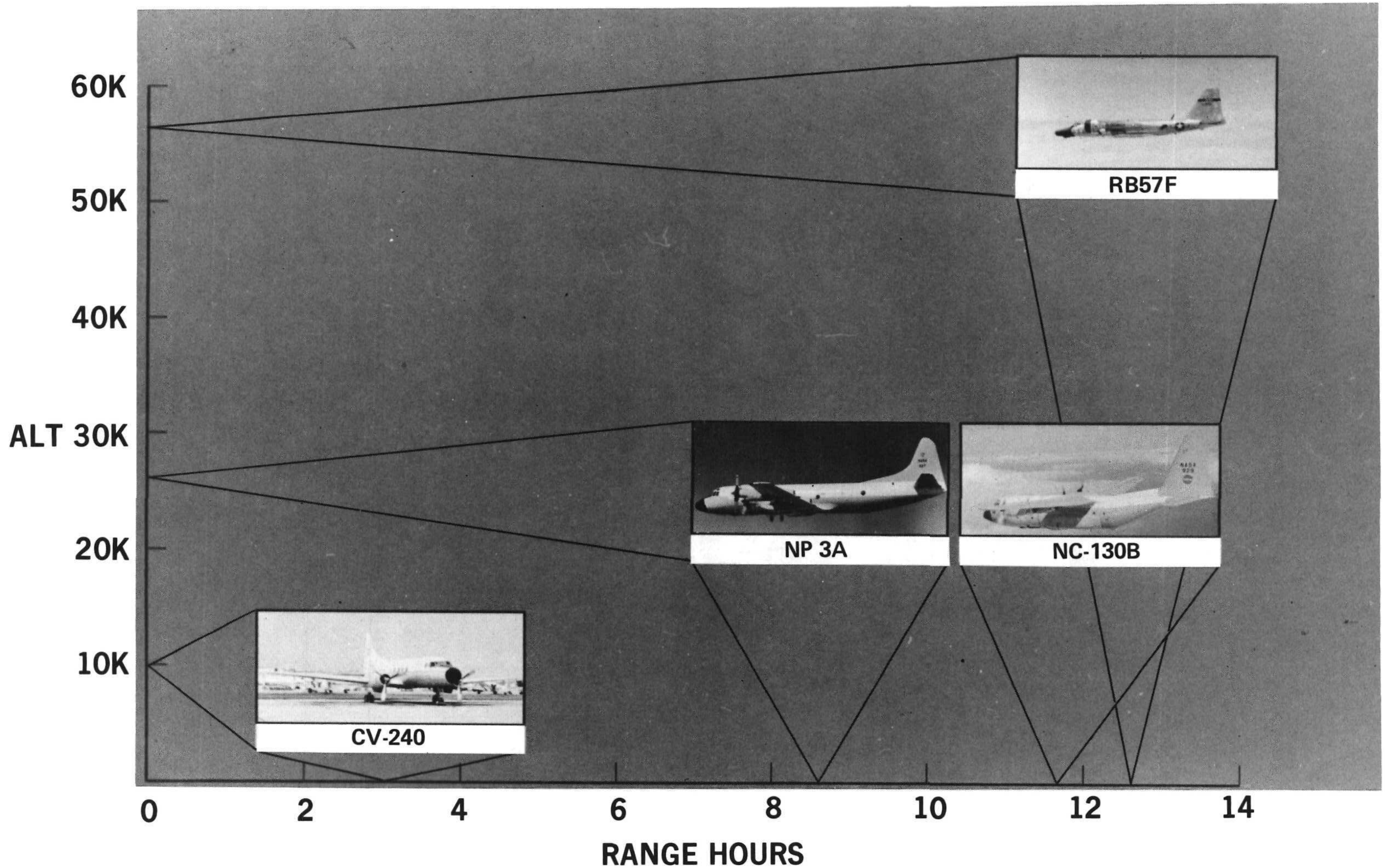



Figure 20.—Aircraft capabilities.

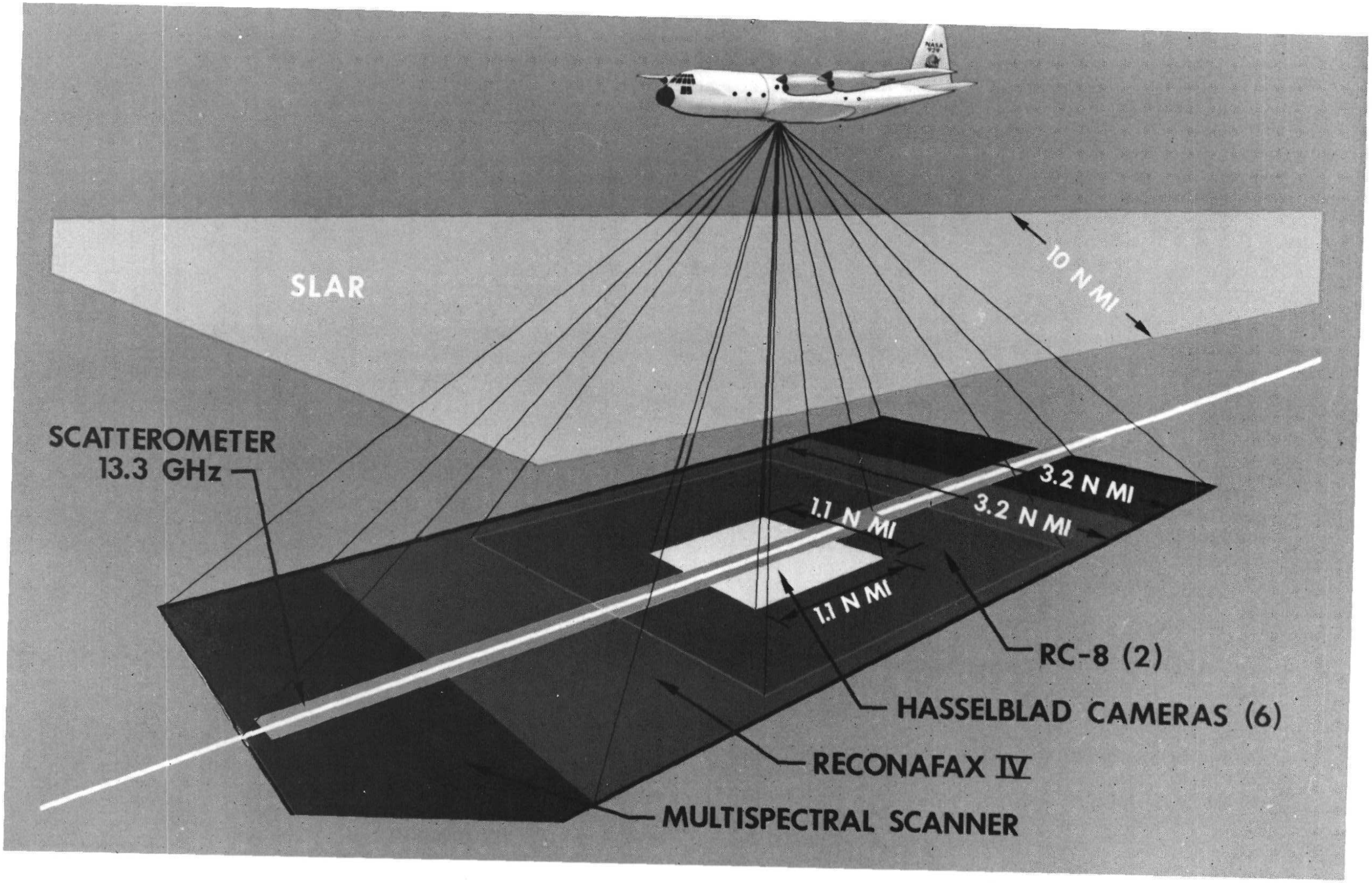



Figure 21.–Lockheed Hercules C-130 coverage at 10 000 ft.

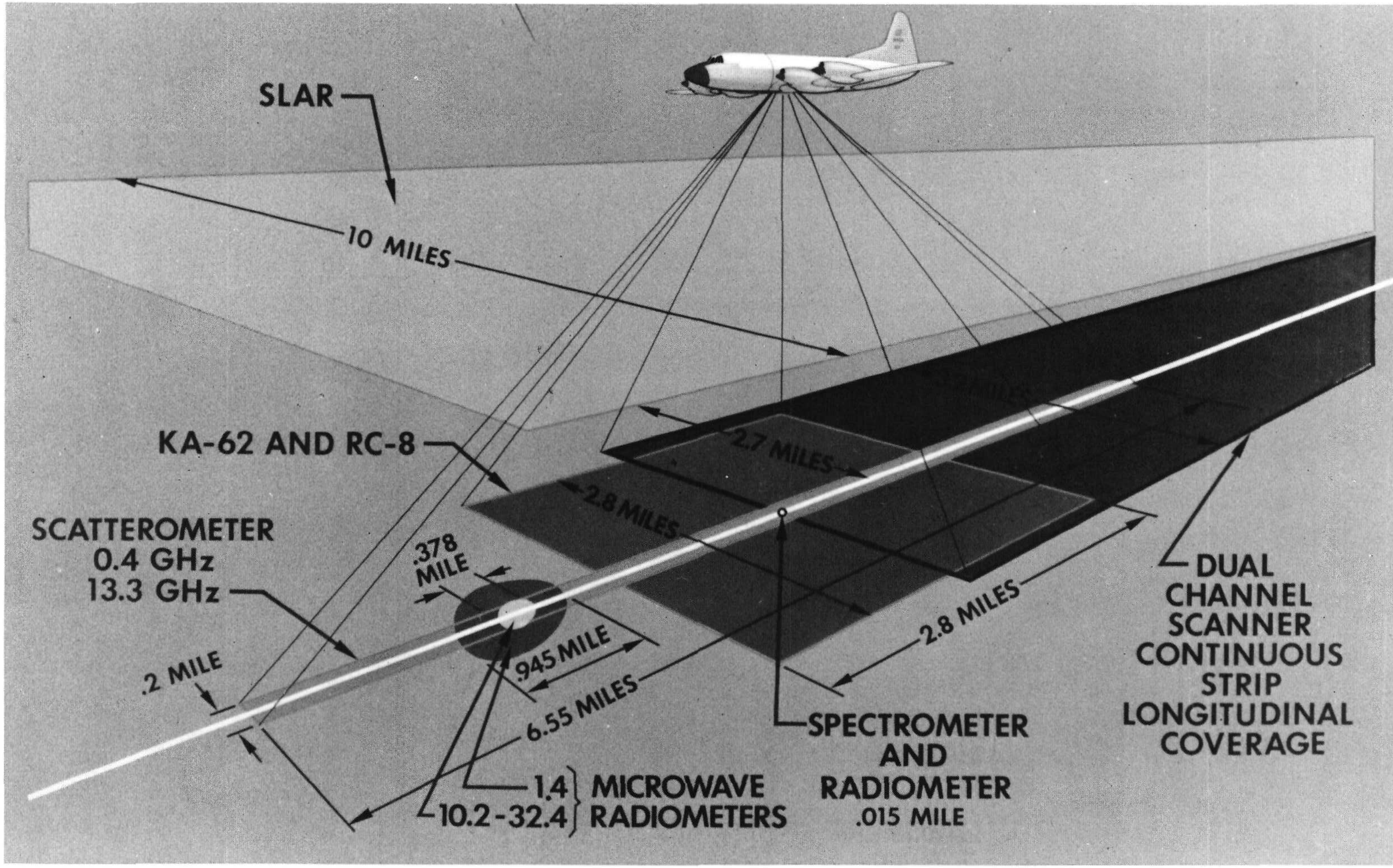



Figure 22.–Lockheed Electra P-3A coverage at 10 000 ft.

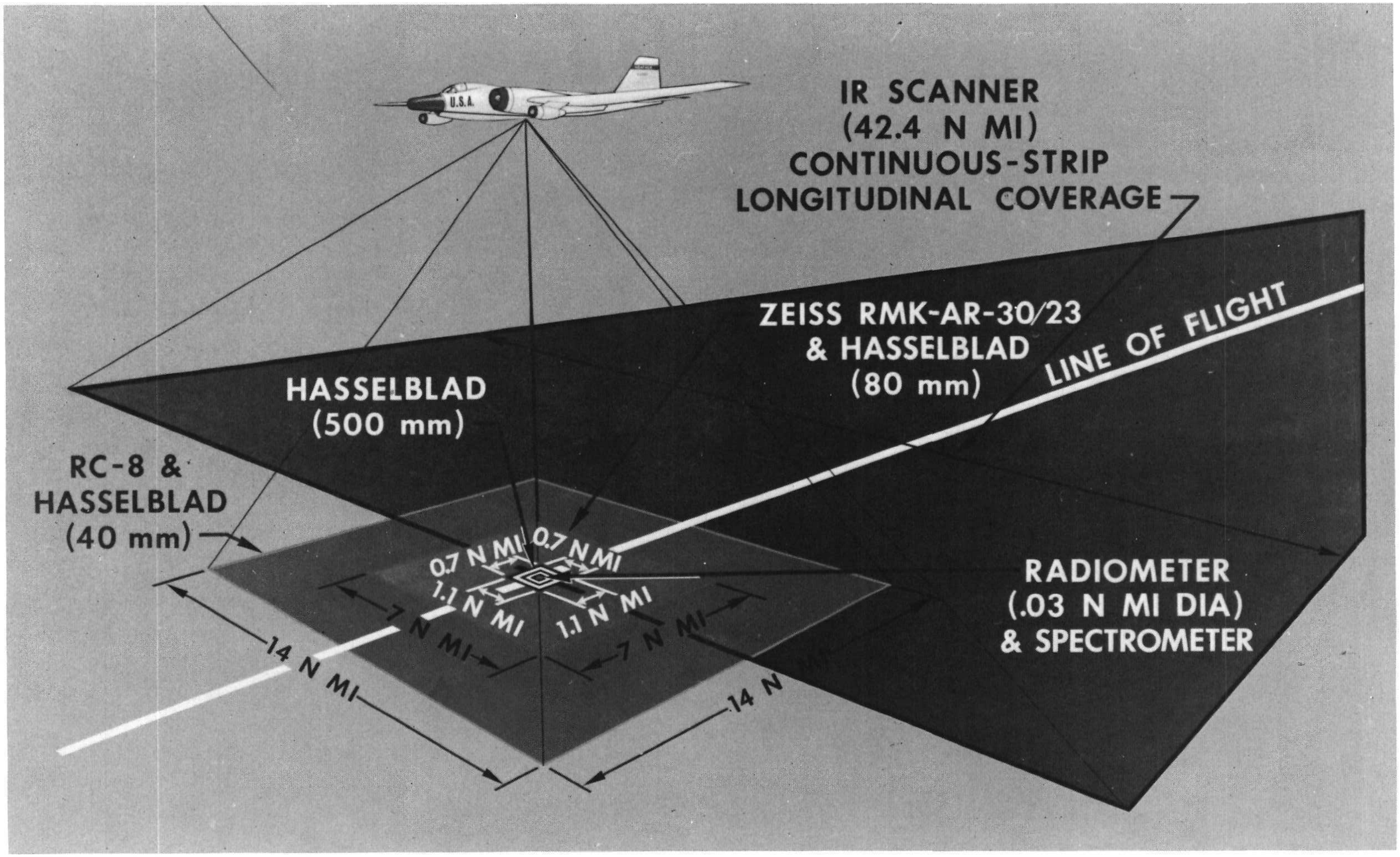



Figure 23.–RB57F coverage at 60 000 ft.

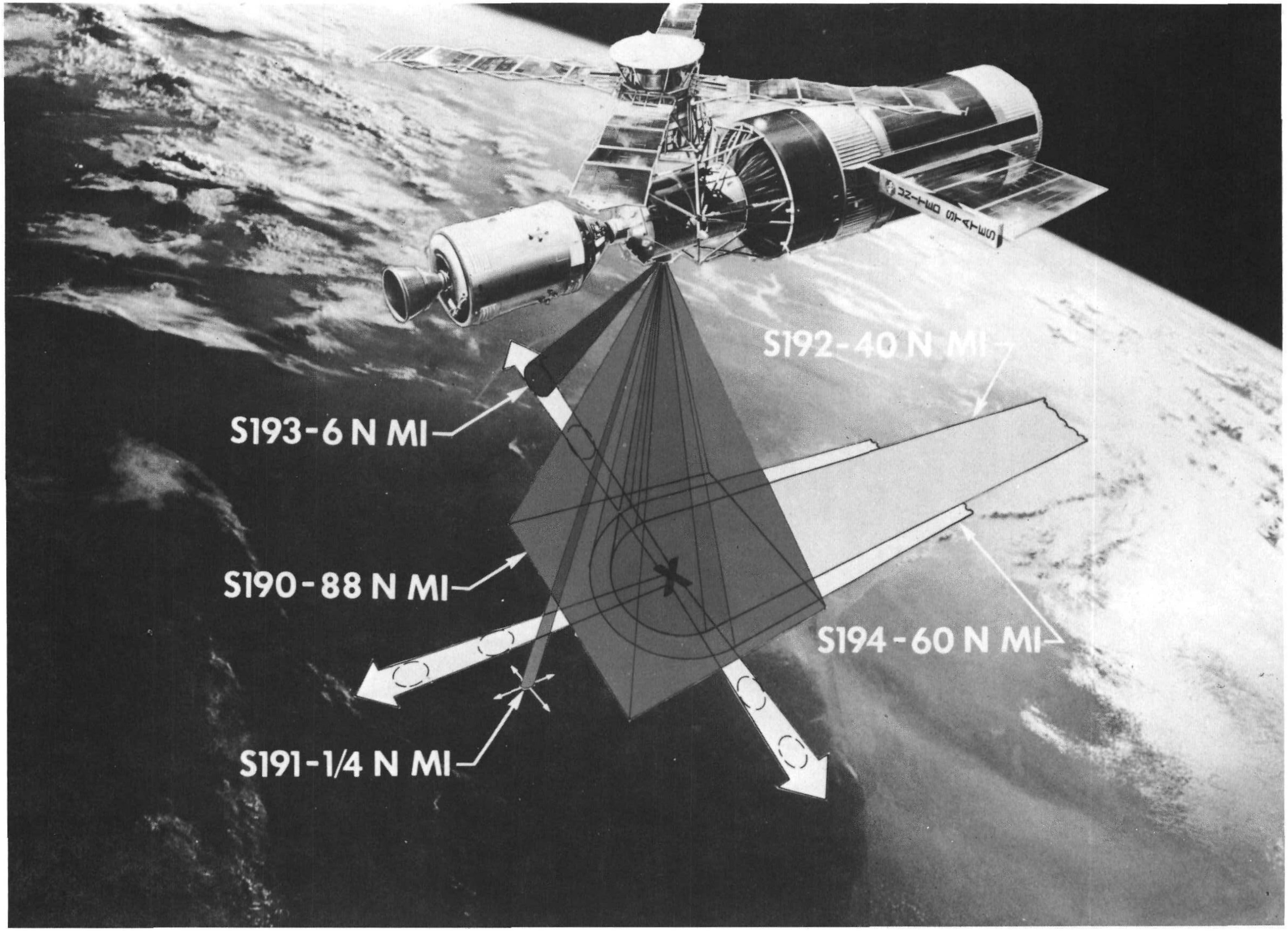



Figure 24.–EREP ground coverage.

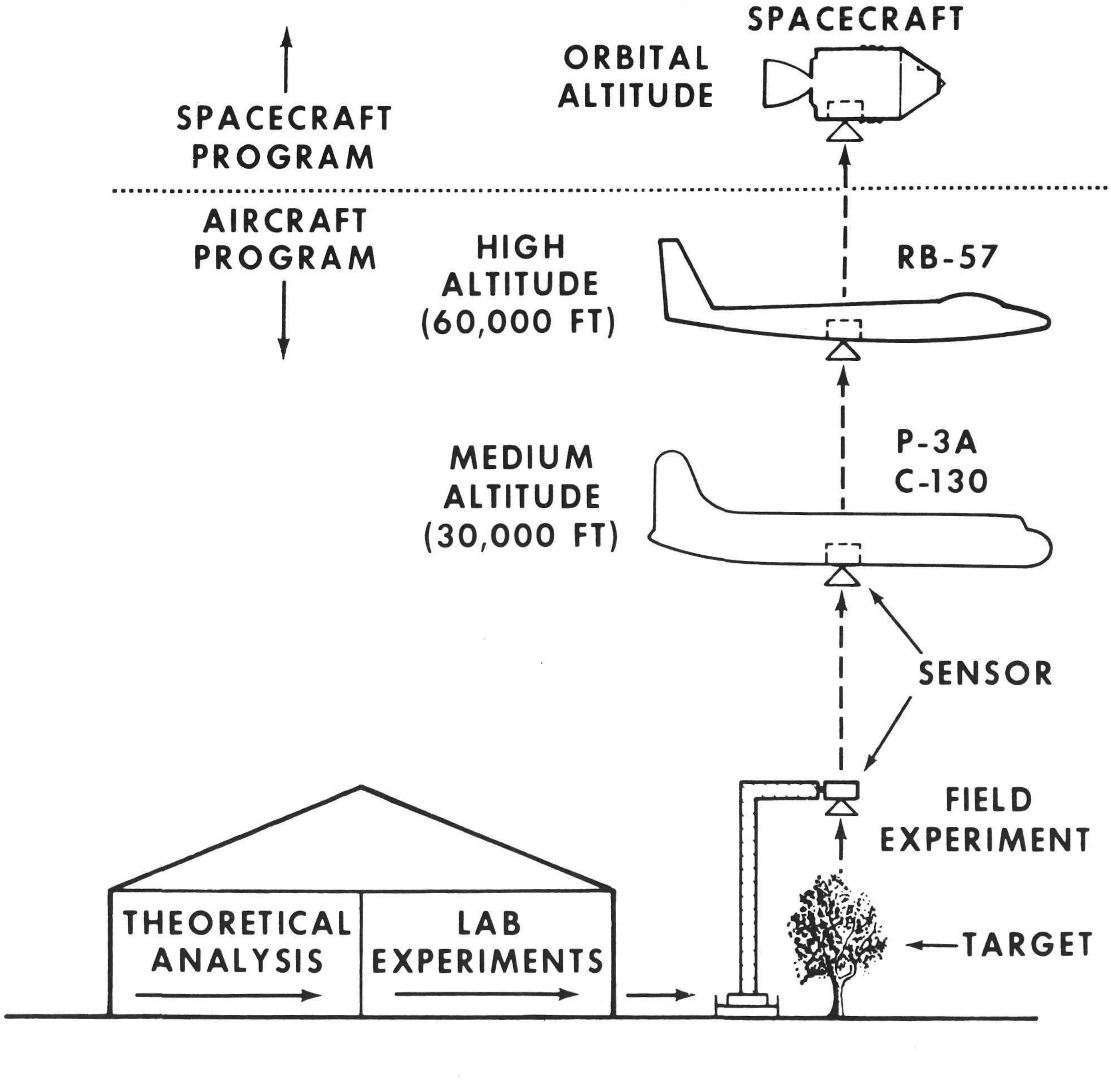



Figure 25.–Development of remote sensor techniques.

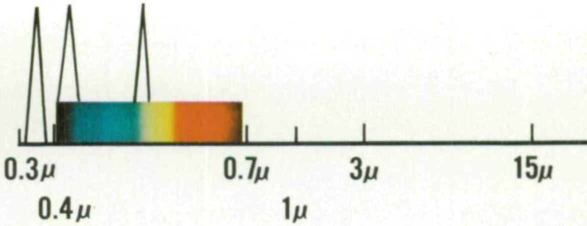



Plate 1.–Agricultural area, Davis, Calif., color-wavelength translation, ultraviolet, visible; blue, 0.32 to 0.38μ; green, 0.40 to 0.44μ; red, 0.52 to 0.55μ.

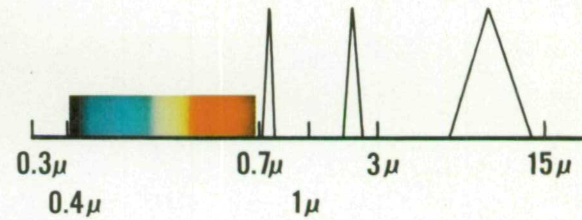
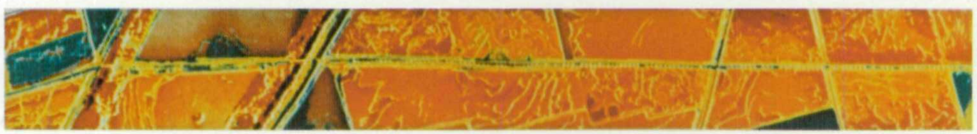



Plate 2.–Same area as in plate 1, color-wavelength translation, infrared; blue, 0.72 to 0.80μ; green, 2.0 to 2.6μ; red, 8.0 to 14.0μ.



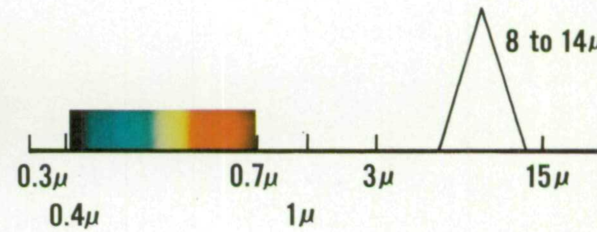



Plate 3.–Same area as in plate 1, apparent temperature is color-coded. Highest temperature is violet. Temperature decreases through the sequence violet, blue, green, yellow, orange, red (wine), brown, black. Black is lowest temperature.

Plate 4.–Same area as in plates 1 to 3 and figure 13; red, relatively mature green rice; blue, immature rice; green, safflower; black, bare Earth.

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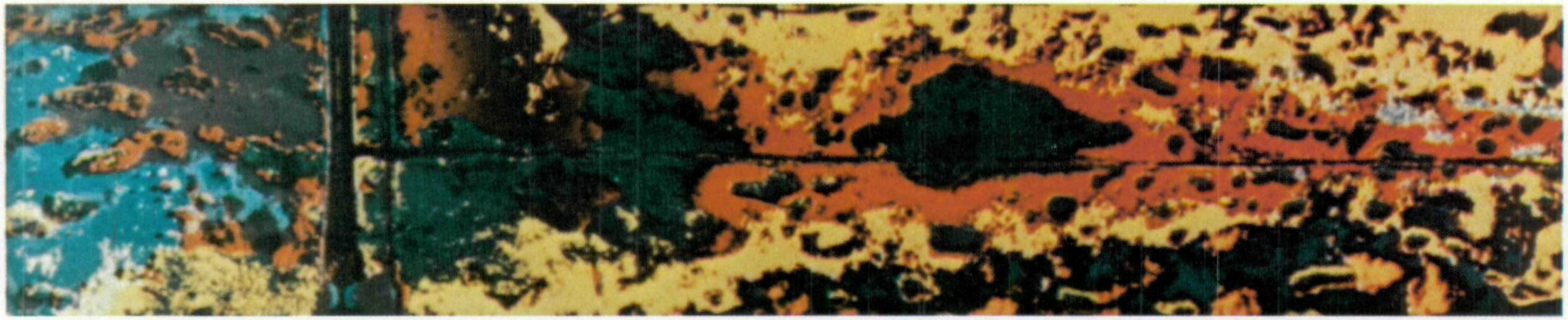
Plate 5.–Oil does not show in infrared but in ultraviolet is lighter than surrounding water. (A)0.8 to 1.0$\mu$; (B) 0.32 to 0.38$\mu$.

(A)

(B)

Plate 6.–Kelp is brighter than the water in the infrared where oil did not show at all. Kelp is darker than the water in the ultraviolet, in contrast to oil which was brighter. (A) 0.8 to 1.0$\mu$; (B) 0.32 to 0.38$\mu$.



A

B

Plate 7.–(A)Everglades color recognition map used to determine types of vegetation; (B) Map units 3 and 4 of same area.

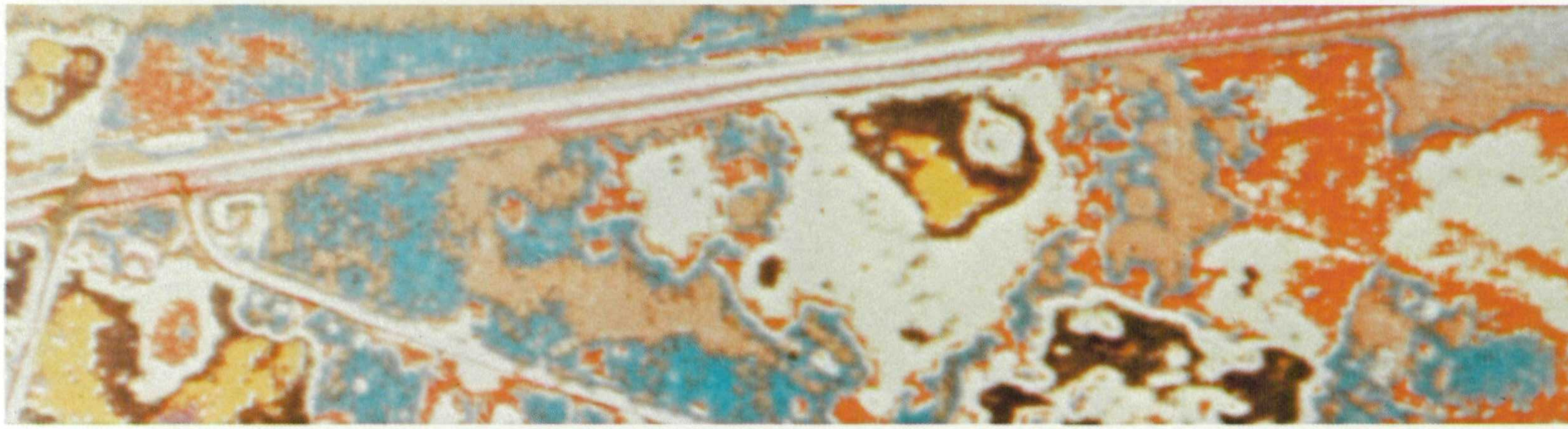


Plate 8.–Infrared photograph showing concentric pattern of changing temperature indicated by color.

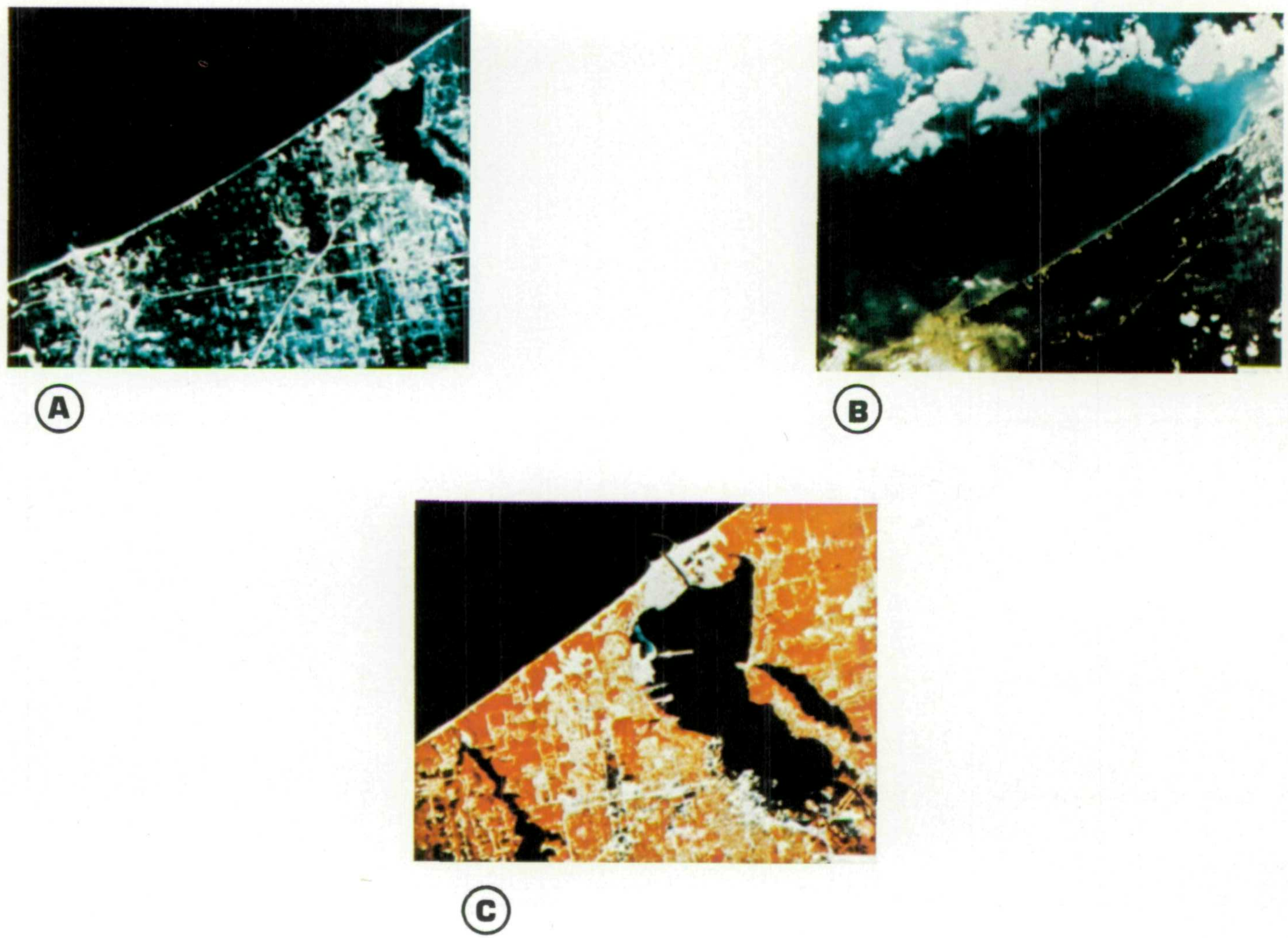



Plate 9.–Lake Michigan pollution patterns. (A) Pollution from urban areas; (B) Southern end of lake showing air pollution and near-shore industrial effluent; (C) Dominant source of pollution due to outfall of papers plant. See also plate 10.

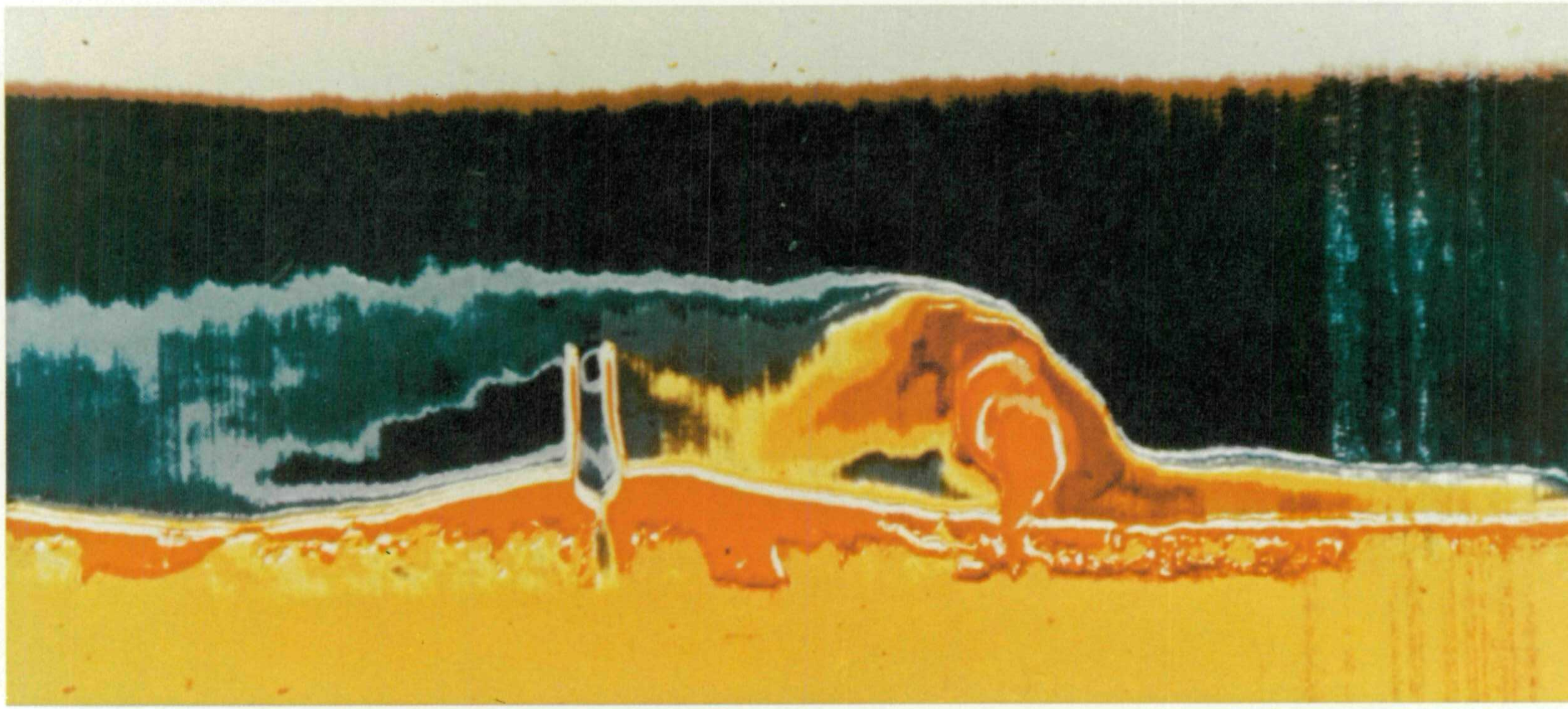


Plate 10.–Thermal enrichment from power plant on shore of Lake Michigan. Color-coded temperature shows mixing zones: Red, 78.7° F; pastel red, 78.2° F; magenta, 77.6° F; sepia, 77.0° F; tan, 76.4° F; orange, 75.8° F; yellow, 75.3° F; blue-green, 74.8° F; cyan, 74.2° F; pastel blue, 73.6° F; dark blue, 73.0° F; violet, 72.4° F.

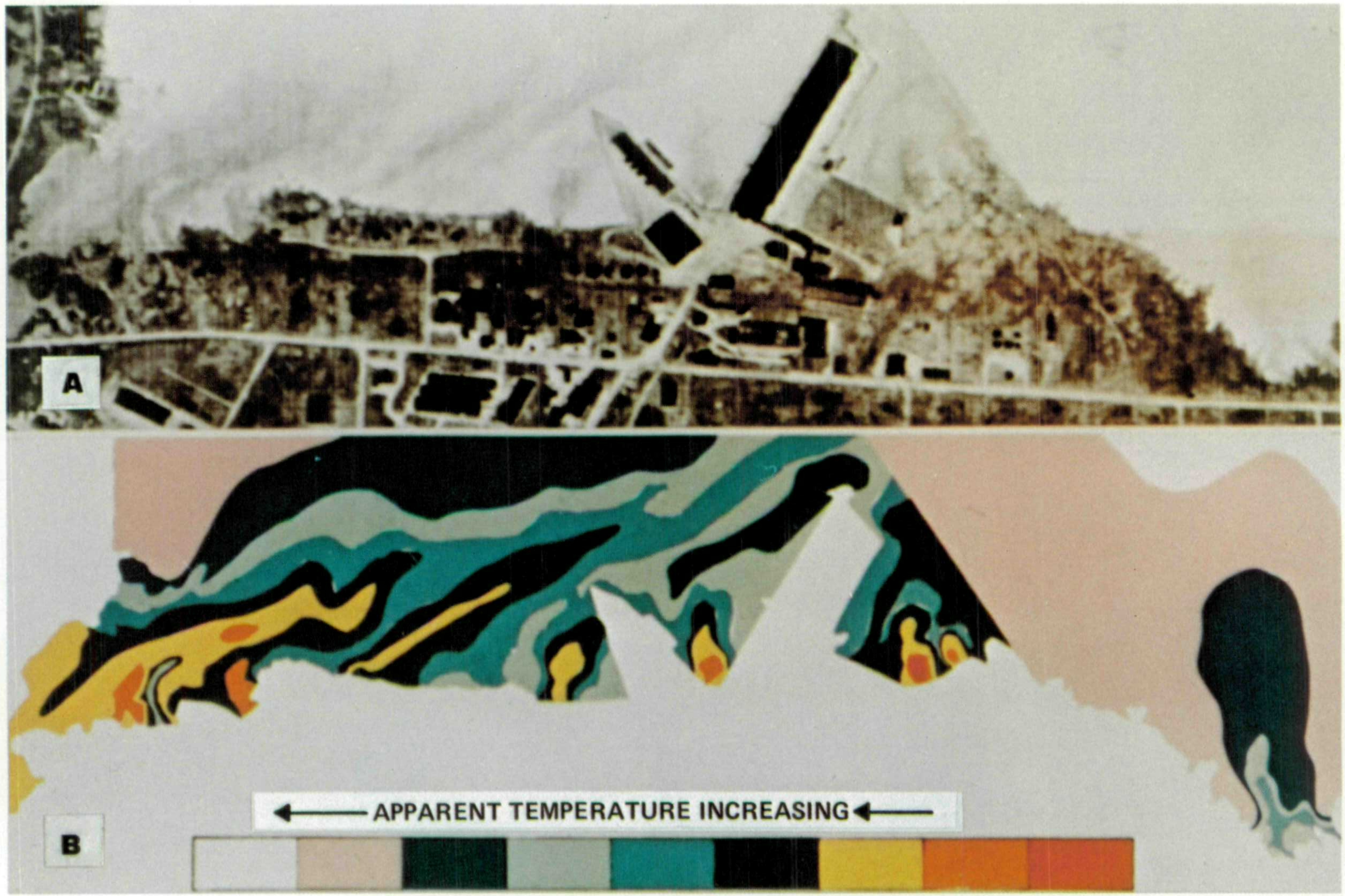



Plate 11.–(A) Infrared image (in the 4.5 to 5.5$\mu$ range) of Hilo, Hawaii, showing escape of fresh water (cold) into the ocean. (B) Map showing distribution of film density (apparent temperature), Hilo, Hawaii. Cool water discharge in red, orange, and yellow.

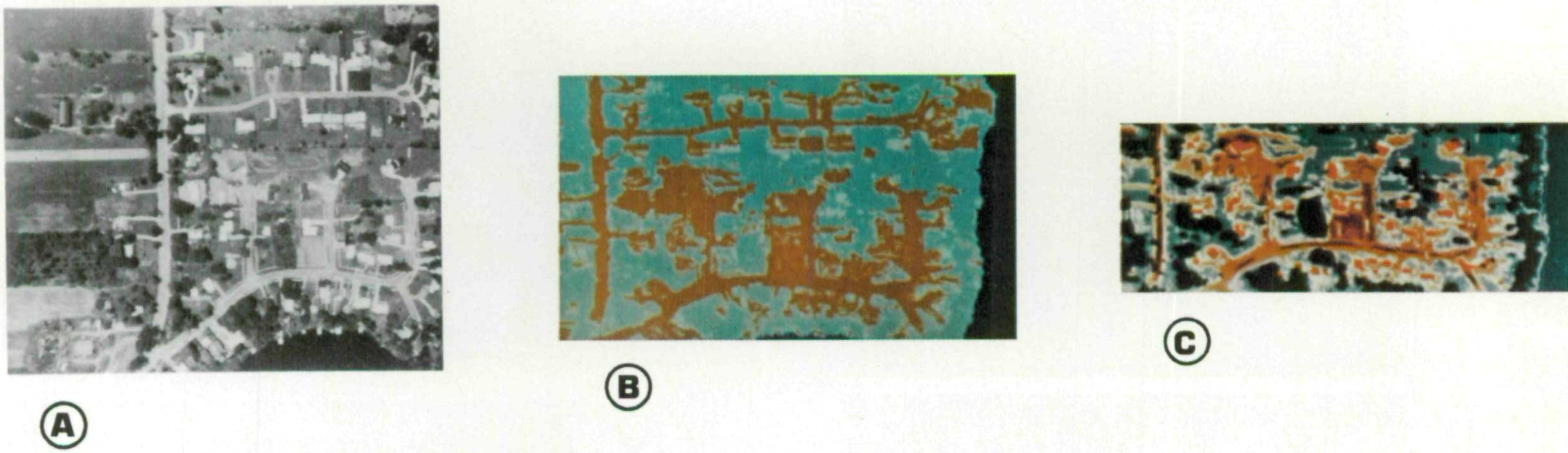



Plate 12.–Watershed characteristics as affected by urban growth. (A) Photograph of suburban area under study; (B) Recognition map identifying the vegetative, nonvegetative, and water areas; (C) Recognition map identifying important materials.

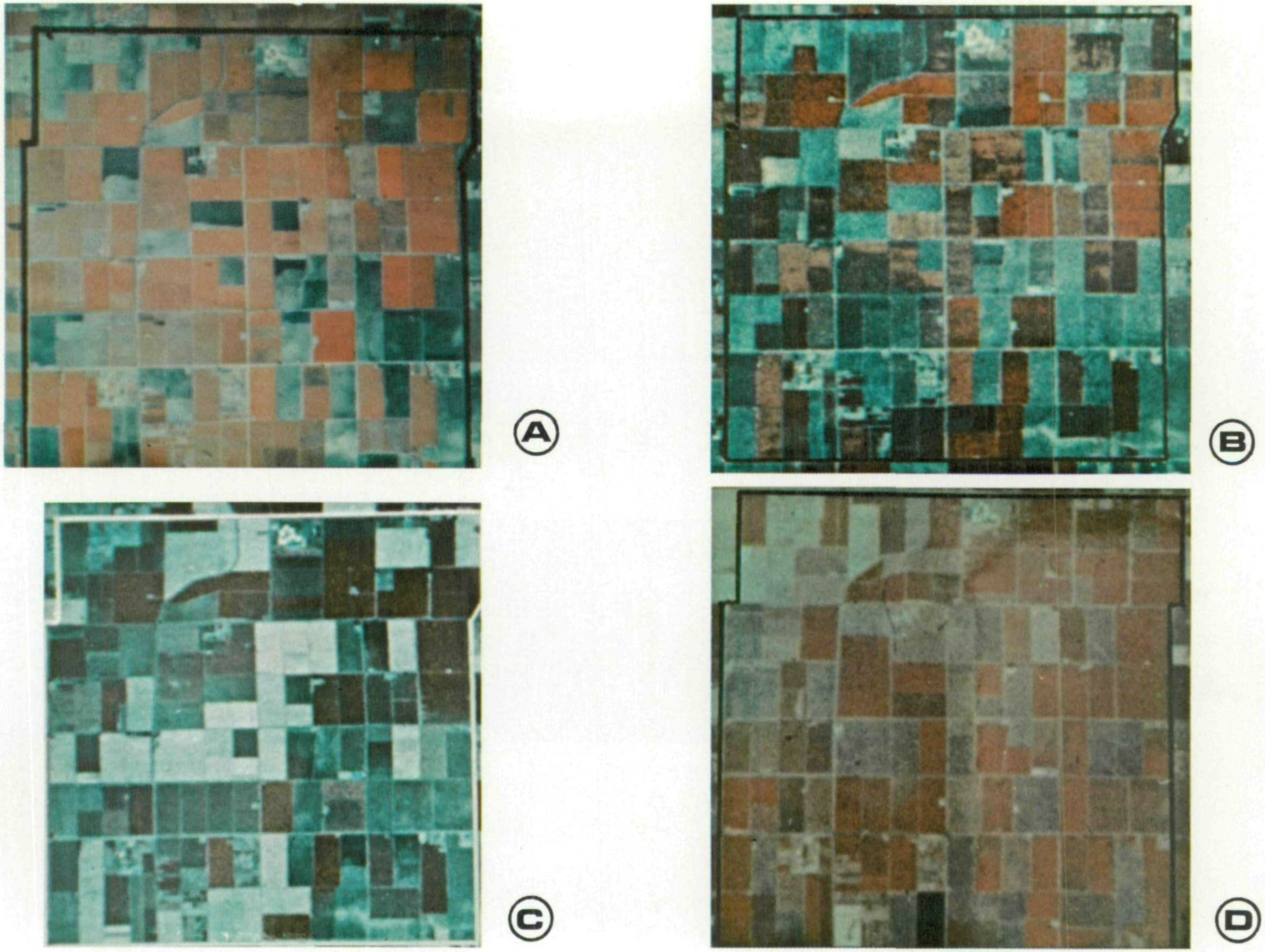



Plate 13.–Infrared Ektachrome sequential photography of Mesa, Arizona, agricultural study area. (A) March 1969; (B) April 1969; (C) May 1969; (D) August 1969.

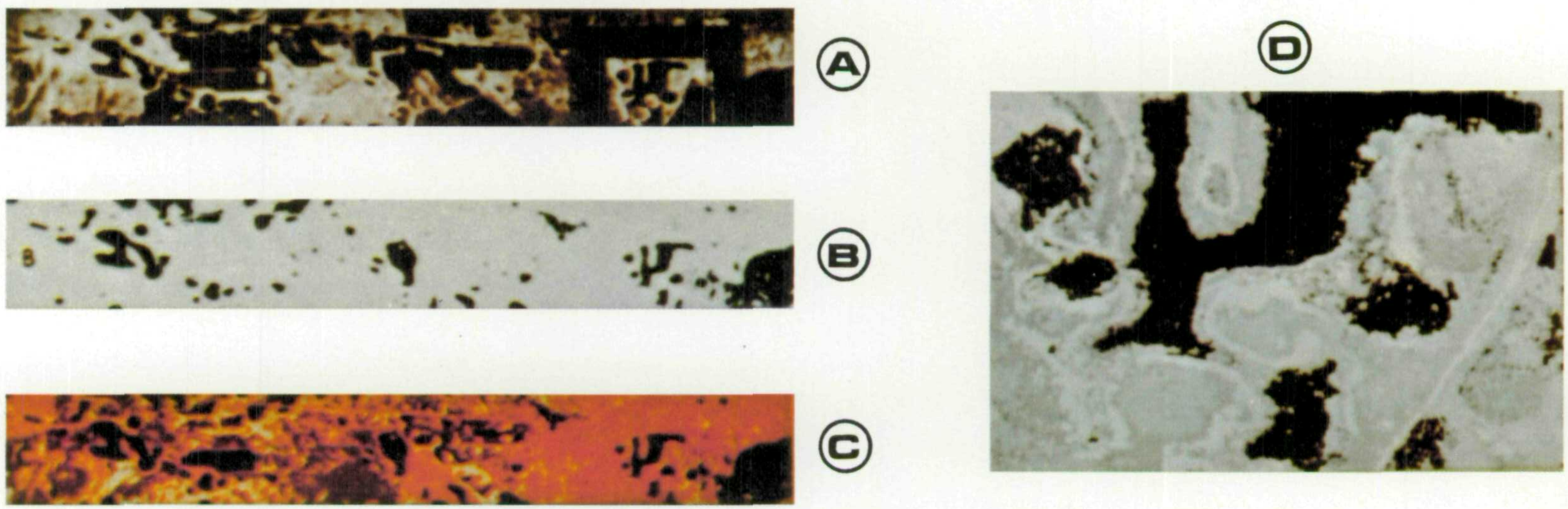



Plate 14.–Wildlife study. (A) 0.8 to 1.0μm imagery; (B) Analog computer recognition map for water; (C) Recognition map for various land-use features; (D) Digital map of water area.

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# Industrial Waste Pollution

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**Johns Hopkins University**

In natural surface waters, inorganic elements and organic compounds are found in varying degrees of concentration. The natural aquatic environment considered here is defined as containing relatively low concentrations of organic substances and as being aerobic. In such environments the prime movers in biodegradation processes are the saprophytic bacteria. They utilize organic materials as food in their normal metabolic functions. Part of the organic material is broken down into simpler forms that are used as building blocks for cellular growth and reproduction. Another part is oxidized to provide energy for cell synthesis, locomotion, etc. In any real biological system there is a third organic fraction consisting of fragments of compounds originally present which are also broken down more slowly. Thus, inorganic and organic materials serve useful purposes in most surface waters by aiding in the support of the aquatic life.

In most surface waters, and the Chesapeake Bay is not an exception, there is a variety of aquatic life present. Under normal influences, the food chains that have developed in the Chesapeake Bay system have developed in response to evolutionary adaptation involving relatively long periods of time acting in concert with the dilute nature of the aquatic medium. Hence, the nature and extent of elemental and organic compounds of the Chesapeake Bay have critical limitations special to the resident and transient organisms that reside within the Bay and its tributaries. Within certain limits, however, some exposure of the aquatic organisms residing in the Bay to relatively higher concentrations of both organic and inorganic materials may not be detrimental and may even stimulate biological activities in a favorable way.

On the other hand, the occurrence of particular kinds of organic matter may adversely affect beneficial water uses. Organic substrates may deplete oxygen, impart color, produce foams, produce toxic conditions, or result in objectional tastes and odors, as well as inhibit penetration of light through the phototrophic zone. What becomes significant, then, is the type and concentration of the various polluting materials in relation to their effects on water quality and, especially, on aquatic life.

Natural surface waters comprise a dynamic environment. The smallest forms of life, the bacteria, serve as the first links in the aquatic food chain, and they are capable of utilizing most organic compounds as food. In their metabolic processes the original substances are altered (biodegraded) forming intermediate compounds. These compounds may ultimately be degraded to carbon dioxide and water. The intermediate chemicals which are created by such biodegradation at the bacterial level may behave much differently in the aquatic environment than the parent compounds. It becomes obvious then that the study of the behavior of organic chemicals in the aquatic environment involves a highly complex system. It should also be apparent that the subject should be treated systematically and comprehensively within the next few decades if we are to maintain, and indeed enhance the multiple use of the Chesapeake Bay under all the various influences to which it is likely to be subjected.

General sources or organic matter entering the Chesapeake Bay are:

(1) Surface runoff from cities and towns located within its drainage
(2) Industrial waste waters
(3) Treated and untreated domestic sewage
(4) Metabolic byproducts of aquatic life, including the products of bacterial biodegradation.

All four sources contribute significantly to the total organic load received by the Chesapeake Bay waters.

## CHARACTERISTICS OF INDUSTRIAL WASTES

Broadly speaking there are four general classes of inorganic and organic contaminants that could be considered to be industrial wastes.

### Inorganic Chemical Wastes

Metals such as copper, zinc, chromium, and others are discharged from industrial sources quite routinely in various valence states. The fate of both stable and radioisotopes of these elements in estuarine waters can influence their ultimate disposition in the Bay and thus their biological influences. Bioconcentration of relatively low levels of these elements to many times the concentrations found in water have been reported commonly for benthic filter-feeding invertebrates. Organo-metallic complexes have been shown, in the case of mercury, to affect their toxicity in a way that is not clearly understood at the present time. The chemical chelation of such metals by naturally occurring organic substances can facilitate food chain concentrations of such substances. These food chains must be understood in more detail.

Numerous inorganic ions and compounds are commonly discharged (Na, $SO_4$, NaCl, K, and others) and they appear to ecologically influence the salinity locally. Estuaries, such as the Chesapeake Bay, can assimilate such ions quite readily without serious impact upon the biota of the Bay if the point of introduction and method of introduction are regulated.

Other inorganic materials such as the rare Earth elements are found only in trace quantities in the Bay's waters, and they should not be allowed to discharge in high concentrations into the Bay. The author has noted that some of the fishes found in the Chesapeake Bay respond rather quickly to such elements, and thus removal of these elements to levels approaching ambient levels must be required.

Nutrient materials such as nitrogen and phosphorus can be found in industrial discharges. Compounds of ammonia are not uncommon. The biostimulatory effect on phytoplankton can produce nuisance conditions locally that might require regulatory action. A later paper will discuss in more detail the ecological implications of such nutrient discharges.

Potential synergistic reactions of substances discharged from separate industrial outfalls have, in the past, produced toxic conditions in surface waters. Ammonium and copper have such potential synergistic action (from a toxicity point of view) and there are numerous other inorganic ionic complexes that behave in a similar way.

### Naturally Occurring Organic Wastes

A second category of industrial pollutants involves naturally occurring organic wastes. This category would include those wastes from food-processing industries, paper and pulp industries, petroleum products, and the like. This category represents those organic compounds which are normally found and in which there is a relatively large technology existent involving the biodegradation and industrial waste treatment.

### Synthetic Organic Wastes (Exotics)

A third category involves synthetic organic wastes. These unnatural exotics include categories such as biocides, the familiar pesticides and herbicides, and their byproducts, including the waste products of their formulation. Significantly many of these exotics can be altered in such a way that the altered form is more toxic or more damaging to natural aquatic life than the parent compound. Other organic compounds which are produced in rather high volume and exposed to surface waters include various organic plasticizers, detergents, and an almost infinite number of complex compounds similar to the materials listed above. Their impact involves one of relatively reluctant biodegradation and, of course, potential toxic influences upon aquatic organisms.

### Thermal Effluents

A fourth category involves thermal effluents produced as a result of cooling waters used in industrial processes and, of course, in the condensation of steam in electric generating facilities. Less data are available to predict precisely the local ecological impact of relatively large electrical generating facilities within complex estuaries like the Chesapeake Bay.

Obviously considerable value is gained through thoughtful siting, construction, and operation of industrial operations which typically require considerable quantities of cooling waters for their operation. Experience within the Chesapeake Bay system has emphasized the need for careful use of biocides within the cooling water system. Moreover numerous scientists have demonstrated the fact that there is a highly important relationship between the amplitude of temperature rise above ambient temperatures ($\Delta T$) and duration of exposure to this $\Delta T$ which will, in no small way, determine the ultimate biological impact of thermal effluents within the Chesapeake Bay system. Thus the ecological impact of thermal power plants is a highly specific and individual question involving very complex interrelationships which must be taken into consideration early in siting and design of such facilities.

Because of the ecological uncertainties of plankton entrainment into cooling water systems, as well as the hydraulic entrapment of fish into intake structures, there remains considerable question whether the condenser systems of such plants should be designed for the relatively low temperature rise (5-10° C) and high volumes (up to 5000 CFS) or whether higher temperature rises and subsequently less water is the ecologically preferred system. Obviously no general set of criteria (thermal and cooling water volume limits) will serve under all hydraulic and ecological conditions in systems as diverse as the Chesapeake Bay. Thus, the ecological impact of a thermal power plant (or a system of power plants) will be a highly specific and interrelated question sufficient to challenge aquatic scientists and engineers alike in reconciling the need to maintain systems like the Chesapeake Bay within the range of their ambient thermal fluctuations including seasonal thermal diversity.

One of the most effective ways to achieve control of any of the above waste categories is the requirement that detailed material balance inventories of ingredients, products, and waste compositions be supplied to regulatory agencies for their use in protecting the Chesapeake Bay from uncontrolled release of industrial byproducts. The form of this data could, for example, be in terms of pounds waste per thousand pounds of product per day. Such information has not in the past generally been used either by individual industries or by regulatory personnel to account for the substances discharged or lost from the separate or mixed formulation processes typical of any industry. This information is needed if the control of emission rates into the environment is to be achieved.

## EFFLUENT EVALUATION TECHNIQUES

It is quite obvious that no single parameter is sufficient to express the potential pollution characteristics of an industrial waste in the aquatic environment. Rather, several are needed if a reasonable estimate is to be made.

Important considerations in the preliminary evaluation of organic and inorganic chemicals include their structure, composition, and chemical properties. For example, straight chain, branching, ring structure, etc.; and their chemical composition, for instance, the elements and grouping, their redox state, carbon content, and various properties such as solubility in water, volatility and density are important in planning laboratory phases of effluent evaluation. Insight as to the biodegradability in chemical and biological waste treatment systems and their toxicity and biostimulatory influences upon aquatic organisms must be known prior to their discharge into the Chesapeake Bay or its tributaries.

Various laboratory techniques reported in the literature have been designed to measure and predict, to a degree, what the fate and effects of organic compounds will be in the aquatic environment. These techniques normally confine the problem to a manageable number of variables while retaining as many as possible of the important factors of the natural environment being simulated. These factors are so numerous and their influences so interwoven that model systems used in the laboratory are necessarily limited. However, despite the shortcomings, through continued effort and experience, it has been possible to derive information that can be extrapolated and used in predicting the impact of inorganic and organic wastes into natural systems such as the Chesapeake Bay.

## OXYGEN UPTAKE STUDIES

Without a doubt free oxygen is one of the most important elements in the aquatic environment for the support of aquatic life. It is soluble in water only to a limited degree, less than 10 milligrams per liter at normal surface water temperatures. When available, dissolved oxygen is used by bacteria and other micro-organisms in the oxidation or stabilization of organic material in water. High organic loads on the aquatic environment may stimulate the organisms to such a degree that oxygen is removed from the water faster than it is replaced from the atmosphere or by photosynthesis. When this condition develops, another group of micro-organisms tends to predominate. These bacteria can utilize materials other than oxygen as hydrogen acceptors and thereby partially degrade the organic material. However instead of innocuous byproducts of aerobic oxidation (carbon dioxide and water) that occur in the presence of free-dissolved oxygen, the degradation from anaerobic bacterial action usually results in the production of relatively energy-rich intermediate compounds, some of which can be toxic to aquatic life, and all of which require ultimate oxidation.

In essence the biochemical oxygen demand (BOD) test consists of measuring the depletion of dissolved oxygen in a sample during or after a period of incubation, five days being used as a standard interval of time. The dissolved oxygen level is usually measured by either chemical methods, such as the Winkler method, or by the use of oxygen-sensitive electrodes.

The results of the BOD test are normally expressed in terms of oxygen. The depletion occurring in five days is considered to be due to the stabilization of carbonaceous rather than nitrogenous materials. The five-day depletion is generally more than half of the twenty-day or ultimate BOD (ref. 1).

Manometric respirometer techniques provide another means of assessing the biodegradability of organic materials. While BOD values can be obtained from respirometer data, the usual applications are somewhat different than those of dilution bottle techniques mentioned above. The higher level of activity of the respirometer flasks more nearly simulates a biological treatment unit than a natural-surface water body.

Results of respirometer studies may also be expressed in terms of oxygen uptake and are usually in the form of continuous records rather than cumulative depletion, depending upon the frequency of data collection. These techniques are especially well suited for rate studies involving oxygen demand.

The chemical oxygen demand (COD) test is designed to provide a measure of the organic content of a sample more rapidly than the BOD test. It can also be used with highly toxic samples. Like the BOD test it can be used with both single component (pure) and multiple component (mixed) samples.

The COD procedure consists of reacting the sample with potassium dichromate under acidic conditions at boiling temperature. Reflux condensers are used to provide the escape of volatile components of the sample. The oxidant is present in excess and the amount consumed is determined by back titration with a reducing agent. Catalysts are required for certain classes of compounds (ref. 1). Chloride concentrations have been reported to interfere with this analysis (ref. 2).

The Total Carbon Analyzer is an instrument that provides a very rapid and accurate method of measuring the total carbon concentration in an aqueous sample and it shows much promise for many areas such as waste treatment and ecological impact studies. In the operation of the instrument a sample of between 20 and 40 microliters in volume is injected into a stream of oxygen gas in a furnace heated to 950° C. A catalyst is present to ensure complete oxidation. All of the carbon in the sample is converted to carbon dioxide and the steam which is created is condensed and removed. The oxygen-carbon dioxide gas stream passes on through a non-dispersive infrared analyzer which is sensitive to carbon dioxide. Results in terms of $CO_2$ levels are recorded commonly on strip chart recorders. The peak height of such charts is proportional to the original amount of carbon in the sample. Equipped with automatic sampling devices, the carbon analyzer has been used quite advantageously to monitor industrial waste water streams (ref. 3). There seem to be very few compounds which do not react completely in this combustion apparatus.

## BIODEGRADABILITY TREATMENT STUDIES

Many types of laboratory scale models and pilot plants have been developed to evaluate the treatability of waste waters. They are readily adaptable to studies with organic chemicals to determine whether and to what degree these materials might pass through a treatment plant and reach an aquatic environment such as the Chesapeake Bay. The models of all forms of biodegradability treatment systems have been developed for laboratory use and incorporate features of the activated-sludge biological waste-treatment process.

These studies of biodegradability have been very useful in predicting the behavior of organic chemicals in traditional waste water treatment systems. Studies of the reaction rates which influence the time needed for biological waste treatment and, ultimately, the size of the waste treatment system needed have been used to predict whether the waste treatment system can be designed. Moreover, predictions relative to the nature of the biological flock produced and its removal from waste waters through settling can be useful in preventing the discharge of organics into natural surface waters. In essence four general biodegradability patterns have been reported to occur as a result of exposure to organic chemicals. *A first type* involves material which is readily susceptible to biochemical oxidation. *A second type* exhibits the pattern of very slow oxidation involving, presumably, bacterial acclimation to the organic carbon source. *A third type* shows rapid oxidation only after a considerable lag period, again involving very long and specialized bacterial acclimation phenomena. *A fourth type* illustrates toxicity at the bacterial level in which no biochemical attack of the organic compound is measurable.

## TOXICITY BIOASSAY EVALUATION

The most appropriate animal for toxicity studies in the aquatic environment is probably the fish, although considerable work has been done by some other author, with crustaceans and insects. Fish serve as very sensitive and subtle analytical tools in studying the effects of various inorganic and organic materials in surface waters. The character as well as the degree of toxic effects can often be observed and thus the ecological impact can be approximated.

Basically the toxicity bioassay involves exposing the test animal to various concentrations of substances of interest for a given period of time. For fish the period is usually one to four days. Standardized procedures have been developed for controlling dissolved oxygen levels, pH, temperature, and the concentration of the test materials (ref. 4). Fish size, age, and history are additional factors which must be considered. Selection of appropriate species and the dilution water depends upon local conditions and the purpose of the bioassay. The type of information which may be obtained from fish bioassay studies are many and varied. The most common is the median tolerance limit (TLM), that concentration at which half of the specimens die in a given exposure period. This is very similar to the LD50 value. This value is more readily determined, but probably of less interest than the minimal concentration which causes death or permanent damage upon long term exposure. Changes in the behavior of the specimens prior to death may provide important information. Studies of fish flesh tainting and influences upon reproductive success are equally important.

Fish bioassay data are in common use today throughout the nation although it has been found worthwhile to have such tests performed by experienced laboratory personnel rather than as a routine monitoring parameter. While some special equipment is necessary, the real problems arise in maintaining the specimens in healthy, normal condition prior to and during the test. Secondary losses of the test compound through evaporation, adsorption, and biodegradation must be prevented or controlled for the period of the bioassay. Environmental factors such as pH, temperature, dissolved oxygen, and sudden changes in other factors such as photoperiods, etc., have a significant influence on the test results. Bioassays generally yield relative rather than absolute results. Some chemicals are proportionally more toxic when in combination than when alone so that synergistic influences must be fully evaluated. Great care must be exercised in extrapolating bioassay results from the laboratory to the field because of the large number of important factors, of which I have only mentioned a few.

## BIOSTIMULATION

Though an enormous amount of effort has been expended on bioassay work in this area, very little of this work is directly applicable to the assessment of industrial wastes in receiving waters, the design of waste treatment systems, or to waste management. The complexity of the response of algae to the variety of macronutrients and micronutrients has severely limited the development of a rational model for predictive purposes using the biostimulation studies.

The biostimulation test usually employed, the batch culture test, is, unfortunately, proving to be inadequate to give more than qualitative results and even these results are very difficult to interpret. The continuous culture bioassay is a more applicable test for receiving waters, yet the relation between laboratory results and in situ response has not been fully established.

Like toxicity this test should also be correlated with the total ecosystem response, especially since the response it is measuring (productivity) is the primary source of food for ecosystems. Once this is accomplished the test will have relevance for ascertaining the effects of waste discharges into coastal waters, and some quantitative relation can possibly be made between the laboratory tests and the system response for use as a waste disposal guideline.

## ECOLOGICAL BEHAVIOR OF INDUSTRIAL WASTES IN SURFACE WATERS

### Surface Film Phenomena

Surface materials are found in the form of films, lenses, scums, foams, and particulate matter or detritus. Particulate matter may be found associated with film or with scum or foam, or with all of these materials. To a certain extent small quantities of all these materials can be found in all coastal waters and estuaries. Oceanographers have long been aware of the formation of natural sea slicks on the oceans and in the coastal zones and estuaries. Generally the source of surface sea slicks is considered to be planktonic in origin arising from oils produced in plankton blooms which are released when the plankton die. Planktonic oil slicks are a quite common phenomena of tidal estuaries such as the Chesapeake Bay.

Investigations of the surface materials of waste origin have been rare. In recent years numerous investigators have reported the presence of foams, oils, floating debris, and surface organic films and sludges carried by the wind to beaches and shore areas. The identification of the source of surface slicks and films is, with the exception of oil spills, a rather poorly developed science. Generally only crude oil is spilled accidently and in massive quantities as evidenced by the Torrey Canyon, Ocean Eagle, and recently the Santa Barbara Channel incidents. Unfortunately crude oil is generally a complex mixture of hydrocarbons and other substances, some being highly volatile, which makes a meaningful analysis of the properties of the material rather difficult. Review of recent literature suggests that the results of these spills have produced, for the most part, a material which is relatively non-spreading and, in most cases, limited to the surface only. Experience gained in response to these large-scale oil spill incidents suggests that surface containment through skimming and containing structures is the most appropriate method for handling such spills. Attempts to emulsify or homoganize spills into the open water column have proved, in most cases, to aggravate the biological impact of such incidents. The loss of the lighter hydrocarbons, such as the gasoline, results in the build-up of the heavier tars and asphalts which tend to agglomerate and either are carried into beach areas or sink to benthic layers with relatively poorly described ultimate impact on the benthos. Discharge of municipal and industrial wastes into estuarine and coastal waters without skimming and removal of floatage has, in the past, proven to be a rather poor water management practice. Moreover bacterial counts taken from beach sands and waters located on the Pacific and Atlantic coasts have shown bacterial counts to be relatively high and directly related to tidal movements of sewage outfall plumes of both industrial and municipal origin.

Aside from the concentration of microbial populations adsorbed onto suspended particles of the water column as well as the surfaces of the bottom and shore zones, the surface film of water has been shown in some instances to concentrate larger bacterial populations per unit volume than the underlying water. Zobell (ref. 5) has explained such bacterial accumulations to be a result of the following:

(1) Surface tension of the film itself
(2) Low specific gravity of bacteria
(3) The buoyancy of lipids and gases associated directly or indirectly with bacteria

The surfaces of coastal waters are involved in biological stabilization of wastes (however dilute they may be) through the influences of four major natural phenomena (ref. 6). These are:

(1) Bacteria tend to concentrate in the surface film.

(2) The film moves with wind currents at speeds in excess of measured ocean current.

(3) Internal waves, winds, and currents cause horizontal compaction and concentration of materials in the surface film.

(4) Dispersion or diffusion of those surface film materials in underlying water appears to be surprisingly small.

**Interfacial Phenomena**

This general category includes a vast number of different phenomena. Some of these are liquids and liquid emulsions; the selected adsorption of organic and inorganic nutrient substances on gas, liquid, and solid interfaces; flocculation and sedimentation of suspended matter at the location where saline water encounters fresh water in estuaries, typically in the middle part of the estuary; and the effects of deposition of digested sludge on the bottom of the estuary or coastal zone. The basic principles underlying most of the surface reactions taking place in the liquid bulk differ only in complexity from those described above for surface films. But water circulation and suspension of the film complicate the phenomena considerably. Most of the waste waters from large municipal and industrial outfalls are weak suspensions and solutions of both inorganic and organic materials. Natural surface waters are extremely dilute solutions of inorganic salts, atmospheric gases, and extracted organic materials. Under most conditions these two types of solutions mix and react slowly over relatively long periods. Significantly the biological organisms that live in estuaries such as the Chesapeake Bay are adapted to these relatively low concentrations and commonly react adversely to both sudden and long term discharges of both treated and untreated waste substances.

Emphasis on the relatively dilute nature of most waste streams is made primarily because of the need to recognize the inherent difficulty of treating both domestic and industrial waste effluents so as to produce completely clarified and purified solutions. Under even the best conditions of current and foreseeable design and operation procedures, we will be required to disperse treated waste waters from our most heavily populated areas into surface waters, most of which will ultimately mix with estuaries such as the Chesapeake Bay. My point is that because of the volumes involved and the relatively dilute nature of both the waste streams and coastal waters, we should consider the physical, chemical, and biological processes that occur when such solutions ultimately mix. With regard to the subject of this paper, the major biological processes which are involved with waste stabilization are bacterial fermentations which occur on interfacial surfaces. Exploitation of such processes is the major mechanism of waste stabilization with conventional biological waste treatment systems and, on a somewhat reduced scale, in all nonsterile solutions of water.

Recall that during the conventional biological waste treatment the waste waters are distributed over large surfaces. This occurs when soil, sand, and gravel beds are irrigated and when beds of stones are intermittently flooded. We use intermittent flooding and controlled spray distribution to secure ventilation and adequate oxygen supply for the large BOD resulting from bacterial fermentations at the surfaces. In doing so we also provide additional air-water surfaces and it has been repeatedly noted that these air-water interfaces concentrate organic materials from solution. Large organic capturing surfaces are also produced by entrained air bubbles in the great variety of biological aeration treatments that have been developed. Of significance is that surfaces do capture materials that tend to depress the interfacial tension of solutions and colloidal suspensions, including nearly all types of soluble organic wastes and very fine organic solids. Of course, such simple physical surfaces become saturated after the irrigant comes to equilibrium with the interfacial film with relatively little net change with time. It is at this point that biologically active surfaces become important in the natural biodegradation of wastes introduced into surface waters.

Largely as a result of observations of Zobell and his colleagues in the 1930's, we can predict that marine bacteria and other micro-organisms are concentrated in direct proportion to the surface area available for such adsorptive phenomena. Bacterial cells approach colloidal dimensions, and the physical systems that favor concentrations of organic molecules at interfaces also favor concentration of organic molecules in the micron and submicron size range, especially when the solution suspensions are weak, as is the situation with well-mixed waste discharges in coastal waters. Observation of emergent vegetation along the shores of all surface waters reveals a microhabitat for such micro-organisms on nearly any submerged or partially submerged object. Examination of the relatively thick films of micro-organisms that actually appear on such submerged surfaces reveals that such growths are commonly a millimeter thick, especially in mixing zones from discharged wastes, and the mass of living material in them is much greater than might be anticipated at surfaces wetted with weak organic colloidal suspension. Very clearly surfaces actually favor the growth of micro-organisms and this growth sticks to the surfaces. These films are essential for the biodegradation of organics introduced into coastal waters and they serve to continuously oxidize organics while renewing themselves. These biological surfaces adsorb and temporarily store organic solutes which are available for oxidation by the cells of the film for the yield of energy necessary for the formation of new cells. From a bioenergetics point of view such energy exchanges are extremely inefficient and it has been observed that less than one percent of original organic matter is converted to cellular material.

Biological films within the water column perform with high efficiency the job of energy degradation and commonly can be shown to contain many types of bacteria. Mixed populations oxidize organic wastes more efficiently than single species, and an effective population will contain groups that oxidize the fermentation products of primary species. Protozoa, rotifer, worms, snails, and many high taxa are able to feed on the bacterial film with high efficiency especially in the shore areas of estuaries that contain submerged vegetation and substrates. The transfer of material and energy from one predatory species to another looses energy and carbon dioxide from the aquatic ecosystem, and the total energy removal by such a complex society of aquatic organisms is always higher than that of a less diverse group.

It is important to realize that interfacial phenomena involving biological films will also be expected to occur on all surfaces of suspended solids entrained in waste water and coastal water mixing areas prior to their settling out of solution. Also, any tidal or man-influenced turbulence will tend to resuspend flocculated organic and inorganic materials and thus aid in the maintenance of relatively large reactive surface areas for the biodegradation of fermentable wastes. Planktonic organisms, such as diatoms, have also been observed to provide excellent surface substrates for bacteria concentration and thus appear to be involved in the process of biological stabilization within the water column.

It should be noted that marine bacteria, fungi, actinomyces, and other micro-organisms can utilize a wide variety of organic and inorganic materials as food, provided that it has available energy. As noted above, some waste discharges from both municipal and industrial discharges contain some organic substances that do not occur in nature. Experience with biological waste treatment has shown that many of these materials can be biodegraded by micro-organisms, but it is not possible at this time to predict that a given material will be attacked by looking at its chemical formula. Bacteria are highly adaptable with time to even the most complicated organic structures, providing that other more easily biodegradable and energy-providing substrates are not available. Problems occur largely because of this inherent preference of bacterial populations for the more energy-rich and fermentable domestic organics over more complex and chemically elegant materials often discharged in low concentrations into estuaries such as the Chesapeake Bay.

Settling of flocculated and adsorbed organics does occur in time and benthic accumulation of such organic debris ultimately occurs. Both aerobic and anerobic biological stabilization of introduced waste organics and the cellular debris of organisms residing in the water column above is known to occur in the bottom layers of estuarine and coastal waters. Provided that preliminary treatment of discharged wastes has occured (skimming, screening, primary settling) benthic loads of fermentable waste should not exceed the assimilative capacity of these layers. Experience with inorganic waste substances such as metallic wastes, isotopes, pesticides, etc., suggest that benthic filter-feeding organisms, especially annelids and molluscs, are likely to concentrate non-biodegradable substances to many times the levels found in the water. Such benthic invertebrates have adapted to filtering relatively large volumes of highly dilute solutions per day in their straining and filtering processes. In doing so the flocculated organics and organic-inorganic semi-solids that settle to the bottom provide benthic populations with essentially all of their energy and nutrient needs. Excessive deposits of solids have proven to be responsible for the disappearance of this most desirable tropic level in the aquatic ecosystem. Significantly toxic wastes are especially damaging to benthic populations of filter feeders and the relative influence of such waste products is generally poorly understood in natural surface waters.

The role of benthic silts in the biological stabilization of wastes discharged into marine waters appears to be much less than that of waters from which they settled. Marine muds were found by Renn (ref. 7) to strongly adsorb soluble nitrogenous organic waste materials of planktonic origin. Muds were found to exert little, if any, direct effect upon the rates of efficiency of anaerobic bacterial decomposition of the same planktonic materials. The fact that marine muds adsorb nitrogenous organic materials may be significant, however, in determining the normal course of breakdown in benthic layers. Soluble organic matter released by autolytic or digesting processes of benthic invertebrates may also be localized in the mud where anaerobic changes and low temperatures prevail. The adsorption of organic and inorganic materials onto the surfaces of suspended silts from land sources appears, then, to be a major mechanism in the transfer of waste materials from the open water to benthic layers in estuaries and coastal waters. Such materials are likely to be available to benthic animals and thus require review and study of possible toxic influences upon benthic organisms as well as their incorporation into biological food chains that involve man either directly or indirectly.

Knowledge of the extracellular products of planktonic organisms is exceedingly limited. Although a variety of materials are liberated from rapidly growing algal cells (carbohydrates, fatty acids, amino acids, polypeptides, growth substances, vitamins, enzymes, and antibiotics) we do not at the present time know of the influences of even the most obviously important group, the antibiotics, upon the survival of enteric pathogens that are associated with waste discharges. These pathogens have been repeatedly shown to die off rapidly in sewage oxidation ponds containing abundant algal growth (ref. 8). Such large scale die-offs could be the result of the liberation of large amounts of antibacterial substances during such algal blooms, but field demonstration under natural conditions is yet to be performed. Little is known of the chemical nature of such natural antibiotic substances, but, clearly, research is needed before meaningful appraisals can be made.

### Benthic Phenomena

The use of estuaries and coastal zones for the disposal of treated and untreated domestic and industrial sludges has left considerable questions regarding the impact on the benthos. Research currently underway by Pierce and his associates at the Sandy Hook Marine Laboratories has shown that the deposition rates and the growth rates of the sludges on the benthos are more biologically devastating than had been predicted prior to the disposal operation. The potential impact of sludges that contain considerable quantities of toxic materials must be regarded with the utmost concern. Leaching of nutrients contained within such sludges is also of considerable potential impact on estuaries and coastal zones receiving such sludge deposits. Relatively little life has been reported to exist upon these sludge beds and indeed in relatively large areas surrounding the sludge beds. Some possible topics of investigation of these beds over the next few years must include at least the following areas:

(1) The rheological properties of submerged digested properties including the growth of the sludges as a result of continued deposition

(2) The leaching and exchange of materials at the sludge interfaces with the open water column

(3) The rates of decay and change in properties of the submerged sludge

In conclusion, the fate of industrial and domestic wastes, both treated and untreated, which reach the waters of the Chesapeake Bay and its drainage must continue to be of utmost interest to scientists, engineers, and regulatory agencies if we are to keep up with the demand upon the Bay waters for assimilating waste materials. Indiscriminate discharges of industrial wastes must be controlled, and the burden of proof relative to the ultimate effect of the discharged materials upon the Chesapeake Bay, its water, and its populations must rest upon the industrial community. While a great deal of scientific data remain to be collected with regard to the waste-assimilative capacity of an estuary with the proportions of the Chesapeake Bay, the ultimate impact and fate of inorganic and organic industrial waste products within the waters of the Chesapeake Bay can be predicted in a general way through some of the procedures outlined in this paper. This type of information coupled with data regarding the biological populations residing in the Bay and the physical mixing and dispersion mechanisms within the Bay—both subjects which will be covered in later papers—should give the regulatory agencies, concerned citizens, and scientists some of the information they will need to make the management decisions that will be required in the coming years.

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# Some Applications of Remote Sensing in Atmospheric Monitoring Programs

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Since air masses move in unconfined spaces, pollutants introduced into the air in one region are absorbed into the global circulation pattern, thereby affecting other regions. Pollution control strategies must recognize such effects and coordinated efforts are necessary. The unilateral ban on use of DDT in the United States offers a good example. If Mexico does not follow suit and continues to use large amounts of DDT for pest control, it is quite likely that the persistent chemical will find its way into many areas of the United States. This could be accomplished by the carryover of aerosols from aerial spraying, fine particulate matter and even birds (ref. 1); a good portion of our bird population migrates south each year where these migrants could easily absorb DDT.

Lead aerosol is a common air contaminant in urban areas and available data indicate that combustion of leaded gasoline is the major source of airborne lead in urban areas (ref. 2). One extensive study indicates that the atmosphere of the northern hemisphere contains about 1000 times more lead than the southern hemisphere as a result of man's contribution. The study also showed through geochemical measurements of sea water, sediments, and snow from remote areas that the level of lead in the environment is steadily increasing (refs. 3 and 4). Lead moves into other phases of environment especially through the scrubbing action of rain.

Recently mercury contamination has been observed in some of the northern lakes of the United States. There are virtually no industries in the catchment area of these lakes and one plausible explanation is that mercury also moves through the air medium. Eventually it seems to enter the aquatic environment.

The aforesaid emphasizes the need for a broad view in air-resources management. Remote sensing technology, although in an embryonic stage, may provide bases for extending our horizon. Present techniques of air quality measurement are generally dependent on Earth-bound sensors and reflect emphasis on local or regional management. One example of the regional approach is the program of the Department of Natural Resources and Environmental Control in New Castle County, Delaware. The 11-county Philadelphia Metropolitan Region encompasses New Castle whose population in 1970 was estimated at 386 000 (fig. 1). The population density of the northern half of the county (where most of the people live) is approximately 1460 per square mile. On a state-wide basis the population density is only 271 per square mile. Consequently our major air pollution problems are in northern New Castle County.

The air quality of New Castle County is determined by using a network of four primary stations and ten secondary stations (fig. 2). The primary stations are housed in self-contained trailers having internal dimensions of 16-foot length, 8-foot width, and 7-foot height. The instrumentation in the trailers is manufactured by various companies such as Technicon, Beckman, and Mine Safety Appliances. The entire monitoring system was supplied by Litton under a turnkey contract. Each of the primary stations (table 1) has the capability of continuously measuring the following air-quality indicators:

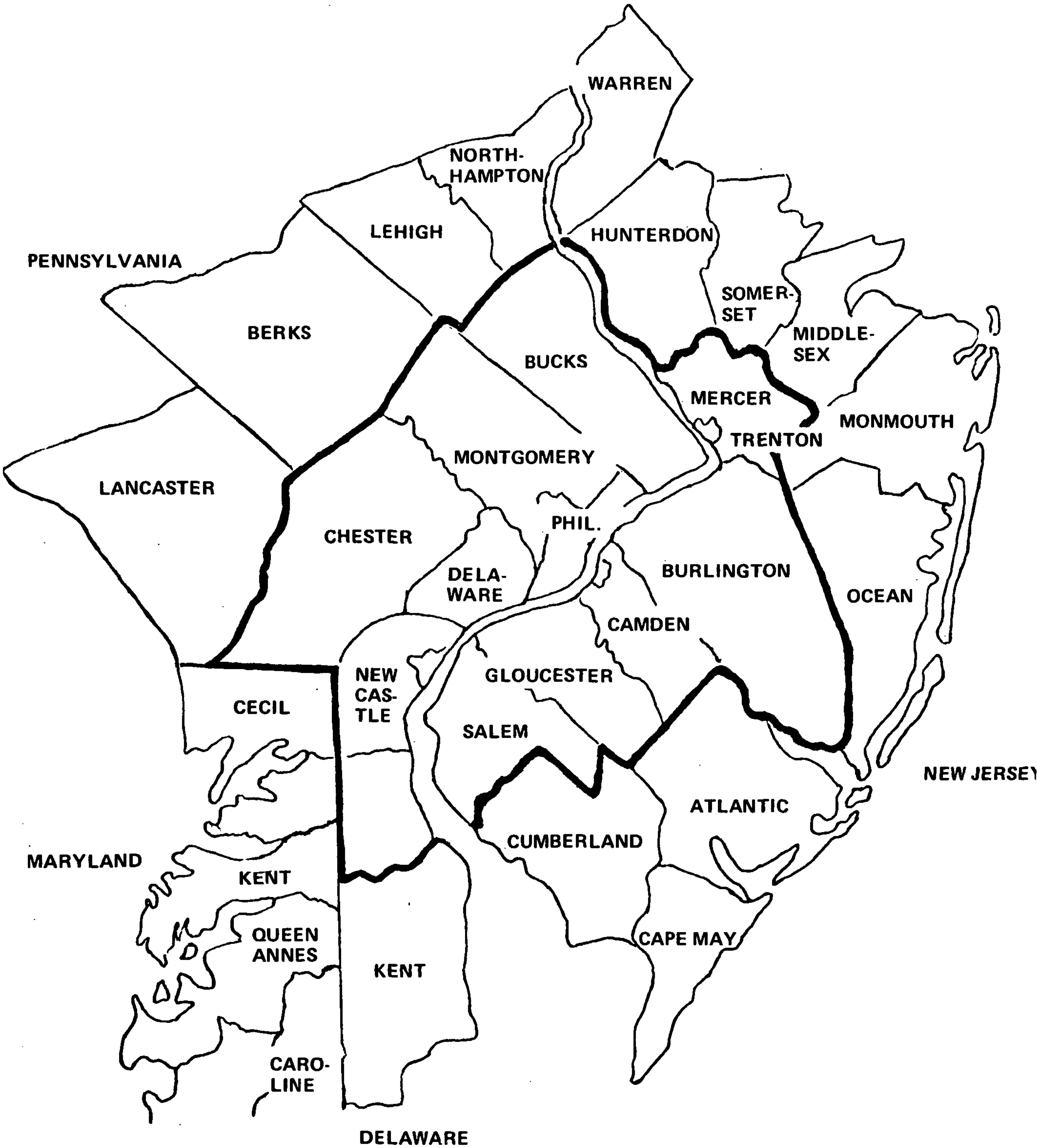


Figure 1.–Metropolitan Philadelphia air-quality control region.

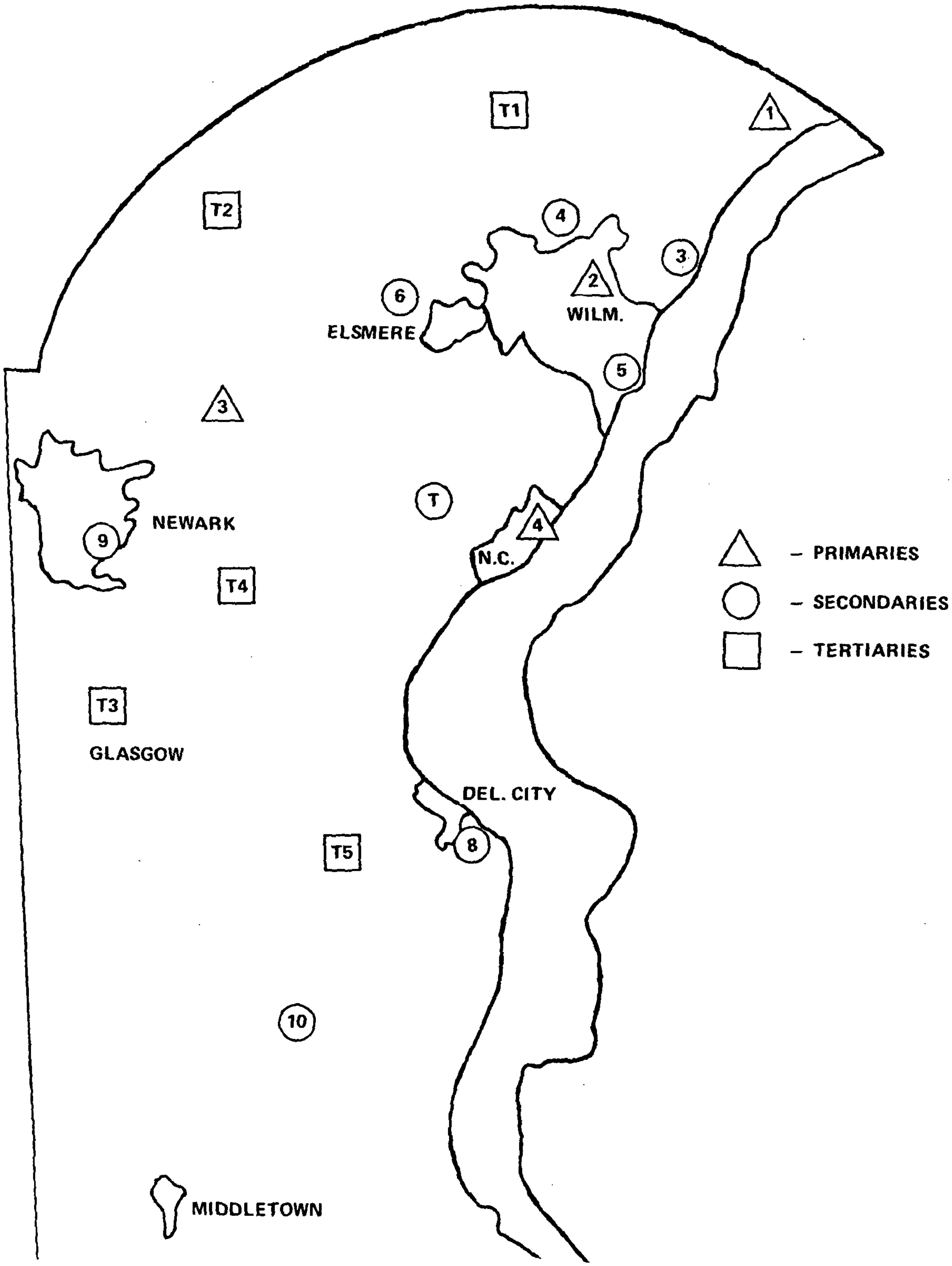


Figure 2.–New Castle County air-quality monitoring network.

| | |
|---|---|
| Wind direction | Total hydrocarbons |
| Wind speed | Carbon monoxide |
| Sulfur dioxide | Ozone |
| Total oxidants | Particulate matter |
| Nitrogen oxides | |

As a backup for the primary system a series of ten secondary stations are also operated in New Castle County area. These stations have the capability of measuring sulfur dioxide and particulate matter on a continuous basis, and sulfation rate and dustfall on an integrated basis (table 2).

The signals from each of the sensors are electronically isolated, conditioned, and multiplexed. Each remote station is scanned every three minutes from a central data acquisition unit. The scanning cycle initiates a sequential transfer of data from the remote to the central station over leased, low grade telephone lines. The analog signals from the multiplexer are converted into digital information prior to transmission (figs. 3 and 4). A mini-computer in the data acquisition center maintains 15-minute, 1-hour, 6-hour, and 24-hour moving averages for each air-quality indicator at each of the four stations. These values are always available on hard copy. The 15-minute average is recorded on magnetic tape for storage and future processing. The tape is periodically shifted to the data processing center at Dover for statistical analysis.

The total cost of this system is approximately $250 000. The real-time operation of this sytem offers quite a challenge in spite of sophisticated design of electronic components and instrumentation. There is still no substitute for frequent routine maintenance and calibration.

The data generated by the primary and secondary network offers a good measure of the general air quality in northern New Castle County. Figure 5 indicates the sulfur dioxide isopleths. The highest isopleths indicate areas of major industrial activity, including power production. The isopleths for suspended particulates are shown in figure 6. A hot spot is indicated in the Wilmington Marine Terminal area where there are several industrial emissions. Since New Castle County is bordered by the vast Philadelphia Metropolitan Region, the emissions from that area have a definite and deleterious interaction on local air quality in Delaware. This is shown in figure 7. The reduction of sulfur dioxide emissions in that region north of the state will materially improve the air quality within the State of Delaware.

An extensive survey of all emissions from New Castle County was conducted and the inventory yields information on the principal sources affecting air quality. Table 3 shows the contribution of sulfur dioxide emissions from various sources. Power generation, industrial processes, and industrial fuel burning account for almost 98 percent of the total emission into the atmosphere. The contribution of particulate emissions from various sources shown in table 4 indicates that power generation, industrial processes and fuel burning, again, account for almost 95 percent of the total emissions.

Although the initial emphasis is on the reduction of sulfur dioxide and particulates, we are concerned about other air pollutants such as carbon monoxide, nitrogen oxides, total oxidants, and heavy metals. In studies conducted by the University of Delaware Agricultural Department (ref. 5), oxidant damage to tobacco plants has been observed in Sussex County. This county with an area of 1000 square miles and an estimated population of 79 000 is quite unlikely to have high oxidant levels. However it is inferred that the oxidants may be carried over from the Washington-Baltimore metropolitan area into Sussex County through the general pattern of air circulation. Additional measurements are certainly needed to prove this cause and effect relationship. This observation further reinforces the comment made earlier on the movement of air masses from one region to another.

One recent example of the damage by air pollution is of interest in this context. Approximately two years ago, the Diamond Shamrock Chemical Corporation, which manufactures chlorine at Delaware City, found a leak in the system through which chlorine gas had escaped. A farmer nearby claimed damages to his standing crop of corn and demanded compensation. Inspection at the ground level indicated that such damage did occur and he was compensated by the company. If airborne sensing capabilities were available at that time, it would have been possible to precisely assess the damage caused in the entire area, including the corn crop. This is another illustration of the need for wide area coverage by airborne or other remote sensing devices.

Yates (ref. 6) suggests a satellite covering the entire globe once every 12 hours in a polar orbit. He claims that it can

TABLE 1.—Operational Characteristics of Primary Air-Quality Monitoring Network

LOCATION:
In specially designed, 8 X 16-foot trailers with environmental controls.

DATA GENERATED:
(a) Settleable solids–Dustfall buckets
(b) Sulfation rate–Lead candles
(c) Particle count–Sticky paper
(d) Suspended particulates–Hi-vol sampler
(e) Sulfur dioxide–West-Gaeke procedure, Technicon, continuous
(f) Nitrogen dioxide–Saltzman procedure, Beckman, continuous
(g) Ozone–Mast, continuous
(h) Total Oxidants–Neutral potassium iodide procedure, Beckman, continuous
(i) Total hydrocarbons–Flame ionization, MSA, continuous
(j) Carbon monoxide–Infrared detector, MSA, continuous
(k) Soiling index–Reflectance units, RAC, continuous
(l) Wind speed–Litton Systems, continuous
(m) Wind direction–Litton Systems, continuous

DATA REDUCTION:
(a) Continuous data–15-minute averages output on hard copy and stored on magnetic tape for automatic data processing.
(b) Manual data–transferred to punch cards for automatic data processing.

TABLE 2.—Operational Characterstics of Secondary Air-Quality Monitoring Network

LOCATION:
In specially designed structures, either portable trailers or prefabricated wooden structures. Structures are 7 X 10 feet with controlled environment.

DATA GENERATED:
(a) Settleable solids–Dustfall buckets
(b) Sulfation rate–Lead candles
(c) Particle count–Sticky paper
(d) Suspended particulates–Hi-vol sampler
(e) Soiling index–AISI tape sampler
(f) Sulfur dioxide–Conductivity method, 30-minute averages
(g) Gas sampler–24-hour average of five selected gases

DATA REDUCTION:
Manually transferred to punch cards, automatic preparation of statistical reports.

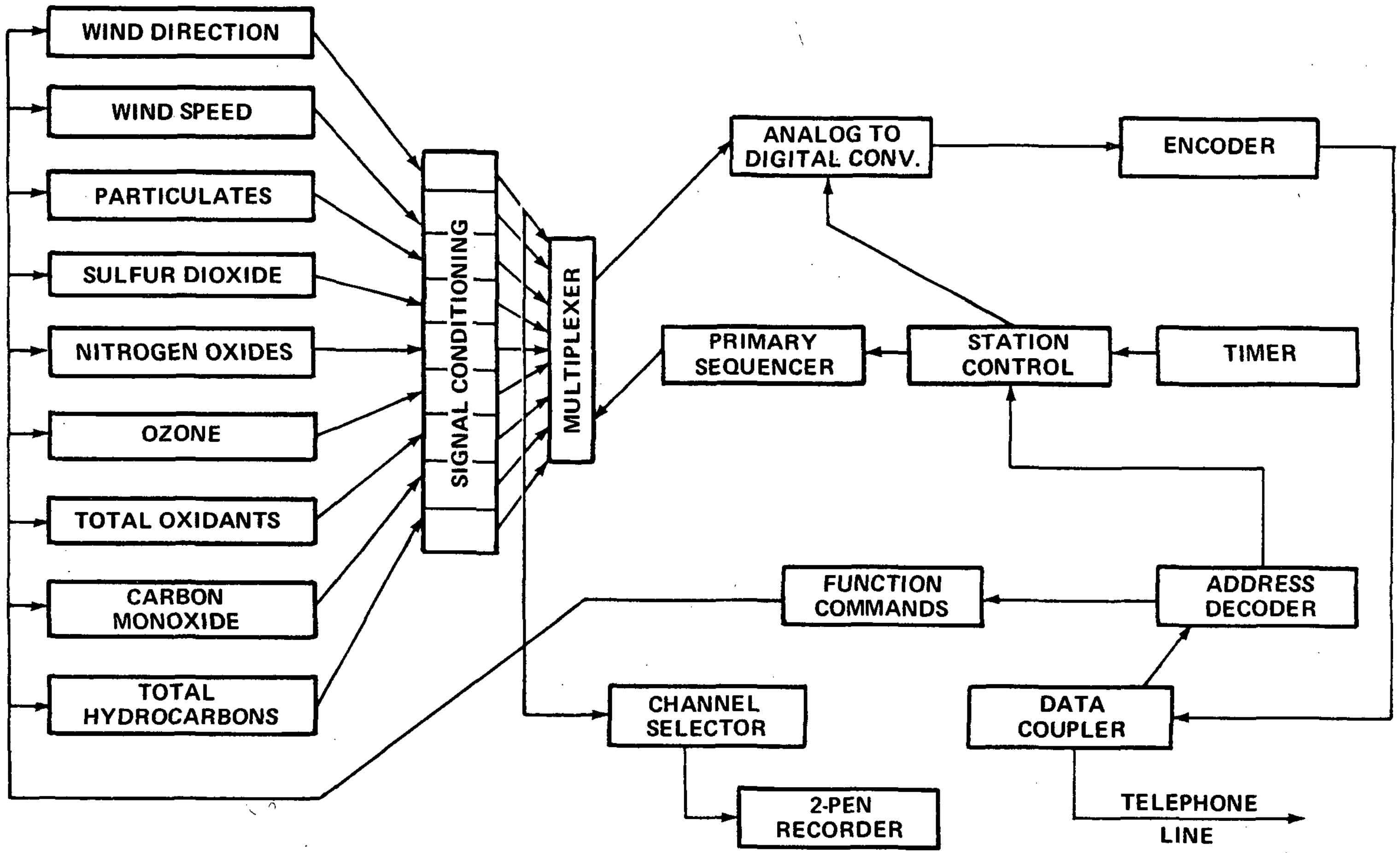


Figure 3.–Delaware primary monitoring station.

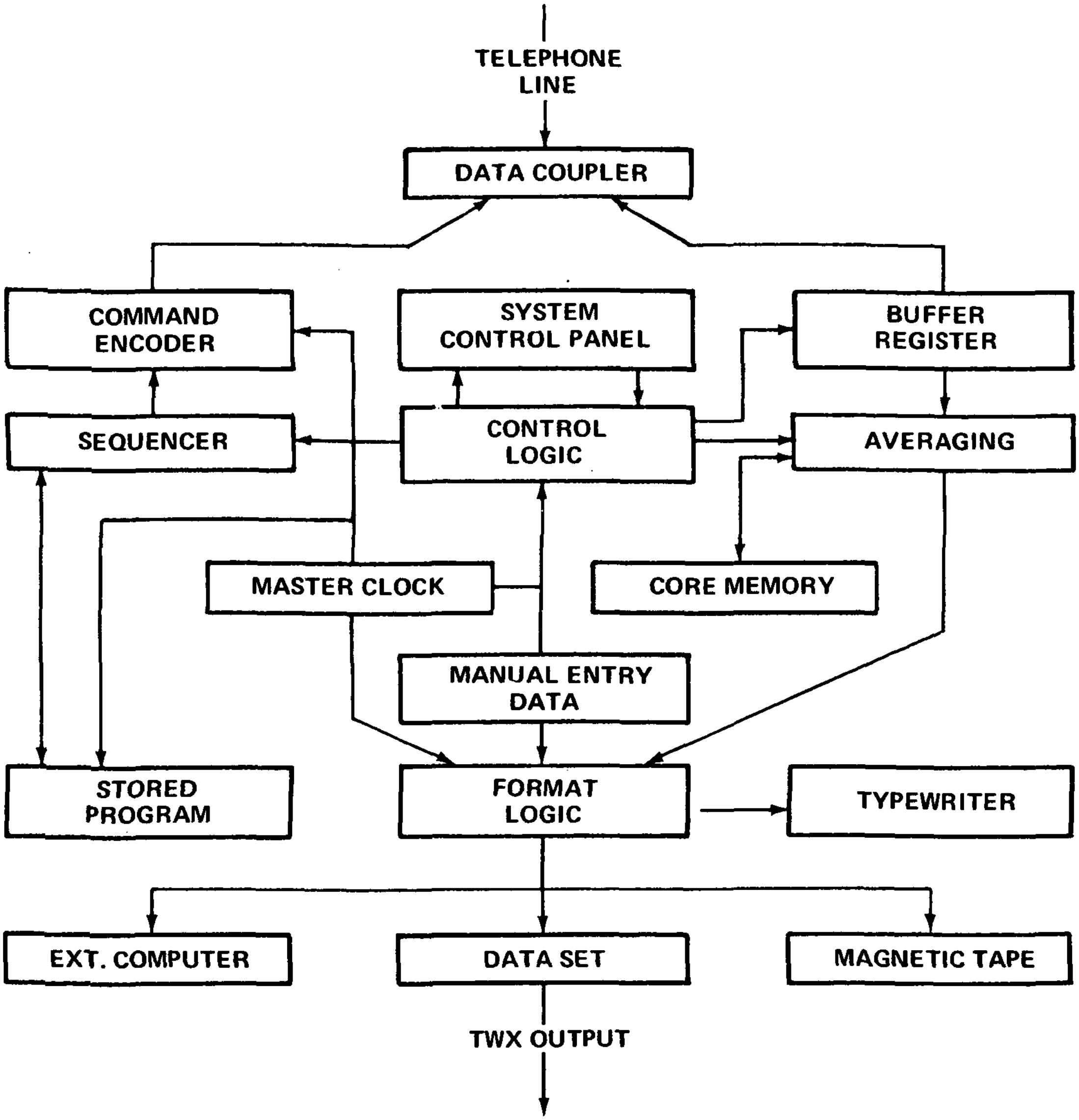


Figure 4.–Central station functions.

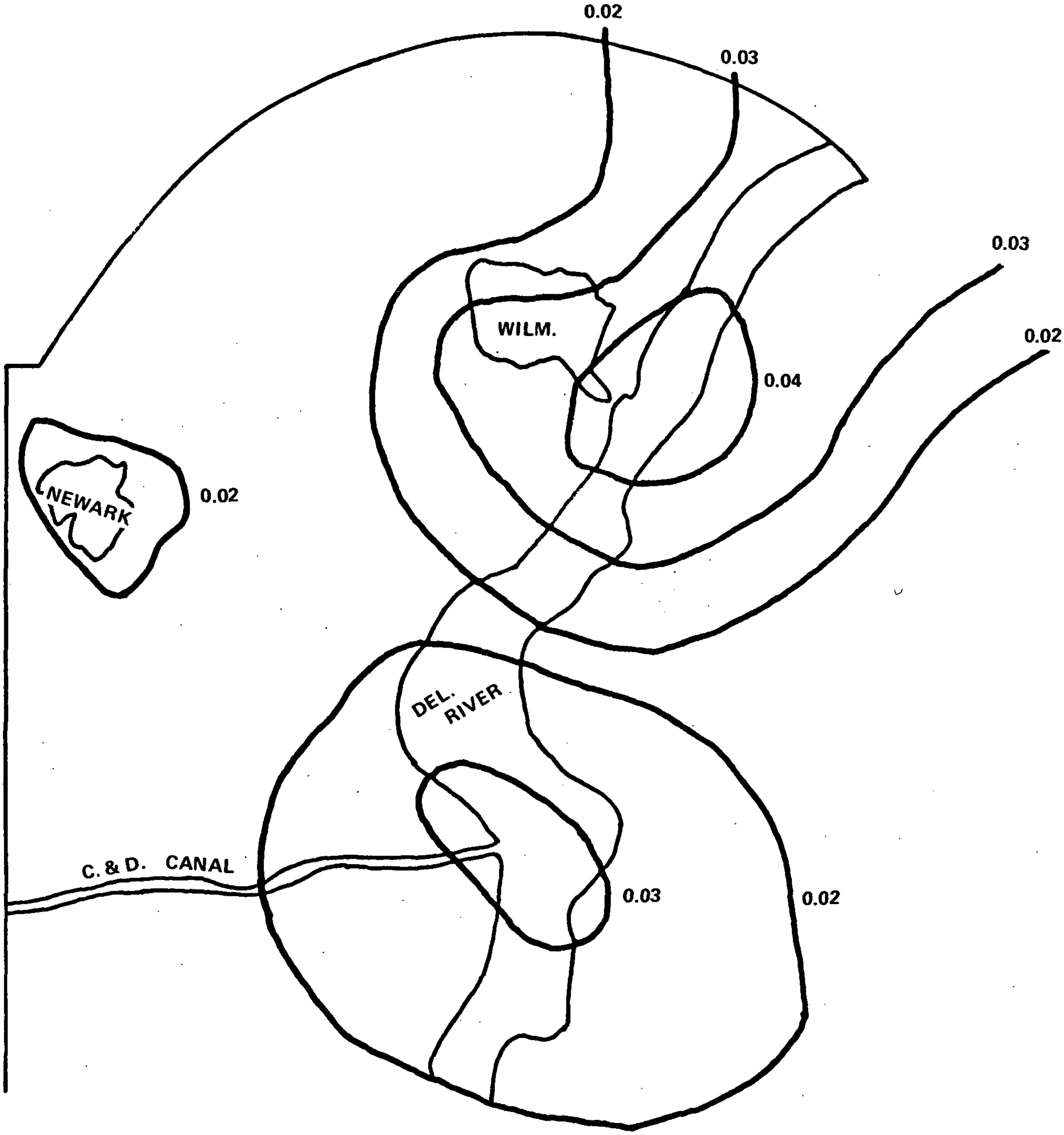


Figure 5.–Sulfur dioxide isopleth for New Castle County.

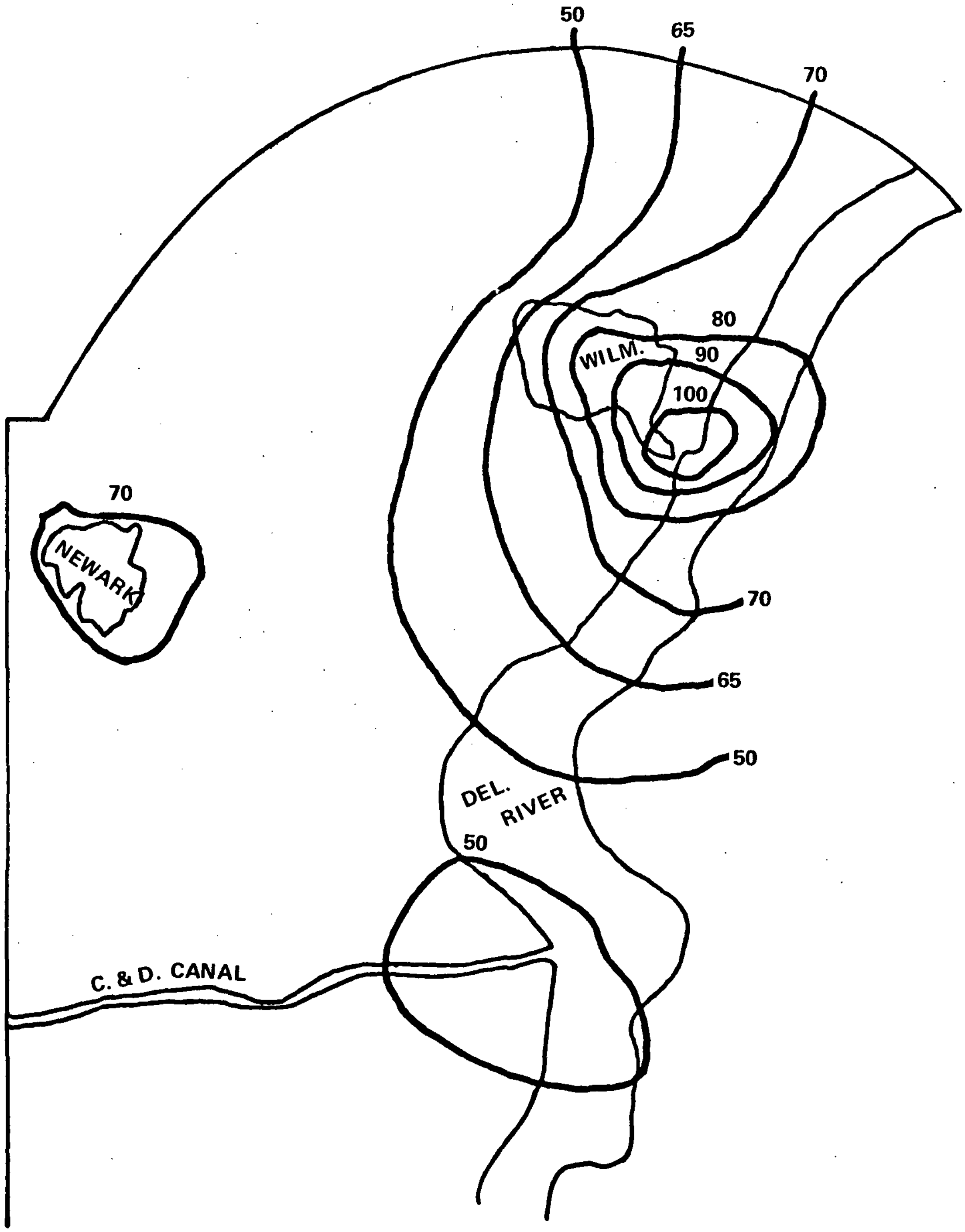


Figure 6.–Suspended particulate isopleth for New Castle County (geometric mean, $\mu g/M^3$).

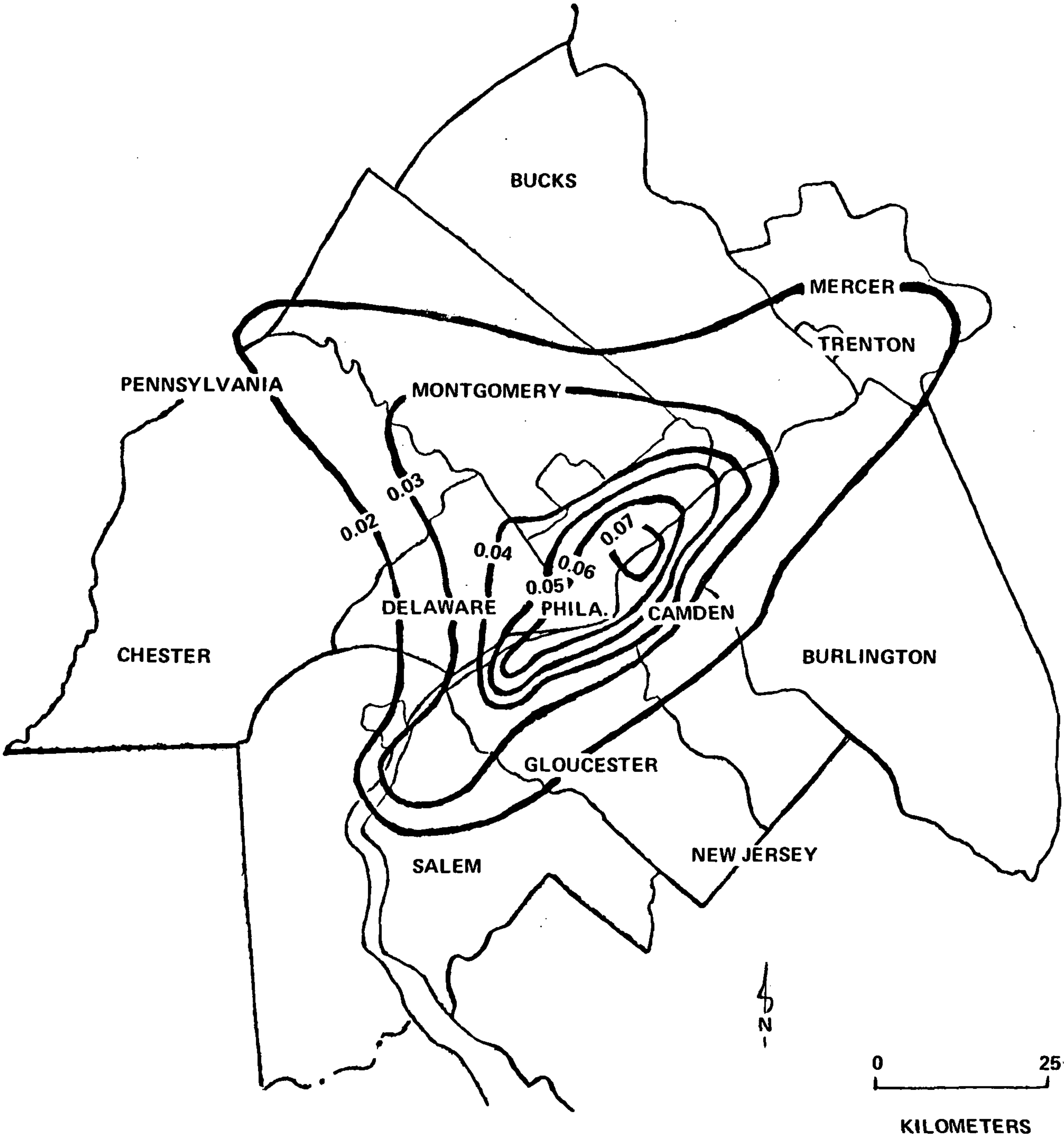


Figure 7.–Sulfur dioxide isopleth for the Philadelphia air-quality control region (arithmetic mean, ppm).

TABLE 3.–Contribution of Sulfur Oxide Emissions from Various Source Classifications

| Source classification | Present emission (tons/year) | Proposed allowable emissions (tons/year) |
|---|---|---|
| Residential fuel burning | 2100 | 2100 |
| CIG fuel burning[a] | 1200 | 800 |
| Industrial fuel burning | 29 000 | 13 800 |
| Power generation | 106 500 | 30 000 |
| Industrial process | 50 200 | 9600 |
| Mobile | 550 | 550 |
| Total | 189 550 | 56 850 |
| Reduction of present emission levels | | 70% |

[a]Commercial, institutional and governmental (CIG).

TABLE 4.–Contribution of Particulate Emissions from Various Source Classifications

| Source classification | Present emission (tons/year) | Proposed allowable emissions (tons/year) |
|---|---|---|
| Residential fuel burning | 800 | 800 |
| CIG fuel burning[a] | 150 | 150 |
| Industrial fuel burning | 3600 | [b]3600 |
| Power generation | 21 000 | [c]1900 |
| Industrial process | 16 000 | 1400 |
| Mobile | 750 | 750 |
| Total | 42 300 | 8600 |
| Reduction of present emission levels | | 80% |

[a]Commercial, institutional and governmental (CIG).
[b]Possible reduction due to lower ash content of low sulfur fuel not indicated.
[c]Based upon change from coal to oil that is dictated by Regulation IX.

provide a synoptic coverage which has never been possible with local sensors because the resources to install and operate such a vast network have never been, and in all probability, never will be available for that purpose.

A new family of remote sensing equipment based on optical methods and absorption characteristics are now becoming available. Barringer and Schock (ref. 7) cite a program of research to develop instrumentation which can detect a range of gases and vapors by optical methods with sensitivities in the parts-per-billion range. Their instrumentation technique is based on spectral absorption characteristics exhibited by many gases in the ultraviolet, visible and infrared portion of the spectrum. Jacobs and Snowman (ref. 8) suggest laser techniques for air pollution measurement based on the use of a carbon dioxide isotope laser working in the infrared band and a remote mirror. Yates (ref. 6) lists experiments already conducted by the Nimbus 4 series satellite wherein measurements have been made on temperature, water vapor mapping, atmospheric temperature profile, ozone, minor atmospheric gases, and changes in solar radiation.

Früngel (ref. 9) claims the use of a spark gap to generate ultraviolet pulses in the microsecond range which are transmitted to a receiver that notes changes induced by moisture droplets or impurities. Hanst and Morreal (ref. 10) describe the development of iodine infrared and carbon dioxide lasers which are forced to emit spectral lines which fall on the infrared absorption bands of atmospheric pollutants. Rendina and Grojean (ref. 11) explain the operation of a commercial electron impact spectrometer for high resolution analyses of gases and vapors.

Randerson (ref. 12) explains the use of photography from satellites for studying air pollution. Several photographs obtained during manned spacecraft flights illustrate opportunities for studying plume configuration and the extent of coverage.

The aforesaid indicate the interest developing in application of remote sensing to many environmental problems. We are very much interested in applying some of these techniques to obtain necessary information. Our specific needs in the Delaware Bay Region can be defined as follows:

(1) Area-wide remote sensing is needed for indication of hot spots and pollution sources. For example, determination of the concentration of carbon monoxide at various locations would be of much value. Further, it is desirable to tag air masses so that the fate of this pollutant can be determined.

(2) Plume characteristics must be determined to assess diffusion phenomenon. Three-dimensional measurements will assist considerably in refining dispersion models.

(3) The prediction of inversions, the extent of pollutant buildup and the depth of the inversion layer may yield invaluable inputs for emergency episode planning.

(4) The dispersion and lifecycles of radioactive materials released by nuclear power plants are of utmost concern for the well being of our citizens.

(5) Remote sensing of vegetation may provide bases for assessing damage to crops and trees by air pollutants. Ground level surveillance can be improved using such information. Present techniques require constant movement of mobile monitors to follow the plumes and measure their ground effects.

(6) The fate of pollutants in the atmosphere is of great value to air resources management programs. Information on the decay or chemical conversion of pollutants will help in improving our assessment capabilities.

This paper covered briefly the instrumental capabilities to monitor air quality at ground level and examined the role of remote sensing in the atmosphere. The need to relate both systems is urgent. We suggest that a program be developed in the Chesapeake and Delaware Bay areas to carry on the experimentation of remote sensing of the atmosphere.

The correlation of information with ground level systems, the development of prediction and warning systems, and the development of mathematical models would allow the manager of air resources in the broad area of the Chesapeake and Delaware Bays to anticipate problems before a crisis develops. Since such remote sensing capability can deal with more than one parameter—such as air—it may be more feasible to include water and land as a part of the complete environmental monitoring system. While we do not wish to appear chauvinistic, Delaware appears to be in a unique position because historical information is readily available on its water and air environment. This uniqueness extends to other areas, such as wildlife movement, and is expected to broaden in 1971 to include surveillance of biota of the total estuarine areas including marshlands.

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# Agricultural and Urban Pollution

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I have modified the scope of this paper slightly to include urban pollution because the pollution problems produced by the agricultural industry are essentially the same as those produced by municipalities. We know that environmental degradation occurs as a result of the discharge and the byproducts from both sources.

In the case of agricultural activities, the terrain has and still is being modified to convert it to crop production. In the livestock industry, large populations of animals are being concentrated into relatively small areas to meet the economic pressures of meat production. With the human population, the numbers of people are not only increasing but are also concentrating. Probably more important, countless square miles of terrain have been denuded and modified to make way for highway and street construction or for the development of housing units. From both sources the results are the same. We have increased siltation; we have increased organic loading; and we have increased nutrient loading.

## SEDIMENT LOADING

Those of us with responsibilities in the Chesapeake Bay and its tributaries could cite many areas where the intended uses of the water have been contravened as a result of either agricultural or urban activities or both. I am not going to infer that the Chesapeake Bay is dead. Far from it; it is still one of the most beautiful and healthy estuaries in the United States. It has its problems, however, like all other bodies of water that are adjacent to human activities, but these are primarily confined to its tributaries. Figuratively speaking, several of the Chesapeake Bay's appendages–the tributaries–have "gangrene" with atypical discoloration extending from the extremes of the fall line down to the main body. Loren Jensen[1] mentioned some of these situations, and estuarine ecologists, like medical doctors, are fully aware that an otherwise healthy body may be destroyed by an infection which originates in the extremities. In fact, the extremities are far more prone to difficulties than the main body because of poor circulation and frequently the inability to flush out poisons and contaminants.

Now let us breifly review the degradation produced by the introduction of agricultural and urban wastes into estuarine systems. Wellman and others have established that agricultural activities may increase the erosion rate per square mile by a factor of 10 of so. Also in the initial steps of urbanization, the erosion rate per square mile may be increased by a factor of 1000 over that of an adjacent unmodified area. Because of this, the two sources cannot be separated when discussing turbidity and sedimentation.

According to the classical definitions of pollutants, silt and clay particles are generally classified as inert, inorganic materials. We know that they are inert only in that they exert no biochemical or chemical oxygen demand on the water. Chemically, however, they are quite active because silt particles especially are characterized by surface charges or sites capable of exchange reaction. This occurs when they come in contact with quite a few of the organics. The best example would be the florinated hydrocarbons or the polyclorinated biphenyls (PCBs), inorganic materials, ions such as the heavy metals, or even the nutrients such as phosphates. The absorptive capacity of silt particles is usually characterized and correlated with the pH value of the suspension or the solution. It is, therefore, characterized by an effect or relationship to the zero-point-of-charge (ZPC) of the species. Since the pH value of estuarine and marine water

[1] Loren B. Jensen: Industrial Waste Pollution. This conference.

is usually above that of the ZPC of many of the species with which we have concern, suspended solids can effectively remove ions from solution, carry them downstream, and deposit them, making them part of the bed load or remove them from the soluable form and incorporate them with the sediment load.

These reactions almost completely nullify the effluent standards that have been imposed by many state and federal regulatory agencies. An industry may, for example, meet any effluent standards merely by increasing the volume of effluent without increasing the contaminant loading. When the effluents are discharged into turbid waters, the ions or the molecules that might be discharged almost completely become a part of the sediment load rather than a part of the true solution. In doing this, the specific concentration is insignificant, but the total loading per day or per month becomes the significant factor. The aqueous phase, the solution a short distance below an effluent pipe, may be quite free of the contaminant when water samples filter through a membrane filter; however, the concentration of the contaminants in the sediment may be extremely high. This is only a temporary removal from the biological system, however.

We know that many of the marine and estuarine filter-feeding organisms have the ability to strip ions, especially the absorbed ions, from particulate materials as the particles pass through the digestive track. Also, the action of many of the forms that bore into the bottom can mix this loading down through the sediment mass and, in some cases, remove them from the biological cycle; in other cases, they can return them to the biological cycle. Because of the mechanisms and the relationships between ions that may have originally been in true solution to the particulate material, we can see that much more information is required by the regulatory and management agencies regarding the turbidity levels and the movement of settleable solids than is generally available. Phosphate ions are readily absorbed on the surface of particulate material when the pH factor is within the proper range. Although phosphate is a pollutant in many estuaries, especially in upper tidal systems, the reaction with the suspended solids prevents the phosphate from being flushed from the system as part of the normal flushing action into the ocean.

The standing crop and the primary productivity of estuarine systems is also adversely affected by the high turbidity level. The autotrophic planktonic forms, plants that are responsible for energy fixations in the aquatic environment, are dependent upon sunlight for this fixation. Therefore, the quantity of organic material is directly related to the depth of light penetration. In some of our more turbid systems the depth of light penetration may be less than a meter and in some cases less than a foot.

We are very much concerned about temporary turbidity or temporary suspensions of silt and clay particles that are produced when wind-induced waves touch the bottom and therefore resuspend and re-sort material that has been deposited over the shallow areas and bring it back into solution. Haven's data, for example, indicates that the suspended solid loading may be much higher on a windy day during low-flow fresh water inflow periods than on calm days during relatively high fresh water inflow periods. In fact, the variation within days in suspended solids can be as great as the variation between days. These loads are especially harmful to the aquatic environment. They not only absorb and scatter light particles but, since the suspensoids settle quite rapidly after the wind subsides, they can mechanically entrap phytoplankton and planktonic animal forms and carry them to the bottom where they may be destroyed.

Several species of our important estuarine animals are either sedentary or sessile; therefore, they are especially vulnerable to the processes of sedimentation or the results of sedimentation. The Virginia oyster, indigenous to the Chesapeake Bay region, has a life cycle that is characterized by the release of the sex products, external fertilization and development, and a planktonic stage through the larval development until the setting time, usually 14-30 days, depending upon water temperature. If the larval form, the planktonic form, is able to survive this stage, it still depends upon the condition of the bottom. It requires a relatively clean, hard surface for setting or settlement and additional development into the adult stage.

Silt-covered surfaces are just not suitable. Therefore, in the case of the oyster, the animal is dependent upon the levels not too far exceeding the natural levels from the time the sperm and the egg are released into the water until they settle and develop into the adult form. Even the adult can be covered and smother through adnormal sedimentation.

The other commercially important species of mollusk, the soft clam and the hard clam, also have planktonic larval forms which are susceptible to death or destruction by settleable material; however, the adults can live in softer bottoms; they are slightly mobile; and, therefore, they can survive a little better than the oyster.

Turbidity and siltation are forms of estuarine pollution, in that, the physical geometry of systems may be altered by the formation of bars and shoals; the water currents may be modified by bathymetric changes; the water quality can be degraded and aquatic life suppressed. Also, the intended uses can be contravened either through the reduction in the aesthetic value or just a general deterioration of the environment. The adverse effects of destruction caused by sedimentation are not as dramatic as the catastrophic kills that can be produced by municipal or industrial waste. However, the end result is the same.

## ORGANIC AND NUTRIENT LOADING

I mentioned that the second product of agricultural and urban activities was excessive organic loading. I am not going into detail on this phase because, with conventional treatment and advanced waste treatment, there really is not too much of an excuse today for aquatic systems to be overloaded organically. However, in the treatment and without advanced waste treatment that incorporates nutrient removal, over-enrichment or hyper-enrichment can result.

There are several sources of nutrients: nitrogen, phosphorous, possibly carbons, and trace elements that can produce this type of degradation. These sources include the agricultural activities from the beef factory operations, the broiler factories, the egg factories, and the piggeries. Also included are certain industrial activities, especially those involved with the production of agricultural chemicals, certain synthetic fibers, and, of course, municipal activities. I am not going to use the term eutrification because, in my opinion, it simply does not apply to estuarine or tidal systems; however, whatever term used, the symptoms and the end results are the same.

Over-enrichment can result in the production of atypical phytoplankton populations, populations where the standing crop or the biomass far exceed normal level. Probably one of the more serious and least understood is, in over-enriched environments, the phytoplankton composition frequently changes from beneficial forms to obnoxious weed forms—from forms that can be utilized by animals at the higher trophic levels to forms which apparently have little if any value in the system.

Another thing that can happen is that the aesthetic value of the body of water can be reduced. No one really cares to look at, to swim in, or to wade in a body of water that is pea-soup green so that when he comes out, he will be green.

Also, subminimal oxygen levels can be produced at night due to cell respiration and cell decomposition. The upper tidal Potomac is notorious for developing these symptoms each summer. The engineers are constantly asking the biologists to give them hard numbers on how much nitrogen, phosphorus, or carbon that water can assimilate without the production of aquatic nuisance conditions. There is really no stock answer. Each system is different. Much of the literature has been developed from work on lakes. One simply cannot transfer information from lake studies to dynamic systems such as streams or tidal systems. We know that the taxpayers should and the engineers do sincerely hope that phosphorous is most frequently the cause of these agents.

However, my experiences and the recent literature indicate that in dynamic systems such as tidal systems, during the relatively low fresh-water inflow periods of summer, the period when aquatic nuisance conditions and environmental degradation quite frequently occur from over-enrichment, available nitrogen is probably more frequently the limiting factor; therefore, in order to actually reduce aquatic nuisance conditions, nitrogen removal is also necessary. Our recent work on Virginia's three major estuaries—the James, the Rappahannock, and the York—the Chesapeake Bay Institute's studies in the Potomac and the Upper Chesapeake Bay and the Jaworski and Lear Water Quality Office comprehensive studies on the tidal Potomac have yielded similar results regardless of the salinity of the enriched waters.

Several factors, however, must be considered when discussing the elements that stimulate phytoplankton activities. First, the Chesapeake Bay and its tributaries are literally loaded with the measurable nutrient elements during the late winter and early spring when fresh water discharges are high. During this period, especially in the tributaries, the turbidity levels are high, and this alone limits photosynthetic activity; but probably the most important species of plants that are primarily responsible for environmental degradation in the fresh water part, namely the microcystis and acystis group, are fresh water forms that do not develop in large enough numbers to cause difficulties. Later in the season as the fresh water inflow volumes drop off, the nitrogen levels drop down also. During the late summer, the available oxidized forms of nitrogen are down at minimal level.

In the James River, which one might expect to be highly enriched from the fall line down to the mouth, the minimum phosphorous levels are usually found between 10 and 15 parts per thousand. Toward the mouth of the James River, the so-called available or soluable phosphorous levels increase. When we first saw these data we thought it might be attributed to the population concentration in the Hampton Roads area. However, the same phenomenon occurred in the York River with complete absence of enrichment near the mouth and likewise in the Rappahannock River.

We are all very much concerned about the phytoflagellate blooms, the red tides, or mahogany water as it is commonly called in Maryland that occur in the lower tributaries and in the Chesapeake Bay almost every summer. We know from talking with several natives that they observed red tides during dog days each summer when they were children. One thing we do not know is if the frequency and duration of these red tides are increasing. We do know that red tide blooms appear to stress many species of estuarine life and we know quite conclusively that they are capable of bringing about the demise of quite a few jelly fish.

In summary then, agriculatural and urban wastes exert many similar stresses upon the estuarine environment. Several of the upper tidal tributaries are now loaded to the point where the intended uses are being contravened. We might sum up by saying that unless the ailments of the extremities are cured, the main body of the Chesapeake Bay will eventually be degraded until it is useful only for commerce and recreational activities.

# Estuarine Turbidity, Flushing, Salinity, and Circulation

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One of the stated objectives of this conference is to identify the primary environmental problems of the Chesapeake Bay area. I am aware of and have contributed to three major studies that identify the primary environmental problems of the Chesapeake Bay: The Corps of Engineers' study of the Chesapeake Bay; the State of Maryland's interagency planning study of the Chesapeake Bay; and the free-institution NSF-sponsored study of the Chesapeake Bay. Another, not too recently, was the State of Maryland-sponsored Smithsonian-run study by a committee of experts on problems of the Maryland portion of the Chesapeake Bay. At least these studies encompassed the whole Bay, and included management of research programs in the Chesapeake Bay. So, it seems that we have had adequate studies to identify the primary environmental problems of the Chesapeake Bay.

As a point of departure at this conference, we might have started by taking one of these studies and then asking what sensors might do. When I mentioned this to some of my colleagues they indicated that only half of the audience will have heard me before on these subjects. However, for the benefit of the other half of the audience I will describe the distribution of salinity and the circulation pattern, as well as speak about turbidity and flushing.

First note that the Chesapeake Bay is the largest estuary on the Atlantic coast of the United States. Estuaries may be grouped according to their geomorphological character, and the Chesapeake Bay falls into the group called "coastal plain" or "drowned river-valley" estuaries. According to one subsclassification of such estuaries are what are called "partially mixed" estuaries; that is, the vertical structure while showing some variation in density, salinity, temperature, and other properties with depth does not exhibit the sharp interface that occurs at such salt-mud estuaries as the Mississippi where the tidal velocities are very small. In the Chesapeake Bay the tidal velocities are large compared to the velocities that would be induced by the river flow alone. Consequently, the Chesapeake Bay has partial vertical mixing.

## SALINITY

The Chesapeake Bay roughly is 180 miles in length and 40 miles at its widest point. The main river is the Susquehanna, supplying 50 percent of the total fresh water that enters the Bay. More important, it brings in between 85 and 90 percent of the fresh water that enters above the mouth of the Potomac. The Potomac, the second major tributary, brings in about 11 percent of the water that enters the Bay. The James is next, bringing in about 5 percent. The York and the Rappahannock together provide about 5 percent, and then all of the rest of the tributaries add their little bit.

The salinity varies regularly up the length of the Bay and up each of the tributary estuaries. The winter average surface value varies from over 23 parts per thousand at the mouth of the Bay on up to less than two parts per thousand near the head of the estuary at the Susquehanna flats. A similar decrease occurs as we move up the Potomac, up the Rappahannock, up the York, and up the James. In general the salinity not only decreases coming up from seaward but also shows a gradient across the Bay. The gradient, with fresher water on the western shore and eastern shore, in part results from more fresh water input on the western side of the Bay. It would occur even if there was only one source of fresh water because of the effects of the Earth's rotation. If we look in detail, say, in the James River where there is one primary source of fresh water, one finds that there is a lower salinity on the right side looking seaward than on the left side because of the effects of the Earth's rotation. This is a winter condition which is also an average condition for all seasons.

In spring, the salinity decreases at Poole's Island. Where there were about six parts per thousand in winter, there is now about one part per thousand; salinity generally decreases throughout the Bay and throughout all of the tributaries in spring.

In summer, salinity distribution is not too different at the surface than in winter.

Autumn is the time of highest salinity; we find about seven parts per thousand at Poole's Island, increasing to something like 29 at the mouth. This, again, is surface distribution.

Looking at depth distribution for the summer–40-foot distribution of salinity–we also see something about the distribution of depth; actually at 40 feet there are connections made by dredged channels on up the Bay. But, there is a central deeper portion of the Bay nearer the eastern shore over much of the Bay, and the salinities are greater there.

The salinity distribution at 60 feet, again, shows the shape of the Bay:The very narrow channel greater than 60 feet in depth runs along the spine of the Bay as it also does in Pocomoke Sound and some other places. If we ever deepen the channel to 50 feet or more all the way to the sea, some considerable work would be involved. Probably some significant changes in the dynamic structure of the salinity regime would occur if the isolated pockets were connected.

Looking at the salinity distribution along the length of the Bay and along the maximum depth, we see, by vertical exaggeration (compared to horizontal), that the bottom looks rough but it is not that bad. There is a basin in the center with somewhat shallower depth near the mouth than in the central regions if we follow just the deepest portions. The other point that is noticeable is that the water is fresher on the surface than it is at depth. There is a downward pushing of the isolines in the surface layer and upward pushing of the isolines of salinity in the deeper water. This is exactly what happens; that is, typically, the pattern with salinity near the 15-parts-per-thousand line is located at the surface at a point about 37° 50′ north and it intercepts the bottom at 39° 5′ north–a distance of about 70 miles. Hence, there is at any point a vertical gradient in salinity but not a sharp gradient. The surface region has approximately uniform salinity with depth for a ways, then a region of transition, and then in the deeper water, more uniform distribution with depth. This is the appearance of the summer depth distribution.

The spring average shows the salinity distribution moving down with greater vertical stratification.

With respect to salinity surface and bottom salinities vary seasonally; the vertical gradient varies seasonally with the average difference between salinity at the surface and at 40 feet being greatest in the spring and least in autumn; surface salinities are greatest in autumn and least in spring.

## CIRCULATION AND FLUSHING

The most obvious water motion in the Bay is motion of the tide. It moves back and forth at speeds varying from one-half a knot to 2 knots, depending on the location. There is a generally increasing tidal current moving up the bay from the mouth, decreasing in the middle reach, and then increasing again in the upper Bay with area constriction such as Sandy Point giving local regions a higher velocity. This oscillatory motion of the tide is superimposed upon a non-tidal circulation pattern, distorting the vertical pattern of the tidal motion.

Current velocities vary from the surface to the bottom during the flood period and during the ebb period. (Of course the flood direction is opposite the ebb direction. The ebb velocity is the velocity during the part of the tide when the water is flowing seaward.) The ebb velocity is stronger at the surface and decreases with depth. The flood velocity is weakest at the surface and increases with depth down to a level near the bottom. So there is a region in which the ebb current exceeds the flood current in the upper layers and a region in which the flood current exceeds the ebb current in the lower regions. If a proper average is taken over the tidal cycle, the velocity varies from the surface–the positive mean velocity toward the sea. The tidal mean velocity goes from some value, in this case about 1500 millimeters (0.5 feet) per second which is about 20 percent of the amplitude of the tidal oscillation, down to zero at 3 meters, and then it increases up the estuary in the lower layers.

This general circulation pattern can be modified. In general we find that the boundary between the seaward-flowing upper layer is thicker on the right-hand side of the estuary looking seaward than on the left. The landward, up-estuary flowing, layer is thicker on the left-hand side of the estuary looking seaward than on the right. This boundary sometimes gets tilted until it intercepts the surface so that we have essentially seaward flowing water in the right side of the estuary looking seaward, and up-estuary flowing water on the left, superimposed on the tide. This does occur in some cases, particularly in the James—the estuary which has been studied so much by VIMS.

Water comes in along the bottom from the ocean into the estuary. It has to flow back out again; it cannot just pile up. The river comes in providing an upper layer flowing seaward, and a layer flows up the estuary from the ocean in the deeper water that must go seaward again. There is some vertical flow from the lower layer to the upper layer all along the estuary, and this augments the flow on the upper layer as it flows out. So there is a very small amount of vertical motion, something like $10^{-5}$ meter per second. When distributed over the whole horizontal plane at mid-depth, it involves a large volume of water. It can, however, be measured either directly or indirectly. These measurements show that the vertical motion is peak at mid-depth.

A schematic diagram of the way the estuaries behave shows river flow in, and there is an increasing volume rate-of-flow seaward. In the upper layer, there is a flow inward from the ocean and a decreasing landward flow or up-estuary flow in the lower layer. This decreasing flow augments the upper layer and its seaward flow by vertical motion. If in a given river flow, coming well downstream, large volumes of flow accrue in the estuaries. Ten times the river volume flows out and nine times the volume comes in, the difference between the outflow and inflow must always be just equal to the fresh water volume added. This is representative of a very simple estuary.

The Chesapeake Bay is much more complicated because it is an estuarine system involving a number of tributary estuaries. In simple estuary systems, for instance, we would expect that the seasonal variation in salinity would be most pronounced at the upper parts of the estuary and decrease as we move down the estuary and that, in fact, the minimum salinity would occur at the upper estuary first and may be delayed until much later in the season further down the estuary. This is not true in the Chesapeake Bay. Essentially, the minimum salinities occur at almost the same time throughout the Bay within a few weeks—not several months as in some estuaries. Further, it is an interesting thing that the annual range in salinity is constant over about 85 percent of the length of the Bay.

From Poole's Island down to somewhere between the Rappahannock and the York River, the annual range in the salinity is about seven parts per thousand, average. It drops off slightly in the lower 15 percent of the Bay to about five parts per thousand. This is unusual in an estuary that has a single fresh water source. With multiple sources of fresh water coming in the estuaries we have the salinity condition stated above. These are typical salinity variations, with depth: 15 parts per thousand in the upper layer; 18 parts per thousand in the lower layer. We also see that though the vertical motion involves a very weak motion, it involves a large volume of water because the vertical flow is taken over a large area. Note that between two sections where the salinity is 21 and the salinity is 27, twice the river flow is vertical from the lower layer to the upper layer.

Not all estuaries behave in a typical two-layered pattern. The major tributaries such as the Potomac, the James, possibly the York and the Rappahannock do, though not always. The Patuxent estuary behaves over much of its length, say, 2/3 of the time like a two-layered estuary, a typical characteristic estuary. Some of these tributary estuaries do not behave as a two-layered estuary, in particular those with small fresh water inflows. The Patapsco estuary in which the Baltimore harbor is located is an example of this kind of a tributary system to the Chesapeake Bay. The Patapsco is controlled primarily by the fact that in the Bay off the mouth of the harbor there are two processes that control the vertical salinity gradient: The counter motion, which tends to bring fresher water down at the surface and saltier water up at the bottom, trying to make the salinity difference between the surface and the bottom very high, is countered against a vertical mixing which tends to destroy the vertical gradient. The resulting vertical gradient is the result of the balance between these two processes, of counterflow on the surface in the deep waters and the vertical mixings.

Baltimore harbor is on a tributary that does have its own river inflow; the harbor is a drowned river valley, but the fresh water inflow is very small. In fact, it would take 350 days or about a year for the local fresh water inflow to fill the volume of Baltimore harbor. Baltimore harbor and most of the similar small tributaries are essentially filled with Bay water. But as we move into Baltimore harbor, we find that, though the mean salinity top-to-bottom does not change, the distribution changes. In the Bay off the mouth of the harbor we see five parts per thousand at the surface and 15 parts per thousand at depth, a very strong vertical gradient. At the head of the harbor we see a little over eight parts per thousand at the surface, higher than out in Bay, but at the bottom a little over 10 parts per thousand, lower than out in the Bay.

In other ways, there is less vertical gradient, the point being that there is not the mechanism to maintain the vertical gradient but there is a mechanism of mixing to destroy it. A density situation is now created in which Baltimore harbor looks like the ocean to the surface waters of the Bay; that is, they are fresher, less dense, and so they flow over the top and flow into the harbor. The deeper bottom waters in the Bay are denser than the waters in the harbor so they also flow into the harbor. There are now two inflows, one at the surface and one at the bottom. For continuity an outflow has to take place at mid-depth. So this is a three-layer system and was first discovered for Baltimore harbor.

There are some other tributaries which are not as deep as Baltimore harbor. Baltimore harbor is a unique tributary estuary in that it has a depth essentially equal to the depth of the open Bay. A number of tributaries such as the Severn, South, Back, Bush, and Gunpowder Rivers have depths that interconnect only with the surface layers of the Bay. In these tributary estuaries the flushing and circulation patterns are driven primarily by the density difference between the waters of the Bay adjacent to the mouth of the tributary estuary and the waters in the tributary estuary. Again these are tributaries with relatively low fresh water inflow, and they are essentially filled with water from the Bay. The salinities in these systems lag behind the salinities in the Bay. The salinities are minimum in the spring and maximum in autumn.

The salinities in the Bay are always going through some time variation. During the time from early winter to early summer when the salinities are falling in the Bay, the Bay waters are less saline than the tributaries so the Bay waters flow into the tributary on the surface, and the tributary waters flow out at the bottom. On the other hand, during the time that the salinities in the Bay are increasing, from early summer through late fall, the waters of the Bay are higher in salinity than the waters of the tributary, so the reverse process occurs with inflow of Bay waters along the bottom and outflow along the top. This means that twice a year there is a period of minimum flushing of these tributaries. It would be a problem except that the salinity regime as a simple sinusoidal curve does not work that way. There are short-term ups and downs. These short term ups and downs in the inflow and in the salinity also result in some renewal of water in the tributaries.

The tributaries are essentially pumped by this fluctuation in the salinity regime of the Bay. In Baltimore harbor this kind of flow pattern represents a flow of 17 000 cubic feet per second or about one third the flow of the Susquehanna River. It really initiates because the Susquehanna River contributes heavily to the fresh water supply, creating the density gradient that allows this to go on. The local tidal portions could never do this. Thus, the harbor flushing time or mean-residence time, is about 10 days.

## SEDIMENTATION AND TURBIDITY

I was also asked to talk a little about sedimentation and turbidity. I understand turbidity to mean some effect on the optics of the system from suspended material. Most of the suspended material affecting the optics is inorganic suspended sediment. I am going to talk about the clastic sediment in the upper Bay; that is, the fine sediment that essentially exists in suspension in the upper Bay. There are two primary sources of the clastic sediment—the marginal shore erosion sources and the river discharge.

First let us consider the marginal sources. If we look at the system from near Baltimore, across the mouth of the Susquehanna, and on around to Tolchester, we can note either the deposition or erosion in volume, the average volume lot per mile of coastline. We would see that there is very little deposition but that there is highly variable erosion from one coastal segment to the next. Two adjacent segments can show quite large differences in the amount of erosion because of the exposure and the type of soil.

The major input for the upper Bay is the Susquehanna River. The sediment and sediment concentration increase when the river flow increases. That means that in terms of total flux, we are squaring the effects of the river; that is, we not only have a larger volume rate of flow but also high concentration.

Note the periods of time when the sediment supply occurs. During the springtimes of 1966 and 1967, for example, there was a major supply of sediment during each spring. Probably 70 percent of the sediment coming into the upper Bay occurs within a relatively short time, perhaps as small as two weeks and certainly as small as two months. When the sediment comes in, it is distributed into the upper Bay. For a short period of time there are actually higher sediment concentrations in the Susquehanna and the upper portions of the Bay. The concentration—there is a peak of 60 parts per million—decreases going downstream. This occurs only during the period of a high flow. During the rest of the year, the distribution of suspended sediment, in parts per million, actually is lower in the input source—the river—than it is down in the Bay. We have what we call a classical turbidity maximum. Down in the Bay we notice that the maximum is higher toward the bottom than toward the surface; the turbidity is higher within the Bay than it is in the major source, the Susquehanna River.

Let us examine the reason. Consider the tidal current oscillating about zero, going from maximum ebb to maximum flood. Lines of concentration of sediment at 2 and 4 meters from the surface show that the concentration of sediment was quite steady, being relatively unrelated to the tide. This ranged between 10 and 20 parts per million. Now if we go to the 4- to 6-meter interval, we see at 4 meters not much variation in sediment concentration with time except when the tidal current got quite large; but beginning at 6 meters we see near the times of maximum ebb and maximum flood the concentrations increase, in this case, from about 15 parts per million to over 35 parts per million. Near the bottom (9½ meters), say, at 8 meter depth, the large fluctuation in sediment represents what happens at 9 meters. We notice that at 9 meters, ½ meter off the bottom, the concentration varies from about 20 parts per million at slack water to as high as 280 parts per million at the peak of the ebb or flood tide so that this maximum turbidity is caused by the resuspension of sediment during flood and ebb of the tide. It is probable that the sediments go through this cycle over and over again. This is why if one digs a trench or channel from Poole's Island on up to the C & D Canal and puts the sediments where they can be stirred not only by the tide but by the wind, they are going to be recycled repeatedly until they finally get in the channel again.

During the period of high river flow the fresh water extends from the mouth of the Susquehanna down almost to Poole's Island. If at that time we look near the front where the effects of salinity just begin with depth, a sharp increase in density occurs. During that time there is a high inflow of sediment, and some peak sediments appear, riding on the density layer. This is the only time, however. Mostly, the concentration of sediment is largest at the bottom. But for a short time of year near the front where there is high river flow and there is a fairly sharp front between salt and fresh water, we do see this maximum suspended sediment riding on the turbidity layer.

## REMOTE SENSING

One of the things I have been trying to emphasize throughout this paper is the behavior of the circulation of the Bay. It is a pertinent feature in considering, for example, distribution of pollutants, processes that bring juvenile croaker from their spawning grounds into the Bay, or maintaining certain new plankton which migrate vertically with a diurnal cycle and spend practically the same amount of time in the seaward flowing layers as they do in the landward flowing layers. (They are kept from being swept out of the estuary because of this two-layer circulation pattern.) These are things that involve depth in a three dimensional system.

I have not discussed lateral distribution though it has some interesting implications. I have discussed longitudinal and vertical distribution, but if we are going to sense anything about the physical circulation pattern, we have to do it three dimensionally; we have to look vertically. I just mention that because I do not think any remote sensors have this capability.

If we had looked at charts of temperature, we would see generally that temperatures follow the seasonal pattern of air temperature with some modification by the influence of the ocean. That is, the Bay is warmer in the upper end than in the lower end in summer and colder in the upper end than in the lower end in winter. Temperature does exhibit some very large year-to-year and short-term fluctuations at any given point. A sweep through the Bay shows some very large fluctuation with space. It may only appear so since we do not have very many points in which we have long-time climatic information on the distribution of temperature. Particularly, we do not have synoptic data on temperature in which we can say this is the way the temperature pattern looks at a given instant of time to the bioata and hence relate this possible gradient and anomolies in the natural field to what might occur, say, from a heated discharge; one might learn something about this phenomenon from remote sensors.

At a few places we have some daily temperature measurements which can be averaged over monthly and yearly periods. Note that the Bay is very noisy, temperature-wise. A plot of the departure of temperature from the 50-year mean at one location shows that the range in the annual average, plotted for August or February temperatures, gives very similar results. The total range in variation is over 6° F and the year-to-year variation can have averages over as much as a 14-year period almost 1½° F above or below the long-time average. I think that more information on this noisy temperature spectrum would be worthwhile.

# Remote Sensing and Extractable Biological Resources

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## GLOSSARY

Several terms[1] merit definition or clarification as they are used in this consideration of the potential uses of remote sensing in relation to extractable biological resources of the Bay.

*Remote sensing*: Used to describe any non-contact reception of signals from the resource, with emphasis on long-distance sensing.

*Extractable*: Includes those organisms and materials now harvested and also those which are potentially useful.

*Biological*: Applies to both the organisms and their products.

*Resources*: Encompass those taken from the Bay for use and the organisms which are essential for the support of the harvested species.

## RESOURCES

The extractable resources of the Bay have not been accurately measured. Those harvested for commercial sale are recorded with reasonable accuracy, but the recreational catch and the potentially useful species and quantities are not. It is possible, however, to make some pertinent summary statements about them.

### Commercial Fisheries

These fisheries vary considerably from time to time in species composition, quantity landed, and value, but the summary by McHugh (ref. 1) provides useful data. I will blend those with my own impressions.

Recent catches landed in Chesapeake Bay ports have been about 500 million pounds per year. In 1967, these had a dockside or primary value of approximately $35 000 000, and retailed for a total at least three times that amount.

The oyster is the most valuable resource, producing about one-half of the dockside value, but only 5 to 10 percent of the weight landed. A benthic or bottom species, the oyster usually occurs only on the shoulders of the floor of the Bay where sediments are firmer and oxygen depletion is less likely than in deep waters. Most oysters are in less than 25 feet of water. They are semi-buried with the lip of the shell exposed to the water. Seed areas, producing a crop of small oysters which can be transplanted to other areas, are reasonably well identified. Many beds are self-sustaining while other oyster grounds are useful only for growing transplanted seed. Oysters have very great potentials for increased production since the Bay is exceptionally suitable and since they feed near the base of the food web where the quantities of available nutrition are greatest. These molluscs are intimately related to the environment and respond rapidly and measurably to improvement or degradation of the water around them. They are remarkable accumulators, and therefore provide useful information on heavy metals, pesticides, and other environmental contaminants.

Clams are also molluscs, and now contribute about 10 percent of the commercial value. Soft-shell clams are produced

[1] Ref. No. 71-28, Natural Resources Institute.

almost entirely in Maryland, while the larger harvest of hard-shell clams is in Virginia. Both live in the bottom. The hard-shell clam digs to several inches below the sediment-water interface, and the soft-shell clam may be a foot or more in the bottom. Both extend dual tubes up to the water for intake and excurrent water flow.

The blue crab is the leading food species by weight, and 70 to 90 million pounds have been landed in recent years. It is so variable in abundance that crop prediction would be of exceptional value. Except during larval stages almost all of its life is spent on or near the bottom with semihibernation while slightly embedded in the sediments during the winter months. The life history of the blue crab involves the entire Bay system and emphasizes the biological unity of that system.

These benthic oysters, clams, and crabs provide about 75 percent of the total value of commercial fisheries of the Chesapeake Bay. Fish yield the remaining 25 percent of value although they involve about 80 percent of the weight landed.

The menhaden sometimes provide 300 to 400 millions of pounds of fish, dominating the weight of all commercial fisheries landed. The fish is used for fish meal, oil, and valuable secondary products. The catch has seriously declined in recent years, but there is some evidence of recovery. Menhaden are migratory and show a strong schooling pattern. One remote sensing system, visual sensing from a small plane, is extensively used by the industry with 18 to 20 planes in use along the Atlantic Coast and 32 to 35 along the Gulf (ref. 2). They locate schools from an altitude of 500 to 1000 feet by noting reddish-brown colored areas or a large abrasion on the surface. The pilot sometimes assists further by directing the set of the purse net around the school.

Alewives are herrings which live in the sea but, like other anadromous species, migrate annually back to fresh water for spawning. These, along with river herring and the hickory shad, contribute 30 to 40 million pounds of fish to the annual Bay catch. They are used as food for people and their pets and as bait. Demand is not high, and many biologists see substantial potentials for increased yield from this species.

The shad is also an anadromous species, but one which is declining in catch. Dams, pollution, and heavy fishing have all been charged with contributing to decline. Present demand is not great. Shad spawn in fresh water, spend their first summer in the Bay, and then go to sea. At about four years of age, they return to the Bay and successfully select the bay, river, and tributary of their origin. Their sensor and sorter systems for this remarkable sequential selection and response are not known.

The striped bass, locally called rock, is highly prized as food, and recent catches have ranged from 5 to 8 million pounds. The species uses the entire estuary, and a small percentage of the Chesapeake population spills out into the ocean to become a large percentage of the North Atlantic catch. Striped bass migrate to spawning areas near the fresh-salt water interface, and these areas are fairly well-identified. They are especially vulnerable to damage from pollution, especially from the many cities and towns located near the fall line at the upper end of easy navigation from the Bay.

Many other fish enter the commercial catch in smaller quantities including bluefish, gray sea trout, yellow and white perch, croaker, spot, sea bass, butterfish, flounders, swellfish, eels, carp, catfish, and others. For every useful species there is serious need for increased ability to measure abundance and track movements—both of which are susceptible to remote sensing.

### Recreational Fisheries

Hundreds of thousands of people fish the Bay each year, and they catch millions of pounds of fish. Accurate statistics are not available, but careful estimates by experienced scientists suggest that sport catch of some species, like striped bass, equals or exceeds the commercial catch in weight and far exceeds it in value. Principal species also include white perch, bluefish, croaker, spot, sea trout, and flounders as well as crabs, clams and a few oysters. Recreational fishing, like other leisure-time activities, is rapidly increasing and the trend is most likely to continue.

### Reptiles, Birds, and Mammals

The diamondback terrapin was long a gourmet species but is now in little demand. Abundant in many tributaries, they and other turtles live a semiaquatic life.

Since the Chesapeake lies on the eastern fly-way for migrating waterfowl, large populations visit the area for winter feeding. Native populations of black duck, mallard, and other species remain throughout the year. The total number of ducks, geese, swan, and related waterfowl in Maryland alone, as estimated by annual aerial survey, has ranged from 750 000 to 980 000 in the last five years.

Mammals abound in the large wetlands of the Bay region. Over 200 000 muskrats were caught in 1970, and mink, otter, fox, raccoon, and nutria are also of commercial value.

### Potentials

Many species are unused or underutilized in and around the Bay. Caution should be exercised in efforts to increase the extraction of proteins and other biological materials from the estuary, because present trophic relationships might be damaged or other undesirable effects might be achieved. Serious consideration could, however, be directed toward use of several large crops.

Marsh grasses of several types, rooted aquatic plants, and abundant macroscopic algae offer potentials. They make essential contributions to the nutritional cycles of the Bay, but there may be a surplus available for harvest.

Among fish, several herrings, the hogchoker, anchovies, silversides, and white perch all maintain large populations worth exploring for exploitation. Bloodworms and several small molluscs also may have use.

The plankton populations have never been used directly for human purposes. They contain large quantities of organic material, although it is pertinent to note that high total production is frequently achieved through rapid turnover rather than through huge standing crops. The total plankton contains egg and larval stages of almost all estuarine species, and due caution should be exercised in selecting areas and seasons for possible harvest.

### Negative Resources

Sea nettles are sometimes abundant and can cause considerable personal annoyance and economic damage. Such species of plants as Eurasian water milfoil and water chestnut have invaded portions of the Bay and caused damage by crowding out other species, clogging waterways, increasing local sedimentation, deposition of injurious seedcases, and by other means. Surveys of these plants by low-flying airplanes have been of assistance to ground-level studies of distribution and abundance.

### Supportive Resources

There is insufficient knowledge of the nutritional requirements of most Bay species to permit quantitative determination of the importance of various foods. Several biological resources are thought to be essential, however. The complex wetlands, for instance, act as giant factories of organic material as well as large areas of protective habitat for juvenile fish and other marine life. The phytoplankton and zooplankton populations must be available in suitable quantity and quality to feed the useful species. Small fish, especially the anchovy, silversides, and young menhaden, are consumed in large quantities by predacious fish, and their abundance may determine the availability of desired fish. Management efforts must take these factors into proper account if the extraction of biological resources is to be optimal.

## REMOTE SENSING PRACTICE AND POSSIBILITIES

Reception of information which is useful in managing or harvesting resources can involve both direct observation of the organisms and indirect evidence obtained through associated events or biological products.

**Sensing Organisms**

Bottom species have always presented serious difficulties in surveying. These include oysters, clams, crabs, many benthic fish, and some plants. The oyster beds of the Bay were first surveyed early in the century by use of piano wire attached to a drag towed along the bottom. An experienced hand on the wire, roughly calibrated by scattered samples from the bottom, assisted in outlining the areas of useful oyster populations. Some of these outlines are still useful, and practicing oystermen still feel the dredge cable for information. More recently a first effort to apply high resolution sidelooking sonar as a scanning device was attempted by Westinghouse (ref. 3). Detection of shelled areas was possible, but discretion between shell and oysters was not.

At the Symposium on Remote Sensing in Marine Biology and Fishery Resources held in January at Texas A&M, Kelly reported considerable success in discerning, surveying, and predicting shallow-water (less than 4 meters) beds of edible mussels, eel grass, and green algae (ref. 4). Photography with Ektachrome and panchromatic film, with various filters, was of considerable value at altitudes of 3000 to 5000 feet. He suggests the many values such synoptic observation might serve. Higher altitudes are useful for obtaining patterns, but lower altitude observation appears to be essential for interpretation. He expressed the opinion that present satellite imagery probably does not provide sufficient resolution for use in such studies.

In the Chesapeake Bay, beds of vegetation are readily visible from planes, and species patterns are strongly suggested. About 5 to 7 years ago, serious consideration was given to the use of visual and photographic surveys for Eurasian milfoil, but experienced observers could not distinguish it from consorting species except at or near ground level. Turbidity is relatively high, but the annual period of minima in late winter may be useful, as might the exceptionally good visibility noted by skin divers in Eastern Bay and other specific regions.

Potentials appear to be seriously limited for obtaining information on oysters, clams, and crabs by remote sensing. There are serious difficulties involved in crossing air-water interface and penetrating the suspended material in Bay waters; the biological habits of these species are not helpful. Clams live in the bottom and are visibly detectable only by the small pits around their siphons. Oysters are difficult to discern for skin divers. Crabs work their way slightly into the bottom in winter and frequently crawl very close to it in summer. All do have shells much harder than the usual substrate, and this may offer opportunities for sensing. All of them might, however, carry small sensors to obtain in situ information on physiology and behavior.

Swimming species, including most fish, squid, and a few other forms, have also been sensed by various primitive and sophisticated techniques. Many species can be identified accurately by underwater acoustical sensors, and sometimes helpful information can be obtained on density. In a converse sense, fish can hear and respond to acoustic signals and that ability has been used through both primitive noise makers and more elaborate equipment for attracting and catching them.

Acoustic sensing is now a precise and valuable tool. Midttun (ref. 5) describes present echo-sounding and estimation techniques in Norway and other countries. They can assist in locating fish and estimating abundance, and they sometimes indicate the species. He provides comment on some of the pertinent limiting conditions and also suggests ways in which computer competence can improve the general method.

Implanted radio transmitters are already in use in the Bay and at other coastal sites. Carlson (ref. 6) used them to track the movements of shad transplanted above the Conowingo Dam on the Susquehanna River. J.A. Mihursky and T.S. Koo, at the Chesapeake Biological Laboratory, are employing them, respectively, to learn the response of striped bass to the intake and outfall conditions at power plants, and to learn the behavior of fish in the Chesapeake and Delaware Canal as it undergoes enlargement. As with salmon on the West Coast, these sensor systems have present value which can be enhanced by further miniaturization.

Spectrophotometric techniques may eventually be useful in relation to schooling fish like menhaden, striped bass, bluefish, and baitfish. Drennan (ref. 7) reported that the spectral reflectance of fifteen schooling species (in impoundments and held near the water surface) were separable by species and different from sea water. He calculated the expected reflectance curves obtained from a plane at 1000 feet with the fish at a depth of 50 centimeters, and estimated that fish could be detected if they occupied 10 percent of more of the area under the surface.

Drennan also discussed the embryonic possibilities of using a laser. Sensors of these coherent beams of monochromatic light are able to measure distance, and therefore to detect difference in distance, with fantastic precision. He cites airborne bathymetric sensing through water 250 feet or more in depth and measurement of wave height with accuracies in terms of inches. Further he noted that his spectrophotometric studies showed that the tested species of fish had a reflectance of 3 to 9 percent of the wavelength band of interest, while sea water varies from approximately 0.3 to 3 percent. Such laser equipment is apparently within the load capabilities of planes and satellites.

The surface manifestations of fish and other organisms have already been noted in part. Schools of menhaden and cow-nose rays can easily be seen from the air. Exceptionally dense and colorful plankton populations are highly visible in the form of red or mahogany tides of dinoflagellates and the paint-green surface populations of algae in the Potomac, below Washington, in summer. More subtle signatures of surface and near-surface populations are probably detectable.

The edge of the Bay, containing hundreds of thousands of acres of various types of marsh and wetlands, offers exceptional opportunities for advantageous use of remote sensing. Such techniques, from planes, have been used for specific areas for several years. As reported elsewhere in the Conference, Maryland is now surveying some of its wetland areas, and the Chesapeake Center for Field Biology of the Smithsonian Institution is making detailed analysis of photographic coverage of the Center by infrared and visible-light photographs. Richard Anderson at the American University and others are examining the possibilities of determining the species present, their distribution, relationships to various environmental parameters, and the changes which are occurring with time. Remote sensing at all levels from surface to satellite appears to have unique and high value for the definition, understanding, and management of such edges.

Aerial species, including ducks, geese, swan, and other birds, have been surveyed by eye from small planes to provide valuable population estimates. Efforts to utilize photographic surveys for this purpose have generally been disappointing. At least two other remote sensing uses are, however, quite promising.[2] Wild-fowl habitat information can be rapidly, accurately, and repetitively obtained. Attached radio transmitters have been essential in W.J. Sladen's efforts to track the movements of whistling swan during spring migrations. Other uses will probably emerge.

### Sensing the Associated Environment

Meteorological information should have value to fishery biologists–else every fisherman is wrong in his legendary use of weather to predict catch. In the Bay, the specific effects of cloud cover, weather systems, and other patterns on fish distribution and behavior are not established. Perhaps they could be examined with profit.

Chemical features of the Bay of importance to biological events include salinity and the complex which is termed "water quality." Since the sensing of such features is discussed elsewhere, no further comment is appropriate here.

Physical circumstances which may be helpful in understanding, managing, and using biological crops include flow lines, eddies, depth, bottom contours, color, silt, temperature, surface abrasions, and emitted light. Only the last, which might not be treated by others at this conference, merits special comment.

At the Texas Symposium, Hornig (ref. 8) discussed the use of stimulated fluorescence in detecting and identifying fish oils. He used an arc lamp as a stimulant, and could distinguish the spectra emitted by a half dozen species of fish. He concludes that arc or laser stimulating of fluorescence provides a new and useful supplementary technique.

Drennan (ref. 7) considered some of the possibilities of using fish-stimulated bioluminescence to locate fish. In the Chesapeake Bay, bioluminescence occurs year-round from the comb-jellies or ctenophores, which are most noticeable in summer; from *Noctiluca* and other dinoflagellates; and from less obvious species. Drennan noted that the light reaching a sensor is affected by several important factors, but that present capabilities of intensifying images by a factor of up to 75 000 may provide a highly useful tool. It seems worth exploration in the Chesapeake Bay.

Secondary biological evidence on populations can frequently be obtained. The food of fish, such as plankton or prey fish, may be more easily detected that the predator. Birds wheeling over schools, frequently feeding on the small prey of larger carnivores, are valuable indicators and might be susceptible to scanning. We must beware, however, of the same birds wheeling over garbage. Finally, fish products–like oils from prey–may be useful as indirect evidence.

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[2]Personal communication from Vernon D. Stotts, Maryland Waterfowl Project Leader.

## POSSIBLE USES OF DATA FROM REMOTE SENSING

### Research

(1) To locate and inventory species. Synoptic and repetitive samples are especially valuable for observing changes with time in the sessile species.

(2) To examine relationships of species to associated environmental events and alterations.

(3) To assist in learning the behavioral patterns, including seasonal movements, schooling behavior, diurnal and other short-term patterns, and responses to environmental circumstances.

(4) To search for new resources.

(5) To provide clues on the best design of many types of research.

(6) To assist research on the best possible uses of remote sensing.

### Management

(1) To assist in continuing inventory.

(2) To help measure exploitation rates and distribution.

(3) To guide control efforts to enhance desired forms and reduce undesired organisms.

(4) To assist efforts to make optimal uses of wastes, especially of heat and nutrients.

(5) To monitor pollution and other unfavorable environmental circumstances.

### Fishing

(1) To determine distribution and abundance of sessile target species.

(2) To locate mobile species, estimate yield potentials, and guide specific fishing activities.

(3) To assist in developing improved short-term and long-term forecasts of abundance and distribution.

## OPERATION CHESAPEEK

From this brief review it is evident that there is urgent need for remotely sensed information about biological resources and that there are and will be valuable instruments, platforms, and techniques for obtaining such data. There are not, however, many present uses of such data. I suggest that a research and observational program be designed and completed for two purposes:

(1) To determine experimentally and from previous experience here and elsewhere the best possible application of the unique capabilities of remote sensing to Chesapeake Bay resource problems, with special attention to the uses of aerial surveys.

(2) To develop a long-term pattern for useful surveillance of Chesapeake resources.

The research phase will probably require at least two years of coordinated studies, including the following elements:

(1) Satellite observations by the widest possible variety of sensors.

(2) High- and low-level planes with selected sensors.

(3) Simultaneous ground truth for each type of aquatic, semi-aquatic, marginal, and terrestrial habitat which has been defined for this or other purposes, obtained at intervals corresponding to seasons or other biologically significant units of time.

(4) Testing of the greatest possible variety and combinations of sensors, films, filters, frequency of observation, and altitudes.

The observational phase will require:

(1) Regular repetition of selected coverage on defined schedule and use of defined elevations, sensors, films, filters, and other techniques.

(2) Availability of equipment and staff for supplemental, exceptional, and urgent observations.

(3) Wide distribution of films and other products to scientists, resource managers, and fishermen (as well as to planners and users in many other fields).

(4) Effective assistance in interpretation for all potential users.

(5) Maintenance of a continuing program of research to improve the design, quality, and use of remote sensing operations for Chesapeake Bay.

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# Agriculture and Forestry—Identification, Vigor, and Disease

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The Chesapeake Bay watershed is situated in the middle of a rapidly developing region which is becoming very heavily populated. The condition of the vegetation and general land use is most important in maintaining a suitable environmental quality of both the land and the Bay. The vegetation not only provides food, feed, and fiber, but protects the soil from erosion and the Chesapeake Bay from siltation and high turbidity.

The agricultural production of the tidewater region of the watershed is of great value to the human population. The economic value is estimated to be about $500 million per year. The agricultural production and forestry is threatened by urban encroachment and pollution in addition to the usual plant diseases and insect and other infestations. Accurate inventory and assessment of these threats are required.

Poor management of agricultural areas is leading to erosion and depletion of fertility. Better ecological knowledge is required to understand the problems so that better land management could be effected.

This paper describes the agricultural and forestry areas in the watershed as well as the production of the watershed; outlines major problems of the watershed; discusses remote sensing as it relates to identification of plant species and vigor, pollution, disease, and insect infestation; and presents the recent results of remote sensing of the Rhode River watershed.

## AGRICULTURE AND FORESTRY

The Chesapeake Bay watershed including the tidewater counties of Maryland, Virginia, and Delaware covers an area of about 100 by 200 miles or about 20 000 square miles. This area is divided as follows:

| | Square miles |
|---|---|
| Maryland | 6800 |
| Virginia | 6700 |
| Delaware | 2100 |
| Chesapeake Bay and tributaries | 4400 |
| Total | 20 000 |

The Bay receives water from a watershed of about 65 000 square miles with over 50 tributary rivers. The Susquehanna River drains 50 percent of the basin. About 15 000 square miles are in the coastal plain and about 50 000 square miles are in the Piedmont region.

Of the 20 000 square miles of the Chesapeake Bay watershed, 15 600 square miles are land. Table 1 shows the distribution of this land into forests, agricultural land, pasture, urban areas, and marsh wetlands.

The forest land covers an area of slightly over 6 million acres or 9450 square miles. Forests include 68 percent of the tidewater counties of Maryland, 60 percent of Virginia, and 48 percent of Delaware. The total value of the cut timber (stumpage) is about $13 million in Maryland, $13 million in Virginia, and $0.5 million in Delaware.

The forests of the Chesapeake Bay include the combination of oak, hickory, and pine as the major type, but, in the

TABLE 1.–Land Use in Chesapeake Bay Watershed

| Use | Maryland (percent) | Virginia (percent) | Delaware (percent) |
|---|---|---|---|
| Forest | 68 | 60 | 48 |
| Agricultural crops | 23 | 23 | 32 |
| Pasture | 6 | 2 | 2.5 |
| Urban/industrial | 3 | 6 | 9 |
| Coastal marsh | – | – | 8.5 |

southern part, the combinations are oak with hickory, oak with pine, loblolly pine with shortleaf pine, and oak with gum and cypress. In many areas with better soils there are a large number of mixed mesophytic deciduous species with maple, tulip tree, beech, gum, various species of oak, floodplain species of ash, elm, maple, sycamore, birch, and many other species. The main timber trees are red and white oak, tulip tree, pine, sweetgum and various other hardwoods.

The agricultural cropland of the tidewater counties covers an area of 2 348 861 acres or 3670 square miles. The agricultural cropland of the watershed in Maryland is 23 percent, in Virginia 23 percent, and in Delaware 32 percent. The value of agricultural crops and livestock of this region is an estimated $500 million dollars.

Figure 1 shows the agricultural crops of the Chesapeake Bay watershed. These include mainly corn, soybeans, barley, potatoes, tobacco, peanuts, hay, and tomatoes and other vegetables. The eastern shore of Maryland is agriculturally suited for truck crops because of its sandy productive soil, sufficient water, and long growing period. The most important crops are soybeans, corn, wheat, and vegetable crops. On the western shore of Maryland the major crops are hay, corn, tobacco, wheat, and some soybeans and vegetables. In the Virginia region, the main agricultural crops are corn, soybeans, peanuts, wheat, barley, and tobacco. In the Delaware area the main crops are corn, soybeans, hay, barley, rye, oats, and lima beans, and other vegetables.

The livestock and poultry industry is fairly extensive and includes dairy and beef cattle, hogs, and chickens. In Delaware the value of the livestock, poultry, and products is about $95 million per year.

Extensive vegetation along the Chesapeake Bay shoreline includes salt marshes and wetlands. This vegetation is estimated to be 8.5 percent of the land area in Delaware alone. These areas are of great importance to wildlife and production of aquatic life. The main vegetation is grass of various types, saltbush, cattail, and many other species of plants. Salt grass is mowed in some of the regions and is valuable for mulch and other uses.

Floating aquatic vegetation has been a major cause of clogging in the navigable waterways. In 1968 an estimated 200 000 acres were infested with European waterfoil *Myriophyllum spicatum*. However, the plant decreased greatly in amount due to disease.

Figure 2 shows the state parks, state wildlife management areas, state forests, private research and natural areas, and national wildlife refuges. The total area in the watershed is about 400 square miles. Much of this is located in salt marshes and wetlands. The wildlife includes many species of birds and mammals, both terrestrial and aquatic. The main hunted species are ducks and geese, quail, rail, rabbit, squirrel, and deer.

## PROBLEMS

### Ecological Understanding and Proper Land Management

The major problem is to achieve proper understanding of the ecology of the region. Optimal land management requires accurate census and inventory of present land use, changes and trends in use, and adequate knowledge of such specifics as the soils, rainfall, erosion, fertility, pests, food, animal feed, and timber requirements. The data then must be analysed and synthesized for land use planning.

In Virginia, a conservation-needs inventory was published in February 1970 showing that 52 percent of the land needed conservation treatment of some kind. This includes 64 percent of cropland, 70 percent of pasture, 46 percent of woodland and 33 percent of other land. Susceptibility to erosion and unfavorable soil conditions in the root zones were the most serious problems. This report was based on available data, "grass roots" knowledge, and committee estimates.

Some areas in the watershed are farmed using very poor practices, resulting in loss of soil and fertility. Much worn out and eroded land is abandoned and reverts to unused unmanaged scrubland. Abandoned tobacco land is a major source of this problem. Accurate inventories of these areas are needed.

The total land area in farms in Maryland was about 5 million acres in 1900 and about 3.5 million in 1955. There is a decrease in cropland at present on the western and northern shore areas but an increase on the eastern shore.

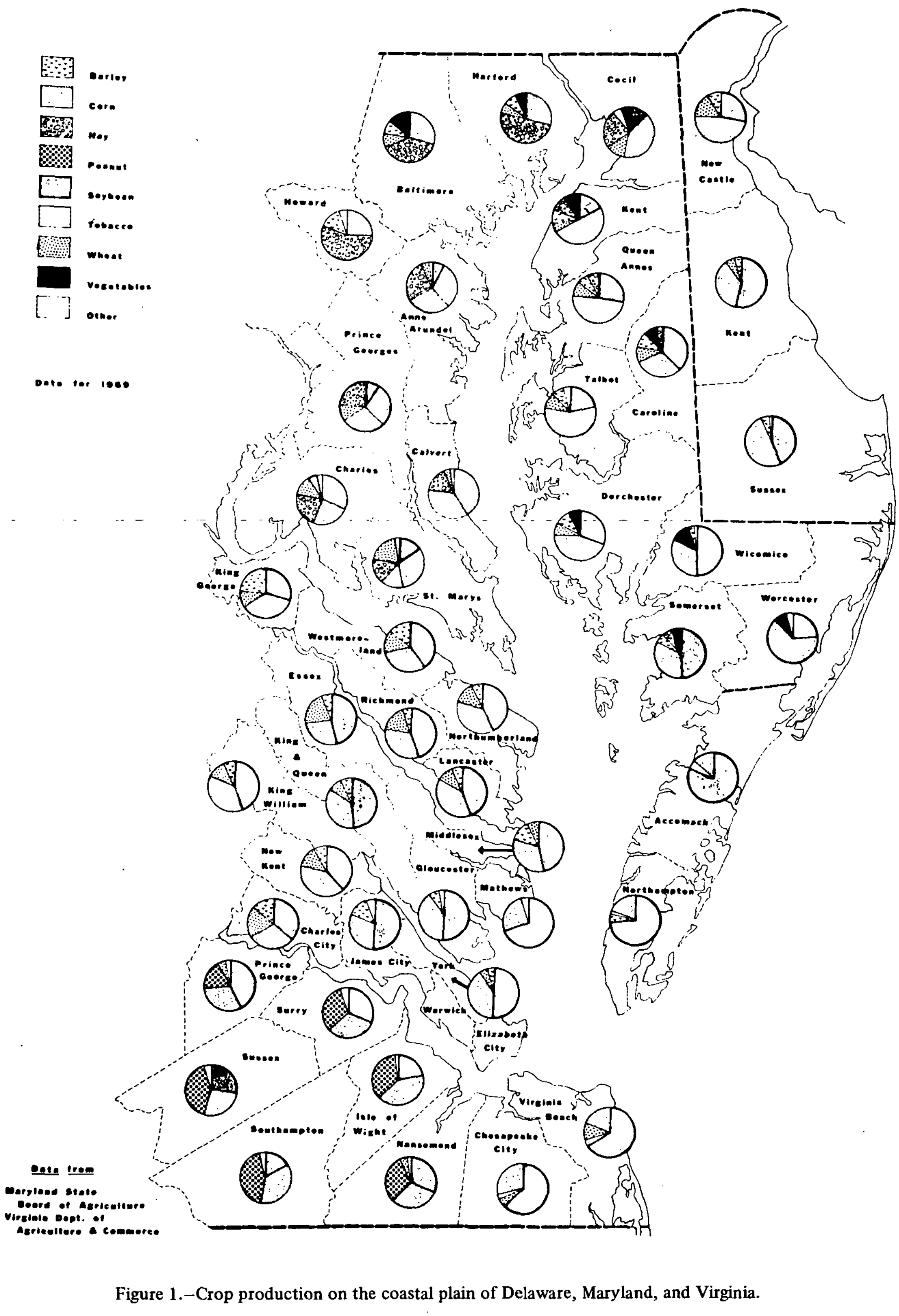


Figure 1.–Crop production on the coastal plain of Delaware, Maryland, and Virginia.

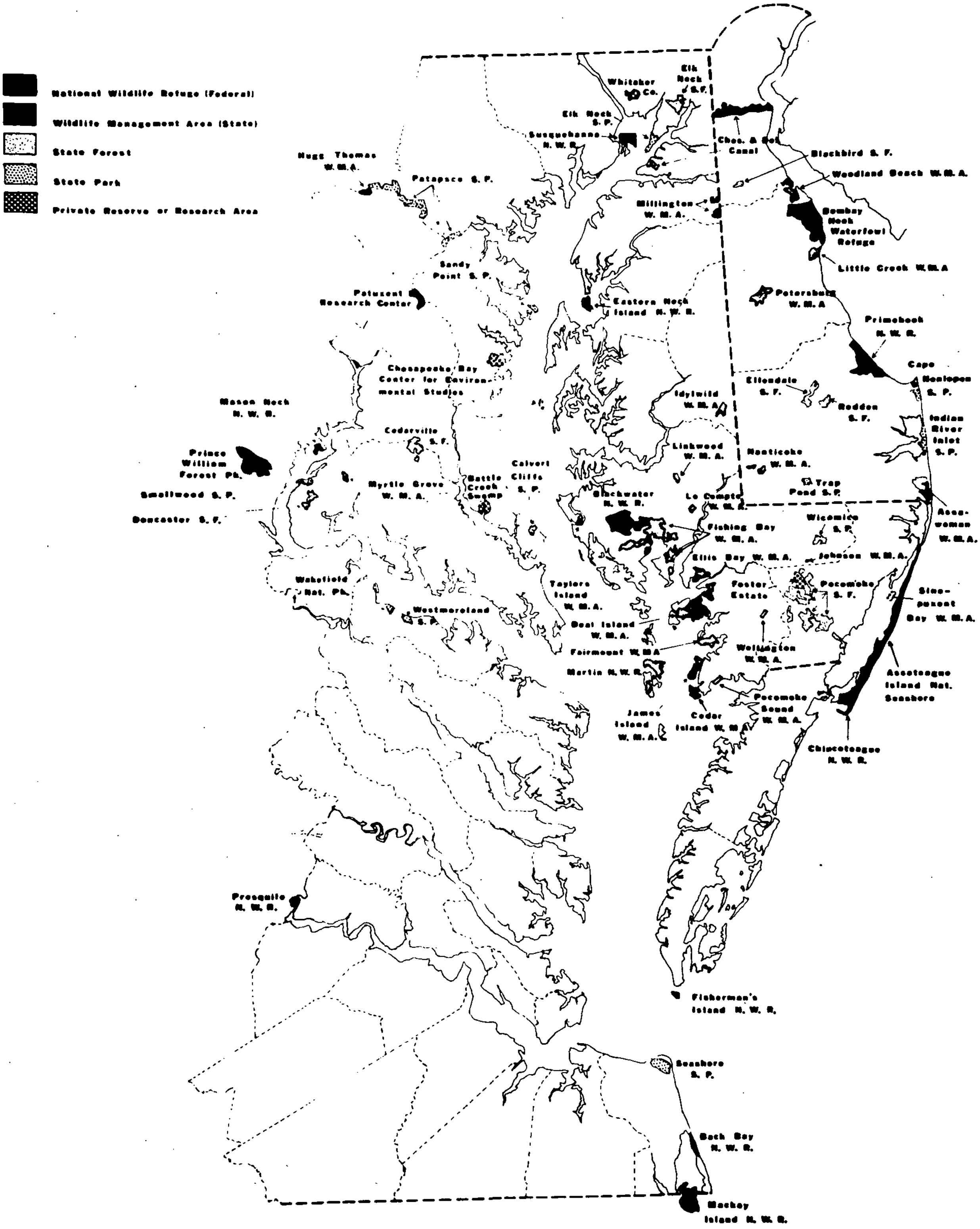


Figure 2.–Protected areas on the coastal plain of Delaware, Maryland, and Virginia.

#### Population Increase

A second major problem is the population increase in the watershed. Population expansion and suburban encroachment result in development of urban areas with housing, paving, industrial facilities, highways, and other facilities. Installation of these facilities results in destruction of forests, agricultural land, and waterfront. In addition, the bulldozing, grading, and changes in drainage result in greatly increased erosion and pollution. The presence of people, with accompanying air pollution from burning of coal, factory exhaust, automobile exhaust, and other air pollutants, results in air pollution injury to plants and destruction or damage to various species. (The population of the immediate Bay area was 2.8 million people in 1960 and is expected to double by 1985.)

Remote sensing can document these changes accurately and show the rate of urbanization and loss of forest and agricultural area. Eroded areas and resulting sedimentation in the streams and estuaries can also be observed.

#### Damage to Agricultural Crops and Forests

The major causes of damage to the agricultural crops and forest of the watershed are air pollution, diseases, insect infestations, and drought.

The air pollution damage to agricultural crops, forests, and livestock in the watershed is relatively unknown and needs to be assessed. It has been estimated that the total damage to plants in the entire United States from air pollution is about $500 million per year. The watershed is heavily populated, contains large cities, industrial areas, and many automobiles. Some of the crops such as tobacco and vegetables are quite susceptible to air pollution damage. Surveys of air pollution damage to plants should be concentrated in the vicinity of and down wind from major cities and industrial areas.

Plant diseases are known to cause much damage to many agricultural crops and some damage to forests in the watershed. Some of the most important plant diseases are southern corn leaf blight, soybean stem blight, potato leaf blight, and root rot of various forest species. The southern corn leaf blight is expected to be very serious in the watershed in the 1971 season and could result in nearly complete loss of the crop. The T-strain of hybrid corn presently planted in the region is highly susceptible, and overwintering blight in the region from 1970 is anticipated to be the source of severe damage. Accurate surveys in the 1971 growing season are essential.

Insect damage to the agricultural crops of the watershed is fairly extensive and most of the crops require insecticide treatments. In addition nematodes and spider mites also produce damage. Surveys of the insect damage are required to permit proper treatment. A special problem is the southern pine beetle which is destroying much loblolly pine in the watershed. Studies have already been carried out to determine the effectiveness of remote sensing to detect insect infestation of the pines.

## REMOTE SENSING

#### Vegetation and Animals

Identification of species of plants by remote sensing has been developed into a science for certain species. Aerial photography has been used for about 30 years in studying vegetation, especially in forestry. Identification of species of vegetation by multispectral remote sensing has been developed rapidly during the last few years. A major advance has been the use of spectral signatures that permit identification without necessarily resolving spatial properties. Identification of certain species of forest, range, or crop plants can be determined with a high degree of accuracy and precision if the right conditions and techniques are utilized. The correct combination of spectral bands at the right altitude, season, time of day, condition of crop, and with proper light conditions, permits accurate identification in the hands of experienced photointerpreters.

Forest surveys of conifers and deciduous species have been made with accurate species identification in mountainous and other areas. A forester who knows the species of conifers and deciduous species in some areas can readily identify all of the species using color infrared photography. Identification of species on air photographs is difficult in the eastern deciduous forest where there may be many species which appear quite similar in various spectral bands during most of the summer. Air photographs taken at the time of fall leaf coloration helps identify species and groups of species.

In the identification of plant species in the fields of forestry, agriculture, and ecology, sensor-signature research is the single most important pacing element upon which progress depends. Specifically, accurate data on emission and reflectance properties of biological and physical materials are needed. This includes variations of reflectivity and emissivity with wave length (i.e., spectra) and with spatial position (i.e., shape), polarization introduced by the material or its condition, and variations of reflectivity and emissivity with time, including diurnal and seasonal cycles.

Crop plant identification of various species in monoculture has progressed rather rapidly. It is presently possible to distinguish between closely related species, such as wheat and oats, using multispectral sensing under specific selected conditions. The identification characteristics using many spectral bands have been computerized so that automatic identification is potentially possible.

Multispectral sensors using a variety of regions of the electromagnetic spectrum has been shown to be highly effective in making identifications not otherwise possible. This includes particularly the spectrum from 0.3 to 15 microns from ultraviolet to infrared and, in addition, microwave and radar. Use of photographic film from 0.3 to 0.9 micron images allows additional selection of methods. Multiple processing systems further enhance the effectiveness of remote sensing. In photography the pictures can be enhanced by color and electronic methods and accurately measured with densitometers.

The use of remote sensing for making censuses and counting wildlife and domestic animals is now limited to surveying animals the size of sheep or larger. Present techniques include low altitude aircraft photography using black and white, color, and infrared film, and infrared optical scanning.

Animals can be observed and their movements, migration, and effects on the environment determined. Larger animals, particularly larger ungulates such as deer, elk, and cattle can be distinguished by an infrared thermal scanner in the 8 to 14 micron range with a 3 milliradians (3 feet/1000 feet altitude) field of view with a 1°C temperature differential between the animal and its background. This is a compromise between temperature sensitivity and resolution. Successful population census counts have been made of white-tailed deer using infrared sensing. Ideal conditions for detecting animals were little or no wind, snow background, high overcast sky, daytime, and absence of leaves on deciduous trees. Differentiation between different animal species by infrared scanning would be possible only with animals of very different size.

Cattle, sheep, and horses were differentiated and counted using panchromatic black-and-white film at 1:5000 scale during early morning hours, with winter-spring green grass. In cultivated areas the correlation of ground count to image counts was excellent, but in open range, errors were greater. Good results were obtained using color transparencies at 1:2500 scale in addition to black and white at 1:5000 scale.

Larger flocks of geese, ducks, and seabirds can be observed by remote sensing. Swan have been counted on Chesapeake Bay using infrared film. Bird migration has been studied using radar. Nocturnal bird migrations have been scanned by radar equipment at the NASA Wallops Station.

Changes in plant growth vigor may be due to disease, insect and animal damage, air pollution, soil pollution or mineral or nutrient deficiency, senescence, insufficient water supply, or other causes of physiological stress. These may result in changes of geometry and density of foliage, including loss of leaves, loss of turgor in leaves, wilt and shrivel, browning or change in color of the leaves, exposure of bark and branches and shadow areas as well as a decrease in evapotranspiration, and an increase in temperature of the leaves. All of these factors produce changes in the spectral signatures of the plants and show that a change has occurred. From examination of air photographs it is not usually possible to identify the cause of change unless accompanied by ground-truth observations which identify the cause. Since many of the changes produce effects sensed in the near infrared but not visible to the human eye, remote sensing using infrared film and infrared scanning can detect early changes in plants before a trained observer can detect them on the ground.

Identification of plant disease and insect infestation is very important, especially during the early stages, to permit more effective treatment or to take appropriate action. Also it is very helpful to be able to make rapid surveys to determine the extent and specific area of the outbreaks. Experimental studies of plant disease and insect infestations have shown that many types of outbreaks can be detected using multispectral sensing, particularly in the infrared. A variety of plant disease outbreaks has been detected by remote sensing using infrared. Some of these techniques are already being used with various degrees of success in certain areas. Various insect pest infestations have been identified using remote sensing. Identification of beetle-infested trees has been of main interest.

#### Ecological Changes

Alteration of natural ecosystems is, of course, manifest in all resource problems. Without change–depletion, erosion, pollution, accrual, or epidemic–the problem is seldom recognized. This is perhaps the easiest type of information to procure by repetitive aerial surveillance and has been exploited with photography in the visual wavelengths. Thus, with time, old conventional aerial photography may gain value as indices to change, but until repetitive aerial reconnaissance is widely practiced, long-term and widespread change, man-caused or natural, will often be difficult to assess. Once trends of change or the consequences of technology are evaluated, alternatives can often be developed from the same data. This is perhaps the most promising application for photography from spacecraft.

In the study of the ecology of an area, use of infrared photography, multispectral sensing, and particularly sequential survey can show many changes and dynamic processes. The following have been remotely sensed or are showing great promise for the future:

Fire–including fire, smoke, burn area, and revegetation

Wind–damage to crops and forest

Flooding–extent of flood and damage assessment

Waterlogging of soils

Erosion–increase of gullies and river erosion

Disease–crop and forest diseases, local and epiphytotic

Insect infestation–crop and forest, and locust plagues

Drying–low moisture in plants, drought

Grazing–overgrazing, animal trails

Salinization–mineral deficiency; e.g., chlorosis

Harvesting of crops and indication of yield

Lumbering–volume of timber cut

Weed infestation and spread

Radiation effects on survival and growth

Planting and growth

Revegetation and pioneer plants

Leaf out and flowering, color change, and leaf fall

Maturing of fruit and crops

Succession of vegetation communities

Vegetation zones and community boundaries

Cultivation of nonarable land; fencing

Change in land use

Sequential surveys using "change detection analysis" greatly enhance the entire remote sensing system. More specific identifications can be made as well as identification of significant and important changes. These may be very short time periods, measurable in minutes, involving fires, animal movements, or floods, or the changes may take days or weeks and involve changes in animal migration and movement, fires, floods, vegetation changes, insect outbreaks or disease infestations. Changes over months involve crop changes including maturation, harvesting, disease and insect infestation, lumbering, clearing, reseeding, overgrazing, and others. Changes involving years include plant succession, forest growth, land use change, and urbanization.

## REMOTE SENSING OF THE RHODE RIVER ESTUARY

Ecological research involving the use of remote sensing (multispectral aerial photographic techniques) was initiated by NASA Wallops Station and the Smithsonian Institution in September 1970. The study site is the Rhode River estuary watershed which is located about seven miles south of Annapolis on the western shore of Chesapeake Bay (fig. 3). The watershed includes about 12 square miles of land area and about four square miles of estuary. The Smithsonian Institution owns 1272 acres of relatively undisturbed land which is the location of the Chesapeake Bay Center for Environmental Studies. The watershed is the site of an ecosystem study and a community action planning program. Studies are underway by scientists from the Smithsonian, Johns Hopkins University, the University of Maryland, and the U.S. Geological Survey (fig. 4).

The Rhode River watershed is well suited for the remote sensing program because of its convenient location and because many of the characteristics of the much larger Chesapeake Bay watershed, which NASA has already chosen as a prime target study site, can be studied there in smaller scale.

The objectives of the Rhode River watershed project are:

(1) To evaluate the applicability of remote sensing data to analyses of the composition of forest, field, agricultural crops, and marsh vegetation in the Chesapeake Bay area

(2) To determine how well these data correlate with soil types and the various physical, chemical, and biological factors of the water surface of the Rhode River estuary

(3) To determine the value of remote sensing in studying population encroachment and community and suburban planning and development

The results to date of the vegetation studies are summarized here:

The Rhode River watershed is predominantly an agricultural area which is slowly becoming more heavily populated by suburban encroachment. The eastern shore of Rhode River is populated by the towns of Mayo and Beverly Beach. The western shore remains undeveloped since most of it is owned either by the Smithsonian or by families interested in the preservation of wildlife and the natural environment of the area. This particular shoreline (approximately 13.5 miles long) is one of the largest relatively undisturbed areas remaining on the western side of the Chesapeake Bay. The topography of the Rhode River watershed is chiefly rolling upland, much dissected by narrow stream valleys which broaden to level floodplains along the courses of Muddy Creek, the principal tributary stream.

Approximately 45 percent of the land area of the watershed is cultivated to grain, tobacco, and truck farms. The recent farmers have wisely left most of the stream valleys and floodplains covered with forest, so soil erosion is presently minimal. Forests cover approximately 35 percent of the watershed. The remaining 20 percent includes abandoned fields, marshes, and the towns of Mayo and Beverly Beach (fig. 4).

The watershed has been flown by NASA helicopters, the University of Michigan's DC-7, the NASA's RB-57, and the Air Force's B-57. The area has been photographed using black-and-white and color infrared, and black-and-white film, color film, and infrared scanning from 4.5 to 5.5 microns and 8 to 14 microns. Various areas have been flown in the summer, fall, winter, and early spring.

The search for reliable ground-truth correlations with remote sensing data has followed two approaches:

(1) The preparation of a detailed vegetation map of the entire watershed

(2) The selection of four small areas for intensive study of young and moderately mature deciduous forest, recently abandoned farmland, and salt marsh

A detailed reconnaissance and mapping of the forest vegetation in the Rhode River watershed was begun in November 1970 to obtain ground-truth data which could be correlated with a photographic survey of the watershed

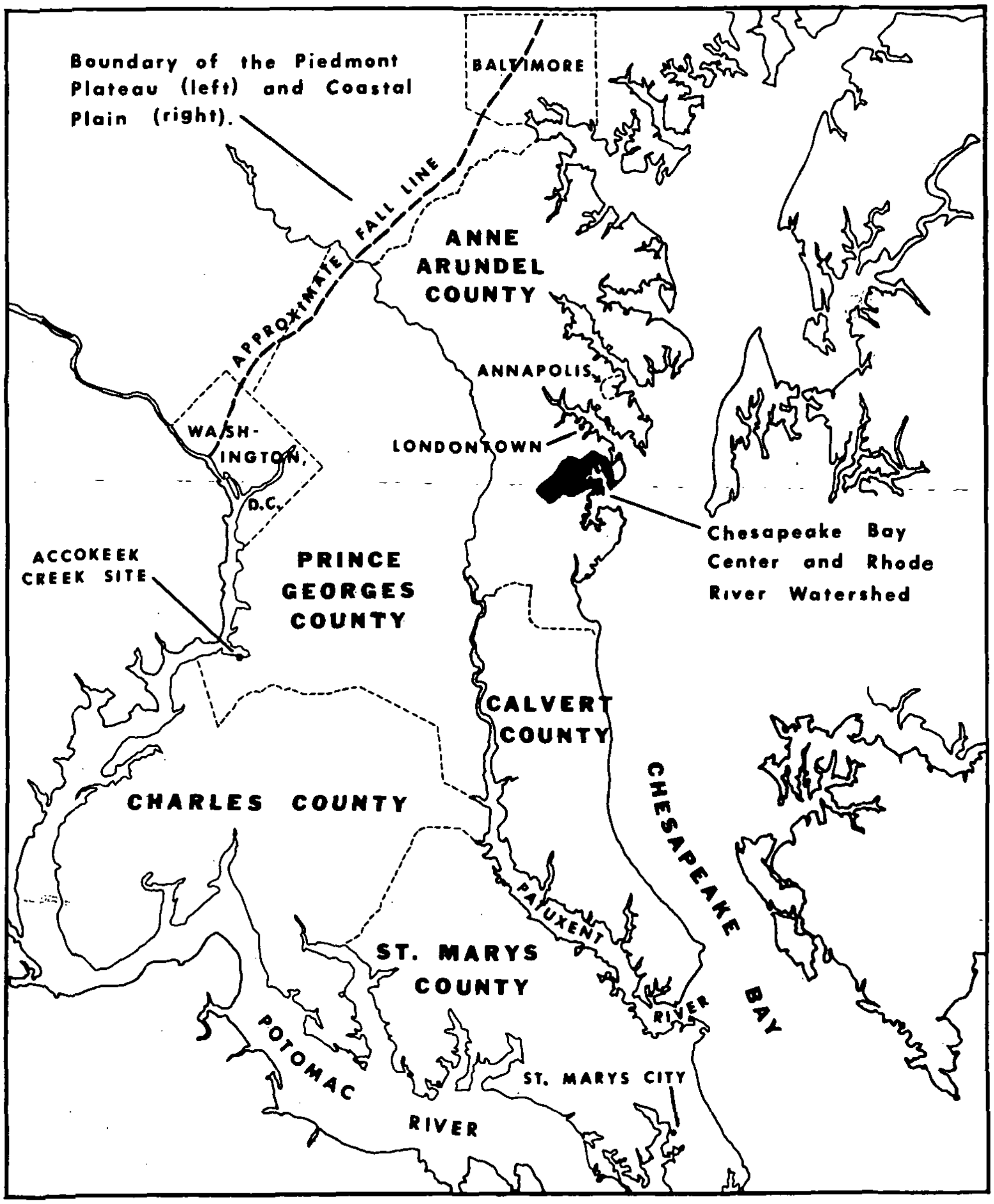


Figure 3.–Location of the Chesapeake Bay Center and related sites, west shore.

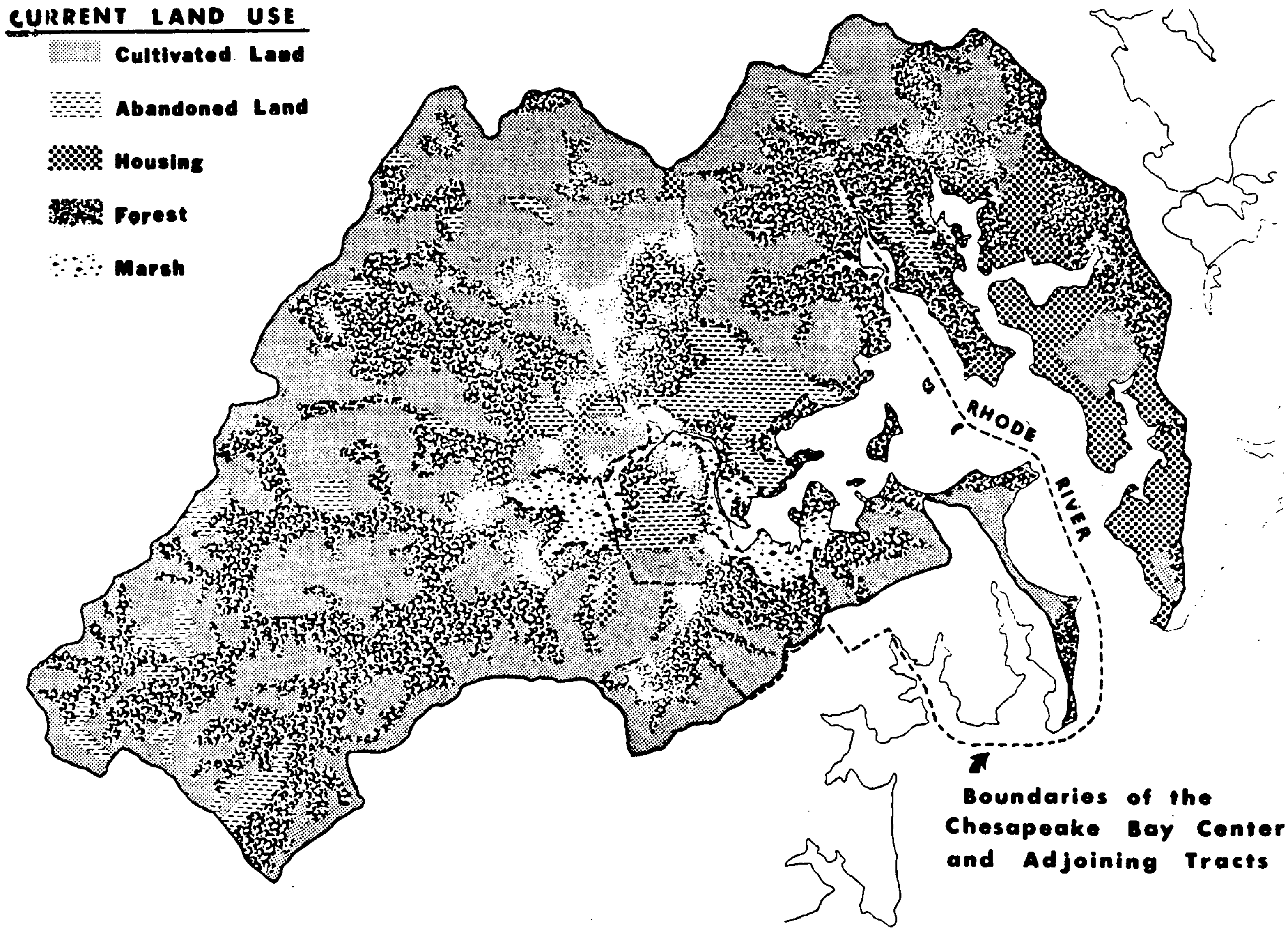


Figure 4.–The watershed of Rhode River.

under different seasonal conditions. Since most of the watershed which is not under cultivation is covered with deciduous forest, completion of the field survey was desired before all the leaves had fallen.

The forest areas were surveyed on foot. The composition of the canopy was typed on the basis of species which dominated or characterized particular forest communities. Typing was done on a biomass-dominance basis where the species of greatest biomass were considered dominants in an area (biomass was determined subjectively from basal area, height, coverage, and density determinations). These types were recorded on topographic maps. Those features of the subcanopy vegetation which might be observable from the air in winter or early spring were noted (the presence of flowering dogwoods, evergreen, honeysuckle, etc.). Major topographic variations and the presence of streams and swampy areas were also recorded because of their potential value in aerial identification of forest vegetation types.

The vegetation was mapped on a mosaic of aerial photographs taken in 1968 at a scale of 1:5000. Forest types, types of vegetation in swamps, and abandoned fields were also mapped.

Remote sensing data have already confirmed the locations of stands of coniferous trees and of several patterns in the hardwood forest canopy. Increasingly close correlations between the field notes and the remote sensing data are expected as more photographs of the watershed are examined and continued study of the four test areas provides more criteria for the identification of plant associations, individual species, and environmental features.

For more detailed correlation of aerial photos with ground data, four intensive study sites were selected in the watershed. The four test areas were photographed several times in different spectra and at different altitudes providing the best material for establishing reliable criteria in identifying single trees or the composition of small stands. Plant communities were most easily delimited in the salt marsh and abandoned fields. In these areas also, the relatively low level of vegetation facilitated the placement of markers visible from the air to pinpoint specific locations. Exact locations and community boundaries have been more difficult to place in the forest areas, and work there has concentrated on individual trees that are easily discerned, both from the air and ground.

In the Hog Island marsh study, the island was mapped for correlation of hue, chroma, and value, as well as crown texture, with individual trees. The delineation of individual crowns has been accomplished with stereoscopic analysis of photos taken from low altitude (1200 feet).

Attention has been given to the identification of photographs of vegetation over the entire watershed as well as over the four intensive study sites. In some cases individual plants or small, homogeneous stands are distinguishable from the background vegetation. Recent winter photographs show understory species and ground cover which may be valid indicators of canopy types, differentiation of conifer types, and drainage patterns.

Large, isolated trees along roads in the watershed were identified and recorded during the fall on 1:5000 scale maps and notes taken on their color and amount of leaf fall. These data are being used in conjunction with the intensive study area data for correlation of leaf color on the ground and on aerial photos.

Variations in the colors of autumn leaves were used to attempt to distinguish species of deciduous trees on aerial photographs. Although weather and other environmental factors might influence the time of leaf changing from year to year, the colors should provide a permanently reliable indication of the species.

The majority of tree species consistently turned a single color, usually fading to brown, although variations still occurred over the crowns of individual trees. A few species, notably dogwood and black gum, could be easily recognized consistently by their colors. Such species as sweetgum, sassafras, and red maple often exhibited a mixture of red and yellow leaves on the same tree. Observations of changes in leaf coloration were made for 18 species of trees and shrubs in late October and for 23 species in early November. Based on preliminary study of the photos available, natural color and color infrared film allowed the greatest differentiation of vegetation types, individual species, and drainage patterns. Transparencies were superior to prints because of the higher resolution and intensity of color. Stereo photos are essential for differentiating crowns in the intensive study areas and for identifying drainages over the whole watershed.

Low altitude (1200-foot) photos are superior to those of higher altitude for positive identification of individual trees; this superiority is due to haze reduction (especially in natural color photos) and increase in scale. Because of the variety of leaf colors in fall, photos in that season were deemed best for general photointerpretation. Winter photos were superior for characterization of understory, ground cover, and drainage patterns as well as being most useful for identification of conifers, semi-deciduous hardwoods, and hardwoods with highly reflective branches such as beech.

## ACKNOWLEDGMENTS

I would like to express appreciation for the excellent assistance of Susan Weck and Daniel Higman, botanists on the Rhode River Estuary remote sensing project, who have carried out detailed field studies and helped in preparation of this report. It is also a pleasure to acknowledge the help of Charles Vaughn, Technical Representative for the Contracting Officer from NASA Wallops Station.

# Recreational Uses

**ELBERT COX**
**Commission of Outdoor Recreation**
**Commonwealth of Virginia**

Like other agencies, the Commission of Outdoor Recreation can benefit from the application of space-age technology in its field of operation. The Commission's responsibility is to gather pertinent information on the recreation supply and needs of the Commonwealth and from these data prepare and update a statewide comprehensive outdoor recreation plan: the Virginia Outdoors Plan.

The Virginia Outdoors Plan outlines, in detail, recreation plans for the entire State. The plan calls for certain areas to be set aside as state parks, local and regional parks, scenic highways, byways and parkways, natural areas, scenic rivers, and public game and fish management areas. The Commission's interest in the Chesapeake Bay area also includes the development of private outdoor recreation projects and any problems which relate to protection of the outdoors and the natural environment. An example is the Commission's involvement in the primary environmental effects of dredging and landfill upon estuarine areas. To this end, the Commission reviews and offers comments on dredging applications and related projects as they are proposed.

An initial problem in comprehensive outdoor recreation planning is the availability of data. Suggestions for possible development must be followed up by detailed investigation. Information must be gathered relating to topography, ground water conditions, biotic life, access to surface water, and surrounding land use. Much of this needed information is quickly discernible from high-altitude infrared color photography as well as from conventional black-and-white air photography. As we gather experience we foresee the desirability of thermal infrared photography to detect trends in environmental evolution.

The greatest advantage we anticipate at this time is increased speed of interpretation from existing coverage. Without presently obtainable overflight viewing we must require advance scheduling of field trips, running into several months' time. Often this means the difference between acquisition or loss of a critical land parcel.

At the present time we could utilize high altitude imagery for study of the recreational potential of such areas as Fisherman's Island, the Barrier Islands, and potential bayside state park locations on the Eastern Shore.We can also obtain preliminary material from 1969 and 1970 imagery without waiting for the completion, later this year, of the Recreation and Tourism Study of the Eastern Shore.[1]

At present, we are looking forward to the results of a study of experimental applications of remote sensing techniques to outdoor recreation planning.[2] This experimental study will provide a good opportunity to test application of remote sensing technology in the collection of data for outdoor recreation planning. We feel that after the study has been completed, we will have a better understanding of the most appropriate ways to incorporate remote sensing data into the recreation planning process. We can then suggest lines of further action and analysis.

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[1]The study is being conducted by the Virginia Division of State Planning and Community Affairs with financial assistance from the Economic Development Administration of the United States Department of Commerce.

[2]This study is being conducted by the Department of Environmental Sciences of the University of Virginia under the direction of Wallace E. Reed and H. Grant Goodell. The experimental proposal was submitted to the Bureau of Outdoor Recreation.

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# Engineering Works and the Tidal Chesapeake

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## INTRODUCTION

This paper discusses the tidal tributaries of the ocean and the coastal areas of the mid-Atlantic Bight and the ecological significance of engineering projects. While occasional reference may be made in this paper to remote sensing of problems engendered by engineering works on maritime environments and resources, principal efforts along those lines are reserved for the group discussion to follow.

The Chesapeake Bay drainage basin encompasses almost 65 000 square miles and provides space and partial resources for over 11 million people (1960) in New York, Pennsylvania, Maryland, Virginia, and the District of Columbia. Two other states, Delaware and West Virginia, to a lesser extent are part of this basin. Major residential, industrial and commercial, military, and recreational activities in the mid-Atlantic area make their demands on the environment and resources and contribute to the economic and social well-being of the populace. Certain social and economic disbenefits often accompany these activities. Population growth in the basin is increasing as are economic and social activities and other user activities.

Reference 1 includes many of the vital statistics on the Chesapeake Bay drainage basin. Numerous other studies in all fields have reported upon many natural, economic and social features of the Bay. Still others on these and additional subjects are in process.

While I have chosen to focus on the tidal portion of the Bay—in addition to the open coast and adjacent oceanic areas—the statistics of the tidal portion are no less impressive. The tidal area in comparison to the entire basin contains 7 million of the 11 million people in the basin, most of them on the western shore and the rest on the eastern shore of the tidal portion of the Bay.

The Bay contains attractive and extensive shorelines (estimated at about 10 000 miles), of which over 5000 are in Virginia. Vast expanses of water separate land masses, ports and harbors, commercial and industrial sites, and residential and recreational areas. Therefore, high-area demands for goods and services generate a large amount of engineering activity in this area (refs. 2 and 3).

Considerable local, state, national and international attention is being given over to problems of wisely managing the environments, their resources and their various uses in the active coastal areas. The coastal zone of the oceans is a major resource concern of all countries. The Chesapeake Bay is the largest estuary of the eastern coastal zone of the United States.

Among the multiple-use activities that have an impact on the features of the tidal Chesapeake and its tributaries is the prosecution of projects which result in fixed structures or morphological changes (often both) in the shorelines, bottoms, and waters. Oceanic or coastal areas are subject to the same uses or pressures.

Construction projects may be large—such as the Conowingo Reservoir or Chesapeake Ship Channel, or small—like a 200-foot bulkhead or pier on a residential shoreline. Large projects may have significant effects on tidal waters, depending on their proximity and nature. Small projects, ineffective by themselves, may collectively induce deleterious effects on environment. Large projects also may interact in this way.

All together, engineering activities are significant in the lives of estuaries and man (ref. 4). The Chesapeake tidal system contains many examples of their significance.

## TYPES OF ENGINEERING PROJECTS

Engineering activities or projects can be classified in several ways other than by size. Should a project be located in or near tidal waters and be large and ecologically significant, it could be described as *direct* and have *large-scale effects.* If a project is nearby and small in ecological significance, it could be described as *direct* and have *small-scale* impact. Were its location or input removed from tidal environments, it could be described as an *indirect* type project. Its ecological impact would often be *small* but could be *large*, depending on project size and other features.

As indicated above, direct, small-scale impact projects can combine and have large ecological and economic impact. Projects can have an impact whether the activity is in the maritime area or many miles away.

An example of small indirect projects that can have collective impact would be the farm pond. This type of water and silt-retention reservoir, individually small, can be numerous and of large aggregate capacity, interrupting flows and storing large quantities of water and silt, taken together. The same multiplication effect occurs when numerous jetties or groin fields are built, or many small wetland tracts and bulkhead fields are filled in adjacent regions.

## HISTORICAL TRENDS

Not until recent decades has there been much concern over the environmentally deleterious effects of engineering projects. Ecological awareness has only recently begun to match the need and urge for development and growth. Not only have the size and number of engineering projects increased since 1900, the ecological and economic impacts have enlarged.

In considering ecologically significant activities, we should consider the sizable canal construction, clearing activities, other transportation and agricultural works that were executed during early colonial and post-colonial times. Not all ecological effects have been perpetrated in this century. Some changes, indeed, were wrought by the American Indians who used fire for hunting.

The massive military works and municipal, industrial and commercial projects of the pre- and post-bellum period of the nineteenth century undoubtedly wrought their ecological changes. Comparison of early military and civil charts (around 1850 to 1860) and maps with those of the early 1900s reveals significant alterations in shorelines and bottoms. Since 1900 rapid and accelerating increase in number and size of projects has been the rule. Even cursory comparison studies carried to present times provide graphic proof of this trend. Since 1945 growth has been greatest.

It is worth noting that estuaries and tidal tributaries are often systems on their way to extinction due to long-term natural processes. While it is difficult to determine the exact stage of this process for any particular estuary at any given time, this factor must be considered. At some point man-induced effects could be ecologically as well as economically useful. We cannot overlook, therefore, purposeful and beneficial projects.

## EXAMPLES OF ENGINEERING PROJECTS

A complete catalog classified by direct and indirect type, large and small size, for projects in the Chesapeake Bay drainage basin would be useful. However, it is not essential to present such a complete listing here, even if one were available or easily developed. Rather, I would prefer to name a few examples of different categories, presenting them by a scheme related to their intended goals or impacts on natural forces. The breakdown here is according to whether they result in geomorphological alterations or flow modifications; or whether they are defensive or retentive, are primarily related to building sites, or are structural.

### Geomorphological Alterations

This type of engineering project results in changes in the topography of the bottom or shoreline, or provides connection between two bodies of water. Each has its environmental impact depending upon size, location, and the geophysical and biological features in the zones affected.

Aquatic geomorphological modifications are those carried out under the water, usually in or on the bottom.

Many small channels serving residences, piers, and minor waterways exist, are being built, or are projected. Private piers and small public and private marinas and landing points exist by the thousands. Usually larger government-developed harbors occur by the hundreds in the Bay region. Density is greatest in heavily populated and industrialized areas.

Intermediate-sized channels exist in almost every major eastern and western shore river that is tributary to the Bay and these channels number in the dozens. There is hardly a tidal stream or reach in the entire Bay which does not feel the bite of the screw, scoop, clamshell or rotary-head dredge.

Major channels and harbor projects include the Chesapeake Ship Channel leading up-bay to ports on the Rappahannock, Potomac and Baltimore harbor, and the Hampton Roads access channels and the Hampton Roads harbor area. These are extensive and continually maintained (figs. 1 and 2). All have been under frequent consideration for deepening and enlargement. Deepening usually produces geophysical and biological changes of greatest magnitude. Maintenance dredging also contributes its effects, depending on the extent of basin alteration, method of dredging and the method and location of spoilage areas.

Spoil bank and overboard disposal areas are types of engineering developments that are frequently associated with dredging projects, usually as an important ancillary activity to channeling. Early practices of spoiling immediately adjacent to a developing channel have diminished as engineers began to realize that rapid filling usually resulted. Remedial off-site spoiling has raised costs of spoil disposal, whether onshore or overboard. Off-site spoiling has increased the demand and need (the two may be different) for spoil areas.

The proposed James River navigation project–the channel from Richmond to the nearby Atlantic–is an excellent example of a major channel improvement project requiring extensive off-site disposal areas. Many of these will replace spoil sites in reaches where overboard disposal was once extensively practiced. To merely deepen the channel from its present 25 feet to 35 feet will necessitate disposal of 46 508 000 cubic yards of spoil in the reaches above the James River Bridge at Newport News. Earlier practices of overboard disposal are being actively discouraged in many places. Yet disposal in low-lying wetlands seems less suitable.

To establish the Chesapeake Ship Channel in the Virginia portion of the Bay at its 42-foot depth required disposal of 14 309 200 cubic yards of materials. Studies by Brehmer (ref. 4) made during and after deepening of the Rappahannock shoal reach indicated that neither the dredging nor the overboard disposal practices produced much ecological damage. Despite this and other similar findings, there is obviously a limit to overboard spoilage in a bay as shallow as the Chesapeake. Indeed some areas are filling so rapidly by natural process that overboard spoil disposal must be strongly discouraged.

Channel and turning basin improvements in Baltimore harbor and Hampton Roads likewise generate vast amounts of spoil. So great is demand for spoil disposal space that the Corps of Engineers must seek additions to the 2500 acre Craney Island disposal area. This area will have reached its capacity in the short 30-year period between 1949 and 1978 (fig. 2). It will eventually be filled to a level 18 feet above mean-low water.

Ecological and economic problems of spoil disposal are massive and worthy of much more scientific study and engineering examination than has been accorded them to date.

Terrestrial geomorphological modifications are accomplished on or into highland or fast land.

Terrestrially centered projects are no less numerous than channels since many residential and commercial sites result from filling out from former shorelines or cutting channels into the land. Three types are easily distinguishable: (a) those that bridge land barriers and open communications between bodies of water, (b) those that result in new land, and (c) artificial dead-end waterways designed to produce waterfront. The last two may be collectively called shoreline modifications.

Connections between water masses (canals, gaps, and cuts) are projects that are least numerous but usually sizable. Many are vintage. For example, in Virginia the Dismal Swamp Canals (ref. 6) connect the lower Bay to Albemarle Sound. Canals connect the Elizabeth or Nansemond River on the northern end and the Northwest or Roanoke River on the southern end. The cuts and gaps, such as Dutch Gap, which were constructed to shorten the tidal James below Richmond (fig. 1) are also examples of ancient canal projects. Efforts to develop these connections date back to 1785. Remnants of many other canals exist in the Chesapeake Bay drainage basin (ref. 6).

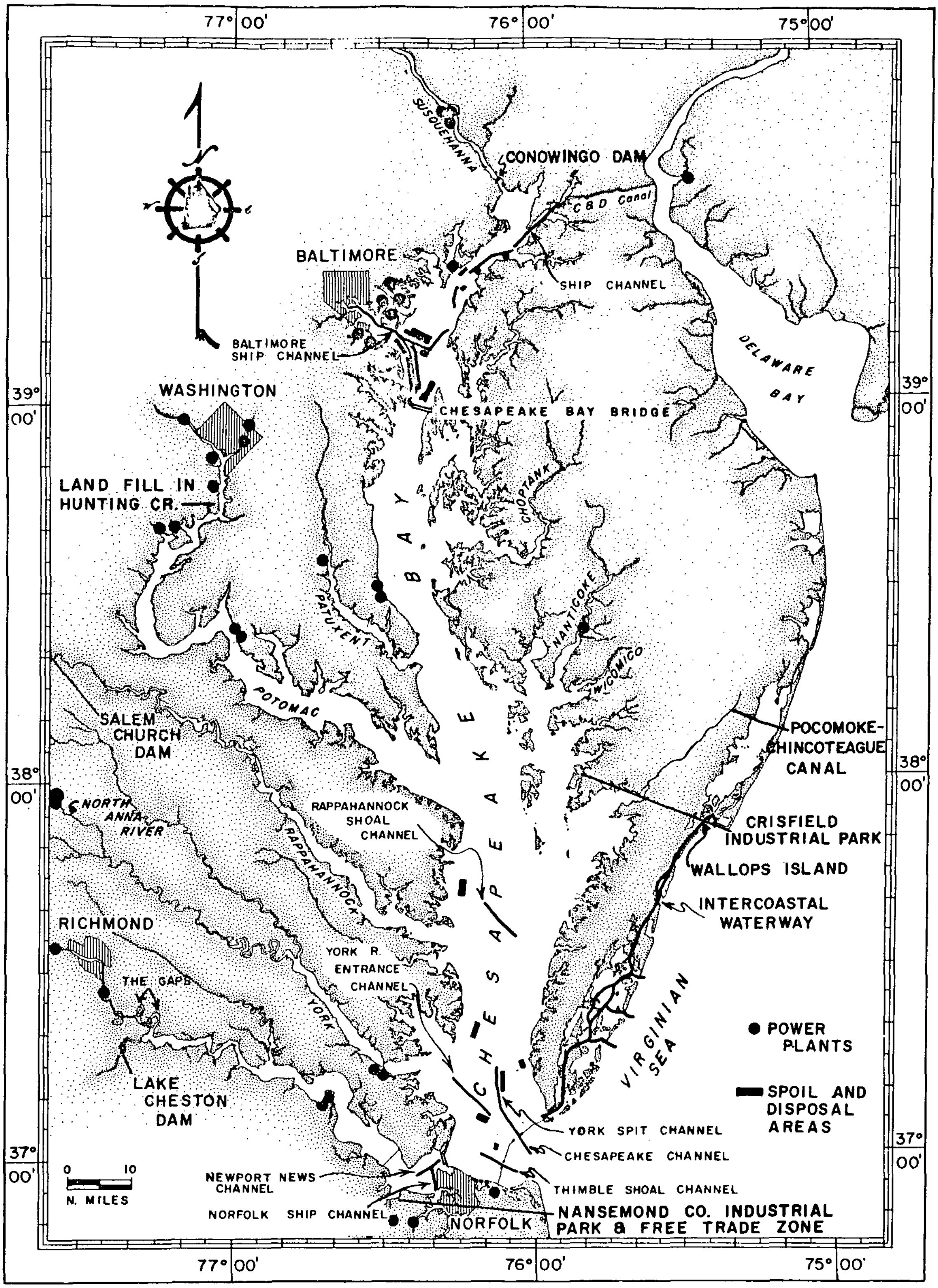


Figure 1.–Chesapeake Bay showing certain engineering projects.

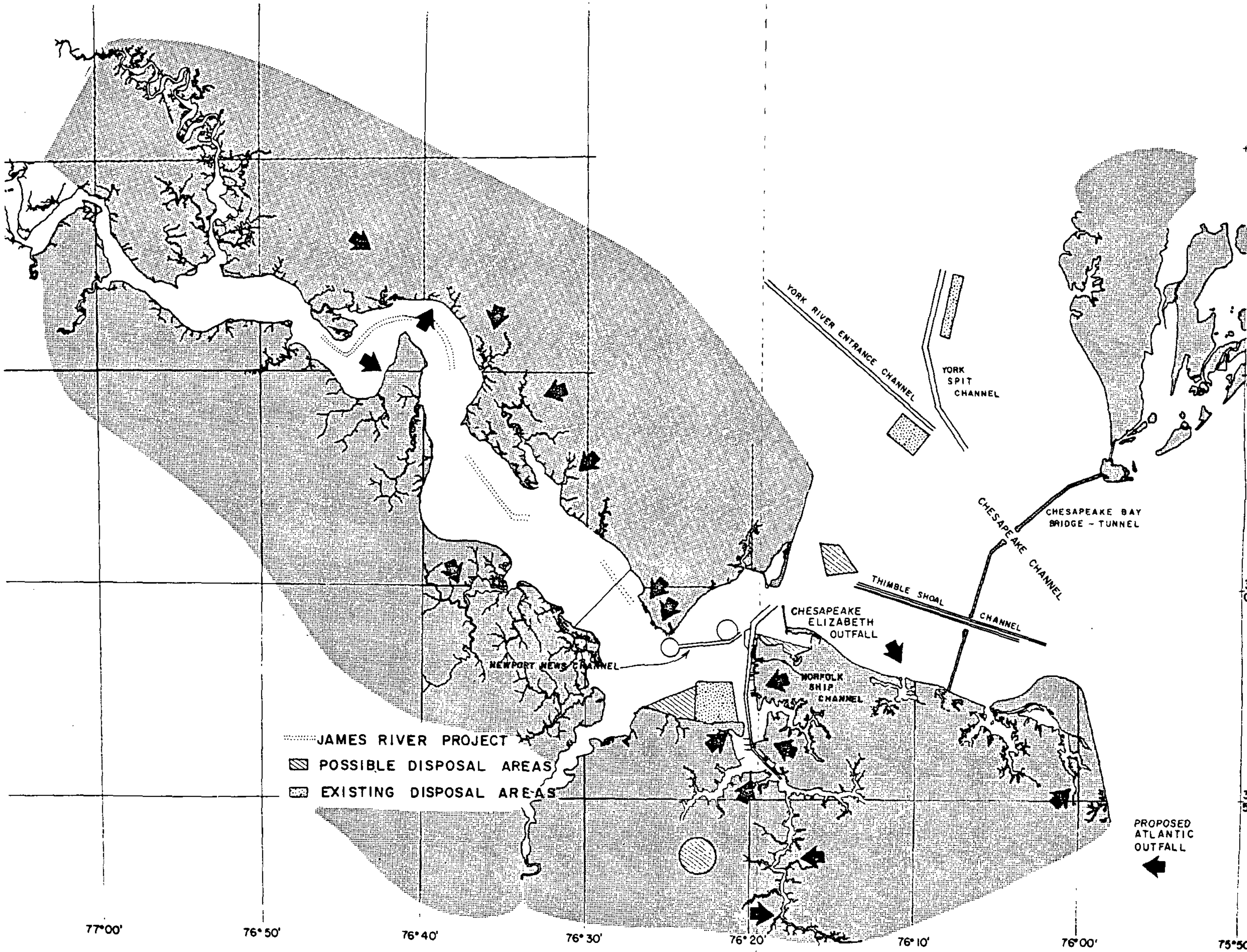


Figure 2.–Outfalls, channels, and spoil areas in the lower James River.

The Chesapeake and Delaware Canal is the most celebrated of the recent land-cut canal works in the Chesapeake Bay region, though the Intracoastal Waterway of the DELMARVA peninsula is again quite active (fig. 1).

The proposal to deepen the Chesapeake and Delaware Canal from its presently authorized depth of 35 feet to 42 feet has drawn much attention because this man-made and currently lock-free waterway connects waters of differing salinities–(ca. 1 percent on the Chesapeake side and 5 percent on the Delaware side). Such deepending would divert about 1650 cubic feet per second more fresh Susquehanna River water from the Chesapeake Bay to the Delaware Bay. There has, therefore, been concern for the effects on salinity distribution in Maryland and Virginia waters of the Bay. The Susquehanna supplies the Chesapeake with almost 50 percent of the entire fresh water inflow from rivers. Significant reduction of inflow by diversion through the C and D Canal could cause significant salinity changes and related problems to the Bay area. Similar shunting to provide fresh water in any sizable amount to localities in New York, Pennsylvania, New Jersey, or Delaware would have similar effects. Several projects designed to remove fresh water from the Susquehanna are, indeed, extant.

The Intracoastal Waterway extending from Ocean City inlet on the sea side of Maryland to Fisherman's Inlet on the Chesapeake Bay connects the high-salinity seaside lagoons and bays to each other. Classed as an alongshore canal by Cronin, Gunter and Hopkins (ref. 4), this project is under consideration for maintenance dredging and modification.

The dike and fill projects which extend fast land out into areas once covered by wetland or water fall in the shoreline modification category. Seaward movement of land is the usual direction of this type of engineering project. Occasionally, however, waterfront is developed by dredging canals into fast land–the third type mentioned in the listing preceeding this exposition. Huge turning basins at the ends of these cuts are often stagnant cul-de-sacs.

It is difficult to estimate the number and total extent of landfill and waterfront-cut shoreline alterations in the Chesapeake Bay. Even more difficult is it to enumerate the purposes for which these smaller projects were made. The detailed analyses which would yield the basic data are only now being done in the lower Chesapeake Bay (ref. 3 and Wass and Marcellus[1]).

Massive projects which are developed for large-scale residential, commercial, or industrial purposes are more easily detected and enumerated because of their higher visibility. Since demand for waterfront facilities is greatest around centers of high population and commercial or industrial activities, the main focal points are easy to detect or predict. These regions include Baltimore and adjacent areas, Washington area and the adjacent upper Potomac River, Richmond-Hopewell area in the upper James River, and the Hampton Roads area at the mouth of the James River. Virginia Beach and Ocean City are also active, especially featuring finger-type or Venetian waterfront development (ref. 4).

Estimates of waterfront usage and rates of landfill in Virginia areas are provided in Wass and Wright (ref. 3). Similar reports have been developed by Metzgar and his associates for upper Bay waters (ref. 7).

In the Hampton Roads region, shoreline extension for commercial reasons has been most extensive, with marked changes in shoreline contours since 1850 and even earlier. Overlaying of charts from 1850, 1900, 1930, and recent years clearly shows the shallows of the lower James to have been much reduced in areas by bulkheading and landfill, and the shoreline to have been made much more regular in outline.

The Eastern Branch of the Elizabeth River to Willoughby Spit reach, the Newport News to Old Point Comfort reach and Western Branch of the Elizabeth to Craney Island reach–all provide excellent examples of this type of change. Hundreds of landfills of all sizes have been responsible.

The Craney Island spoil disposal area mentioned above is a large one (fig. 2). The possible point waterfront development at Newport News opposite Hampton Roads is a smaller one. Likely landfills upstream of the point at Newport News will fill much of the remaining shallow area between the point and the James River Bridge. Together, these large and small Hampton Roads area projects greatly affect economic and ecological scenes. They produce large changes in the morphology of the shorelines and, likely, effect profound modifications of currents in the lower James River. All should be examined during design and presented in the James River Hydraulic Model–jointly operated by Virginia and the Corps of Engineers–at the Waterways Experiment Station at Vicksburg. Baltimore harbor and adjacent Patapsco River have been much affected by similar projects.

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[1] Wass and Marcellus: Personal communication.

As indicated above, the Ocean City-Rehobeth Beach region of the eastern shore has experienced considerable finger-type and other extensions of shoreline. Similarly, Virginia Beach is site of residential and recreational landfills or cuts. A few are located elsewhere on the lower peninsula of Virginia and in the northern bay of Maryland. Pressures for their increase in numbers, size and geographical spread will surely grow. Wetlands of the Norfolk, Chesapeake and Virginia Beach areas have almost disappeared as a result of dredging and filling. Wetland elimination continues, and this trend is apparent in other areas of high activity.

New proposals for wetland filling and extensions of island and mainland shorelines are submitted weekly to state and federal agencies for permit approval. Scarcely a month goes by without a Goodwin-Island, Mumfort-Island, Smith-Island, or similar project being proposed. So rapidly has this trend developed and burgeoned that both Maryland and Virginia have become alarmed, along with all other coastal states. Assemblies and agencies of both states seek better methods of planning and management of wetlands, shorelines and shallows. The files of management agencies such as the Marine Resources Commission, which grants permits for use of state-owned bottoms, and the Water Control Board and Public Health Department are full of proposals for more projects. The Virginia Institute of Marine Science has files full of environmental impact statements on these projects. Federal agencies such as the Corps of Engineers and Environmental Protection Agencies are no less pressured.

### Flow Alterations

Engineering projects that retain water such as reservoirs result in changes in patterns of flow of water, usually fresh water. In some, only a short-term alteration in flow results during initial filling periods. Long-term changes from these, usually low, unregulated dams are most often minor. Other dams are constructed so as to modify or regulate flows on an almost continuous basis.

Dams and reservoirs are of several construction types, sizes and purposes. They are mainly for water supply, hydroelectric power, flood and flow control.

In the coastal plains region, reservoirs are usually shallow and devoted to water supply. Low topography generally prevents large volume storage. Even so, they may considerably change the available fresh water to the tidal tributaries on which they are located. As the water is drawn into municipal and industrial mains to be discharged from the waste-treatment outfalls considerably downstream of the headwaters, salinity as well as current patterns may be altered in both bypassed and receiving reaches. These direct effects may produce marked ecological changes in each.

The Elizabeth River system of the Norfolk-Portsmouth-Chesapeake area is one which has been altered in this fashion. Part of the flow from its headwaters, limited though they are, are trapped in upstream reservoirs and diverted through the water supply mains, put to use, and discharged again through the sewers into the lower reaches of the river. The diversion from Diascund Creek of the Chickahominy system to the Newport News-Hampton area is a longer-distance example of this type of project.

On the lower reaches of the fresh water portion of the Susquehanna River, a series of reservoirs, the biggest being the Conowingo Dam, are used to supply water to Baltimore city and environs. Outfalls pour into the Patapsco and neighboring tidal waters. The Conowingo diversion is one of the largest in the Bay system (fig. 1). An interesting side effect of the large reservoirs and their operation is the abnormal temperature regime induced below the dam when cold and oxygen-deficient water is released through the outfalls located below the epilimnion or the upper thermally stratified layer of the lake in summer and early fall.

Introductions of fresh water pumped from the depths of subterranean aquifers that would not normally enter estuarine areas may reach significant proportions and change salinity patterns. These injections occur from outfalls of large industrial and municipal water users. Several are known in the tidal James.

At times, both flow diversions of surface water and injections of subsurface waters are required.

Usually located above the fall lines, or upper limits of the tide in the Bay tributaries, in the Piedmont or mountainous regions of the Chesapeake basin, multipurpose reservoirs are of varying sizes and types. In every instance, they perform several functions. The farther they are above the fall line the less their influence on tidal waters, as a rule. For example, the proposed Gathright Reservoir, a 344-square mile drainage basin (363 000 acre-feet) on the Jackson River of the James, will have no influence on distribution of salinity in the tidal James. Benefits, though, to water quality in the reach below Richmond are supposed to accrue from dilution.[2] As far as is known, multipurpose Smith Mountain reservoir has little influence on the tidal reaches of the Roanoke River drainage system despite its large volume.

Larger upland reservoirs, numbering in the hundreds, abound on the major tributaries of the Chesapeake drainage basin. Constructed for hydroelectric power, flood control, water supply and other purposes, these units also are capable of changing seasonal patterns of flow, reducing or increasing peak or minimum flows, depending upon operations. They also remove suspended matter and otherwise change the quantity and quality of water available to the lower basin.

The changes produced by large upland reservoirs can be deleterious, i.e., allow pest-bearing, high-salinity waters into shellfish-producing areas formerly free of such pests. The changes can be beneficial, i.e., improve water quality by augmenting summer low flows or reducing shellfish pests by lowering estuarine salinities during their breeding season. As an example, the Salem Church Reservoir (fig. 1) could, if properly designed and operated, be used to increase oyster production by controlling their pests as a result of salinity manipulations. While one would hardly build an expensive dam to achieve this one objective, it could be a significant secondary benefit, were the project soundly justifiable on other bases. Indeed, a study by VIMS' scientists (ref. 8) has indicated just such a possibility.

Clearly, many factors must be considered in ascertaining actual or potential effect. These include the number of projects as well as volume of water stored. For example, many small ponds are constructed to retard erosion, clarify streams, supply water needs of livestock, and for local recreation. These ponds can alter water inflow patterns, especially in dry months and if they are working effectively, they can dry up the flow of sediments which once served to nourish beaches as well as fill channels far downstream.

There is little question that the cumulative effects of thousands of small reservoirs are felt in tidewater. Their effects are felt, not in spring when early rains and melting snows swell the down-rushing flow to near flood levels, but in the seasonally dry period of late summer, fall and winter.

Cumulative evaporation has to be another factor in flow modification, especially from the host of shallow reservoirs involved. A large volume of water, formerly retained in the drainage basin, is lost through evaporation from reservoirs. This shortening of the hydrologic cycle can also modify weather as well as water flows.

The larger the reservoir and the nearer the tidal reaches, the more significant the effects on those waters may be. Especially significant may be those changes in fresh water-salt water balance during the period required to fill the reservoir. Exemplary of this is the North Anna Cooling Reservoir (figs. 1 and 3) on the Pamunkey River tributary to the tidal York River. Due to the large volume of the impoundment in relation to the flow of the stream, time required for filling is estimated at from two to three years. Without proper planning, a significant alteration of salinity patterns could result during the period. Since spawning of certain fish and growth of shellfish is often dependent upon proper salinity levels and patterns, estuarine ecologists at the Virginia Institute of Marine Science have expressed strong concern over biological damages expected to result from the filling. They, and others are concerned, lest the release schedules and volumes of water available for release from this reservoir be insufficient to maintain proper salinities downstream. Unfortunately there are no salinity standards against which to gauge legal requirements for reservoir releases or on which to base judgments of undue interference with ecological norms.

Salinity is an aspect of water quality usually of far greater significance in estuaries than dissolved oxygen. This consideration is an important shortcoming in Virginia's regulatory arrangements. Statements of the nature and extent to which salinity can be modified must be worked out for each major tributary and region. In many instances additional field and laboratory research is required for salinity standards to be properly set but eventually we must establish such management guidelines. Effective mathematical and hydraulic models must be developed and utilized in this work.

It is difficult to determine or predict the downstream effects of a single large reservoir. It is *infinitely* more difficult to predict or detect the synergistic or the counterbalancing effects of numerous reservoirs of all types on the lower reaches of a river system. Quantity and timing of water flows are of concern; also aspects of water quality such as turbidity, nutrients, and temperature may be influenced by reservoir construction and operation. Any or all may have effects, sometimes profound, on receiving tidal waters far downstream.

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[2] VIMS, official communication.

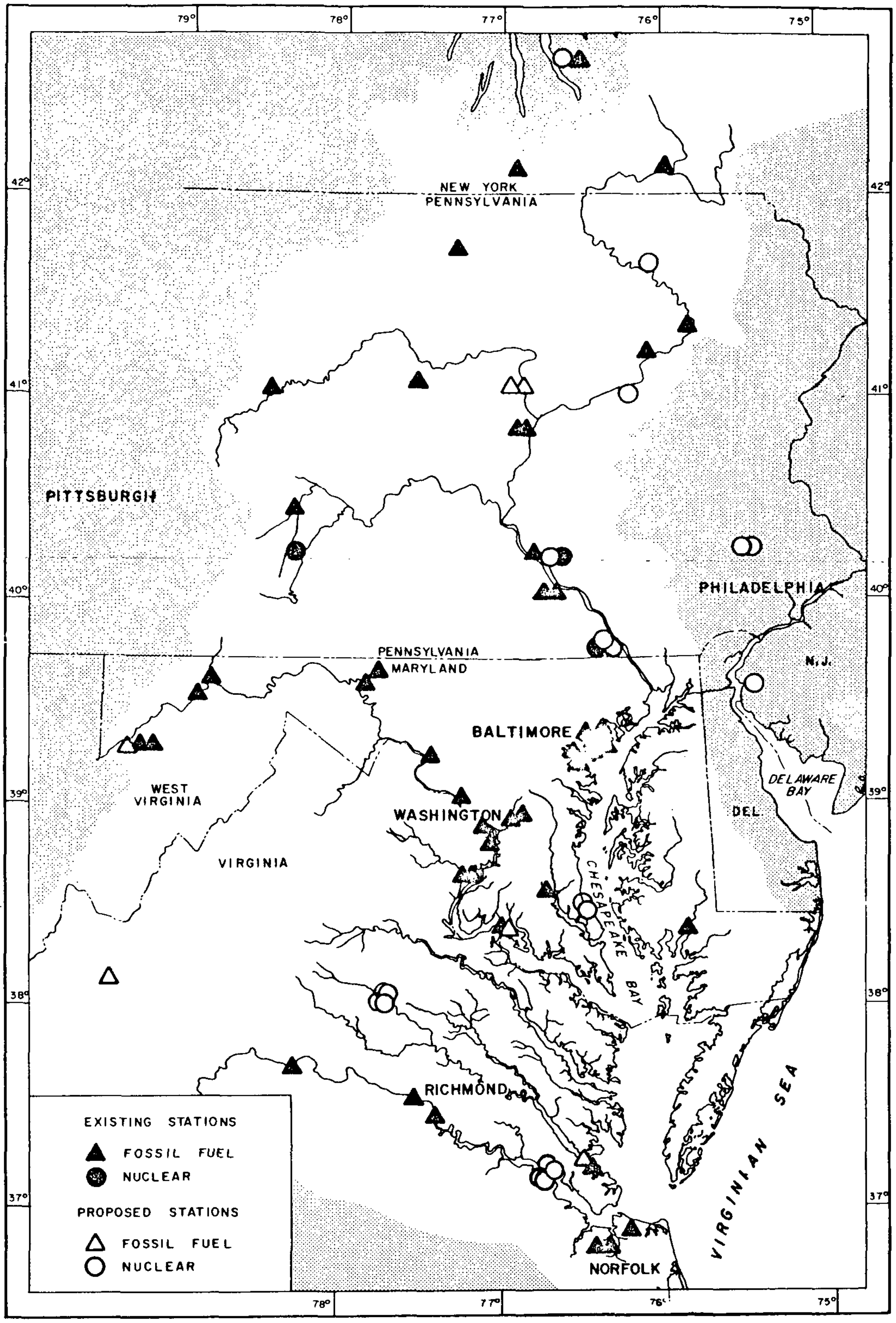


Figure 3.–Present and proposed plant sites in the Chesapeake Bay, as of July 1971.

Hence, engineers, ecologists and geophysical specialists must carefully consider these aspects in designing single reservoirs and systems of reservoirs. A glance at the compendium of actual and potential reservoirs on the upper James basin now under consideration by the Norfolk District of the Corps of Engineers serves to illustrate the complexity of the problem. Couple these difficulties with those introduced by geometrical changes in the tidal reaches far downstream and one has a fair idea of the tasks facing these groups.

Occasionally special problems will prompt massive engineering works. Examples of these problems include (a) protection from flooding of part of the City of Providence, Rhode Island, by storm-driven high water; (b) exclusion of salinity from the upper reaches of the Delaware to protect fresh water supplies; and (c) meeting the anticipated need for large amounts of fresh water for the Hampton Roads cities. Proposals for massive engineering works to solve these special problems include (a) Hurricane Barriers across various places in Narragansett Bay; (b) the Saltwater Barrier across the Delaware Bay at Deepwater Point; and (c) the once-suggested tidal exclusion dam across the Chesapeake Bay.

An engineering project which has arisen several times in the lower Bay region has been the scheme to construct a dam at Jamestown Island, or some similar location. The dam would convert the James above that point into a large fresh water reservoir and provide for deeper draft vessels upstream. Needless to say, such a project would result in great changes in the physical, geological, chemical, and biological features above and below the dam.

The Narragansett project resulted in construction of an hyrdraulic model to examine its impacts and to consider design features. After much testing and design modification, a local protection scheme was chosen from among the options tested. Called the Box Point Project, this barrier has been used several times.

The Delaware salinity barrier was examined in the Delaware Bay model and later abandoned. The Chesapeake Bay proposal has been rejected more-or-less summarily. But the James proposal, while still primarily a paper project, reached the point at which it was officially commented upon in an environmental statement by the Institute to the Governor's office.

In other estuaries, underwater training barriers or wiers have been proposed or carried into actual project stages, but I know of none in the Chesapeake Bay. Certainly overboard spoil disposal activities may have created barriers which affected circulation of bottom waters, at least for a time, but these have been accidental. In time, such projects may come into being.

### Defensive or Retentive Structures

Over the centuries, amateur and professional engineers have developed many structures of differing designs, materials, and methods of construction to prevent moving water from undermining and eroding fast land. These structures primarily exclude or moderate the dynamic forces of the sea or hold the land by stabilizing it; the ultimate goals are (a) to stabilize or build shorelines, or (b) to protect works of man both in the water (channels) or on land (buildings and other structures).

Among the various engineering structures, jetties and groins are used to build shorelines, prevent shore and bottom erosion, support bulkheads in certain situations and prevent channel filling. The majority of jetties are small in size, extending less than 100 feet seaward. However, large jetties are frequently used to protect the entrances to harbors and inlets along exposed shores in various places in Chesapeake Bay and on the exposed open coast. Those at Sandy Point (western terminus of the Chesapeake Bay Bridge near Annapolis), Matapeake (eastern terminus of the ferry which the Lane Memorial Bridge replaced), Smith Point (near the mouth of the Potomac) or Rudee Inlet (Virginia Beach) are examples. That at Kiptopeake made of hulks of World War I concrete transport vessels is one of the largest and most unusual in the region.

Generally speaking, the biological effects of jetties and groins are as local as their geophysical effects. At times, however, large jetties or extensive groin fields (fig. 4) serve to starve shallows and shorelines far downstream (in terms of littoral drift). Starvation may continue for some time depending upon local bathymetric and current patterns. Small jetties are usually insignificant in ecological influence.

Mentioned above under considerations of dike and fill activities, strategically placed bulkheads may alter patterns of movement of soil, sediment and water. Interestingly, also as indicated above, estuaries–like many other natural systems–are often systems on their inevitable course to extinction. Factors in this extinction process include background changes, such as rise and fall of sea level and subsidence and uplift of related land masses. Man can allow

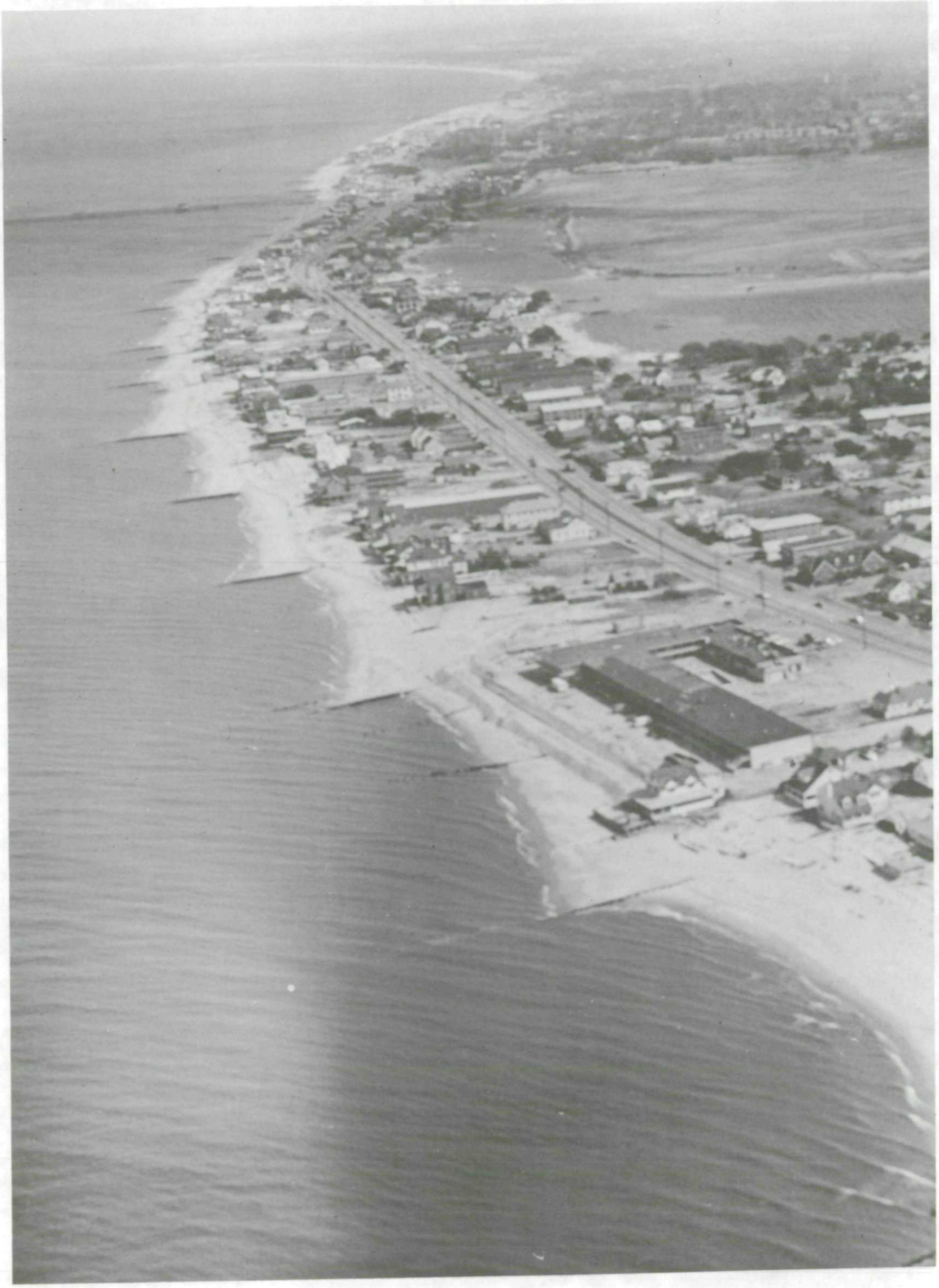

Figure 4.–Groin field at Willoughby Spit.

estuarine systems to progress to oblivion according to their natural procession and at uninterrupted rates. He can do so by not intervening or by counterbalancing interventions. He can hasten the downward process toward elimination by making engineering changes and additions which speed the processes of filling and eutrophication.

Man can, alternatively, reverse the process of extinction by interferring with the balance of erosion and sedimentation through deepening channels and other bathymetric alterations. And he can reverse other processes–geological, physical, chemical and biological–which lead to eutrophication of estuaries. With these possibilities involved, the technological and engineering capabilities of man can be applied to speed the eventual demise or undertake corrective and remedial projects even on large systems like the Chesapeake Bay. We must have the will to do so and arm ourselves with the necessary plans, funds and tools to do so. Among the important factors are

(a) Adequate scientific and technological knowledge of the estuarine system

(b) Adequate simulative and predictive devices like mathematical and hydraulic scale models into which the changes can be introduced and examined deliberately

(c) Creative and responsible organizations and individuals that can weigh and advance the opportunities that present themselves

Uninterrupted natural change can be and frequently is as destructive of specific natural systems as alteration by activities of man. In many instances, only the rate of change and not the results are affected. I do not advocate destructive change or deny the scientific and aesthetic value of observing uninterrupted natural systems. I decry the activities of man which accelerate destruction of those systems. I also urge reason and point out that, given knowledge and the proper tools, we can engineer constructively.

It is not necessary to depend solely upon concrete, bricks, blocks, iron or wood to stabilize beaches or shorelines. By judicious placement of plants and sand, perhaps aided by frail but effective sand fences, we can slow or reverse the seaward or erosive movements of sand. Obviously alterations of geomorphological and biological systems will occur. The environmental and resource significance of such changes will vary according to design, magnitude, and conduct of the project.

### Other Aspects of Sediment Movement

We have discussed specific engineering structures or procedures which serve to stop, slow, or reverse the natural procession of sediments into and through estuaries like the Chesapeake Bay. Other human activities which may have marked influence on sedimentation are (a) agricultural operations, (b) forest harvesting, (c) site preparation for industrial, urban or commercial developments, and (d) highway construction. Some erosion from extensively active agricultural or construction sites is probably inevitable but significant control is possible and essential in all cases.

In areas of high rate of urbanization or large construction and agricultural activities, turbidity of streams receiving runoff is often very high. It is not uncommon for the upper tidal Potomac and upper tidal James to run brown or red from soil deposits, even after a light rain. Public authorities need to be alert to this type of contamination. Excessive turbidity not only damages production of oysters but also reduces photosynthetic activity, to say nothing of increasing rates of deposition in channels and bottoms.

As with salinity we do not as yet possess adequate water quality standards for turbidity, color, or sediment load in tidal rivers. Such standards should be developed since it is essential to prevent damage from this major contaminant.

### Structures

Introduction of structures in tidal, and other flowing waters, inevitably induces alterations in flow patterns–direction and speed of currents, and related natural parameters. Aside from their physical effects, changes such as scour and fill, may be produced in geological features. Additionally, plants and animals may be attracted to the above substrate and the shelter and sustenance these above-the-bottom structures offer.

It has been postulated that even open-faced structures such as pier-borne causeways may interfere with in and out movements of migratory fishes much the same as large-mesh hedging trains or directs them into pounds or traps. The reality of this postualte has not been effectively examined in the Chesapeake Bay, which now has one of the longest of such structures in the world. Thus far, the Chesapeake Bay bridge tunnel (figs. 1 and 2) has been quite effective as a net for military and commercial vessels too large to pass through its openings. However, there is little real indication of interference with anadromous or catadromous fish, or even longshore migrants.

Undoubtedly, the bridge-tunnel at the Capes, those in the Elizabeth and the James, the Chesapeake Bay bridge (Kent Island to Sandy Point, Maryland) and the James River bridge exert mechanical influences on the water. Again, the significance of such influence has not been measured—either out of indifference or inability to do so. Patently, interference differs according to the nature of construction. Solid-fill and open-faced causeways are obviously very different in effects.

Islands that are solid-fill causeways are engineering objects that are more profound in their influence than the "pierced" piered ones, acting to force waters to move around them and assume different current patterns than formerly. Many have noted the patterns of refraction and reflection caused by groins and jetties. Influence depends upon the direction and force of the moving water. If solid-fill causeways are extensive, with few passthroughs they may act as dams to storm water or even resist normal tidal flows. Most common in marshy areas, such causeways may influence not only geophysical features but can also interfere with movements of marsh animals (mammalian, piscine and avian) or even with flux of nutrients from wetlands into adjacent waters.

Examples of such projects abound in the Chesapeake region. For instance, Maryland's Chesapeake Bay bridge (fig. 1) employs short, closed causeways which act as jetties. Many of the bridges in shallow or marshy estuaries of the eastern shore, bayside and seaside, use long-closed, earth-fill causeways interrupted only by draw or swing bridges over major waterways. Often injudiciously placed culverts connect the interrupted drainage areas. The mainland-to-Chincoteague-Island bridge consists mostly of Earth-fill and solid causeways. Similar projects occur on the western shore.

The Chesapeake Bay bridge tunnel from Cape Charles to Virginia Beach employs open-pile causeways, but encompasses four large islands as terminals for the under-channel north and south tunnels. These islands are large, extending about one-fourth of the way across the major Bay opening from Fisherman's Island to the Bay shore of Virginia Beach. They must have consequently produced certain geophysical effects beyond their local realms. Undoubtedly, changes have been wrought in Bay-mouth circulation. However, neither we nor the Environmental Sciences Service Administration, now a part of the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce, have been able to establish any other than high local effects around the pier's causeways and islands themselves.

Large open-face causeways and piers interfere with circulation to a much lesser extent than solid-fill causeways and quays. Nonetheless, they do cause alterations in current flow. Obviously, these changes are greatest near the structure.

As an example, the causeway pilings of the Chesapeake Bay bridge tunnel number approximately 850 in each row. Their faces, which are 4½ feet in diameter plus the tunnel islands aggregate sufficiently to narrow or occlude the opening of the Bay by over 25 percent. As indicated above, changes other than local ones have not been observed. Among those that could have occurred is alteration of timing of flow through the capes, with consequent changes in tides, increased turbulence and increased substrate for attached plant and animal organisms.

Additionally, as fouling organisms increase, so also will diameters of the obstructing pilings grow—resulting in some further obstruction. Not only will pilings grow in cross-sectional dimensions, but roughness factors will also be increased by barnacles and other attachments.

These large mixed communities of attaching organisms are spaced widely across the Bay mouth. Although their contributing larvae, wastes and other biochemical materials may cause changes in the biota of the lower Bay region, their influence on the geographical aspects remains not clear.

If we had the model of the Chesapeake Bay now being developed by the Corps of Engineers, we might have been able to examine the possible effects of the bridge-tunnel—at least those relating to features such as current patterns, tidal levels and sedimentation which can be simulated in such models.

Bridge-tunnel complexes include those existing or under construction between Willoughby Spit and Old Point Comfort in the Hampton Roads portion of the lower James estuary, or those associated with the Chesapeake Bay bridge-tunnel. Whether or not part of a larger complex, tunnels have little besides transitory ecological effects unless constructed in such a way as to protrude above the natural bottom, thus producing a sill. Largest effects occur near the points where they emerge from below the sea floor and constitute a physical impediment to currents, silt and debris.

More importantly, by establishing controlling depths, if placed across main channels—as they usually are—tunnels may have a marked effect on the commercial future of the body of water affected. Long-term economic and sociological significance of tunnels therefore cannot be ignored.

Municipal and industrial water supply systems and waste water treatment plants frequently involve sizable structures that train, engulf, or disgorge large volumes of water and entrained materials. In many, both intakes and outfalls extend seaward some distance, depending on local conditions and design. Secondary wiers and other training structures such as canals may be involved.

Obviously, local current patterns are modified by flows at intakes and outfalls, especially of large water-using facilities like SES power plants. Not infrequently, intake flows are so great as to constitute suction pumps capable of diverting and straining large volumes of water. For example, at full capacity the Calvert Cliffs nuclear power plant will strain 5600 cubic feet per second or 3 456 000 000 gallons per day of water (Maryland Academy of Sciences, 1970). Such huge structures could affect local fish populations and cause problems for the plant operator because of fish intake. Hence this ecological and economic factor must be considered in design and operation of such units.

Intake and outfall structures may serve as jetties or groins if extending above the surface or may serve as training barriers if submerged. The many SES stations throughout the Bay area (fig. 3) all present aspects of this sort, no matter the type of fuel.

As municipalities and associated commercial activities grow, so does the need for large underwater discharge systems or outfalls (fig. 2). Increasingly, the tendency is to collect waste waters into large trunk lines for discharge into the large-volume waters of the main bay or the ocean. Geophysical and biological effects are possible from the effluents and from the "fishing" or blocking action of such structures.

### Mining

Mining of sand, gravel, shell and other materials from the floor of the Bay and its tributaries is not construction. Since engineering is involved and there is considerable similarity between channel dredging and mining, brief mention seems justified. Several companies operating around Chesapeake Bay mine sand, gravel, and shells. Some operate intermittently for special purposes such as shell planting. Others regularly mine for long-term and continuing building material supplies, beach nourishment, livestock and poultry feed, cement manufacture, chemical processing, etc.

Mining does result in alteration of the morphometry or bottom topography of the area being mined. Such changes may be only local, leaving deep holes to be filled by sedimentary processes later. They may, on the other hand, be more significant and fill far from the area of direct mining, i.e., secondary effects. Secondary effects such as (a) slumping and erosion of adjacent shorelines due to undermining or (b) current alteration may be significant, depending upon local conditions and project details. Beside direct disruption of the bottom, its inhabitants and their life processes, activities such as shellfish culture may also be damaged.

Of course, dredging operations include (a) dredging for crabs, oysters and clams, (b) hydraulic, clam shell, rotary-head, and other dredging for channels, and (c) mining. These operations all entail disturbances of the bottom, roiling of sediments, and overboard discharge of silt and other sedimentary materials.

## ENVIRONMENTAL PROBLEMS RELATED TO ENGINEERING ACTIVITIES IN THE BAY

We have seen that the Chesapeake Bay is host to many engineering projects and activities. These range from small channels, bulkhead and fill projects, and piers, to massive or international channels, multiacre bulkhead and fill projects and 18-mile long bridge and tunnel complexes, with all sizes and types between. Each interacts in several ways with the environment in which it is placed. At times these interactions are local and insignificant, at others widespread and large. Size of the project is important in determining its ecological impacts, yet numerous small projects can produce large and multiple, even synergistic, effects.

Projects in the vicinity of the tidal portions of river systems such as the James, Potomac, or lower Susquehanna are likely to have the greatest impact. Reservoir construction and operation far upstream in the mountains or plateaus may also cause damage or improvement in estuarine conditions.

The purposes of engineering projects vary as do their sizes. Variability complicates problems of project engineering and environmental matching, but constructive uses can be made of appropriate project mixes. Understanding interactions caused by variability in purpose, size, and numbers is important because engineering projects and activities can interact. Interactions can produce subtractive, additive, or synergistic effects on the marine and other environments and the resources.

That ecological effects of engineering works vary is clearly established. They need not be deleterious but can be beneficial to the environment. Immediate and long range utility of the work is variable according to our ability to "design in consonance with nature."

Engineering works favor certain locations. Usually these locations relate to location of a resource or other favorable natural feature, or to the distribution of people and their activities. Hence, potential sites are often identifiable far in advance of actual prosecution of the project.

Unfortunately, man's engineering projects tend to congregate. In the Chesapeake Bay, man and his works usually occur where important environments and resources are already located; this doubles the hazard to natural systems (fig. 5). Pressures for increasing numbers, sizes, and types of engineering projects and activities are certain to increase. The rate of increase will be especially rapid in the coastal zones all over the world. The Chesapeake Bay is a resource and environmental system under increasing stress from engineering activities.

By now, many informed people are concerned over maintaining the quality and quantity of our environments and resources to the maximum extent possible, consistent with meeting the needs of the human and other inhabitants of the Earth. Control of population pressures is an important leverage point in any environmental control system–one which cannot be dismissed in the search for overall solutions; yet the problem at hand concerns bringing engineering works of man under better control.

Many environmentalists and engineers are convinced that we must do a better job of matching project to environment while minimizing adverse or maximizing beneficial aspects–including economic balance. They also are convinced that we must determine long in advance suitable sites for the given types of activities, and the location and number of sites that must be left alone to preserve the essential qualities and quantities of environments and resources. Preservation of quality and quantity and improved engineering requires better understanding of environments and resources and their inherent requirements, capabilities and limitation; hence, much research is needed.

Needed are more accurate charting, better knowledge of distribution and types of sites, in relation to geophysical and biological resources, and better understanding of environmental phenomena. These require more and better research and engineering efforts.

## PLANNING, MANAGEMENT, AND RESEARCH

Those concerned with design, construction and maintenance of engineering projects must be aware of interactions between those projects and the environment (a) which surround them or (b) with which they interact, near or far. Projects improperly designed or constructed may not survive the battering, erosive, corrosive or other destructive forces to which they are subjected. Further, they may not accomplish their intended tasks and may even destroy some other environment, resource, or value. Economic losses from ineffectual works in the coastal zone are enormous. Many calculations by military, naval, and civil engineers over the years bear this out. Damage has also been extensive.

Much effort and wealth has been expended to reduce or avoid destructive effects. These include boring and fouling organisms; undermining and battering effects of moving water and winds; corrosive actions of salt water; and obliterating effects of waterborne or aeolian sediments on the works of man. We have made headway and, proportionately, have reduced these effects. Yet the competition continues and much improvement is possible and necessary.

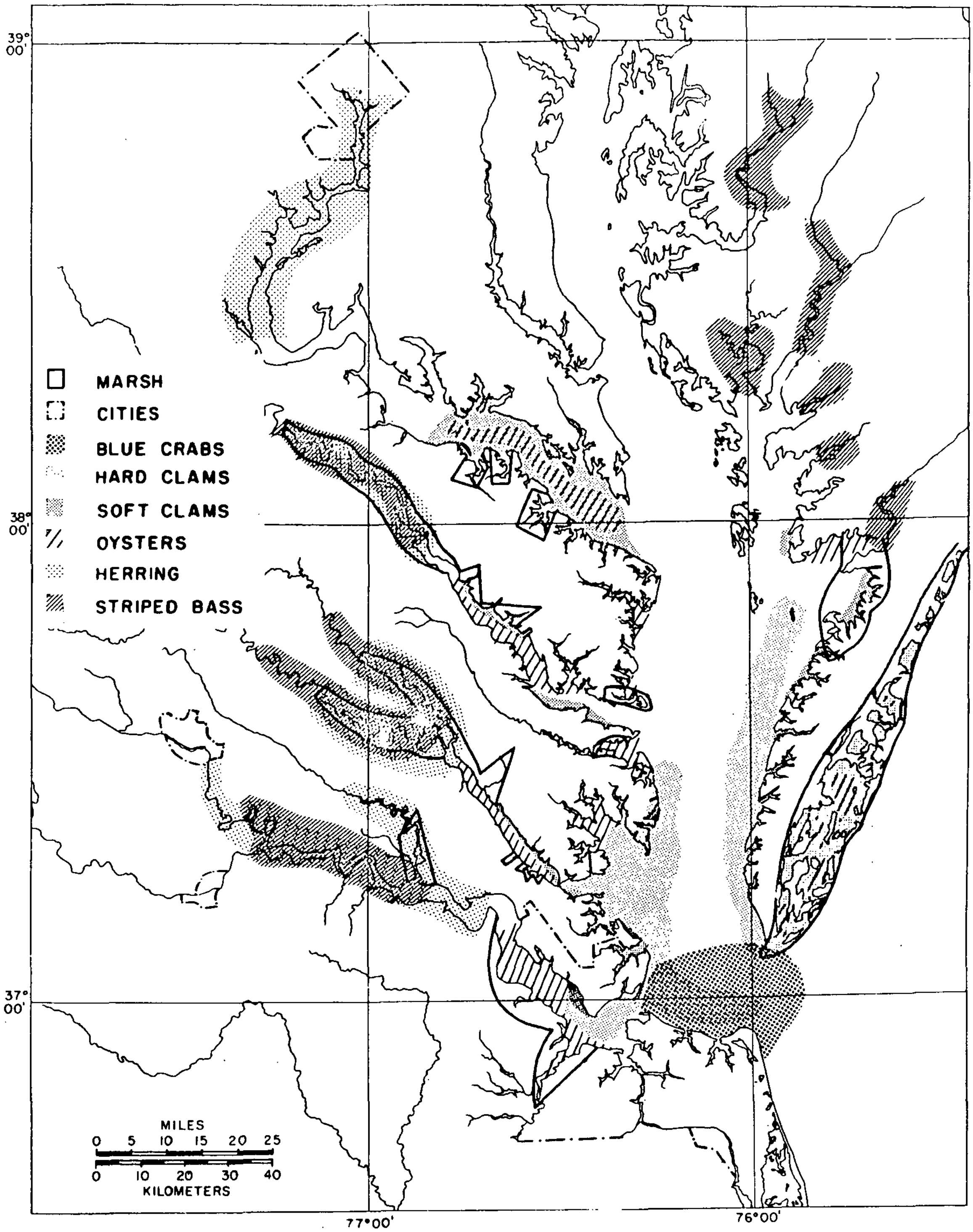


Figure 5.–Disposition of certain important ecological and population features in the lower Chesapeake Bay.

Logical and practical as they usually are, engineers are mindful of the need to understand the milieu in which they and their works must operate. It is important to industry and commerce and the public that engineers be fully apprised of the ecological or environmental factors involved. The greater the level of ignorance extant on this score, the greater the economic cost of engineering sound structures or operations. Overdesign and overconstruction have been the only sound alternative or means of compensation available. But overdesign and overconstruction cost money—usually large sums we can ill afford. In terms of the private and public good, the tighter the design and construction details, the lower the costs of marine projects. Conceivably, a greater number can be accomplished with the same money, if a greater number is an alternative.

Clearly, the engineering fraternity working in the marine environment or with their resources needs whatever help science and technology can render. This includes help from the environmental sciences as well as from applicable remote sensing technology.

From the public vantage point, planning and management of environments and resources of the Chesapeake Bay and adjacent waters are paramount activities. Many local, state, regional and federal agencies devote considerable effort and resources to these tasks. See, for example, the list given in reference 9.

That much remains to be done despite this public-supported effort has been clearly established during the last several years. Numerous studies have concluded that the growing multiuse problems and pressures, including those surrounding engineering projects and mining activities, must be more effectively treated. These studies range from the multivolume studies of the Stratton Commission (ref. 10) to the records (some as yet in process) of the Coastal Zone Hearings of the Subcommittee on Oceanography of the Senate Committee on Commerce, and the Subcommittee on Oceanography of the House Committee on Merchant Marine and Fisheries. One such Congressional Report, that of the Committee on Merchant Marine and Fisheries, was published in 1969 (ref. 11). Others are destined to follow this year. Numerous other state, federal and privately financed studies have reached the same conclusions. There is, thus, ample basis for concluding that planning and management of the resources and environments of oceanic waters and of the coastal zone are primary tasks which must be facilitated.

Planners, public and private, practical and theoretical, find it necessary to have comprehensive knowledge of the systems with which they deal. Those concerned with planning (a) for allocation and user complex environments and resources and (b) for development of complex or important engineering activities are especially dependent. Planners must be aware of the capabilities of the environment to provide benefits and yield resources. They must also be aware of their limitations as well as capabilities to cause mischief and damage. This requires basic environmental and resource information and knowledge of the results of past planning and management efforts.

Management—the overall activity which involves information acquisition and evaluation, planning and control operations—also requires historical and contemporary information about the environments and resources for which it is responsible. These must be allotted and used, allotted and supervised, or managed. Clearly, the original, as well as the digested and integrated data of research are needed, as are timely status reports from appropriate feedback systems.

Both planners and managers must understand the interactions between natural environments and resources, and the works, needs, and activities of man. All sources and means of acquiring information should be available and exploited.

Since much basic information about the environments and resources of the Chesapeake Bay region remains to be assimilated and adapted, basic and applied research and engineering development are needed. Because planning and management are dynamic processes, appropriate and adequate evaluation or monitoring capabilities with feedback are essential.

In situ and remote sensing from distant vantage points offer much to the researcher, planner, and manager interested in environments and resources. The advantages of in situ sensing of environmental conditions are analogous to electrocardiograms in diagnosis and treatment of a heart patient. Intermittent or continuous measurements of important parameters is an essential part of research. Measurements are also important to the monitoring and feedback phases of management, and to the evaluation of planning efficacy.

Some people do not consider in situ sensing and remote sensing as being the same thing. The sensor may be emplaced some spatial distance from the eventual destination of the data, and they prefer to retain the phrase "remote sensing" for sensing from a distance. In the latter configuration, the subject and the sensor, itself, are separated geographically. However one decides this question, it is clear that both types of systems, contact and non-contact, may require instrument design and handling capabilities of the highest order. The National Aeronautics and Space Administration has become noteworthy in its instrument development capabilities.

Despite the recent perfection of sophisticated space exploration, remote sensing is not new to environmental and resource planning and management. Aerial photography has long been used in land-use planning, erosion studies, highway routing, forestry operations, wildlife census, fishery monitoring, fish finding, and in other management or engineering and research operations. There is no question of its utility.

There is also little question that some of the newer remote sensing devices such as infrared thermometers, radar, laser gauges, multispectral sensors and other devices that can be mounted aloft would be increasingly useful. These can be mounted in low-flying, intermediate and high altitude aircraft, rotary-wing aircraft, and tethered or free-floating balloons. Questions do exist, however, concerning what is being sensed, recorded and reported in many instances. Often we know that something is being sensed but do not know exactly what it is or, more frequently, its significance in terms of location and time, accuracy, and precision. Much well-designed and executed work remains to be done to more clearly answer these questions before the full utility of remote sensing in resource planning and management activities will be clearly established. Concerted efforts at acquiring meaningful ground data are required. These seem most difficult to plan, finance, and prosecute.

Many sensors which have been developed can be mounted and operated from spacecraft. All are familiar with the excellent color and black-and-white video and photographic images that have been obtained from manned and unmanned space flights. Utilization of airfoil-level (U-2 aircraft) sensor images and images from space platforms in weather research and prediction and in other activities is also well known. Apparently we are not yet clear, however, on the significance and utility of space images in actual planning and management and engineering activities in the coastal zone. It seems axiomatic that the further removed from the Earth's surface the sensor is, the less detailed and accurate will be its images. But in fields such as this, axioms are frequently not as universal as postulated. Technological breakthroughs may further be accomplished that render high altitude and space observations more useful for particular purposes.

## COMMENTS ON REMOTE SENSING AND CHESAPEAKE BAY

In the research and development phases of the operations of our marine environmental and resources management system, remote sensing would seem to have certain potential. Space and high altitude observations will be useful. Visible region spectral signatures could be used to study injections and dispersion of sediments and detritus from tributaries into larger bodies of water, from outfalls and from bays and rivers to the ocean. These signatures will also be useful in directly tracing dispersion of certain pollutants and phenomena such as natural slicks and fish.

Tracking of water colored by suspended silt and other materials coupled with infrared radiometry and other remote imagery are useful analytical techniques in certain circulatory and temperature studies. A critical need in marine research is development or adaptation of remote imagery techniques that will permit better studies of circulation patterns in the Bay area. Aerial sensing, coupled with drogue and dye releases and other surface activities, will greatly enhance these activities.

Should techniques be perfected and employed in time, they may be useful in the design, verification, and later use of the Chesapeake Bay Model.

As indicated earlier, it is not my purpose to explore the possible applications of remote sensing to planning and management of engineering activities in the Bay. I prefer to leave those subjects to the group discussion to follow since others with far more experience in the technical aspects of remote sensing will be involved.

A stress must be laid upon the need for adequate ground truth acquisition. It is not enough to develop and fly an instrument system. We must know what the instrument is sensing in all four dimensions, or in as many dimensions as possible. And we must recognize accuracy, precision, and significance of the measurements or readings. This most crucial phase of remote sensing systems development has been neglected. Even after more than a dozen years, the utility and possible significance of infrared thermometry in oceanographic research has not been fully established, to my knowledge.

The utility of aerial observations made at low altitudes is clear. What must be accomplished in objective, thorough, experimental fashion with full controls is a stepwise examination of specific remote sensing techniques at set altitudes of 1000, 5000, 20 000, 60 000, 120 000 feet and orbital altitudes or at other suitable increments. Along with simultaneous ground truth observations, these experiments would establish significance of intermediate- and high-altitude as well as space observations of natural phenomena, a most essential aspect.

Considerable attention has been given to priority problems and needs in coastal zone management and in coastal zone research by several scientists at the Institute at large and in its Remote Sensing Laboratories. This joint effort between remote-sensing experts, environmentalists, and other oceanographers resulted in the comprehensive report of J.C. Munday, et al. (ref. 12) which can be consulted for greater detail.

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# Use of Remote Sensing in Shoreline and Near-Shore Management

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My perspective on shoreline and near-shore management is that of a governmental program manager rather than that of a scientist or technician in the field. The disciplines that contribute specialized information to successful decision-making in the shoreline and near-shore zones are best left to these specialists. The function of the Maryland Department of Chesapeake Bay Affairs and other agencies like it is to receive such specialized information, apply it within a legislated system, and make decisions contributing to the legislative objective. Examination of a Bay resource problem from this perspective should suggest problems and opportunities for the application of remote sensing technology that will be somewhat different from most of those already discussed.

Two laws applying to the management of shoreline and near-shore activities form a frame of reference; the first is hypothetical; this can be called the Maryland Tidal Shoreline and Near-Shore Management Act of 197X. It is a law that is rather vague in concept, but increasingly clear in need. Modest development work on such an act is underway in Maryland, and similar ideas are in various stages of development in some other coastal zone states. The second law is the Maryland Wetlands Act of 1970, which has been in legal effect for just nine months.

First, though, here are a few loose definitions. Shoreline activities are defined as those events taking place on land within about 200 feet of shoreline that have an effect on, or are affected by, open water. This excludes some events that might take place near water but are not generally related to it—such as land traffic movement. It includes physical events like earthmoving and psychic events like sitting on a porch and watching whistling swans feed in a cove. Near-shore area is defined as the shallow water area within which man is likely to build something like a pier, jetty, or bulkhead; typically, he may want to modify the bottom to float a deeper-draft boat; create new land or acquire fill material; and engage in activities that affect, or are affected by, other shore or near-shore activities, such as waterskiing, skin diving, hunting ducks, or launching beer cans.

The Shoreline and Near-Shore Management Bill of 197X is written with the recognition that much activity is going on in this zone that affects other uses in the zone and in areas beyond, either landward or waterward. Further, these activities are increasingly competing, resulting in actual and potential conflicts between uses and between stated and unstated *public policies* regarding the zone. In short, the zone is one of multiple use tending toward a less than optimum mix of uses.

The law explicitly recognizes the public and private benefits of the use of the zone for sport and commercial fishing, boating, skiing, and swimming; for the location of residences, summer homes, parks, water-oriented industries, and waste treatment plants; for laying of public utility lines, construction of bridges, and extraction of minerals including fill material. In short, the law acknowledges that some sector of society is benefiting from each use to which the zone is put. Further, the law enumerates the importance of the zone to the area beyond, to the economy of the state, to the Bay and ocean biological productivity, and to the general character or style of the Bay region. Further still, the law enumerates the public costs of shore erosion, noise and nuisance, loss of life and property from floods and accidents, and of ugliness, disease, and disorder. Finally, the law states that there is a natural system to be protected and a tradition and way of life to be preserved.

The purpose of the law is to establish a system whereby the State will regulate man's activities in the near-shore and shoreline area to increase the benefits of the zone and reduce or eliminate the costs and conflicts. This objective is easy to state in the abstract. It is much more difficult to establish a mechanism to achieve it, and still more difficult to execute.

The mechanism is as follows: First, the responsible state agency establishes zone boundaries according to various physical, geographical, and biological categories. Typical questions to be answered in this first step are: Where are the lowlands, where are the steep banks, where is land close to deep water, where is land far from deep water? Where are the coves, beaches, marshes, and mud flats? Answers to these questions sound rudimentary and readily available, but the information involved needs to be put in far more organized and accessible form than it is now.

Second, the agency determines what is going on in the zone. Where is industry, where is dense residential development, where is rapidly expanding recreational home site construction? Where are the concentrations of swimmers, fishermen, and birdwatchers? Again, this seems like common information, but its sources are scattered, disorganized, and highly variable in reliability.

Third, the agency, after public hearings and inter-governmental consultation, draws up guidelines and criteria for spatial location of various near-shore water uses. Certain areas are identified as being better than (or not so good as) others for various kinds of uses and use mixes. For example, limits are postulated for the number of boats and piers a cove can accommodate, the amount of shoreline that can be bulkheaded, and area of the bottom disturbed without sharply affecting biological productivity and other values. Certain areas are identified as being especially suitable for high density boating use, or for retention of natural character, or for use by heavy industry.

Fourth, the State exercises its sovereign regulatory powers to control the uses of the water surface, water column, and bottom to move toward the desired state of optimal use, using as its guidelines in case-by-case situations the criteria developed in step 3.

Fifth, surveillance and enforcement of regulations represent the control and compliance phase of regulation.

And finally, the effects of this regulation are monitored to provide information for making possible changes to the basic guidelines and criteria or to the decision-making process.

This is admittedly a simplistic scheme. There are many difficult steps involved, perhaps the most difficult being that of standard and criteria-setting; that is, the development of a plan. Enormous amounts of data have to be assembled and displayed to make such a program work. Most states, including Maryland, have had experience with regulation of the activities to which I have been making reference. But most of these have been conducted without clear concepts of the existing conditions of the zone, the changed character when given various developmental vectors, regulation achievements to date, and the desired change in conditions over time. In short, the programs have been regulatory programs without baseline information, without goals, and without feedback.

Some aspects of the Maryland Wetlands program relate to information needs and information portrayal. This program, which regulates dredging and filling in State wetlands, and a wider range of activities in private tidal marshes, has the policy objective of protecting and preserving the wetlands of the State. It is but a special case of the more general shore-area regulatory function just described. Only one primary social objective is involved—the protection of the biological contributions of wetlands—and only a few of the many possible activities are regulated. Yet, the problems of execution are essentially the same as those under a more general law.

First, we need to know what is there. The laws call for an inventory and mapping of all private tidal wetlands in accordance with a rather rigorous physical and legal definition. We have needed to look at the Bay area in a new way; that is, to ask for new information. False-color infrared photography taken from 6000 feet has been used when marsh vegetation was at maximum vigor. Then, marsh plant species and associations were identified and from their distribution various zones of tidal influence were inferred. The zones that are subject to regulation are then mapped. Early mapping experience has surfaced some technical difficulties, but this is one of the few feasible approaches, given constraints of time, money, and legal requirements.

In addition to this mapping requirement, which involves at least some sophistication by way of the application of remote sensing, some mundane information needs also exist. For example, our cases must be located. An application typically includes a 1:24 000 scale vicinity map of the area with a small mark indicating the location of proposed work. Somewhere in the Department of Natural Resources, probably a field worker or law enforcement officer knows that site well but this person's description of the site cannot generally be gotten. With a small staff and an application rate that runs to several hundred cases a year, a quick way to get information about land use, vegetation, water depth, topography, and the general character of the area is needed. Furthermore, the accuracy of the plan as it depicts the existing shoreline and the locations of dredged and filled areas should be checked. Presently, short of conducting our own ground survey, we have to rely on the accuracy and completeness of the plans of the applicant.

Further, a rapid, extensive, and inexpensive method of enforcement, surveillance, and inspection is needed. We need, for example, to be able to check on an applicant's conformance with the physical limits set by a license, and to be able to detect illegal dredging and filling operations.

Finally, we need readily available information of a wide variety to serve as the basis of decision-making and as the source of continual upgrading of the rationale behind our decisions.

I would like to close by highlighting one point that Governor Tawes mentioned in his address. Successful management of the shorelines and near-shore areas depends ultimately on public acceptance of the importance of such management and acceptance of the methods by which it is undertaken. If this management is to be rational, it must be based on a realistic popular conception of what the situation is, how it got to be this way, and where it is going.

Imagery from the air seems to me to convey an unusually strong message as to current patterns and trends in Bay shoreline use. To view the Bay from 60 000 feet using high resolution color photography is a most revealing experience even to persons who know the Bay shoreline well. For the general public, for legislators, and for managers without extensive field experience, it is a highly valuable educational experience. I am sure that there are types of imagery and techniques of presentation that would have significant impact on the attitudes of persons other than planners, managers, and scientists. Because there are so many interests involved in shoreline use, and because the problems there are only soluble with broad public acceptance of government programs, the public information aspects of remote sensing are of prominent importance. I suggest that we give attention to this general public use of remote sensing information, as well as to the more specialized potential uses by the scientists and technicians assembled here.

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# Problems of Urban Development and Growth

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The most conspicuous feature of world population growth is its accelerating rate, concentrating in urban areas. As cities increase in number, size, and functional complexity, they become focal points of environmental stress for many reasons:

(1) They consume resources in greater quantities and at faster rates. Can remote sensing reveal new water supplies? Timber sources? Mineral-related structures? Construction materials? Which sensors, which spectral bands, and what resolutions will be most useful?

(2) Cities encounter increasingly severe waste disposal problems in the air, in the water, and on land. Can remote sensing identify pollutants, locate their sources, and trace their dispersal? A report on the state-of-the-art of sensing of pollution has just been completed by the Geographic Applications Program for NASA, and publication is expected soon.

(3) Larger and larger areas are being devoted to transportation networks. Can remote sensors help to determine what new linkages will be needed? Can traffic flows be measured from aircraft or satellite platforms?

(4) Urban agglomerations become dependent upon more distant sources of food. Can we measure urban encroachment on farmlands, and locate new ones or help to intensify the production of old ones?

(5) Cities concentrate people in hazard zones. Can remote sensors help to identify faults and aid in earthquake research? Warn of storms and floods? Identify potential landslide and cave-in areas?

(6) In cities, economic and social problems are intensified as the result of competitive demands by pressure groups for incompatible uses of available space. Can remote sensors provide background data to help policy makers and administrators reach more logical or justifiable decisions?

The answer to all of these questions is a qualified yes. Remote sensing technology can help, but quantified requirements are needed to improve the state-of-the-art, and we will consider current capabilities and future aspirations at the workshop session later.

Two very important problems involved in urban analysis and planning are:

(1) The rapidity of land use and functional change, coupled with delays in obtaining pertinent data promptly by means of traditional techniques

(2) Differences in definition and categorization of urban land uses from place to place, coupled with differences among local studies in time, scale, and purpose

To help solve those problems, the Geographic Applications Program of the U.S. Geological Survey, in close cooperation with NASA, has focused a large part of its effort upon urban change detection and the preparation of an Atlas of Urban and Regional Change, to obtain a national overview of urban conditions, and to measure the environmental impact of urban growth and internal functional changes.

In spite of early settlement of the Chesapeake Bay area, and the function of the Bay as an important shipping lane, urbanization of its immediate fringe has lagged far behind the national average. In 1960, 70 percent of the population of the United States was urban, and samples of the still incomplete 1970 census returns indicate a substantial rise in that figure. In the 23 counties bordering the Chesapeake Bay only 25.8 percent of the population was urban in 1950; 29 percent in 1960; and 30.7 percent in 1970. Even so, one must recognize that the hinterland of the Chesapeake Bay provides targets for its shipping, markets for its fisheries, and sources of its pollution. That hinterland includes the southern third of the highly urbanized Northeastern urban corridor, commonly known as Megapolis, which extends from Norfolk to Boston, and which is rapidly expanding inland from the coastal zone toward the headwaters of the principal rivers that are tributary to Chesapeake Bay.

The immediate hinterland contains one of more than a score of urban test sites (Washington, D.C.) currently under study to develop more effective methods for using remote sensing technology and data from high altitude aircraft and satellite platforms to measure, analyze, and predict urban changes and their environmental impact. The popularly known Census Cities Project of the U.S. Geological Survey's Geographic Applications Program is being conducted in cooperation with the Department of the Interior's Earth Resources Observation System (EROS) Program and NASA's Earth Resources Program.

Twenty-six cities, widely distributed over the United States, and representing urban communities of different sizes, shapes, growth rates, functions, and environmental settings, were selected for the experiment (see fig. 1). More than 20 of them were photographed with nine cameras from 50 000 feet above the surface by NASA overflight missions timed to coincide as closely as possible with the time the 1970 census of population was being taken.

Some significant problems in urban data acquisition have been revealed or clarified to date. Among them, are such problems as:

(1) Determination of the relative effectiveness, for different purposes, of different remote sensing systems, including the use of black-and-white, color, color infrared and multispectral films; radar, scanners, microwave, scatterometers, and other devices

(2) Development of information systems which are compatible with data sources, instrument capabilities, user needs, and cost effective procedures

(3) Creation of simplified models capable of receiving and using small-scale data effectively.

(4) Learning to use surrogate signatures to interpret specifics from what can be seen.

(5) Finding the real utility of remote sensor technology in urban transportation studies, in the extraction of housing and neighborhood quality data from aerial and satellite photography, in locating vacant housing, and in identifying intraurban relationships in complex urban regions.

As indicated earlier, one of the test sites for which remote sensing data are being applied to practical problems of urban planning and policy formation is the Washington, D.C., urbanized area. The U.S. Geological Survey is using data obtained from NASA and other sources, in cooperation with the Metropolitan Washington Council of Governments and the University of Iowa's Institute of Urban and Regional Research, to prepare a land use analysis of the District of Columbia and seven surrounding counties. Plate 1 shows the flight lines and area covered by overflight mission 128 on June 28, 1970, with an RB-57F aircraft at 50 000 feet above the terrain. There were three north-south flight strips, spaced about 18.5 kilometers (11 miles) apart. The diagram in the lower right corner shows the area covered by each of the cameras aboard the aircraft. The legend shows there were nine cameras.

Figure 2 is a diagram of the photos from nine sensors, for a central frame over the Washington test site. On the left are sample frames from three metric cameras, and on the right, sample frames from six Hasselblad cameras. The two RC-8s have a focal length of 6 inches, and produce an image scale of 1:100 000 at a flight altitude of 50 000 feet. One of these cameras has color infrared film with a minus-blue filter. The other camera has black-and-white panchromatic film used with the same filter. Each of the RC-8 photos covers a square about 14 miles on a side, or an area of some 200 square miles. Photographs were taken with 60 percent overlap in line of flight and about 30 percent sidelap between flight lines. This provides stereoscopic coverage and permits three-dimensional viewing. A Zeiss camera with a 12-inch focal-length lens takes pictures at a scale of 1:50 000 and covers a square about 7 miles on a side, or an area of nearly 50 square miles. This camera also is loaded with color infrared film but the lens is fitted with a "D" filter. With the Zeiss camera there is edge-to-edge coverage in the line of flight, but there is some gap in coverage between flight lines in some instances.

The Hasselblad cameras all use roll film, 70 millimeters wide. Three are loaded with black-and-white multispectral film, one with infrared color film and two with color film. Of the cameras with black-and-white panchromatic film, one has a green filter, one has a red filter, and the third contains black-and-white infrared film. These three cameras simulate television cameras which are scheduled to be aboard the ERTS-A platform. In the ERTS data handling systems these three different television images can be combined to form one false-color image. The composite image is represented by the fourth camera, which contains color infrared film and the same minus-blue filter used on the RC-8 cameras with color infrared film. The two cameras containing panchromatic color film have on one a stronger blue filter for

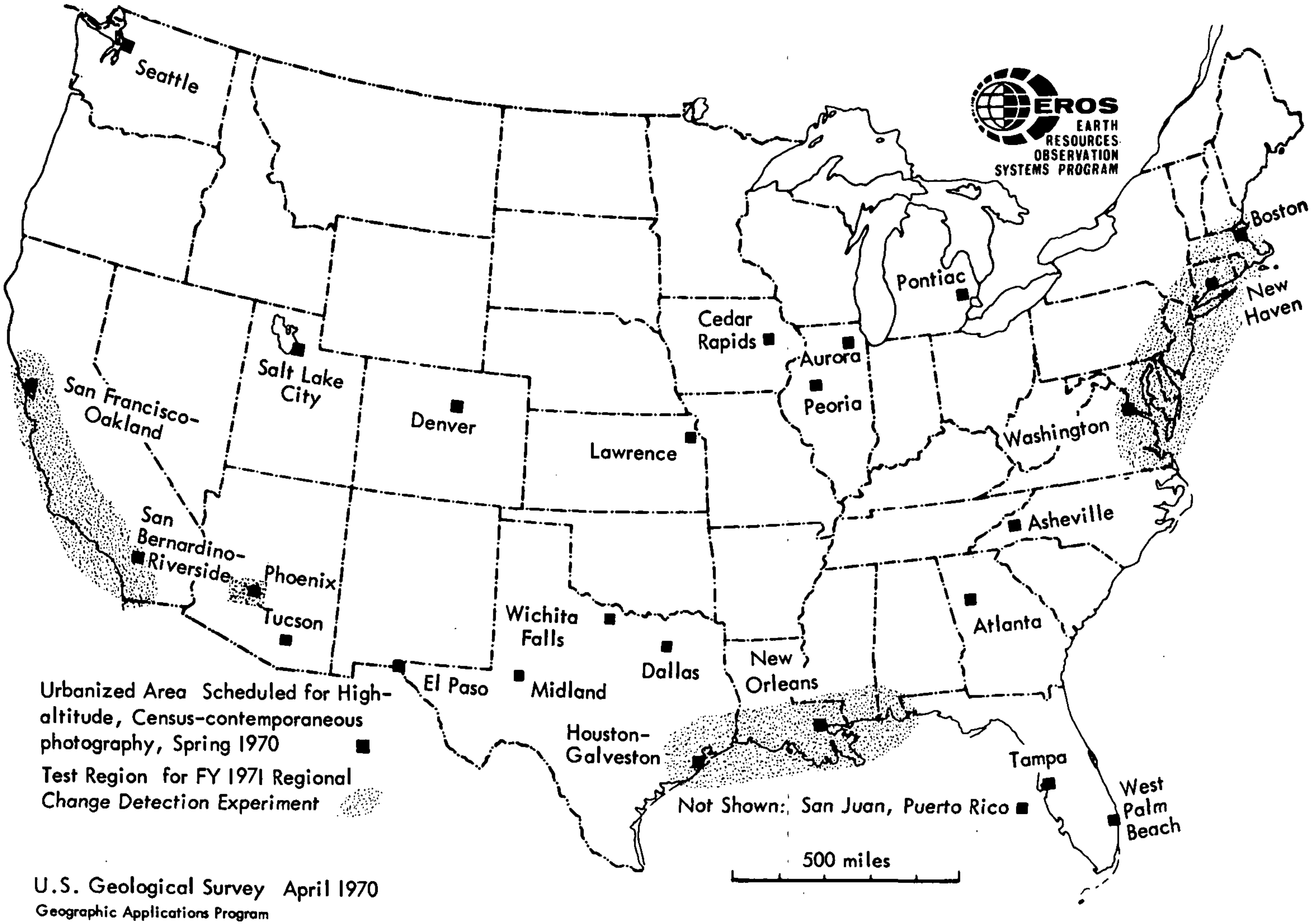



Figure 1.–Map showing urban and regional test sites.

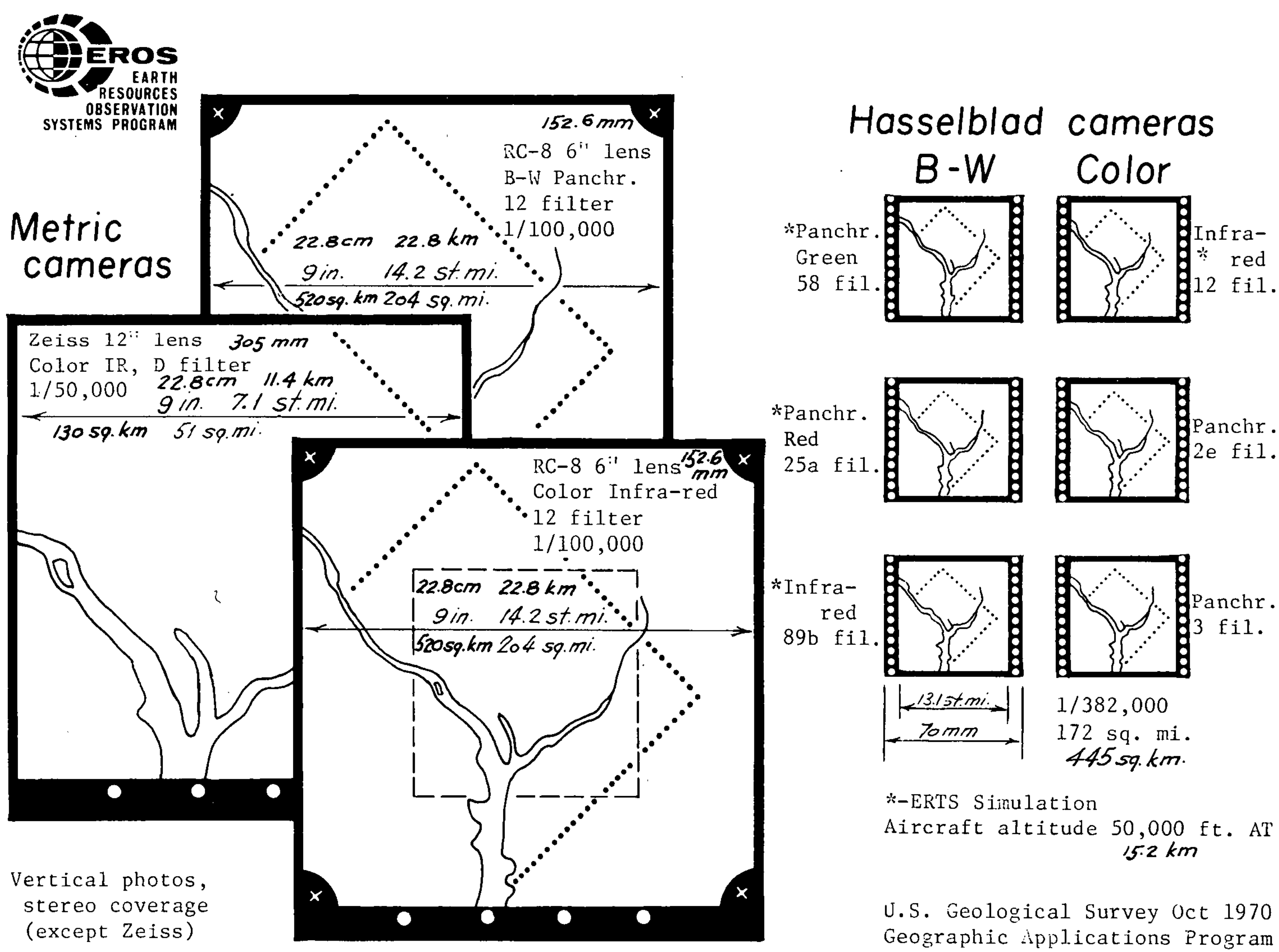



Figure 2.–Diagram of photo sensor set, one frame per camera, mission 128, Washington, D.C.

additional haze penetration, and on the other a no. 3 filter to render the scene about as would be seen through the camera sight at the time the picture was taken. Each of the Hasselblad cameras has a 40-millimeter focal length lens which covers about 175 square miles (slightly less than the RC-8 camera), producing an image scale of 1:382 000 from a flight altitude of 50 000 feet above terrain.

The first step in urban analysis is the preparation of a rectified photo mosaic, fitted with a rectangular coordinate grid. Figure 3 shows a portion of the mosaic of Washington, D.C. This portion is a simulated page for an Atlas of Urban and Regional Change. The grid interval is one kilometer. The publication format will have a mosaic square 20 X 20 kilometers at 1:100 000. This square is placed to the left of the center on a standard page used for computer printout (28 X 38 centimeters). The right hand panel provides legend space for overprints or overlays, or for extension of the map area. Pages may be bound at the top or at the left, or used singly, and folded into reports using the page size of conventional office stationery.

As in other experiments proposed for the Department of the Interior's Earth Resources Observation Systems (EROS) Program, the Universal Transverse Mercator projection and rectangular coordinate system is in use, and all distances and areas are expressed in metric units. Geographic coordinates and bar scales in non-metric units are also shown, however, and the various State coordinate systems can be indexed for users who require them.

The next step in the urban analysis is the preparation of an overlay showing the census statistical areas. A simulation of the census overlay is shown in figure 4. The fine solid lines in the figure represent the census tract boundaries. The numbers represent the census tract identifications. Supplementary overlays could show additional point and line features appearing on the mosaic, or essential to its interpretation.

The next step is the analysis of area features, especially land use. This is illustrated in plate 2, a simulated overlay or overprint for a portion of Washington, D.C. The land use interpretation is plotted directly on an overlay to the color infrared photography at 1:100 000. The smallest mapping unit is a square 0.2 kilometer on each side, or about 11 acres. This is not much larger than the area covered by the blunt end of the color pencil used in the image interpretation, but this minimum-sized mapping unit is larger than the anticipated resolution cells. The legend shows the nested land use classification system presently being tested in the prototype analysis of the Washington,D.C., test site. There are eight urban classes and five nonurban classes. Three of the classes are repeated, so there are really only ten different categories. The urban and nonurban land use categories can be expanded or contracted according to the scale and minimum-size area for mapping purposes. Land ownership information garnered from ground truth may be shown on the supplementary overlay.

After mapping land use to the limits of the mosaic, a single boundary line is drawn around the central mass of urban land uses. This is taken as the boundary of the urban area at the time of the overflight. It becomes the definition that will form the basis for comparison with other urban areas similarly delimited, and for analyzing changes in one urban area at different times.

The next step in the analysis is to measure the area of land in each land use category and to report the totals by census tracts. The information for a particular time period is then stored in computer retrievable format. The land use overlays and area measurements for two different time periods will form the basis for change detection, and for analysis of location, kind, and intensity of change.

Hopefully, the remote sensing study of metropolitan Washington will be expanded next year to include the Baltimore area and the urban corridor between the two cities. The processing of data for the additional area will be similar to the procedures described above but the resultant product will have more specialized applications. In addition to the end products of the Washington Census City study described above, the Washington-Baltimore study will involve the creation of an automated data bank programmed to receive additional information from all available sources, including geology pertinent to the area, hydrology, soils, climatic conditions, population distribution and structure, transportation networks, recreational resources, and other data recommended by policy-making and planning organizations at the federal, regional, state, and local levels.

Not much has been said about urban regions, but, in closing, it is important to emphasize that an urban region can be defined differently for different environmental and human activity phenomena in an area. For example, the boundaries of an urban resources region might be very different from those of a labor supply region; the boundaries for a food resources region might differ significantly from those for industrial resources; and boundaries for transportation networks might be very different from those for recreational resources. How does one define those boundaries or

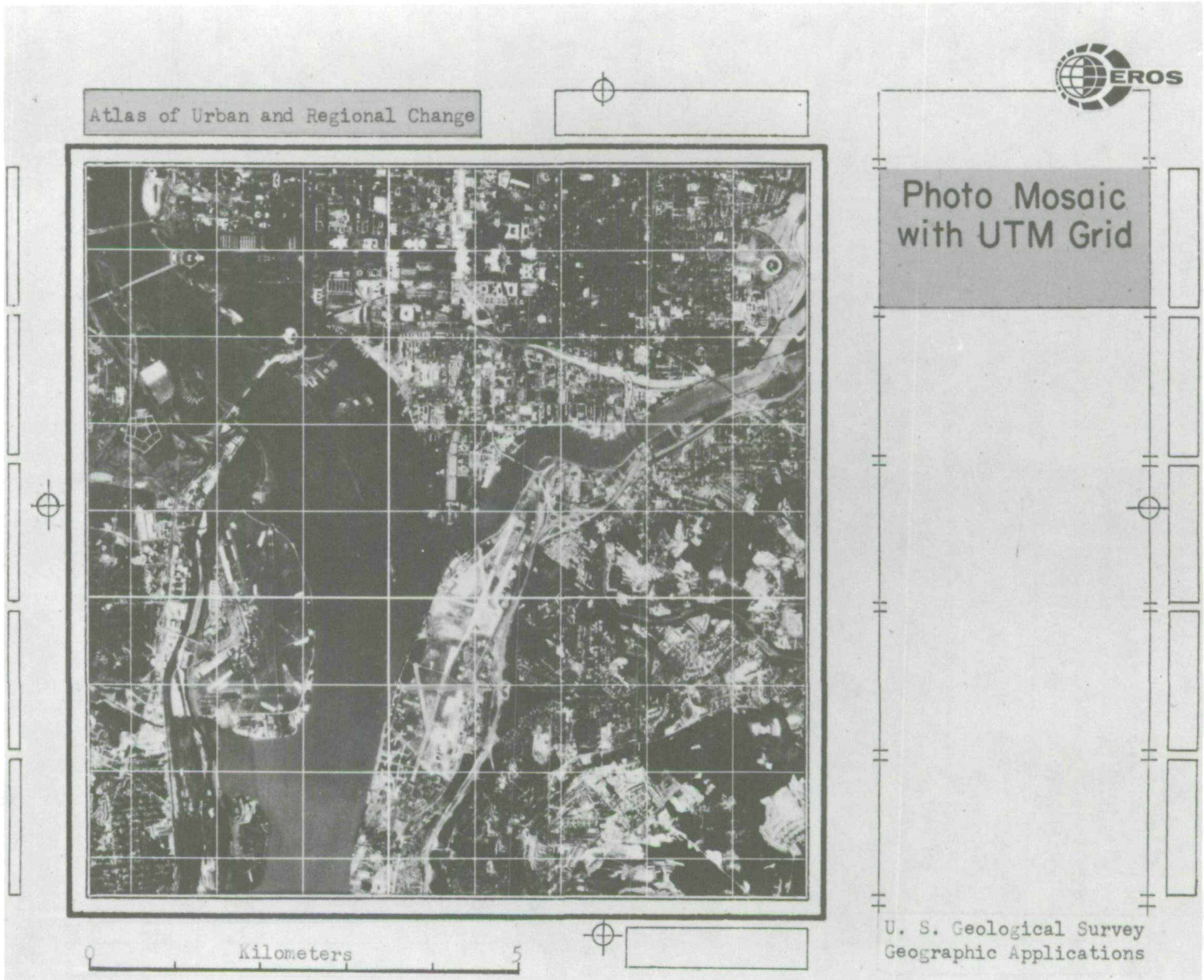



Figure 3.–Atlas of Urban and Regional Change, simulated page with gridded photo mosaic.

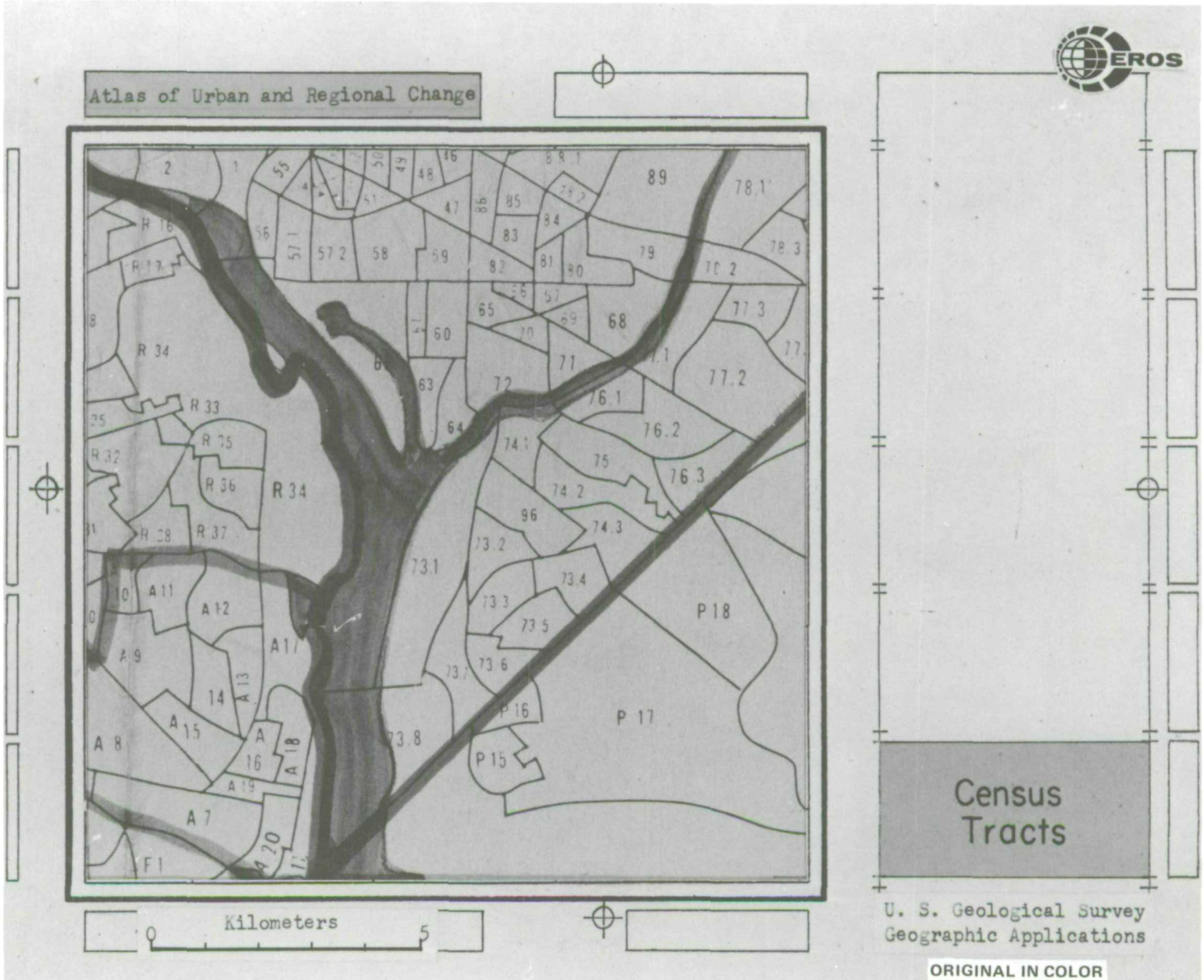
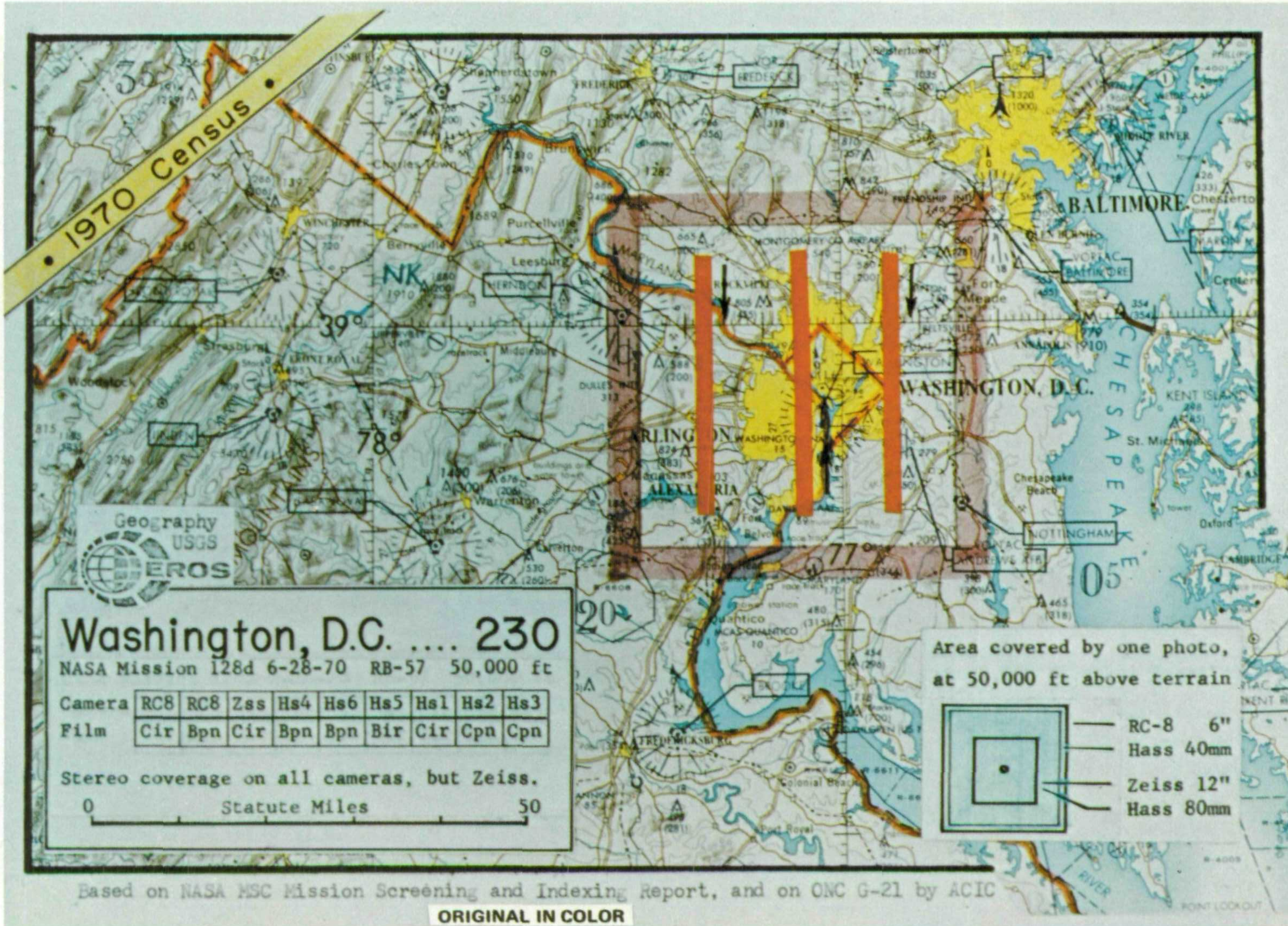



Figure 4.–Atlas of Urban and Regional Change, simulated page with census tract boundaries.

interfaces? Identify them? Measure their movements? Forecast their effects on neighboring cities? These problems and others will be discussed in the work group session.



ORIGINAL IN COLOR

Plate 1.–Map showing flight lines and sensor coverage area, mission 128, Washington, D.C.

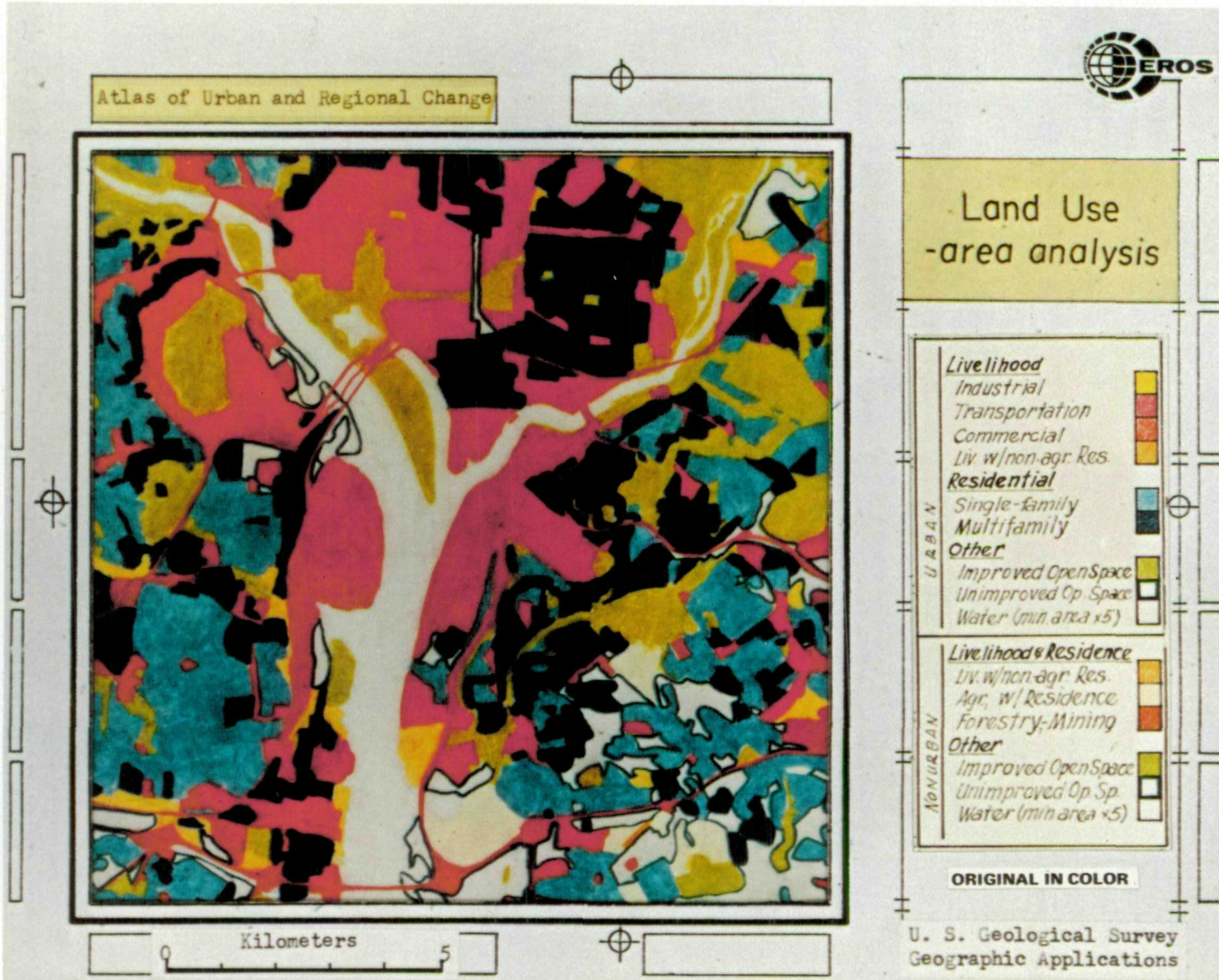



Plate 2.–Atlas of Urban and Regional Change, simulated page with land use interpretation compiled over the color infrared photograph.

# Chesapeake Bay Study

**COLONEL WILLIAM J. LOVE**
**U.S. Army Corps of Engineers**
**Baltimore, Maryland**

Chesapeake Bay, one of the world's most productive estuaries is situated in a rapidly expanding industrial and urban complex. Its location makes it probably more vulnerable to the adverse effects of man's work than any other estuarine system in the world. Saving it from severe damage by man requires a sound management program based on a firm foundation of expanding estuarine technology. Recognizing this need, the U.S. Congress, in Section 312 of the River and Harbor Act of 1965, directed the Secretary of the Army, acting through the Chief of Engineers, to make a complete investigation and study of the Chesapeake Bay basin and, further, to construct, operate, and maintain in the State of Maryland a hydraulic model of the Chesapeake Bay with an associated technical center.

The Chesapeake Bay study is a comprehensive estuarine study. It is multidisciplinary in scope, encompassing the fields of engineering and the physical, biological, and social sciences. This complete study of water utilization and control, involving the largest estuary in the nation and its spectrum of complex problems, is expected to yield significant knowledge of the interactions among many of the physical, chemical, biological, political, and social phenomena of importance to the Chesapeake Bay and other estuarine areas. This study will improve the environmentalist's ability to estimate the impact of man's work on estuarine ecology, based on the methodology to determine the carrying capacity of these important resources. The model is an indispensable tool in a study of such magnitude and scope. We will need to put it to use as soon as feasible during the study to obtain answers to problems which cannot be resolved otherwise. The model, when completed, should rapidly improve progress in our study of the conflicting uses of the Bay as they affect the total environment. The study is scheduled for completion by December 1976.

The objectives of the Chesapeake Bay study can be divided into three broad categories. The first objective is to provide an understanding of the existing physical, chemical, biological, economic, and environmental conditions of the Bay. The study will serve as a focal point for all research and management programs of the various federal, state, and local agencies having an impact on Chesapeake Bay.

The second objective is to define the attainable standards for the water-land resources of the Bay which are required to meet the needs of the people. These standards will be formulated from the following criteria: economic efficiency, regional development, environmental quality, and the well being of the people. Most importantly, the standards set for each water resource activity must be made compatible with all other activities.

The third objective of the study will be to provide a water-land management program to be used by all Bay management organizations for development, enhancement, conservation, preservation, and restoration of the Bay's resources. The program would consist of guidelines, management strategies, and programs that may be needed to assure wise utilization of the Bay's resources. This final study product is not the last word to be said about Chesapeake Bay, but it is a changing guide that can be amended to change in concert with increased knowledge of both this remarkable biological engine and the dynamic societal need.

The study is being managed by the District Engineer, Baltimore, Maryland, whose staff is experienced in managing resource development studies of comparable magnitude to the Chesapeake Bay study. Comprehensive planning experience in many disciplines has been developed and strengthened over time by intense involvement in diverse studies and continuous professional association with other agencies—state, federal, and educational—involved in the social, economic, and technical aspects of natural resource conservation and development. Fortunately the great reservoir of technical capability within the educational and research institutions, as well as from the state and federal agencies of the Chesapeake Bay region, is available in the pursuit of a study of this magnitude and scope.

The State of Maryland and the Commonwealth of Virginia support progressive state planning departments and water resource study and management departments that have been working on Bay problems for a long time. Agencies of the Federal Government that have been engaged in Chesapeake estuarine affairs include many of the component parts of the Department of Agriculture, the Department of Health, Education, and Welfare, the Department of the Interior, and the Environmental Protection Agency, in addition to the Corps of Engineers.

The Chesapeake Bay region is fortunately served by the Chesapeake Research Council, consisting of Virginia Institute of Marine Science (VIMS), and units of Johns Hopkins University and University of Maryland. The council is one of the most significant scientifically oriented groups operating in the Chesapeake Bay area. The Council's many years of vigorous research in the biological and physical aspects of estuarine studies have made the Chesapeake Bay region a worldwide center for estuarine studies. This group has been actively engaged in our study. The VIMS Director represents the Commonwealth of Virginia on the Advisory Group; the Directors of all three institutions serve on the study's Steering Committee. All three distinguished scientists have been involved from the beginning of the study.

The study is conceived, therefore, not only as a multidiscipline, but also as a multiagency effort–coordinated among federal and state agencies and educational institutions. In addition, participation from the public is considered vital to the practical achievement of the study's objectives, and such participation is a firm component of the study.

Extensive interagency coordination necessary to accomplish the objectives of the Act could best be achieved through an advisory group established early in the study. Such an advisory group was organized in September 1967 by General Frank Koisch, then Division Engineer of the North Atlantic Division, who invited the Governors of Maryland, Delaware, Pennsylvania, and Virginia, the President of the Board of Commissioners of the District of Columbia, and Secretaries at Federal Cabinet level to designate representatives to work at field level with the District Engineer, Baltimore, Maryland.

The study was divided into five general areas:

(1) Economic projections
(2) Flood control, navigation, erosion, and fisheries
(3) Water quality and supply, waste treatment, and noxious weeds
(4) Recreation
(5) Fish and Wildlife.

A task group was organized to cover each of the areas. A sixth task group, the steering committee for liaison and basic research, was formed to coordinate the work of the others.

From the beginning, the job of planning for the Chesapeake Bay will be one of decision making. The major decision to be made early in the study is whether the study is to be only reactive in terms of future needs, or if it is to be active in terms of attempting to support a plan to mold the future. Concepts of regional development, economic efficiency, and environmental quality as related to the study will be reviewed continually.

The study's objective is to identify and make a complete investigation of the problems in the system and present a full analysis of alternatives for the systematic resolution of conflicts among all interests. The study will not just compile an extensive inventory of bay-related problems. The role of the Chesapeake Bay Advisory Group in this venture will be to make available to decision makers a thorough analysis of planning alternatives by experts in the various fields connected with the bay environment.

The task groups have thus far done their jobs well. Outlines of programs submitted for inclusion in the study plan reflect serious deliberation and a genuinely cooperative spirit. The study has already begun to pay dividends by stimulating an increasing awareness of other agency programs and problems.

While pursuing each part of the study, constant emphasis is placed on the fact that a tidal waterway of the size of the Chesapeake Bay has a complex and subtle character. The Bay's hidden character could mislead the inexperienced into undertaking expensive works that may not fulfill their purpose, or could cause unanticipated and damaging results.

Because of the complexity of the hydraulic regime of Chesapeake Bay, powerful methods of analysis are required. Mathematical modeling is an excellent tool. It is useful in predicting the gross effects of changes on the hydraulic regime of the estuary. This modeling includes predicting tide elevations, discharges, and average current velocities over a given cross section. Unfortunately, however, information of this character is not sufficient for fine-drawn ecologic design or decision. However the capability of mathematical modeling is considerably expanded when used in conjuction with hydraulic modeling. On the other hand, practically all estuarine physical problems can be solved satisfactorily in a properly constructed and verified hydraulic model. A hydraulic model is least useful in assessing scour and shoaling, but here also it possesses a level of competence not available in other methods of analysis. Some phenomena, such as wind setup cannot, however, be predicted by hydraulic modeling.

The problems most encountered in the estuary appear to be problems of navigation improvement and pollution effects traceable to rapid increase in population and activities associated with urbanization. The hydraulic model will be extensively used in studies related to navigation. The problems that arise from channel improvement are many and challenging. Increasing both depth and width of channels poses the problem of disposal of spoil material. When deposited overside, spoil may return to the channel and add to maintenance problems and costs. The fraction that remains in suspension, causing turbidity, may displace biological processes. Increasing channel dimensions may permit saline water to penetrate farther upstream under fixed fresh water inflow conditions than had previously been possible. A larger channel, permitting heavier traffic of larger ships in the channel could cause increases in shoreline erosion as a function of waves characteristic to vessel speed, draft, and hull shape. Also protective works, breakwaters, training works, etc., unless designed in harmony with estuarine dynamics, could be embarrassingly destructive.

The above problems can be effectively studied through the use of the hydraulic model. The model will be used to determine changes in the current and tidal regime that can result from proposed new construction. The change is superimposed on the model, and compared to the existing regime. The model will help determine in advance the effect on the estuary that major changes in bottom geometry will have on the hydraulic regime including tide elevations and current velocities. More complete knowledge of the extent of salt water intrustion and the effect on magnitude and location of shoaling problems associated with new construction can also be derived through the use of the model.

Other equally complex and critical problems resulting from the effects of accelerating urbanization will be amenable to study by the hydraulic model. One will be the study of effects on the hydraulic regime of the modification of fresh water inflows including both inter- and intra-basin diversion on the tributary streams. The determination of the effects of tributary activities on the Bay environment are of considerable concern to oceanographers and marine biologists working on the Bay. Fresh water diversions of sufficient magnitude can alter the salinity regime of the headwaters of the Bay and affect the spawning opportunities of many species of fish. By altering the salinity regime fresh water diversion can also alter the hydraulic regime and affect the rates of flushing of embayments tributary to Chesapeake Bay.

The most potentially damaging aspect of man's utilization of Chesapeake Bay is the very great discharge of untreated or partially treated wastes into it. This is doubly compounded by discharging the wastes into a highly complex water body, the biological and hydraulic regime of which reacts to hydrologic conditions which develop in drainage basins far removed from the Bay proper.

Through the use of dye injections, hydraulic model studies will be useful in the determination of flushing characteristics of both the bay proper and its tributary embayments. Model studies will also help in locating outfalls where the least damage will be done. Further, where there is a distinct possibility of significant oil spills or of injection of particularly deleterious industrial radioactive wastes the model will be used to define the translocation of wastes through the Chesapeake Bay system, possibly in time to initiate actions which will reduce their damaging effects.

Use of the nation's water resources for the dissipation of waste heat is potentially as dangerous as the unrestricted discharge of the more obvious domestic and industrial wastes. The large generating capacity of contemplated thermal power plants is forcing public utilities operators to look to the estuaries to meet the increased demand for cooling waters.

Little is actually known about heat discharges. Available data indicate that an important aspect of this problem is the location of plants where they will do the least harm. Hydraulic model studies can assist in preselection of plant sites, the determination of change in the hydraulic regime caused by plant construction activites, and estimation of the temperature regime to be imposed on the estuary by heat loading. All of these considerations must precede ecologic impact studies.

The process of land filling and reclamation can cause significant changes in estuarine hydraulics, besides having the potential of being ecologically unsound. Drastically reducing the water area can alter the existing current regime and reduce the volume of the tidal prism, thus reducing the capacity of the area to assimilate waste and flush itself. Here again the hydraulic model will prove valuable in assessing the practicability and long-term effects of landfill operations.

The current systems, tide stages, and water quality factors of Chesapeake Bay are complex and highly variable over time and space. When the works of man are superimposed on a regime controlled by astronomic, meteorological, and hydrologic forces that are as yet incompletely defined, it is immediately evident that even the most geometrically uncomplicated estuary is a difficult water body to evaluate. These difficulties are compounded many times over by an estuarine system as complicated and as extensive as the Chesapeake Bay. The hydraulic model of the Chesapeake Bay will be of great assistance in designing a viable management scheme to guide us in determining the future of the Bay. The task will be both exacting and exciting.

A technical center is included in the planning of the hydraulic model facility at Matapeake. Presently plans for the technical center are of modest proportion. Its proximity to Washington and Baltimore, and to local educational institutions, as well as the availability of waterfront facilities make this an attractive location for increased future development of facilities for estuarine related research.

# Group Discussion on Industrial Waste Pollution

**LOREN D. JENSEN, Chairman**

This work group recognizes that the present trend toward more intensive urban and industrial development has caused the introduction of a great variety of wastes and industrial byproducts into estuarine waters. We recognize that the full scope of the problem and its effects are not yet well defined. This group addresses itself, however, to identifiable conditions, and the potential use of remote sensing in problem areas.

Within the participants' knowledge, certain water-quality characteristics reflected in surficial conditions could be measured by remote sensing techniques. Remote sensing of the water surface has generally been most successful in conditions related to oil spills, thermal differences, identification of planktonic and algal blooms, vegetation at the surface, and biogeographic studies. The use of remote sensing techniques in estimating sediment concentration under certain conditions has also been reported. All of these applications have been successfully verified by extensive ground-truth measurements.

In complex estuarine areas surficial conditions do not necessarily represent the characteristics of the water column. Baltimore Harbor, with its three-layer system, is an excellent example of hydraulic conditions of this type. Water quality characteristics of the seaward flowing middepth, however, cannot be evaluated by existing remote sensing techniques.

The collection of subsurface water quality data and its transmission on command to satellite or aircraft was discussed. The economies of both remote sensing and buoyed data collection systems can only be realized through the use of rapidly responding in situ sensors or probes. Presently available water quality monitoring systems are less than adequate. They are not only subject to mechanical problems, but also to biological fouling and instrument drift. In addition to the above problems, many ion-specific probes are readily inhibited by the presence of substances commonly found in surface waters. Also, the presence of sulfate ions can render a dissolved oxygen probe inoperative.

We noted that millions of dollars have been spent on development of sophisticated remote sensing equipment of impressive performance. However, development of in situ instruments has lagged enough to retard applications of remote sensing to the identification and surveillance of water-quality problem areas. *This is an immediate research and development need.*

Many of the existing water-quality problems are a function of improper industrial site location, where receiving water volumes are inadequate to accept even treated wastes. Remote sensing may prove valuable for initial reconnaissance in the search for site locations where minimum damage will be done.

The work group recognized the desirable value of remote sensing techniques as well as present weaknesses. The group endorses the development, refinement, and integration of rapidly performing hydraulic and water-quality data acquisition systems, both remote and in situ, for monitoring and surveillance activities in the Chesapeake Bay.

Remote sensing can provide an information base for identification and analysis of certain changes that may occur within the Chesapeake Bay region. The hydrologic region is dynamic, having short-term tidal variations, seasonal changes, and perhaps long term trends. Remote sensing provides the only realistic means for large area synoptic coverage of the entire Bay region within a short time period. Remote sensing can identify sources, movement, perhaps the fate of wastes, and even show the long-term response by the hydrobiologic regime. Remote sensing can provide useful information for establishing a network for ground-truth data collection points. The ground data provides a means of calibration and quantification for remote sensing data and, in turn, the remote sensing data provides information between the ground based sensors. The synoptic overview establishes reference data for comparison with repetitive data.

From these data ecological changes can be analyzed and long-term trends can be identified and projected.

## RECOMMENDATIONS

It appears that remote sensing techniques have application in the solution of various specific problems related to industrial pollution. One such problem is location and classification of industrial discharges. Location includes finding the point source of discharge into the Bay and the specific source. Classification might be by categories such as heat, household waste, oil waste, suspended solids, chemical waste and other waste. It also appears that remote techniques may have application in monitoring effluent quantities and contents. In addition, specified water-quality parameters may be remotely monitored.

We recommend that NASA determine the capability of existing remote sensing to assist in discharge location and classification, and to monitor effluent and water-quality; further, that NASA arrange for additional research to extend this capability. It is further recommended that NASA extend its considerable capability for the development of instrumentation into the field of in situ environmental measurement, i.e., the development of a more reliable water-quality monitoring system.

It is recommended that a permanent advisory group consisting of representatives of the various interested agencies be convened to advise and coordinate research and development and the utilization of data from all environmental points of view for the location, identification, and quantification on a systemwide basis.

We know that certain remote sensing equipment can and will serve a useful purpose in detection and identification of effluents along the shoreline. These instruments therefore should certainly be included in the payload of any aircraft designated by NASA for data acquisition over the Chesapeake Bay area. The instruments which we feel should be included are:

(1) Infrared thermal mapper (required specifications are: thermal resolution 0.1°; spatial resolution 2 milliradians)
(2) Multispectral camera (4 to 6 spectral bands of an RC-8 or Hasselblad type camera)
(3) Ultraviolet spectrometer

Additional equipment may be suggested later by the industrial pollution advisory group, based on further research and investigation.

## SUMMARY

Established applications of remote sensing to water pollution induced by industrial outflows are currently limited to certain signatures on black-and-white, color, color infrared, and multispectral aerial photographs, and on thermal infrared scanners and multispectral scanners. Specifically these are visible outflows identified by color or color variances and/or images of thermal anomalies indicated by heat sensing.

The state-of-the-art is still relatively undeveloped. Thermal reactions may be measurable to some extent, but most other signatures are qualitative observations only. It is generally agreed that quantitative measurement of pollutants through remote sensing is some distance away and that adequate technical ground-truth data must be used.

Currently, therefore, remote sensing is a pollution analysis tool serving two useful roles. First, it can be a detector of actual and/or potential pollution. Second, it can be used for continuous post-enforcement monitoring of polluters and potential polluters. In between these two functions is a vast area of industrial processing technology which must be known before pollutants can be accurately identified.

Remote sensing has considerable promise as a tool for analyzing and monitoring industrial pollutants of water. Enough signatures have been established for pollution abatement officials to begin using them in conjunction with other sources of information, in their assessments of problems.

Such sensing equipment as microwave radiometer, sidelooking radar, scintillation detector, and Fraunhofer line discriminator have all shown promise of useful applications. Along with these, image enhancement techniques should help render reliable signatures.

# Group Discussion on Air Pollution

JOHN C. BRYSON, Chairman

There are indications that urban air pollution problems exist in certain areas of the Chesapeake Bay region. Remote sensing will aid in large-scale measurement surveys needed to establish the present baseline pollution contours and levels. Subsequent surveys will permit evaluation of the variations in pollution distribution related to changes in population and industrialization.

To exploit the advantages of remote sensors, a mathematical model describing the spatial and temporal distribution of air contaminants and their relationship with meteorological conditions in the Chesapeake Bay area is urgently needed. Remote sensing can provide the data base for verifying and refining such models.

Remote sensing and local measurement of air pollutants are complementary methods. There is a definite need for improved ground-based instrumentation for use in both local measurements and ground-truth measurements for remote sensing. Remote sensing systems afford an overall view that is impossible to obtain with point measurement sytems. However there are some pollutants that are not easily detected with remote sensors due either to low concentrations or lack of suitable detection mechanisms.

A number of pollutant molecules lend themselves to detection by remote sensing techniques from aircraft and possibly satellite platforms. An example of such instrumentation is the gas correlation analyzer. These instruments, for remote measurements of the total burden of molecules such as CO and $SO_2$ are presently under development and should be continued. Other instrumentation to detect molecules such as $NO_2$, $CH_4$ and $NH_3$ is being researched. In addition, techniques such as laser scattering and infrared absorption should be perfected to measure atmospheric concentrations of selected molecules. Future research and developmental study to analyze and measure other pollutant molecules or atoms, both remotely and in situ, must be continued.

Special models of air and pollutant movements are necessary for air pollution episode planning and control. Since these episodes are due to special factors such as geographical, topographical, or meteorological features or industrialization density, they are unique and will require separate and distinct modeling. Remote sensing techniques, by providing wide-range coverage, could be useful in this case by providing information on the dynamics of the lower atmosphere over the region of interest.

Remote sensing techniques, e.g., multispectral scanning or photography, may be useful for locating areas of high pollution concentration by detecting pollution-damaged trees, plants, and crops. Although this method is qualitative in nature, it might be useful to air pollution control authorities for the determination of sites for the location of more sophisticated instrumentation. The measurements, taken over extended time periods, would also be useful for determining the effects of control measures.

Life cycles of many pollutants in the atmosphere are not clearly understood. Such information is essential for establishing cause and effect relationships and regional mass transfer. Carbon monoxide is one such pollutant whose sources are know but sinks are not yet determined. Remote sensing may be able to provide answers to such problems.

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# Group Discussion on Agricultural and Urban Pollution

**MORRIS L. BREHMER, Chairman**

Water pollution that results from agricultural activities and from the activities of human populations concentrated in urban areas differ only in that the former is introduced into the system with the fresh water run-off from each tributary stream whereas the latter is primarily from point source introductions. An exception to the former would of course be intensive livestock and poultry operations which concentrate large numbers of cattle, swine, chickens, or turkeys into small areas for the more economical production of meat or eggs. The environmental effects resulting from improper handling or treatment of the byproducts of agricultural and urban activities are essentially the same, however. Modification of the natural vegetation and terrain features can increase the rate of soil erosion by as much as 1000 times; organic material capable of depressing dissolved oxygen levels are produced; large numbers of pathogenic, nonpathogenic bacteria, and viruses develop and survive; pesticides and other toxic chemicals are utilized; nutrient elements such as nitrogen and phosphorus are constituents of the organic waste products. Estuaries and tidal waters are all too frequently the recipients of these materials in quantities which exceed the assimilation capacity, and environmental degradation as aquatic nuisance conditions result.

Data acquisition by remote sensing techniques can be of some value in water quality surveillance programs. At the present state-of-the-art, however, the applications are limited by the inability to detect and measure elemental constituents such as oxygen, phosphorus, nitrogen, heavy metals, etc.; organic compounds such as pesticides and PCB's and microscopic organisms such as bacteria and viruses. Value limitations are, however, imposed by the opacity of the water to the electromagnetic radiation now utilized in detection. In other words, only surface parameters can be detected and recorded. In view of the importance of subsurface characteristics, efforts should be strengthened in areas of instrument development and sophistication to permit scans of the entire water column.

The work group is of the opinion that remote sensing techniques can be utilized to locate and quantify levels of surface-suspended solids. These may be located in the upper tidal reaches of the tributary streams, just downstream from the transition zone between fresh and salt water (the turbidity maximum), in the vicinity of engineering projects or construction, and in the vicinity of extensive shoal areas during rough sea conditions. Remote sensing techniques could provide synoptic data on the Bay and its tributaries, provide information when sea surface conditions make in situ measurements difficult, and, if the sensing interval was properly scheduled, provide information on the movement and distribution of settleable solids.

Atypical phytoplankton populations resulting from hyperenrichment are also amenable to detection and measurement by remote sensing techniques. These populations may be characterized either by high biomass levels or by a change in species composition. Both parameters are important in evaluating water quality.

Instrumentation now available can detect patches of phytoplankton on and just below the water surface. Additional capabilities must be developed to quantify and characterize the populations.

Quantification may be possible by relating the chlorophyll-a concentration in the water to the standing crop. The work group is of the opinion that a precision of $\pm 10\ \mu g/l$ chlorophyll is necessary for the data to be of maximum value. Values of less than 25 $\mu g/l$ are considered to be within the normal range, 25 to 50 $\mu g/l$ indicative of atypical conditions, and values exceeding 50 $\mu g/l$ indicating degradation.

We recommend that instrumentation be developed to permit the identification of the groups of phytoplankton by remote sensing methods. Environmental quality is, in part, based upon the species composition of the plants present in the population. As a start, discrimination between blue-green, green, diatom, and flagellate forms would be of value to scientists and engineers involved with water quality and management studies.

Data on the location and density of rooted aquatic plants in shallow water areas can also be determined. Additional information on the species composition of these populations would be of value.

In summary, at the present state-of-the-art there are limited applications for remote sensing techniques in water quality evaluations. If these techniques are utilized certain rules must be observed if the data are to have more than superficial value. These include:

(1) The laboratory development and calibration of instrumentation must be directed to the environmental data needs.

(2) The ground-truth data acquisition program must be closely coordinated and financed by the remote sensing program.

(3) The frequency of remote sensing data acquisition must be governed by the environmental characteristics of the test site. For example, in the initial fixed-wing platform programs, daily flights for a short period may be necessary to determine the variation within the system. In any flexible schedule, the timing should be determined by an advisory committee knowledgeable in the estuarine sciences.

# Group Discussion on Estuarine Turbidity, Flushing, Salinity, and Circulation

DONALD W. PRITCHARD and MAYNARD M. NICHOLS, Chairmen

## RESEARCH GOALS

The work group began by defining the major goals of research in estuarine turbidity, flushing, salinity and circulation. These goals may be broken down into five categories.

### Suspended Materials

(1) To determine the sources, both proximate and ultimate, of the suspended material in the Chesapeake Bay and its tributaries.

(2) To determine the time-dependent spatial distribution of suspended material in the Chesapeake Bay estuarine system, and to relate this distribution to the sources, and to the physical processes that control re-suspension, vertical mixing and sediment transport.

(3) To determine the size distribution of the suspended material in the Chesapeake Bay estuarine system, including variations of the size distribution in space and time, and to relate these variations to the physical processes which control re-suspension, vertical mixing and sediment transport.

(4) To determine the character of the suspended material in the waters of the Chesapeake Bay estuarine system, i.e., the mineralogy of the inorganic materials, and the fraction of the suspended material which is organic.

(5) To determine the optical properties of the suspended material in the waters of the Chesapeake Bay estuarine system, for the purpose of relating the concentration and size distribution to the extinction of solar energy at specific wave lengths as a function of depth, and also to the visibility of divers using artificial light sources having specified spectral characteristics.

### Spatial Distribution of Salinity

(1) To determine the time-dependent spatial distribution of salinity in the Chesapeake Bay estuarine system for all naturally occurring conditions of fresh water-inflow history and weather history.

(2) To develop analytical and numerical models capable of predicting the time-dependent spatial distribution of salinity in the Chesapeake Bay and its tributaries given the time-dependent fresh water inflow to the Bay and its tributaries and also given the time history of certain pertinent meteorological parameters.

### Spatial Distribution of Temperature

(1) To determine the time-dependent spatial distribution of temperature in the Chesapeake Bay and its tributaries for all natural conditions of meteorological history.

(2) To develop analytical and numerical predicting models capable of predicting the time-dependent spatial distribution of temperature in the Chesapeake Bay and its tributaries given the time history of certain pertinent meteorological parameters.

### Velocity Regime

(1) To determine the time-dependent spatial distribution of the deterministic velocity regime, under the various natural conditions of the tide, the salinity distribution, and the recent history of wind velocity and atmospheric pressure.

(2) To determine the statistical properties of the stochastic velocity regime, as a function of the vertical distribution of the deterministic velocity, the vertical distribution of density, the distance from the free water surface and the solid bottom or side boundaries, and the characteristics of the surface waves.

(3) To develop analytical and numerical predicting models capable of predicting the time-dependent spatial distribution of the velocity regime.

### Diffusion and Exchange Processes

(1) To determine the most suitable theoretical expression for the turbulent diffusion when a dynamically passive contaminant is introduced.

(2) To determine the dependence of pertinent diffusion parameters on such factors as the mean current speed, the vertical and horizontal velocity shear and the vertical density gradient.

(3) To determine the most suitable analytical or numerical model, including coefficients, for the exchange between adjacent tidal segments of the estuary, and between the estuary and the adjacent coastal waters.

(4) To determine the pertinent exchange coefficients for intermediate and large-scale exchange processes between adjacent tidal segments of the estuary, and between the estuary and adjacent coastal waters.

## PARAMETERS

To obtain the environmental information required to attain these research goals, the following parameters must be measured:

(1) Current speed and direction of rectilinear components of the vector velocity as a function of $x, y, z$, and $t$

(2) Suspended sediment concentration as a function of $x, y, z$ and $t$

(3) Size distribution of suspended material

(4) Extinction coefficients (optical) as a function of wavelength, and of $x, y, z$ and $t$

(5) Rates of sedimentation (deposition)

(6) Physical and chemical properties of the suspended material

(7) Salinity as a function of $x, y, z$, and $t$

(8) Temperature as a function of $x, y, z$ and $t$

(9) Water surface elevation as a function of $x, y$ and $t$

(10) Volume rate of inflow of fresh water as a function of time and position in the estuary

(11) Wind velocity (speed and direction) and atmospheric pressure over the water surface as a function of $x, y$ and $t$

(12) Concentration of tracer materials (i.e., fluorescent dyes, introduced waste materials, or natural tracers) as a function of $x, y, z$ and $t$

(13) Physical dimensions of the estuary (i.e., shoreline location and depth distribution)

(14) Location of point of measurement (i.e., accurate values of the $x$, $y$ and $z$ coordinates of any of the above measures)

These parameters should be measured according to accuracy and sampling interval requirements given in table 1.

TABLE 1.–Measurement Requirements

| Parameter | Range | Accuracy |
|---|---|---|
| Current | | |
| Speed | [a]0.2 to 100 cm/sec, 3m depth interval | ±2% |
| Direction | 0.1 to 90° | |
| Suspended sediment concentration | | |
| Properties | 1 to $10^3$ ppm | ±1 to 25% |
| Size | 1 to 200$\mu$ | ±1 to 10% |
| Extinction depth | | ±1 ft. |
| Sediment deposition rate | 0.1 to 0.5 ft/month | |
| Salinity | 0 to 33 ppt<br>6 to 36 in. depth intervals–continued to seasonal time interval | ±0.05 to 3ppt |
| Fresh water input/output | | ±5 to 25% |
| Precipitation | | ±5% |
| Tidal height | 0.01 to 0.1 ft, 1 hr interval minimum | |
| Wind | | |
| Speed | | ±2% |
| Direction | | ±10% |
| Tracer concentration | 1 ppb to saturation | 5 to 20% |
| Temperature | 0.1 to 1°C | |
| Physical dimensions | 1 ft depth, 10 ft width | |
| Positioning | 1 to 30m | |

[a]Accuracy and sampling intervals of measurements of current velocity depend upon the specific problem area for which this information is required. Requirements vary from accuracies of ±0.2 cm $sec^{-1}$ (*for velocities up to 100 cm* $sec^{-1}$) *at sampling frequencies of up to 100 times per sec* for studies of the small-scale turbulent velocity spectrum, to accuracies of ±2 percent of the mean velocity, at sampling time intervals of 10 to 30 min, at vertical space intervals of about 3 m, at lateral space intervals of several hundred meters, and at longitudinal space intervals of several kilometers.

## REMOTE SENSING OF REQUIRED PARAMETERS

It is presently possible to make limited use of remote sensing techniques in the following ways:

(1) Some information on the surface current field can be obtained from stereo-photo pairs using the displacement of floating debris.

Also repeated aerial photographs, particularly with use of multi-band color augmentation, can reveal local current patterns from directions of plume patterns of waste outfalls or stirred-up sediment clouds.

(2) Synoptic observations of surface temperatures to an accuracy of the order of ±0.5°C to ±1.0°C is possible with scanning radiometers.

(3) Aerial photographs can be used to indicate horizontal spatial distribution of regions of high turbidity.

Future lasers may be developed to measure vertical and horizontal suspended-sediment concentration distributions.

As for recommendations, it was recognized that the third dimension is important because the Bay is stratified with respect to salinity and turbidity, and it has a significant vertical velocity distribution.

Remote sensing, which is limited to surface information, would be most amenable to vertically homogeneous systems like well-mixed bays and lagoons. Because tidal waters vary so rapidly with time, we need sequential coverage, i.e., every hour or more over a tidal cycle.

The work group recognized several areas where remote sensing might contribute to the Chesapeake Bay model. Remote sensing could yield data on the areas and ecology of near-surface water in local areas, in creeks, and around islands and shoals. In addition, it could yield current patterns in broad areas of the Bay not covered by the sparse network of cross-sectional prototype stations. Since the model is of the fixed-bed type, remote sensing could yield information to verify suspended sediment dispersion patterns, sources and distribution, especially in remote areas of shoals and backwaters. Remote sensing could be of great value in planning prototype station networks so as to secure measurements at critical points and at critical times. Just as remote sensing is used for obtaining prototype data, it could also be used to verify model behavior. In turn, model results might be used as a form of ground truth to substantiate remote sensing data.

# Group Discussion on Extractable Biological Resources

**L. EUGENE CRONIN, Chairman**

The approach of the work group on extractable biological resources was first to define pertinent needs and problems independent of the mode of monitoring, and then to focus on the possible usefulness of various techniques of sensing. It was recognized from the beginning that social, economic, and political problems, not germane to remote sensing, may override some of the basic technical problems related to extractable biological resources. However, urgent needs in the Chesapeake Bay can be defined, and are grouped in five general problem areas: Those associated with a useful inventory of living organisms; those related to the wetlands; those associated with the behavior of various marine organisms; those associated with the environmental conditions of the Bay affecting organisms; and those with models to present total systems and assist in the forecast of future yields in biological resources. These problems are presented, in outline form as follows. See footnote 1 for legend.

A. Inventory, or count, of plants and benthic and swimming animals to establish:
   1. Improved methods of in situ counting, including the signatures of species, groups and communities (1, 2, 3, 4)
   2. Distribution of species (plankton, plants, fish, shellfish and wildlife) (1, 2, 3, 4, 5, 6?)
   3. Sampling techniques for population estimates (1, 2, 3, 4)
   4. Abundances and population dynamics (1, 2, 3, 4, 5?)
   5. Long-term trends and fluctuations (1, 2, 3, 4, 5, 6?)
   6. Quantitative relations between egg, larvae, juvenile, and adult stages (1, 2, 3?)
   7. Number of harvesting units (boats and nets) at any given times for estimates of effort (1, 2, 3, 4, 5, 6?)

B. Behavior of organisms to establish:
   1. Migration patterns of major organisms (1, 2, 3, 4, 5)
   2. Concentration patterns related to spawning, feeding, etc. (1, 2, 3, 4?)
   3. Schooling patterns and detection (type, quantity and species) (1, 2, 3?)
   4. Changes induced by weather and other environmental parameters (1, 2, 3, 4?)
   5. Cyclic behavior (No estimate)

C. Parameters in the Bay system related to organisms:
   1. Temperature, currents, salinity, color, transparency (1, 2, 3, 4, 5, 6)
   2. Long-term changes in parameters (1, 2, 3, 4, 5, 6)
   3. Sediment, pollutant and nutrient loads with time (1, 2, 3, 4, 5, 6)
   4. Inputs and outputs of the total system (1, 2, 3, 4, 5, 6)
   5. Ice conditions (1, 2, 3, 4, 5, 6)
   6. Heat balance (1, 2, 3, 4, 5, 6)
   7. Biological populations or products as indirect evidence (1, 2, 3, 4?)

D. Analysis of wetlands and shorelines to establish:
   1. Boundaries and elevation with variations with time. (2, 3, 4, 5, 6)
   2. Plant and animal signatures and distribution (2, 3, 4, 5)

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[1]Vertical level of sensor (work group estimate):

1 = Sub-surface
2 = Surface
3 = 0-1000 feet
4 = 1000-10 000 feet
5 = 10 000-100 000 feet
6 = Over 100 000 feet

3. Important biological processes (2, 3, 4)
4. Productivity (2, 3, 4, 5)
5. Erosion and deposition (2, 3, 4, 5, 6)
6. Substrate types (sand or mud) (1, 2, 3?, 4?)
7. Impact of pollutants (air and water) (No estimate)

E. Models and forecasting:

1. Fluid dynamics (flow, temperature, and salinity distributions) (1, 2, 3, 4, 5, 6)
2. Physical, chemical, and biological components of ecosystem (1, 2, 3, 4, 5, 6)
3. Biological energy flow (No estimate)

## SUMMARY

The work group considering the applications of remote sensing to extractable biological resources agrees that such sensing has potential for application to some of the important problems of the Chesapeake Bay. Special value is anticipated in understanding and managing the exceptionally valuable wetland and shoreline areas and in providing data on environmental circumstances related to the great biological crops of the region.

The present techniques of sensing from high-level platforms appear to have serious limitations which must be dealt with realistically. The difficulty of penetrating the air-water interface with sensors dependent on electromagnetic impulses is a serious constraint where most of the useful animals are on the bottom or well below the surface of the water. Counting and tracking these animals remain as an exceptionally urgent Bay problem.

The full values of remote sensing for the Bay cannot yet be defined, however, and we urge that they be fully and properly explored. We recommend that a program be developed for such exploration. In relation to biological resources, the program should include: simultaneous ground level analysis of a series of areas typical of the aquatic and marginal areas of the Bay; use of low-level, intermediate-level and high-level platforms as well as those on the surface and sometimes beneath it; seasonal observations; consideration of all feasible sensory techniques; and development of specific recommendations for the long-term pattern of remote sensing.

Most of our consideration has dealt with use of sensors as primary detectors. In addition, the platforms which support them have unique and very high value in receiving, storing, and transmitting the kinds of information which might be received from buoys, drifting sensors, radio-tagged animals and impulse sources.

We are also impressed by the exceptional yield of the sensor-related programs of NASA and its associates in producing valuable instrumentation ranging from in situ blood analyzers to submerged data buoy components to satellite sensors. Many of these can contribute to the effective solution of Chesapeake Bay problems. We encourage their continuing development and application.

Use for biological research and management should be carefully meshed with the use of remote sensors in other important problem areas of the Bay. One or two years of thorough examination and refinement of the optimal program will have high, enduring, and increasing application in the solution of our problems.

The communication achieved by this Conference has already been of unusual value to all of the participants in the work group. We are impressed by the successful blending of information and ideas which have occurred and feel that an appropriate mixture of individuals and agencies is essential in maturing and effecting the program.

# Group Discussion on Agriculture and Forestry

**DALE W. JENKINS, Chairman**

Remote sensing appears to have promise in three major problem areas in agriculture and forestry.

(1) Proper land use planning and management require accurate census and inventory of present land use, changes and trends in use, and adequate ecological knowledge and understanding; e.g., in Virginia a study showed that 52 percent of the land needed conservation treatment while much land was not properly used.

(2) Accurate survey and inventory and systematic monitoring of the natural resources of the Chesapeake Bay area are necessary. This includes coverage of forests, agricultural crops, wetlands, livestock, and land changed to urban and industrial uses.

(3) Accurate survey and monitoring of the damage to agricultural crops, forests, and wetlands caused by plant diseases, insect infestation, pollution, and drought is essential.

These three major problem areas will be discussed in more detail with the specific problems, their importance, and the kind of information that is needed to solve the problems.

## LAND USE PLANNING AND MANAGEMENT

Effective land use planning and management require:

(1) Broad aerial surveys of land use patterns, transportation routes, housing areas, soil types and vegetation areas

(2) Repetitive systematic coverage of changes and trends in land use; e.g., aerial photography is used to evaluate land for setting tax prices (Both high altitude synoptic pictures and low level photography are needed to provide the detail required.)

(3) Information on the rate of population expansion and encroachment (This information must be known to properly plan optimal use of rich agricultural soil, prevention of environmental degradation, and the best use of land for urbanization.)

The contributions of remote sensing to land use planning can be very valuable. There is a need to demonstrate the effective use of remote sensing devices, such as multispectral scanners, to gain acceptance of these techniques by managing agencies.

## SURVEY CENSUS AND INVENTORY

### Forests

Accurate surveys of the total acreage, species of trees, and size classes for timber are needed. Forests are surveyed about once every ten years. The survey is relatively accurate on a large area basis but relatively inaccurate on a small area or county basis. Successful land management requires more detailed information for multiple use of forest areas for recreation, wildlife, erosion prevention and water accumulations for human use.

Special studies are required to show the value of remote sensing to determine the effects of air pollution, fire, hurricanes, and other hazards in forestry. More research is needed on the ability to use multispectral sensing for type, class, and species identification as well as diseases of deciduous forests.

### Agricultural Crops

Accurate surveys of the total acreage, crop types, and crop production are needed. The surveying is done regularly now by the Agricultural Stabilization and Conservation Service (ASCS), especially to determine crop allotments, and by the USDA Statistical Reporting Service. The use of remote sensing could help provide more accurate data, but its value with regard to cost effectiveness and time for analysis, needs to be demonstrated. Sequential surveys of crops grown as well as study of cropping-system changes are needed. We need to have automatic crop recognition capability and effective data reduction methods with high accuracy.

Livestock surveys using remote sensing with good accuracy are needed. This is probably not possible at altitudes higher than 8000 feet since 3-foot resolution is required. The time requirement for analysis of air photographs is presently very high.

### Wetland

There is a very great need for accurate and up-to-date surveys of total acreage of wetlands, the delineation of types of vegetation and species, the biological productivity of each area, including vegetation as well as wildlife and aquatic organisms. Information from ground surveys is hard to obtain because of the difficulties in reaching many of these areas. The wetland areas change so much that surveys must be kept up-to-date.

Remote sensing would appear to have great promise in the survey and inventory of wetlands and this program is highly recommended.

## PLANT DISEASES AND INSECT INFESTATIONS

Increase in yield of certain crops may be possible by using remote sensing through the growing season to study disease and insect outbreaks.

### Corn—Southern Corn Leaf Blight

Remote sensing techniques could be used to monitor spread, determine levels of infestation, amplify and extend ground surveys and develop technology for similar infestations in the future. Early detection of blight is essential to harvesting and replanting with other crops.

### Soy Beans—Mexican Bean Beetle

Nearly 50 percent infestation occurs. Early detection is valuable because 600 000 acres are involved. Effects of various herbicides for weed control should be monitored; weed patterns are changing rapidly because of these herbicides.

### Hay—Alfalfa Weevil

While nothing can presently be done after an infestation, synoptic data can show patterns of spread and serve to warn potential growers of danger.

Repetitive remote sensing could be of value when an area needs irrigation—especially fields of vegetables. Soil temperature could be surveyed for optimum planting time, crop maturity could be monitored for labor force allocation. There is promise of previsual detection of epidemics in crops by using infrared detectors.

### Forest—Southern Pine Beetle

The forests are now being studied with infrared film/filter combinations to detect damage incurred by the southern pine beetle.

### Forest—Gypsy Moth

DDT was holding Gypsy Moth from spreading. Now opposition has stopped control and it is advancing. Defoliation may be observed on oaks. Orchards are also attacked by the gypsy moth.

### Forest—Oak Decline

This is a serious problem due, probably, to insect infestation and root rot, especially on poor soil. Trees usually die in 1 to 3 years and it is detectable only after heavy infestation and thousands of acres are affected. Remote sensing techniques may be able to help solve the management of these forests. Aerial surveys can pinpoint areas that should be cleared.

Remote sensing techniques can provide information for evaluating pollution effects on forests. Downwind of population centers and industrial sites are the forest sites that should be studied. Tobacco and other plants are highly sensitive to many atmospheric pollutants and can be used as sentinels or indicators.

There are many agencies in this area that could gain by using remote sensing techniques. Most are reluctant to invest the large sums needed to establish their own capabilities. A central data source, which many users can share, is needed.

## CHESAPEAKE BAY EQUIPMENT FACILITIES AND DATA BANK

An equipment facilitiy and data bank in the Chesapeake Bay area should be established with capabilities to convert the vast amount of photographic data to readily usable forms. This type of equipment is expensive and the costs are usually prohibitive for individual researchers.

Microdensitometers capable of digitizing the photographic images to allow computer analysis could be used to:

(1) Quantitatively arrange the photographic data in an objective manner
(2) Reduce the time lag or response time in analyzing the data and formulating predictions
(3) Enable unlimited interpretation of the quantitative data for multipurpose uses

The equipment bank would permit or accelerate the development of automatic recognition and mapping techniques. Previous photographic work could perhaps be reused by researchers working in related areas. Various climatic data and natural parameters could be readily available to other workers.

Complete photographic development and processing equipment facilities located in the Bay area would reduce lag time and permit previsual plant injury detection allowing adequate response time for taking corrective action.

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# Group Discussion on Recreational Uses

ELBERT COX, Chairman

Following the suggestions of the conference chairman, the work group summed up a number of problems which are of interest and concern to recreation. The work group is uncertain concerning the applicability of remote sensing in the case of each problem listed and does not consider the list complete or exhaustive. However, the points which are made are illustrative of the overall problems in recreation.

## POLLUTION

Considering the extensive areas of water-to-land interface, a critical problem in recreation is water quality. The work group suggests the need for a readout of approximately one sample per day on the following pollutants: Coliform count, oil, turbidity, and thermal and toxic wastes.

Accuracy required for measurements would be those required by applicable water quality standards.

## STINGING NETTLES

We understand that studies by federal and state agencies are underway on the ecology and physiology of the stinging nettle. If remote sensing could provide current information concerning movement or concentration of stinging nettles and Portuguese men-of-war in relation to specific use areas, opportunities for recreation might be considerably increased.

## WEATHER FORECASTS (LOCAL AND FREQUENT)

Local squalls and lightning storms of severe intensity frequently occur between regular broadcasts. Remote sensors located in strategic positions could provide a continuous warning system for small boat and swimming activities.

## WATER CONDITIONS ALONG BEACHES

Information about wave heights would be of great interest to surfers and swimmers. Undertow velocity rates can change suddenly, becoming hazardous for swimmers. Remote sensors might provide a timely and continuous warning system.

## CONCENTRATION OF WILDFOWL AND FISH

Remote sensing could provide data on the location and movement of wildfowl, wildlife, and fish. Information concerning migration periods, rates of buildup, and identification of species would be of vital interest to sportsmen and conservation officials. These data would have significant value in management and control programs, e.g., prompt reporting of fish kills can lead to preventive action and reduce total loss.

## BEACH EROSION

Accurate records of beach buildup and erosion over a period of time would be beneficial in planning for development and use of recreational facilities. Readings after storms would also be of great interest.

## DETECTION OF MINERAL DEPOSITS AND FRESH WATER SUPPLY

Advance knowledge of sand, gravel, ore, and water deposits can save recreational planners costly mistakes in locating developments. For example, knowledge of sand and gravel deposits would allow for removal of the deposits and reclamation of the area prior to recreational development.

## INSTANTANEOUS CENSUS OF PEOPLE IN CRITICAL AND REMOTE AREAS

Protection of environments and fragile resources requires better information concerning population concentration and activities. For example, the uncontrolled use of beach buggies, marsh buggies, and air boats can result in irreparable damage to beach and marsh areas. Snowmobiles cause similar damage where used.

## LAND MAPPING

Remote sensing of wetland outlines and contours can provide valuable supplementary data to existing maps or charts for site planning and protection. One-foot contours are desired for this purpose.

## CONFERENCE RESULTS

The panel notes that proceedings of the conference will be distributed to all participants without charge. In addition, some procedure for further interchange of information or questions needs to be established.

# Group Discussion on Engineering Changes

WILLIAM J. HARGIS, Chairman

## INTRODUCTION

Problems suggested for possible remote sensing applications fall into three broad categories. Because of interactions there is often a lack of clear separation between these categories. These three categories are:

(1) Research and development problems or applications
  a. Developing understanding of natural phenomena and processes
  b. Establishing environments and resources
(2) Planning and engineering applications
  a. Siting–ecological impact, predictions and evaluations
  b. Site-application engineering
  c. Inventory
(3) Management activities applications
  a. Inventory with uses; continuous monitoring
  b. Ecological impact evaluation
  c. Feedback and control

Additional applications for remote sensing techniques are:

(1) Mapping and charting; improving existing widely used maps and charts with emphasis on soil and vegetation types and extent of characterization and more accurate establishment of interface between land and water
  a. Especially important in the latter are mean-high water, mean-low water, high-high water, and low-low water
  b. Use of plants for geographical location
(2) Inventorying of environments and resources with valuation and statement of uses. Baseline inventory:
  a. Wetlands, shorelines and shallows inventory
    1. Extent
    2. Location
    3. Type
      a. By productivity
      b. By salinity gradients
      c. By topography
      d. By plant types
(3) Monitoring of environments and resources with continuing valuation and statement of uses
(4) Development of scientific understanding of natural features and processes
  a. Basic understanding
  b. Modelling
  c. Prediction
(5) Evaluation of environmental effects of engineering efforts

In almost every case there are acceptable techniques for measurement, the exception being simultaneous synoptic coverage of large areas of the Earth. Unfortunately, surface measurements are laborious and could be augmented promptly or supplanted where adequate remote sensing and suitable and timely platforms are available.

Many of the applications of remote sensing to coastal zone oceanography would also apply to planning and engineering and to management. An exhaustive report[1] has recently been completed for NASA-Langley at VIMS and should be consulted for details. A summary is all that we have attempted here.

## PROBLEMS

If remote sensing techniques can provide a determination of the following types of information, the engineering and management aspects of the solutions to the problems encountered in the Bay area will present no difficulties.

(1) Biological evaluation of productivity of highland, wetlands, and shallows. It is important to establish the nature and extent of wetlands for science and management. In the latter sense, valuation would permit more realistic assignment of uses of limited wetland resources. The same comments apply to shallows and adjacent highlands. Present techniques are too laborious for the large scale actually needed.

(2) Geological and geographical features

- (a) Stability of bottom, and shoreline erosion and accretion. Areas of high and low energy must be established. The information important to engineering projects relates to construction, erosion control, shoreline stabilization, channelization, and flow modification. Available techniques are too laborious for large areas involved.
- (b) Identification and mapping of soil types in wetlands and underwater
- (c) Improved topographic mapping of underwater and adjacent flatland; accurate bathymetry is vital to engineering projects.
- (d) Minerals detection for construction material and foundation planning
- (e) Sediment flux in small and large bodies of water–Chesapeake Bay and tributaries; to give adequate coverage, large scale processes require observation platforms some distance away from the region studied.
- (f) Distribution of suspended solids on a small scale basis–turbidity; impact of engineering projects must be determined with regard to turbidity and suspended solids for a useful water-quality parameter. Rapid surveys are needed in control.

(3) Chemical and physical features

- (a) Distribution of ecological parameters
  1. Salinity
  2. Temperature
  3. Light generation
- (b) Circulation patterns
  1. Salinity
  2. Temperature
  3. Density
  4. Turbulence
- (c) Interactions between water masses; Bay mouth–area interactions by color, turbidity, salinity, and temperature.
- (d) Meteorological data for modelling of air-sea interactions for understanding and prediction of erosion sedimentation and impacts on engineering works

## PARAMETERS OF IMPORTANCE

Some may not be possible or, if possible, only by inference.

(1) Geophysical

- (a) Salinity (*top priority*) $x$, $y$, $z$, and $t$ with depth features

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[1]Mundy, et al.: Priority Problems and Data Needs in Coastal Zone Oceanography. Virginia Institute of Marine Science, 1970.

1.0 percent–Ecology
0.1 percent–Hydrography
Precision should be high.

(b) Temperature (*priority*) especially with depth; $x$, $y$, $z$, and $t$
1° C–Ecology
0.1° C–Hydrography

(c) Density, if not directly measured, $t$ and $s$ will do.
$g/m^3$ ($10^{-4}$)
$x$, $y$, $z$, and $t$

(d) Current (*priority*) $x$, $y$, $z$, and $t$
1. Speed–0.1 knot
2. Direction ±5° true

(e) Turbidity (*priority*) $x$, $y$, $z$, and $t$
1. Transparency
2. Extinction coefficients

(f) Types and movements of bottom sediments (*priority*)
(g) Bathymetry depth to 0.5m for ecology and 0.1m for engineering (*priority*)
(h) Color of water–including incidence of fluorescent and materials of other colors, dyes, tracers, etc.

(2) Geographical
(a) Mapping shorelines and shallows adjacent to flatland ± 0.5m
(b) Establishment of regular water levels in relation to land; (*high priority*) ±0.5m, mean-low water, low-low water, mean-high water, high-high water
(c) Soil types with water content and subsurface waters

(3) Biological
(a) Rooted vegetation (*high priority*), wetlands, shallows, (*high priority* research effort) (terrestrial and aquatic)–Identification to species, genus or order. Higher "resolution" possible. Distribute $x$, $y$ and $t$; extend to ±0.5m, seasonally.
(b) Other aquatic plants–distribution $x$, $y$, $z$ and $t$
1. Micro algae–identification to species, genus or order
2. Phytoplankton–identification to species, genus or order

## GENERAL SUGGESTIONS

(1) Need more effort on ground-truth acquisition (*high priority*)
(2) Need more emphasis on step experiments from subsurface to surface to aircraft at various levels to satellites (*priority*)
(3) Need one or more high-intensity experiments in space and time, using a well-instrumented and observed, but circumscribed, experimental site (*priority*)
(4) Report on coordinating remote sensing activity with broad scale surface activity; i.e., correlate aerial and space overpasses with Bay in situ hydrographic observations being made for other purposes
(5) (*Priority*) Stress must be put in depth penetration to give $z$ dimension.

## MISCELLANEOUS

(1) Minerals; remote sensing of sand report to be published soon
(2) More use of surface experiments with better scheduling of overflights
(3) Establishment of an advisory committee

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# Group Discussion on Shoreline Activities

JOHN R. CAPPER, Chairman

## PHYSICAL ASPECTS

The physical aspects which influence shoreline activities management involve physical influence on shorelines, determination of natural resources, and integration of remote sensing capability with on-going and proposed experimentation on shoreline activities. The area to be covered includes Bay tributaries, the oceanic coast of DELMARVA and the Carolina outer banks to False Cape.

To establish a baseline, a large overlook use of historical data is needed to verify imagery and obtain ground-truth data at times of flight. This should be repeated at least seasonally and after extreme events (Northeasterlies, hurricanes and watershed flooding). Low level imagery for detailed looks at problem areas should be obtained as needed.

Desired positional accuracy would be recognition of objects of 2-foot size within 10-foot accuracy. Additonally:

(1) Determine wave statistics: Determination of wave direction to within 3° and wave length within 4 feet at shoreline and overall.

(2) Determine excursional limits, with storm surges.

(3a) Identify man's structures on shoreline and their effect on adjoining shores.

(3b) Monitor shoreline changes.

(4) If possible, determine hydrography down to –40 feet of water in turbid water.

(5) Determine nearshore water circulation patterns; specifically, littoral currents.

(6) Determine movement of upper Bay and watershed ice and its effects on shorelines.

(7) Determine porosity, water content of shore interface.

(8) Locate and map sand and gravel, shoals and deposits for navigation and economic utilization.

(9) Monitor dredging and disposal of spoils in the Bay.

(10) Monitor river discharges into the Bay waters by different physical characteristics of the waters (plumes) and resulting current paths. Monitor effluent discharges for physical effects on shoreline.

(11) Determine and monitor strand line organisms which assist in shoreline stabilization (eel grass, tube worm reefs).

(12) Monitor salt water intrusion into shoreline areas; i.e., marshes.

(13) Monitor dune migration and stabilization efforts; inventory of dunes.

(14) Map soil types, rock formations, marshes along shoreline for erosion characteristics and mineral deposits.

(15) Search for manifestations of ground water in coastal areas.

(16) Determine subaqueous ground water discharges.

## MANAGEMENT ASPECTS

The work group formed a subcommittee on management problems concerned with shoreline activities. The subcommittee concentrated its efforts on the requirements of the manager concerned with immediate problems of wetland areas, to catch current state-of-demands for data in government.

Wetlands are multi-purpose areas, and management must recognize both competing uses and trends in use. The need for comprehensive, up-to-date information and for time-trend data to support analysis, regulation, prediction and public presentation is evident. At the same time an operating agency's data needs are large in a real extent. The agency must have efficient data-collection, processing, and analysis procedures. Obviously, the agencies must come into use of remote sensing continuously, to avoid an overload of information. Table 1 summarizes the subcommittee's breakdown of the manager's problem areas in shoreline utilization.

Remote sensing can be immediately useful in these problem areas. Maryland is currently well along in an attempt to improve methods and, of course, Virginia Institute of Marine Science is as well. Remote sensing has been applied for years in closely related fields, especially urban management. The problem of wetlands development is, among others, the geographic extent of the problem and data costs are consequently high. We believe that remote sensing has strong application to the area of shoreline management.

TABLE 1.–Categorization of Problem Areas of the Manager

| Category | Time span | Scale and accuracy |
|---|---|---|
| (1) Delineation of wetlands | 10-year | Small |
| (2) Baseline inventory of surface features and trends–acreage and intensity | | |
| (a) Natural resources and features, slope, soil types, vegetation, surface water, mineral deposits | 5-year | |
| (b) Forest by type | 5-year | |
| (c) Agricultural by crop | 5-year with seasonal coverage | |
| (d) Fishing, boats | | |
| (e) Marshlands ecology<br>Vegetation<br>Vigor and Disease<br>Animal life<br>Algae and microorganisms | 2-3 year | |
| (f) Man-induced activities<br>Residential<br>Industrial<br>Recreation and marinas<br>Governmental; highways, bridges<br>Piers, bulkheads, power plants<br>Channels<br>Effluents; temperature, organic, salts and other inorganic chemicals | 2-3 year | Small, in urban areas |
| (3) Surveillance<br>Dredging<br>Construction; all under plan induced above | Bi-weekly | Small |

# Group Discussion on Urban Development and Growth

ARCH C. GERLACH and JAMES R. WRAY, Chairmen

## PROBLEM DEFINITION

The first problem stated was how to prepare an economic base for river basin studies when data are normally collected by administrative units whose boundaries don't match the natural features and whose data bases are not compatible with each other.

Land use mapping on a rectified, UTM gridded photograph or photomosaic (preferably infrared color), overlaid by basin boundary would be an improvement over traditional data collection by administrative units. Quarterly overflights (seasonal) would be desirable but probably not cost effective. Annual overflights would be adequate. Content of photographs at 1:100 000 scale, enlarged to match either 1:24 000 scale topographic map quadrangles, or other large scale inventories, would probably suffice. Infrared color would be preferred for rapid interpretation; thermal scanning would provide supplementary data of value. Some field checks to verify signatures would be necessary, but the uniformity in area and time for data collection, plus applicability of data to physical region boundaries would be a real improvement over traditional data collecting and processing systems.

Second, urban growth and the extent of its effects on the surrounding region should be studied, particularly of areas within or adjacent to depressed-areas, to facilitate equitable taxation, distribution of welfare payments or goods, and planning for transportation linkages, public utilities, and economic activities.

Traditional data gathering techniques through field investigations and air photo interpretation are expensive, and therefore normally limited to the administrative units having larger budgets. A public education campaign could help to solve that problem.

Higher altitude, smaller scale photography would be needed to expand the study area into the urban fringe and the zone of regional influence. Inventorying the distribution of population, resources, and economic potentials of the entire region might justify a single, multi-sensor (infrared color, multispectral black-and-white and scanner) overflight at 50 000 feet. Local authorities could develop their studies from there. Satellite-derived data would probably lack much of the required detail for such a local study, and frequent aircraft overflights would be too costly unless the proposed high-altitude overflight revealed potentials that warranted state, regional or national subsidy of further study. In that case regional councils of government and state agencies would be the logical channels for fund procurement.

The third problem presented was how to coordinate a variety of area studies dealing with population, housing, transportation networks and needs, resource reserves and developments, environmental factors, etc.

A standard photographic basemap or photomosaic should be made, parts of which could be used by different administrative entities and discipline specialists. Black-and-white photography at scales of 1:50 000 through 1:100 000 would suffice, if sidelapped 30 percent and flight line overlapped 60 percent, to make an orthophoto mosaic, UTM-gridded plotting base. Black-and-white photographs, with different degrees of exposure from color infrared photography would be more desirable to expedite photo interpretation, but also more costly. The use of surrogate signatures would be necessary to interpret smaller scale photos. Probably photography at 1:100 000 would suffice for making the desired photobase, parts of which could be enlarged two to five times to meet local requirements.

A fourth problem was presented in the form of a question: What size must an area be to benefit from remote sensing? Would a 400-square mile drainage basin qualify?

Such an area would not be practical on a satellite photograph covering 10 000 square miles, except to give relationship to surrounding area. Remote sensing technology can be applied, however, from low altitude aircraft, and from surface platforms to develop useful environmental models of small areas.

The question was then asked: Can remote sensing be used to expedite soil mapping of areas not currently mapped or likely to be mapped by traditional techniques in the near future?

Some experimental work by the USGS has been done on Apollo photographs of the Southwestern U.S., correlating photographic signatures with vegetation characteristics and known surface geology. Soils identification has been largely limited to the main groups. Other experiments are in progress by David Pettry at Virginia Polytechnic Institute with NASA support. This is a problem for the Department of Agriculture's Soil Conservation Service. The Soil Conservation Service should be urged to experiment with reconnaissance soil surveys at small scales by means of remote sensing technology.

The State of Maryland General Assembly is considering legislation to authorize an intensive study of the Baltimore-Washington urban corridor. How can remote sensing technology help?

Rectified mosaics, being made and gridded by USGS from NASA Mission 144 color infrared photography flown in the autumn of 1970, can be obtained. Use black-and-white, color infrared, color, and multispectral black-and-white photography as well as radar for interpretation of environmental conditions and economic activities in the area.

Some other problems were identified but time was too short to permit detailed analysis of each:

(1) Measurement of urban change

(2) Inventory of environmental factors and resources

(3) Modeling and simulation techniques to predict environmental changes need simplification to receive remote sensing data

(4) New community site and situation analyses; any prospects in Chesapeake Bay area

(5) Identification of hazards–faults, floods, landslides, caverns, etc.

(6) Vacant housing counts?

(7) Land use and ownership inventory to improve tax bases and policies

## RECOMMENDATIONS

(1) Urge NASA Wallops to prepare a list of studies within Chesapeake Bay area by national, state, regional and local agencies revealed by participants at the conference.

(2) Urge Department of Agriculture to investigate further the potential applications of remote sensing technology for reconnaissance soil surveys in areas which now have none.

(3) Request NASA to take a lead role in bringing about interagency acceptance of standard, uniform referencing system for indexing, cataloging, and plotting remote sensing data.

(4) Establish an archiving system for remote sensing data of the Chesapeake Bay area which will be of a nature and quality to satisfy user needs.

(5) Urge that USGS complete a UTM-gridded photomosaic of the Mission 144 overflight photography as soon as possible for use by local agencies.

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