9-1979

Applications of remote sensing to estuarine management : Final report and annual report number 7

John C. Munday
Virginia Institute of Marine Science

Hayden H. Gordon
Virginia Institute of Marine Science

APPLICATIONS OF REMOTE SENSING TO ESTUARINE MANAGEMENT

FINAL REPORT AND
ANNUAL REPORT NUMBER 7
Grant NASA-NGL 47-022-005

Prepared for The

National Aeronautics and Space Administration
Office of University Affairs
Washington, D.C. 20546

John C. Munday, Jr.
Principal Investigator

with

Hayden H. Gordon

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

September 1979

CONTENTS

ABSTRACT

Remote sensing techniques have been applied to problems in estuarine management in the seventh and final year of a NASA grant. A chromaticity technique for multi-date Landsat measurement of suspended sediment has been verified and made operational, and applied to sedimentation analysis of the Bay of Fundy Tidal Power Project. Dye-buoy photogrammetry has been used to measure currents at depth and analyze suspended sediment plumes from hydraulic dredging. Wetland permit sites and beach erosion sites have been evaluated with aerial photography. Submerged aquatic vegetation has been mapped with tide- and wind-synchronized color photography. Virginia state resource monitoring needs have led to implementation of Landsat data processing capability for joint work with NASA Goddard on demonstration projects. This final report contains summaries and tables of the projects and activities of the Remote Sensing Center over the past seven years.

ACKNOWLEDGMENTS

We thank the National Aeronautics and Space Administration, Office of University Affairs, Washington, D.C., for support of this project and associated remote sensing applications over the past seven years. We also thank various governmental agencies involved in this year's applications, including NASA Goddard Space Flight Center, the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Canada Centre for Remote Sensing, Ottawa, Canada, and the Atlantic Geoscience Centre, Department of Energy, Mines, and Resources, Dartmouth, Nova Scotia, Canada.

Many VIMS personnel made major contributions to the applications, and many contributed to field operations, data reduction, photo and art work, and secretarial assistance. We wish to especially thank Mr. Charles Alston, Mr. George Mapp, Ms. Laurie Shem, and Ms. Beth Marshall.

LIST OF TABLES

I. REVIEW AND SUMMARY OF SEVEN-YEAR PROJECT

REVIEW OF SEVEN-YEAR PROJECT

This grant from the NASA Office of University Affairs to the Virginia Institute of Marine Science began in July, 1972. For the first two and one-half years, the Principal Investigator was Dr. John M. Zeigler, Director of the Division of Physical Science and Ocean Engineering. Since late 1974, the Principal Investigator has been Dr. John C. Munday, Jr.

PHASE I

During the first phase, the project was directed toward the remote detection of nearshore circulation. Advances were made both in development of methods of detection, and in applications of the methods.

Developments in methods of detection were in three categories. The first was the utilization of photographic imagery and infrared scanner imagery in characterization of tidal inlet plumes along the barrier islands of Virginia's Eastern Shore. Field experiments were conducted with simultaneous remote sensing overflights by NASA aircraft. These experiments yielded successful delineation of water color and thermal gradients in tidal plumes at different tidal stages, proving that established techniques of image data collection could be used in study of tidal plumes. A second and related development was in the use of field and laboratory analyses of surface data to calibrate the imagery. The tidal plumes were found to generally display distinguishable levels of indicators of biological

activity: plumes were found to be generally characterized by water temperature, salinity, dissolved oxygen, chlorophyll (although sometimes obscured by inorganic sediment), ^{14}C-bicarbonate assimilation (primary productivity), heterotrophic metabolism, and nutrient concentrations. These results with both remote and in situ parameters were not trivial: the combination showed that remote detection of the generalized plume features of water color and temperature was the detection indeed of features associated with biologically and physically important parameters. Hence, remote methods can be used profitably for study of tidal inlet processes involving exchange of biological productivity between the wetlands behind barrier islands and the nearby coastal ocean waters.

The third category of methods development was in the remote measurement of the locations of Lagrangian current-following drogues. One type of drogue was a drogue with a radar reflector, successfully used to plot currents in Hampton Roads. A second type was an instrumented drogue which sensed transmissions from the Omega navigation network and communicated location data to a shore-based receiving station. The development of this "Omega buoy" was pursued far enough under this grant to prove that a differential Omega method is feasible for remote tracking of objects over the continental shelf. The positioning accuracy is 800 m, and the cost per buoy in 1973 dollars is roughly $3,000.

These first phase methods developments were applied successfully in studies of nearshore circulation. Wachapreague Inlet on Virginia's Eastern Shore was studied over a tidal cycle on several occasions. Marsh water was distinguished from ocean water and the size of the tidal plume from the inlet in different tidal phases was determined. There was a close relationship

between the size of the plume at full ebb and the locations of shoaling bars arranged in a semi-circle around the ocean side of the inlet.

The second major application was of the radar drogues to delineate current trajectories in Hampton Roads. The data were used in determining the best location for a new bridge-crossing of Hampton Roads, to be called I-664. As of this writing, I-664 right-of-way in lower Newport News has been acquired and all preliminary engineering studies have been completed. Just recently, the drogue data were once again utilized (and used instead of current meter data!) to show the true currents in the area of the crossing; these currents are being used in the calculation of scouring rates for the bridge pilings (Dr. C.S. Welch, personal communication).

PHASE II

The grant since late 1974 has been directed toward marine and coastal remote sensing applications with a more immediate benefit. A second goal has been to place greater emphasis on applications of remote sensing data from satellites, particularly Landsat.

Our experience has been that the goal of immediate benefits has led to a much greater exploitation of aerial photography by state and local governmental bodies. The second goal of using Landsat data has required a long-term view, and only with sustained effort by NASA, VIMS, and others over several years with the top levels of state government have Virginia state agencies shown more than passing interest in Landsat data. Landsat demonstration projects are currently underway in Virginia, potential benefits of a Virginia Resources Information System including Landsat data are being studied, and VIMS under this grant has established a Landsat data

reduction capability and will be assisting users in the demonstration projects.

Meanwhile, the use of aerial photography of all types is well-established within VIMS and with external agencies engaged in coastal projects jointly with VIMS. The Remote Sensing Center established with the support of this grant is now functioning at a self-sustaining level. A brief prognosis for future financial support and activities is given in the next section.

A brief description of each project conducted in the past seven years is provided in the next-following section titled SUMMARY OF PROJECTS BY YEAR. Following that section is a section of SUMMARY TABLES documenting the history and activities of the seven-year project.

PROGNOSIS FOR FUTURE

FINANCIAL SUPPORT AND ACTIVITIES

The aims behind NASA's support of remote sensing activities have been to develop new operational uses of remote sensing, and to see their incorporation into the national fabric of widely-used technology. Now that this grant is ending, it is timely to see whether or not the above aims have been realized in Virginia with any promise of longevity.

The VIMS Remote Sensing Center in the past two years has been maintained at the same number of personnel, and with a steady increase in capability. With the phase-out of support from the NASA Office of University Affairs, the Center is now totally on its own financially. Costs are roughly $130 k per year (including overhead). For the near future, the financial support will be roughly 50% from research programs, and 50% from external agency-funded applications work in which remote sensing plays a major role. Contracts in hand include submerged aquatic vegetation mapping (EPA), Seasat SAR wave climate (NOAA), Landsat demonstration projects (NASA), and wetlands photography (Army Corps, EPA, U.S. Fish and Wildlife, National Marine Fisheries Service).

There is as yet no support directly from the state government to provide insurance against loss of contract support; however, the Center capability continues to improve and the state remote sensing program may develop

into some support for the Remote Sensing Center over the next one or two years.

The NASA investment at VIMS is, in addition, having impact beyond VIMS in the context of the Virginia Resources Information System (VARIS) program. Substantial input was provided by VIMS at critical and early stages of the VARIS program. The program now is modestly supported by the state (with substantial technical assistance from NASA). To the extent that VARIS involves remote sensing, the NASA investment has spawned a small amount of state support of remote sensing activities. There is a strong likelihood that linkages established between remote sensing users as a result of VARIS will continue even if the VARIS support level remains modest.

SUMMARY OF PROJECTS BY YEAR

A list with a brief description of each project is provided in the following pages. The list is arranged in a yearly sequence beginning with the most recent year, 1978-79 (labeled as 1979). For the years 1972-73 and 1973-74, directed by a different principal investigator, there is one list containing brief descriptions written by the present investigator.

1979

79- 1. Development of an Operational Technique for Landsat Measurement of Suspended Sediment.

Joint work with the Canada Centre for Remote Sensing and the Atlantic Geoscience Centre, Canada has produced an implemented automated system for Landsat suspended sediment measurement. The system adjusts for atmospheric variations between dates, permitting Landsat data to be utilized for quantitative measurement without simultaneous surface data. Landsat data have been used with the technique to show that sedimentation will not impair the Bay of Fundy Tidal Power Project.

79- 2. Implementation of Landsat Capability in Virginia.

The Pennsylvania State University ORSER software for Landsat data reduction has been implemented at the College of William and Mary, Virginia. The VIMS Remote Sensing Center has established a remote job entry capability

for VIMS and off-site Landsat users, and has arranged to assist in Landsat demonstration projects recently initiated by NASA Goddard Space Flight Center.

79- 3. Estuarine Circulation in Three-Dimensions from Dye-Buoy Photogrammetry for Dredging Analysis.

Window-shade drogues measuring currents at depth and emitting dye at the surface were used to photogrammetrically measure currents in the Elizabeth River. The Army Corps will use a model based on the currents and on dredge plume data to select the appropriate dredging technique in future projects for minimizing turbid resuspension of sediments.

79- 4. Aerial Photographic Monitoring of Beach Erosion.

With support from the U.S. Army Corps of Engineers, beach erosion has been monitored using aerial photography. The monitoring is in support of beach preservation and enrichment/nourishment programs.

79- 5. Wetland Permit Site Evaluation.

Permit applications for modifications of wetlands have been evaluated with the aid of aerial photography and photo-interpretation. Compliance with permit criteria has been verified with post-modification follow-up photography. Supporting agencies have included the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the Commonwealth of Virginia.

79- 6. Mapping of Submerged Aquatic Vegetation.

With primary support from the Environmental Protection Agency, submerged aquatic vegetation (SAV) in Virginia's Chesapeake Bay has been mapped using aerial photography and electronic planimetry. SAV maps have been analyzed to determine natural variability of SAV density and possible

causes of abnormal density fluctuations.

1978

78- 1. Remote Sensing Program Implementation in Virginia.

VIMS began in late 1976 to assist the Virginia Air Pollution Control Board in an examination of state needs which could be met using remote sensing, particularly Landsat. This effort developed into a cooperative project involving the legislative branch, executive branch agencies with programs in environmental and geographical resources and management, educational institutions with remote sensing expertise, and NASA, with assistance from the National Conference of State Legislatures. VIMS helped guide this project which involved meetings, workshops, planning studies, and testimony before public agencies. It has now resulted in the passage of a joint legislative resolution which establishes a joint study committee, authorizes the initiation of remote sensing demonstration projects, and calls for continued development of a Virginia Resources Information System. This System will be developed under the auspices of the Virginia Department of Agriculture and Commerce in the Office of Commerce and Resources. A primary data source will be Landsat data. Water quality monitoring has high priority as a demonstration project.

78- 2. Landsat Chromaticity Technique Applied to Sediment Budget Study for Tidal Power Project.

In a cooperative effort begun in 1975, VIMS and the Canada Centre for Remote Sensing (CCRS) have been developing a technique for mapping suspended solids from Landsat data in the absence of surface information. This

technique has now been validated with theoretical study and several sets of field data from the Bay of Fundy, Nova Scotia. Techniques have been implemented on the General Electric Image 100 multispectral analysis system at CCRS. The Atlantic Geoscience Centre at Dartmouth, Nova Scotia, part of the Department of Energy, Mines, and Resources, Canada, has embarked on a sediment budget study utilizing Landsat data analyzed by this technique. The sediment budget study will guide decision-making in plans to construct a tidal barrage in the Bay of Fundy. The tidal barrage is intended to harness tidal power for electric power generation.

78- 3. Remote Sensing Center Applications to User Needs.

New space and equipment have been provided this year to establish remote sensing activities in the context of a VIMS Remote Sensing Center. The Center is providing assistance to various users in acquisition of aerial photography, photo-interpretation, data reduction, and coastal resource analysis. The users include VIMS staff engaged in contract work and operational monitoring and advisory work for the Commonwealth; the users also include outside agencies such as the U.S. Fish and Wildlife Service. The user load on Center operations amounts to two full-time employees, one of which is attached to the Center. In a typical Center project, a marsh of one hectare in Lynnhaven Inlet, Virginia Beach, was preserved after analysis of historical and new photographs led to a plan to put dredge spoil in a different location. In another project, a landowner had illegally destroyed a small marsh on Sarah Creek, Gloucester County, and was ordered to reconstruct it. The plan for reconstruction was based on analysis of historical and new aerial photographs.

1977

77- 1. Elizabeth River Surface Circulation Atlas.

A prototype Atlas of Surface Circulation in the Elizabeth River, Hampton Roads, Virginia was prepared from data collected by sequential aerial photography of dye-emitting Lagrangian drifters. The Atlas leaves show trajectory maps for a variety of wind and tidal conditions. The U.S. Coast Guard, Fifth Coast Guard District, Portsmouth, Environmental Protection Branch is evaluating the use of the Atlas in oil spill cleanup on a day-to-day basis.

77- 2. Quantico Creek/Town of Dumfries Flood Control Dredging.

The town of Dumfries, Virginia, sought a permit to dredge a flood control channel through the Quantico Creek marsh and creek system (0.7 km^2). The U.S. Fish and Wildlife Service at first advised the U.S. Army Corps of Engineers against the permit. After an appeal from Dumfries, aerial photography was obtained by VIMS, and engineering proposals transferred to a mosaic of the aerial photos using a Bausch & Lomb Zoom Transfer Scope. Acceptable engineering recommendations based on the mosaic were prepared jointly by FWS and VIMS, and incorporated into a revised permit application. The Army Corps approved the revised permit application and Dumfries is now opening bids for the dredging.

77- 3. Marsh Changes from Papermill Creek Highway Construction Dyke.

A new highway constructed near Williamsburg, Virginia was routed over Papermill Creek and its associated marsh by means of a dyke and culvert system. In cooperation with the U.S. Federal Highway Administration and the U.S. Fish and Wildlife Service, VIMS has monitored the construction

effects by aerial photography and field studies. A mud wave has developed which has caused the loss of 3,000 m^2 of marsh. Reduced tidal fluctuations are causing a change in the marsh species composition. The FHA will use results from this and another study to formulate guidelines for future highway construction over marshes.

77- 4. Disposal of Spoil from Tangier Island Channel Dredging.

The population of Tangier Island, Virginia in the Chesapeake Bay is dependent on boat deliveries of fuel and supplies. Continuing siltation of channels, which blocks routes to the supply docks, necessitates periodic dredging by the U.S. Army Corps of Engineers. The Army Corps asked VIMS to make recommendations on acceptable locations for spoil disposal from urgently needed dredging. VIMS obtained color and panchromatic infrared photography of the island at high and low tide, and used the imagery to discriminate tidal from non-tidal lands and to classify land use. A detailed report was submitted to the Army Corps containing alternatives and recommendations for disposal sites. The Army Corps has selected one of the alternatives and is proceeding with the dredging.

77- 5. Ownership of the Fisherman Island Complex.

The Commonwealth of Virginia Senate, by a joint Resolution, directed that VIMS perform a study of the ownership of an evolving island complex at the Chesapeake Bay mouth, to determine if Virginia has a claim to ownership of part of the complex. An earlier VIMS study had mapped old island changes using historical photography. New photography was obtained to bring maps up-to-date. Interpretation of the sequence of changes as revealed in the photography has resulted in the conclusion that Virginia has basis for a legal claim to ownership of several parcels of land. Other claims from the

Federal Government and private citizens are already pending in the courts. The Attorney General of the Commonwealth of Virginia will, in all likelihood, enter a claim for ownership of parcels of land identified in the course of the remote sensing analysis.

1976

76- 1. Pig Point Sewage Outfall Revisited.

Using remote sensing, VIMS selected a more northerly site for the Pig Point sewage outfall in Hampton Roads. This new site was adopted by the Hampton Roads Sanitation District Commission. It has also been accepted by the Virginia Bureau of Shellfish Sanitation which had objected to the earlier proposed site because of possible danger to shellfish beds. The new site is being included in the design plan and will be used for construction. The direct result of the remote sensing is that the critical seed oyster beds of Nansemond Ridge will be better protected from bacterial contamination.

76- 2. Piankatank River Pollution Model Dye Study.

Erroneously high dispersion coefficients may result from boat transects leaving the dye patch during water pollution dye studies. Aerial photography and densitometry have been applied as the only method capable of locating and measuring errors.

The Virginia State Water Control Board (SWCB) has given VIMS a contract to produce a mathematical model for circulation and dispersion in the Piankatank River. SWCB will use the model to make decisions for or against future pollutant inputs to the River. The VIMS model is being based on dye dispersion data obtained by boat-borne fluorometry, and will

be submitted during summer, 1976. The correction based on remote sensing will have the effect of reducing the pollutant loading of the Piankatank River.

76- 3. Jackson River Flood Control Planning.

Flooding at Covington, Virginia led Covington to request flood control by the U.S. Army Corps of Engineers. They proposed river bank modification which would involve loss of woodland. Remote sensing was selected as the cheapest and fastest way to evaluate the value of the proposed loss, to be compared with the value of flood control. Imagery was obtained and evaluation begun, but the decision whether to proceed with the modification has been held up due to lack of funds within the Corps.

76- 4. Little Creek and Lynnhaven Non-Point Pollution Model Tidal Prism.

Panchromatic infrared photogrammetry is providing critical data for pollution control models for Little Creek and Lynnhaven Inlets. The Hampton Roads Water Quality Agency (HRWQA) has given VIMS a contract to produce mathematical models for circulation and flushing in Little Creek and Lynnhaven Inlets. HRWQA will use the models for decisions affecting land use and aimed at pollution control. Critical numbers needed in the model are the tidal prisms of the associated Inlet sections; these numbers have been obtained from tide gauge data and water area data determined from panchromatic infrared photogrammetry at high and low slack waters. Remote sensing was the only way to obtain the water area data.

Recently a controversy arose that the model was invalid because of large water area changes; this argument was settled by the remote sensing which showed that area changes were small over a tidal cycle.

Thus, remote sensing justified use of the model and provided critical numbers used as input. The model is being tested and will be submitted to HRWQA for its use in late summer 1976.

76- 5. Isle of Wight Non-Point Pollution Model Tidal Prism.

Storm runoff is being evaluated with the aid of infrared photography. The Maryland Department of Natural Resources has contracted for development of a storm-runoff (non-point) pollution model. This model will be used in making land use decisions, by providing quantitative data on water quality impacts due to proposed land use changes.

Input data are required in 1976 as part of a Phase I contract to VIMS, which is providing data on water runoff and nutrient mass fluxes from eight land use classes. The tidal marsh class data have been obtained via water sampling, tide gauge data, and water area data from panchromatic infrared photogrammetry over a half tidal cycle. The remote sensing method was chosen over a current meter method because all potential marsh inputs and exits were monitored, the time required for installation and maintenance of current meters was eliminated, and some channels were too shallow for the use of current meters.

Model development and testing as part of Phase II will be contracted by the State of Maryland in 1977.

76- 6. Cedar Landing Estates Wetlands Destruction.

Illegal alteration of a York County marsh has been proven from analysis of high altitude NASA photography, historical U.S. C & GS photography, and VIMS shoreline photography. The amount of marsh destroyed was roughly ten acres. The U.S. Army Corps of Engineers has initiated a suit against the developer, based on maps and interpretation derived solely from the

photographs. The historical photographic sequence was the only available source of data.

76- 7. Hampton Salt Ponds Wetlands Protection and Inlet Stabilization.

A map of wetlands boundaries prepared by VIMS from a photogrammetric and remote sensing survey has resulted in change of a bayside development project by the City of Hampton, Virginia. VIMS conducted a remote sensing survey in cooperation with the City, mapping the remaining marshes, suggesting which marshes to preserve, and recommending structures to stabilize an inlet subject to deposition. In response, the City has revised its permit application.

The new application sets the limit to development at the marsh boundaries determined by VIMS remote sensing (with a protective setback distance). Proposed dredging is revised from 470,000 cubic yards below mean low water (MLW) to 88,000 cubic yards, and 130,000 cubic yards above MLW to 4,000 cubic yards, a total reduction of 85%. Channel depth is revised from 12 feet to 6 feet. New methods are proposed to stabilize dredge spoil in disposal areas, and to control sedimentation and erosion during dredging.

The VIMS remote sensing survey has thus resulted in major changes to the project plan, particularly the preservation of 60 acres of marsh. Remote sensing was the primary data source. It was essential for accurate up-to-date mapping. The new permit has been approved by VMRC, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and EPA. The approval of the Virginia State Water Control Board and the U.S. Army Corps of Engineers is still pending.

76- 8. Chapel Creek Wetlands Protection.

The Mathews County Wetlands Board has rejected a proposed development

at Chapel Creek, after VIMS used a photomosaic and photogrammetric measurements to show that a developer's proposed marina would result in direct destruction of one acre of marsh, and alter or threaten five additional acres. Stereoscopic evaluation of the imagery revealed the presence of steep banks on the surrounding water body which would be eroded by boat wakes. The Board denied the development permit by a vote of 3 to 1.

The remote sensing was crucial to understanding the developer's hazy proposal, to allowing quantitative evaluation of the threatened marsh, and to convincing the Board of the fragility of the marsh and its setting.

76- 9. Dyke Marsh Restoration.

Old marsh boundaries and marsh zones are being mapped from aerial photographs. The National Park Service plans to restore old boundaries with dredge spoil.

76-10. Hughlett Point Refuge Plan.

The Army Corps, with assistance in photointerpretation from VIMS, is preparing a plan for a wildlife refuge in a woodland/marsh area. The Army Corps is waiting to implement the plan.

76-11. Coastal Shoreline and Dune Dynamics.

Photogrammetry of shorelines and dunes of Virginia and North Carolina is being exploited to elucidate coastal dynamics. This research study, funded by the U.S. Coastal Engineering Research Center and assisted by remote sensing, will have significant impact on coastal land use practices of both Virginia and North Carolina. Both states are assessing land use policy in the controversial area below Back Bay National Wildlife Refuge. Aerial photography is a primary data source, along with field surveys, and ground control for new imagery.

76-12. Wetlands Permit Applications Evaluations.

Continuing development pressure on Virginia wetlands is being met more and more often with analysis and interpretation of aerial photography. VIMS now reviews many wetlands permit applications forwarded from the Virginia Marine Resources Commission by means of aerial photography, which is faster than ground survey and permits quantitative measurements of marsh areas. VIMS personnel can make more informed recommendations to VMRC. This has a significant impact on wetlands protection because VIMS recommendations are generally accepted without alteration by VMRC.

76-13. Fishermans Island Vegetation Mapping and Erosional History.

Astonishing changes in the morphology of Fishermans Island at the mouth of Chesapeake Bay have been mapped by VIMS from old and new aerial photographs. The Director of the National Wildlife Refuge on the Island has declared these findings have forced him to adopt a new management policy of permitting natural changes to occur unimpeded.

1975

75- 1. Grandview Nature Preserve Shoreline.

Aerial photography of dye buoys provided a comprehensive overview of circulation at Grandview, Virginia. The City of Hampton decided to build a nourishment groin at the location specified by VIMS in order to protect a recreational beach. The City has also acted upon recommendations based on the photography for stabilization of inlet to the Nature Preserve.

75- 2. Newport News Point Sewage Outfall.

Aerial photography of dye buoys showed the circulation flow field at different tidal stages. A new and better location for a sewage outfall

was determined. The Hampton Roads Sanitation District Commission has built the outfall in the new location.

75- 3. Portsmouth Oil Refinery.

Aerial photography of dye buoys was used to determine oil pollution hazard zones. The final decision on the refinery has not yet been announced.

75- 4. Hampton Bar Dredging Monitor.

Aerial photography was used to plot dredge plumes. Results revealed a hazard to shellfish grounds. The dredging schedule was altered to protect the shellfish.

75- 5. Windmill Point Artificial Marsh.

Aerial photography of dye buoys revealed currents in the neighborhood of an artificial marsh constructed on dredge spoil. The U.S. Army Corps of Engineers determined suitable locations for turbidity monitoring in its analysis of the artificial marsh concept.

75- 6. Pig Point Sewage Outfall.

Aerial photography characterized the dye plume during a dye study of a proposed outfall location.

1972-1974

74- 1. Dam Neck Sewage Outfall.

EOLE data and other oceanic circulation data were analyzed to determine the fate of effluent from a proposed sewage outfall at Dam Neck. It was found that the outfall would permit beaching of effluent. The regional sanitation commission therefore ordered new studies of the proposed outfall.

74- 2. James River Drogue Study.

A radar drogue study involving NASA WFC and LRC was conducted in the lower James River for the Virginia Department of Highways. The data were used to choose a preferred route from several alternatives for a new bridge-tunnel crossing of Hampton Roads. Construction is beginning in 1978.

74- 3. Omega Buoy Development.

Development work proceeded on a buoy for offshore circulation studies. The buoy determined its location using Omega Navigation System transmissions and relayed location data to a shore-based receiving station. Field tests conducted in fall 1974 showed feasibility and promise (final results were reported in 1975).

74- 4. Wachapreague Inlet Studies.

Circulation studies were focused on the role of Eastern Shore inlets in nearshore oceanic circulation. Wachapreague Inlet was selected as a target inlet. With photography and thermal infrared imagery, NASA overflights and coincident surface investigations elucidated the size and dynamics of the inlet plume on ebb tide. Results revealed offshore movement of plumes from successive ebb tides.

74- 5. Skylab Surface Truth.

A radar drogue study was conducted in support of a Skylab study with assistance from NASA LRC and WFC at the mouth of Chesapeake Bay. Ebb tide results showed convergence of surface waters on the southerly side of the Bay mouth, and greater speeds beyond the mouth.

SUMMARY TABLES

This section contains a series of tables which document the history and activities of the seven-year project. The tables are separate lists by grant year of

1) projects by type of cooperating external agency (Table 1),

2) projects by type of remote sensing data (Table 2),

3) external funding in support of projects under this grant (Table 3),

4) methods developed and where used (Table 4),

5) recent professional activities (Table 5),

6) significant agency contacts (Table 6),

7) statistics on use of Remote Sensing Center facilities (Table 7),

and 8) publications related to grant activities (Table 8).

Following the above lists is Table 9 of equipment obtained under this contract and the present equipment inventory of the Remote Sensing Center. The present inventory includes equipment obtained wholly or partially on this grant and equipment obtained on other funding support. Some equipment was acquired from federal and state surplus.

TABLE 1

PROJECTS BY TYPE OF COOPERATING AGENCY

Foreign

1979,78	Canada Centre for Remote Sensing; Canada Atlantic Geoscience Centre--Landsat chromaticity technique--Bay of Fundy

Federal

1979	NASA Goddard--Landsat capability in Virginia
1979	NASA HQ--Evaluation of Landsat for water quality analysis
1979	ACE--dredging analysis using dye buoy photogrammetry
1979	ACE--beach erosion monitoring
1979	ACE--wetland permit evaluations
1979	EPA--SAV mapping
1978	FWS--illegal marsh destruction and restoration
1978	ACE--marsh preservation via dredge spoil relocation
1977	Coast Guard--Elizabeth River Surface Circulation Atlas
1977	ACE, FWS, town--Quantico Creek/Dumfries dredging
1977	FHA, FWS--Papermill Creek highway construction
1977	ACE, State--Spoil disposal from Tangier Island
1976	ACE--Jackson River flood control planning dredging
1976	ACE--Cedar Landing Estates wetlands destruction
1975	ACE--Windmill Point artificial marsh
1974	NASA--Eole buoys
1974	NASA--Skylab surface truth
1973	NASA--James River drogue study

State

1979,78	Remote sensing program in Virginia
1978	VIMS Remote Sensing Center
1977	Fisherman Island ownership
1976	VBSS--Pig Point sewage outfall
1976	VSWCB--Piankatank River pollution model dye study
1976	Maryland DNR--Isle of Wight non-point pollution model
1975	VBSS--Hampton Bar dredging monitor tidal prism
1974,73	VIMS--Wachapreague Inlet studies
1974,73	VIMS--EOLE buoys
1973	VSHD--James River drogue study

Regional

1976	HRSDC--Pig Point sewage outfall

Regional (cont'd.)

1976	HRWQA--Little Creek/Lynnhaven non-point pollution model tidal prism
1975	HRSDC--Newport News Point sewage outfall
1975	HRWQA--Portsmouth oil refinery
1974	HRSDC--Dam Neck sewage outfall

County

1976	Mathews--Chapel Creek wetlands protection

City-Town-Local

1976	Hampton--Salt ponds wetlands protection
1975	Hampton--Grandview shoreline protection

Abbreviations:

ACE	U.S. Army Corps of Engineers
EPA	U.S. Environmental Protection Agency
FHA	U.S. Federal Highway Administration
FWS	U.S. Fish and Wildlife Service
VIMS	Virginia Institute of Marine Science
VBSS	Virginia Bureau of Shellfish Sanitation
VSWCB	Virginia State Water Control Board
DNR	Department of Natural Resources
VSHD	Virginia State Highway Development
HRSDC	Hampton Roads Sanitation District Commission
HRWQA	Hampton Roads Water Quality Agency

TABLE 2

PROJECTS BY TYPE OF REMOTE SENSING DATA

Satellite/Navigation Systems

1979-78	Landsat chromaticity technique--Bay of Fundy suspended sediment
1974	EOLE buoys
1974,73	Omega buoys
1974,73	Skylab surface truth

Mixed Satellite and Aerial Imagery

1979,78	Remote sensing program in Virginia
1978	VIMS Remote Sensing Center
1974	Dam Neck sewage outfall

Mixed Aerial Imagery

1977	Fisherman Island ownership
1976	Cedar Landing Estates wetlands destruction

Medium-Altitude Imagery

1974,73	Wachapreague Inlet studies

Low-Altitude Imagery

1979	Elizabeth River dredge plume analysis
1979	Beach erosion monitoring
1979	Wetland permit evaluations
1978,79	Submerged aquatic vegetation mapping
1978	Marsh preservation at Pleasure House Creek
1978	Sarah Creek illegal marsh destruction, and restoration
1977	Elizabeth River Surface Circulation Atlas
1977	Quantico Creek/Dumfries dredging
1977	Papermill Creek highway construction
1977	Spoil disposal from Tangier Island dredging
1976	Pig Point sewage outfall
1976	Piankatank River pollution model dye study
1976	Jackson River flood control planning
1976	Little Creek/Lynnhaven non-point pollution tidal prism
1976	Isle of Wight non-point pollution model tidal prism
1976	Hampton Salt Ponds wetlands protection
1976	Chapel Creek wetlands protection

Low-Altitude Imagery (cont'd.)

1975	Grandview shoreline protection
1975	Newport News Point sewage outfall
1975	Windmill Point artificial marsh
1975	Portsmouth oil refinery

Surface Radar

1973	James River drogue study

TABLE 3

EXTERNAL FUNDING IN SUPPORT OF PROJECTS

Other remote sensing funding completely separate from this grant is omitted.

The list includes funding agency, topic, and amount devoted only to remote sensing.

1. 1972-73.

   None.

2. 1973-74.

   None.

3. 1974-75.

   a. NUS Corporation. A surface circulation study of middle Elizabeth River.
      $6 k.

   b. Newport News Shipbuilding and Dry Dock Company. Hampton Bar dredging project.
      $5 k.

   c. Hayes, Seay, Mattern and Mattern. Newport News Point sewage outfall.
      $6 k.

   d. McGaughy, Marshall and McMillan/Hazen and Sawyer. Pig Point sewage outfall.
      $10 k.

4. 1975-76.

   a. McGaughy, Marshall and McMillan/Hazen and Sawyer. Pig Point sewage outfall revisited.
      $12 k.

   b. U.S. Army Corps of Engineers. Covington aerial photography.
      $0.5 k.

   c. Hampton Roads Water Quality Agency. Little Creek and Lynnhaven water quality model.
      $5 k.

1975-76 (cont'd.)

d. Maryland Department of Natural Resources. Non-point pollution model.
$1 k.

e. Virginia Office of Coastal Resources. Wetlands permit evaluations.
$1 k.

5. 1976-77.

a. Virginia Office of Coastal Resources. Wetlands permit evaluations.
$2 k.

b. Federal Highway Administration. Marsh changes from highway construction.
$5 k.

c. VIMS. Support of VIMS Remote Sensing Section.
$3 k.

6. 1977-78.

a. VIMS. Support of VIMS Remote Sensing Center.
$15 k.

b. U.S. Department of Commerce. Coastal zone management planning.
(P) * $150 k $5 k.

c. Virginia Office of Coastal Resources. Wetlands permit evaluations.
$2 k.

7. 1978-79.

a. VIMS. Support of VIMS Remote Sensing Center.
$10 k.

b. NASA LRC. Plant geography and water quality data of Chesapeake Bay waters of Virginia's Eastern Shore (Ground Truth Data).
$3 k.

c. U.S. Fish and Wildlife Service. Remote sensing services in various projects.
$5 k.

d. U.S. Army Corps of Engineers. Aerial photography of dredge spoil disposal sites.
$0.5 k.

1978-79 (cont'd.)

e. U.S. Army Corps of Engineers. Aerial photography of beach nourishment sites.
$2 k.

f. U.S. Army Corps of Engineers. Aerial photography of beach erosion sites.
$1 k.

g. Environmental Protection Agency. Mapping of submerged aquatic vegetation.
$73 k.

h. U.S. Army Corps of Engineers. Dredge plume analysis via dye-buoy photogrammetry.
$3 k.

i. U.S. Army Corps of Engineers. Wetland permit photography.
$2 k.

TABLE 4

METHODS DEVELOPED ON GRANT AND USED ELSEWHERE

1. - 2. 1972-74.

a. Differential Omega buoy for oceanic circulation. Virginia Institute of Marine Science.

3. - 4. 1974-76.

a. Tidal prism measurement using sequential panchromatic infrared photography. Office of Naval Research. Tidal inlet dynamics. Contract awarded to R. Byrne, VIMS.

5. 1976-77.

a. Remote sensing of dye buoys. U.S. Department of Interior Bureau of Land Management. Georges Bank surface circulation. Contract awarded to EG&G and Raytheon. Consultant C. Welch, VIMS. (EOTECH Estuarine and Oceanic Technology Corporation, in 1976 began marketing dye-releasing drogues and buoys. Purchases made by EG&G/Raytheon (see above). EOTECH developed their products independently of the VIMS dye buoys.)

6. 1977-79.

a. Chromaticity analysis of Landsat CCT data. Canada Department of Energy, Mines and Resources. Sediment budget of Bay of Fundy. Principal investigator: Dr. C. Amos, Atlantic Geoscience Centre, Nova Scotia.

7. 1978-79.

a. Remote sensing of dye buoys for nearshore circulation analysis. Office of Naval Research, Geography Programs. Dynamics of nearshore bar formation. Contract awarded to V. Goldsmith, VIMS.
$69 k.

b. Color aerial photography of submerged aquatic vegetation with photointerpretation and electronic planimetry. Environmental Protection Agency. Mapping of submerged aquatic vegetation (SAV) in Virginia. Contract awarded to R. Orth and H. Gordon, VIMS.
$73 k.

1978-79 (cont'd.)

c. Remote sensing of dye buoys and drogues for circulation analysis in three-dimensions. VIMS. York River circulation studies. In-house support to C. Welch and L. Haas.
$5 k.

d. Tidal prism measurement using sequential panchromatic infrared photography. Cooperating State Agencies. King Creek tidal prism. Contract awarded to C. Cerco, VIMS.

e. Circulation studied with remote sensing of dye buoys. U.S. Environmental Protection Agency. Chesapeake Bay Sediment studies. Contract awarded to R. Wetzel et al., VIMS.
$1 k.

TABLE 5

REMOTE SENSING PROFESSIONAL ACTIVITIES

1979 ONLY

1. Appearances

a. Workshop. 8-9 May 1979. Determination of Water Quality by Remote Sensing. NASA Headquarters. Invited participant.

b. Annual Meeting. 19 March 1979. American Society of Photogrammetry. Hydrospheric Sciences Committee. 2nd Deputy.

c. Conference. 10-15 June 1979. International Symposium on Satellite Hydrology (Fifth Annual William T. Pecora Symposium). Sioux Falls, South Dakota. Present paper.

d. Conference. 2-5 October 1979. Eastern Regional Remote Sensing Applications Conference. NASA Goddard Space Flight Center ERRSAC. Water Quality Forum leader.

2. Academic

a. Teaching Remote Sensing of Environment, graduate course, School of Marine Science, College of William and Mary. Spring 1979, 4 students.

b. Remote Sensing Center: Present Employees and Faculty Status:

J.C. Munday, Marine Scientist C, Associate Professor.
H.H. Gordon, Marine Scientist B, Instructor.
C.J. Alston, Laboratory Technician B
G.R. Mapp, Graduate Student Assistant.
L.T. Marshall, Clerk Typist C

c. Graduate Student Advisor:

G.R. Mapp
H.F. Hennigar

TABLE 6

SIGNIFICANT AGENCY CONTACTS

1. U.S. Fish and Wildlife Service

   Various small projects. Frequent consultation. FWS has established a branch on VIMS property.

2. Virginia Executive Task Force for Virginia Resources Information System

   Consultant J.C. Munday.

3. Virginia Coastal Management Office

   Numerous requests through VIMS Department of Wetlands for aerial photography and photo interpretation.

4. U.S. Army Corps of Engineers

   Numerous requests for aerial photography and evaluation of dredge spoil alternatives.

5. NASA Goddard Space Flight Center ERRSAC

   The programs for the Landsat chromaticity technique for suspended solids measurement, implemented on the Image 100 at the Canada Centre for Remote Sensing, have been transferred from CCRS to ERRSAC.

TABLE 7

VISITS, SEARCH REQUESTS, AND USE OF

THE VIMS REMOTE SENSING CENTER

In the past year, the Center has been utilized by six federal agencies:

U.S. Army Corps of Engineers,
U.S. Fish and Wildlife Service,
U.S. Geological Survey,
U.S. Environmental Protection Agency,
U.S. Department of Commerce, NOAA, and
NASA Goddard Space Flight Center, NASA Headquarters;

2 state agencies:

Virginia Marine Resources Commission and
Office of Coastal Resources Management Program;

4 academic institutions;

3 industrial/consulting firms;

3 miscellaneous regional governmental bodies; and

7 VIMS departments.

Center facilities are used by non-center personnel at the rate of 3 person-visits and 10 man-hours per day. The most popular facilities are the aerial photographic archives, the light tables, the electronic planimeter, and the time-sharing computer terminal (Apple II) link to the Computer Center. Camera use is restricted to Remote Sensing Center personnel and thus photography requests result in personnel-provided services.

TABLE 8

PUBLICATIONS RELATED TO GRANT ACTIVITIES

1973

Welch, C.S. and L. Haas. 1973. Application of remote sensing to study nearshore circulation. NASA Annual Report No. 1, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 85 p.

1974

Zeigler, J.M., C.S. Welch, and L. Haas. 1974. Application of remote sensing to study nearshore circulation. NASA Annual Report No. 2, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 90 p.

1975

Boon, J.D., III. 1975. Hampton bar dredging project, Newport News Shipbuilding and Drydock Company Borrow Site - Monitor of Turbidity and Sedimentation. Virginia Inst. Marine Science, Gloucester Point, VA, 46 p.

Fang, C.S., C.S. Welch, and H.H. Gordon. 1975. A surface circulation study in middle Elizabeth River. Report to NUS Corp. Virginia Inst. Marine Science, Gloucester Point, VA, 66 p.

Munday, J.C., Jr. and T.T. Alföldi. 1975. Chromaticity changes from isoluminous techniques used to enhance multispectral remote sensing data. Remote Sensing of Environment, 4:221-236.

Munday, J.C., Jr., R.J. Byrne, C.S. Welch, D. Stauble, E.P. Ruzecki, D. Baker, and H.H. Gordon. 1975. Applications of remote sensing to estuarine problems. NASA Annual Report No. 3, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 100 p.

Neilson, B.J. 1975. Newport News Point circulation study. A Report to Hayes, Seay, Mattern and Mattern. Virginia Inst. Marine Science Special Report in Applied Marine Science and Ocean Engineering No. 87, Gloucester Point, VA, 105 p.

Orth, R.J. and H.H. Gordon. 1975. Remote sensing of submerged aquatic vegetation in the lower Chesapeake Bay. Final Report NASA Langley Research Center, Contract NAS 1-10720. Virginia Inst. Marine Science, Gloucester Point, VA, 62 p.

Penney, M.E. and H.H. Gordon. 1975. Remote sensing of wetlands in Virginia. Proc. 10th Intl. Symp. Remote Sensing of Environment, Env. Res. Inst. Michigan, Ann Arbor, p. 495-504.

1976

Boule, M.E. 1976. Geomorphic interpretation of vegetation in Fisherman Island, Virginia. M.S. Thesis, Virginia Inst. Marine Science, Gloucester Point, VA.

Munday, J.C., Jr., H.H. Gordon, C.S. Welch, and G. Williams. 1976. Applications of remote sensing to estuarine management. NASA Annual Report No. 4, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 122 p.

Welch, C.S. and B.J. Neilson. 1976. Fine scale circulation near "Foxtrot" in Hampton Roads, Virginia. Virginia Inst. Marine Science Special Report in Applied Marine Science and Ocean Engineering No. 86, Gloucester Point, VA, 36 p.

1977

Alföldi, T.T. and J.C. Munday, Jr. 1977. Progress toward a Landsat water quality monitoring system. Proc. 4th Canadian Symp. on Remote Sensing, Quebec City, p. 325-340.

Gordon, H.H. and J.C. Munday, Jr. 1977. Lagrangian drifter design for the determination of surface currents by remote sensing. Proc. 6th Annual Remote Sensing of Earth Resources Conf., Univ. of Tennessee Space Inst., Tullahoma, Tennessee, 19 p.

Hennigar, H.F. 1977. Evolution of coastal sand dunes: Currituck Spit, Virginia - North Carolina. In Coastal Processes and Resulting Forms of Sediment Accumulations--Currituck Spit, Virginia - North Carolina (ed. V. Goldsmith), Virginia Inst. Marine Science Special Report in Applied Marine Science and Ocean Engineering No. 143, Gloucester Point, VA, Chap. 27, 20 p.

Munday, J.C., Jr. and H.H. Gordon. 1977. Progress toward a circulation atlas for application to coastal water siting problems. Proc. Conf. Application of Remote Sensing to the ChesapeakeBay Region (Coolfont Conf. Center, Berkeley Spring, West Virginia), Univ. Maryland, College Park, MD, NASA Conference Publication 6, p. 345-358.

Munday, J.C., Jr. and H.H. Gordon. 1977. Elizabeth River surface circulation atlas. Virginia Inst. Marine Science, Gloucester Point, VA, 15 p.

Munday, J.C., Jr., H.H. Gordon, and H.F. Hennigar. 1977. NASA Annual Report No. 5, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 41 p. + app.

1978

Alföldi, T.T. and J.C. Munday, Jr. 1978. Water quality analysis by digital chromaticity mapping of Landsat data. Canadian Journal of Remote Sensing 4(2):108-126.

Munday, J.C., Jr., C.S. Welch, and H.H. Gordon. 1978. Outfall siting with dye-buoy remote sensing of coastal circulation. Photogram. Eng. and Remote Sensing 44(1):87-96.

Munday, J.C., Jr., P.L. Zubkoff, J.E. Warinner, III, E. Ferrez-Reyes, H.H. Gordon, and K.A. Moore. 1978. Plant geography and water quality data for Chesapeake Bay waters of Virginia's Eastern Shore. Virginia Inst. Marine Science Data Report Number 14, Gloucester Point, VA, 27 p.

Munday, J.C., Jr. and H.H. Gordon. 1978. Applications of remote sensing to estuarine management. NASA Annual Report Number 6, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 33 p. + app.

1979

Munday, J.C., Jr. and T.T. Alföldi. Landsat test of diffuse reflectance models for aquatic suspended solids measurement. Remote Sensing of Environment 8:169-183.

Munday, J.C., Jr., T.T. Alföldi, and C.L. Amos. 1979. Verification and application of a system for automated multidate Landsat measurement of suspended sediment. In Satellite Hydrology, Proc. Fifth Annual William T. Pecora Symposium, June 11-14, 1979, Sioux Falls, SD, 27 p. + fig., in press.

Munday, J.C., Jr. and H.H. Gordon. 1979. Applications of remote sensing to estuarine management. NASA Final Report and Annual Report Number 7. Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 38 p. + app.

Zubkoff, P.L., J.C. Munday, Jr., R.G. Rhodes, and J.E. Warinner, III. 1979. Mesoscale features of summer (1975-1977) dinoflagellate blooms in the York River, Virginia (Chesapeake Bay Estuary). In Toxic Dinoflagellate Blooms, D.L. Taylor and H.H. Seliger (eds.), Proc. Second Intl. Conf. Toxic Dinoflagellate Blooms, p. 279-286.

TABLE 9

EQUIPMENT OF THE REMOTE SENSING CENTER

Item	Source: NASA	Source: Other
Kelsh plotter (surplus)		+
Brumac densitometer	+	
Bausch & Lomb ZT4-H Zoom Transfer Scope	+	
Numonics Electronic Planimeter	+	
K & E Polar Planimeter	+	
Gordon Ent. parallax bar	+	
Drafting light table		+
Hasselblad 500 EL/M 70-mm camera (2)	+	+
- Magazine (2)	+	
- 50-mm lens (2)	+	
- 80-mm lens	+	
- prism finder (2)	+	
- intervalometer	+	
- command unit	+	
Nikon F2 Photomic 35-mm camera	+	
- 55 Auto-Micro Nikkor lens	+	
Apple II Computer		+
- disk drive		+
Hitachi B & W TV		+
Panasonic Color TV		+
Integrated Data Systems Printer		+
Fairchild CA-8 9-inch camera		+
Aircraft camera mounts: 9-inch, 70-mm	+	
70-mm developing tank	+	
Wild photocopy stand		+
Porta-Trace light tables (4)	+	
Bell & Howel slide cube projector	+	
Richards light table GFL-940MC (surplus)	+	
Linear amplifier 100-watt	+	
Camera carrying cases (3)	+	
Recordak microfiche reader		+
Digi-data 9-track tape recorder		+

Item	Source: NASA	Source: Other
Craig 9417 earphones	+	
Velbon tripod	+	
Allied Radio Shack power pack (4)	+	
Nu-Arc light table (surplus)	+	
Morse contact printer (surplus)	+	
Litcom Omega receiver	+	
Data General minicomputer (surplus)	+	
Data General tape drive & controller (2)	+	
Wang tape recorder	+	
Data General interface (2)	+	
Raytheon direction finder	+	
Biological Inst. Omega down converter	+	
Wavetek HF sweep generator	+	
Tektronix amplifier & oscilloscope	+	
K & E transit and tripod	+	
Allied Radio Shack CB radios	+	

II. LANDSAT DATA PROCESSING IN VIRGINIA

IMPLEMENTATION OF THE ORSER SYSTEM

A satellite and aircraft multispectral scanner digital data processing system was purchased from the Pennsylvania State University, Office for Remote Sensing of Earth Resources (ORSER) in the fall of 1978. The package (known as ORSER) consisted of software programs on a magnetic tape, and a users manual with documentation for installation on an IBM 370 computer system. The system has been implemented on the College of William and Mary IBM 370 Model 158 computer, which is part of the Southeastern Virginia Regional Computing Center with terminals throughout southeastern Virginia.

The computer tape with ORSER programs was copied to a working tape, and the source code for the most important programs moved to disk for editing. Calls for system subroutines not available at William and Mary were removed, and executable load modules were made to permit the most rapid program run-times.

All programs necessary to perform a classification of multispectral scanner data have been tested in their basic form (i.e. using mostly defaults) and produce reasonable results. The following programs have been run: TPINFO, SUBSET, STATS, CONSOL, UMAP, NMAP, CLUS, AND CLASS. In addition, a new program has been written to display a land/water separation map on a dot matrix printer (Printronix). This program compresses up to six normal line printer panels into one panel, and allows a quick-look at a

large geographic area to identify specific areas for detailed analysis. Table 10 lists and describes those computer programs now available in Virginia for processing Landsat (MSS) data.

The ORSER data processing system is being configured to run under the control of IBM Time Share Option (TSO); users at remote locations will be able to submit and control jobs, and receive output. To simplify job submission, Control Data Sets have been written which contain the basic Job Control Language (JCL) statements for running each of the programs. TSO Command Lists (CLISTS) have been written which at one step call the JCL and identify the options to be used during a particular run of a given ORSER program.

The ORSER load modules are stored on disk (rather than on tape). Blocks of data used in detailed analysis are moved from the raw data tape to disk, giving the user rapid control of program flow. Output is written on disk which permits results to be quickly scanned at the user's terminal. All data can also be dumped on a remote line-printer or at the computer center and subsequently mailed to the user.

TABLE 10

IMPLEMENTED ORSER PROGRAMS

AS OF SEPTEMBER, 1979

Computer Program	Function
TPINFO	Outputs information about the contents of an MSS data tape.
SUBSET	Subsets one or more areas of interest from an ORSER or LANDSAT tape onto ORSER format.
STATS	Computes statistics for training areas, including mean vector, standard deviation, correlation and variance-covariance matrices, eigen values, and frequency histograms.
CONSOL	Consolidates data blocks from different tapes onto a single tape.
UMAP	Maps areas of local spectral uniformity.
NMAP	Outputs a brightness classification map (grey scale map) that shows overall land patterns in data.
CLUS	An unsupervised classifier that develops a set of spectral signatures by clustering.
CLASS	Generates a classification map from a set of input category mean vectors or signatures.
LWPRINT	Outputs a special dot density map to separate two categories on a single spectral channel.

JOINT WORK WITH

NASA GODDARD ON DEMONSTRATION PROJECTS

The Eastern Regional Remote Sensing Applications Center (ERRSAC) at NASA Goddard Space Flight Center has been working with the legislative and executive branches of the Virginia state government over the past three years to introduce Landsat data to regional users within the state. NASA has held various meetings throughout the state with potential users of Landsat to explore the potential for applying Landsat data to state and local needs. In addition, demonstration and training sessions have been held at ERRSAC to further acquaint users with Landsat data processing and information display.

With the initial steps to acquaint users with Landsat data well under way, attention is now turned to achieving a state-wide, in-state Landsat data processing capability. During the year, the VIMS Remote Sensing Center purchased the ORSER multispectral scanner processing software and implemented the system at the Southeastern Virginia Regional Computing Center at the College of William and Mary. The next step is to train state users to use ORSER remotely from their own facilities. This is being accomplished via demonstration projects between ERRSAC and users. VIMS will complete installation of ORSER with the help of ERRSAC. A small contract will provide for scientific/programming interface between the users performing demonstration projects (under the auspices of ERRSAC) and the

Virginia ORSER system. The contract will begin in October, 1979 and will continue for eight months. Help will be provided both for users who are familiar with digital processing of Landsat data and for users who are generally unfamiliar with computers. Emphasis will be placed on helping users through the TSO capabilities of the computer network. It is anticipated that, as problems arise, a user can contact VIMS for real-time help in order to maintain continuity of processing.

An important aspect of the project will be to evaluate the utility of ORSER data processing relative to Virginia's needs. The demonstration projects will serve as a basis for documenting the cost of running ORSER, time to complete a classification, ease of handling the system, and suitability of output products. The results will determine the future course of Landsat data processing in Virginia.

FUTURE EXPANSION OF LANDSAT CAPABILITY

As groups throughout the state of Virginia begin to use the ORSER processing capability, the direction for future expansion of Landsat capability will become more apparent. For the immediate future two areas will be stressed: making more of the ORSER software operational, and adding the OCCULT pre-processor package.

The next ORSER program to be implemented is a parallelepiped classifier, PPD, which runs somewhat faster than CLASS. The program RATIO will be added to permit ratioing of two spectral channels. The next priority will be to add more data analysis programs for more complete statistical computation and display. Finally, cartographic correction programs and data management programs will be added as user needs dictate.

The OCCULT system is an interactive language developed by NASA Goddard ERRSAC personnel to aid the ORSER user. Its purpose is to assist non-computer oriented users in setting up and submitting ORSER programs. It includes a data base management system and output retrieval system. It is designed for users who want to use ORSER as an image analysis system, but who cannot justify the effort to acquire and maintain proficiency in IBM job control language (JCL), and details of ORSER control card formats. OCCULT will be installed at the College of William and Mary Southeastern Virginia Regional Computing Center, and, as soon as operational, will be evaluated against Virginia's needs as a part of the ORSER evaluation.

As the ORSER system becomes more fully operational, and user experience is acquired, attention will be focused on the best media for output products. The normal geographic display of categorized data from runs of ORSER is the traditional line printer map. These use letters, numbers, or other symbols to represent different classes. Line printer maps are generally rather hard to interpret, take up a large amount of space, and often must be viewed at a distance to convey the proper visual impressions and information. The ORSER system is capable of generating output tapes for map display using other devices than the line printer, such as the Dicomed printer with color photographic print output. A Dicomed printer is available at nearby NASA Langley Research Center. There are also other facilities throughout the country which can take ORSER output tapes and produce maps in color. As experience with ORSER increases, and the particular needs of state users are determined, the proper form of output products will become more apparent. This will, in turn, determine whether Virginia should have in-state capability for producing quality final display maps, or whether outside services will suffice.

LANDSAT WATER QUALITY SOFTWARE ADDITIONS

Last year (Annual Report Number 6, 1978) it was reported that the intention at NASA Goddard ERRSAC was to incorporate water quality software in the ORSER package. One step toward this goal has been the acquisition by NASA Goddard ERRSAC of the chromaticity package from the Canada Centre for Remote Sensing. The transfer of software took place in May, 1979. ERRSAC has begun to implement the chromaticity package on its own facilities and will be conducting its own independent evaluation of the chromaticity technique. In addition, the University of Wisconsin software for trophic state classification is under evaluation.

At present neither of the above software packages is implemented in Virginia. However, some elementary pieces of the chromaticity technique are in use at VIMS for research pruposes. The chromaticity package will be implemented at VIMS as time permits.

STATUS OF VIRGINIA RESOURCE INFORMATION SYSTEM

The Virginia House of Delegates in 1978 created a joint subcommittee to study the development of a Virginia Resource Information System (VARIS) (see Annual Report Number 6, 1978). The subcommittee was organized, and undertook a study of needs for such a system. Among other activities, it studied documents and recommendations presented to it by an Executive Branch Task Force on VARIS created by the Secretary of Commerce and Resources.

In the 1979 legislative session, the subcommittee was provided with $25,000 to continue its study and directed to make a final report to the legislature by December, 1979. The subcommittee is still relying heavily on the work of the Executive Branch Task Force.

The Task Force has been meeting regularly. This year it has surveyed needs of state agencies to determine the potential benefits of VARIS should it be created.

The VARIS concept includes remote sensing for gathering resource data, and particularly the application of Landsat to resource data collection. The Task Force is now at the point of examining the capability for Landsat data processing in Virginia, and what expansion of Landsat capability would be appropriate to meet future state needs in the context of a VARIS program. The ORSER capability now implemented by the VIMS Remote Sensing Center is of critical importance in these deliberations. Discussions with the Task Force are in progress.

REMOTE SENSING CENTER SPECIAL FACILITIES

Graphics Calculator

The Numonics Graphics Calculator has seen wide use throughout the Institute for recording digitized data onto magnetic tape for computer processing. In the project for photographic mapping of submerged aquatic vegetation, the unit was used to calculate grass bed areas, and record both area and x-y perimeter on tape. The results constitute a computer data base for grass beds in Virginia in 1978.

Other uses of the facility include recording of output traces from wave gauges, and output from a rapid sediment analyzer. The unit has also been used to record longitude, latitude, and depth information from historical hydrographic charts for computer interpolation and replotting. Some real-time data processing has been accomplished using the graphics calculator interfaced to the Apple computer described below.

Apple Computer

The Remote Sensing Center has acquired an Apple II microcomputer with 48 k words of memory and a floppy disk drive. Output is to television or a dot matrix printer. The Graphics Calculator has been interfaced to the unit. The system is used as a smart terminal to a host computer over telephone lines at 300 baud (30 characters per second). ORSER programs have been implemented using the Apple linked to the College of William and Mary

Southeastern Virginia Regional Computing Center.

The microcomputer is also capable of doing routine data processing for the Remote Sensing Center, and may be used in the future to automate the photo index system.

Fairchild 9-inch Format Camera

During the past year the Remote Sensing Center acquired on loan a Fairchild CA-8 9-inch format aerial camera. Added to the existing Hasselblad 70-mm and Nikon 35-mm cameras, the CA-8 has given the Center a complete aerial photographic facility for meeting state needs in coastal remote sensing. Frame charges have been established and have been accepted by users.

III. APPLICATIONS IN THE CURRENT YEAR

DEVELOPMENT OF AN OPERATIONAL TECHNIQUE FOR LANDSAT MEASUREMENT OF SUSPENDED SEDIMENT

INTRODUCTION

Landsat measurement of aquatic suspended sediment can be very useful to many water quality monitoring programs and engineering studies. It is a practical and economical method for repetitive measurements in large and/or numerous water bodies, and, of possible remote sensing data sources, Landsat is inexpensive in terms of marginal cost to the user.

For widescale application, an operational system is needed for Landsat measurement of suspended sediment, that is, an implemented system employing verified Landsat data reduction techniques, whose results are reliable and repeatable.

Appropriate data reduction techniques for Landsat measurement of suspended sediment have been sought by many authors since the advent of Landsat in 1972. One very recent study aimed at universal methods appropriate for multispectral scanner data is that by Holyer (1979). Other studies have been referenced in earlier work.

Joint work began in 1974 between VIMS and Mr. Thomas Alföldi of the Canada Centre for Remote Sensing in Ottawa, Canada, and more recently, with Dr. Carl Amos of the Atlantic Geoscience Centre, Dartmouth, Nova Scotia, Canada. This joint work has produced an implemented system for Landsat suspended sediment measurement. Verification tests have been conducted using

surface data from the Bay of Fundy, Nova Scotia. The system is available for testing on surface data from other sites around the world. The method of data reduction is chromaticity analysis, reviewed below and described in earlier publications, which permits adjustment of atmospheric variations between dates of Landsat over-passes.

The system has been used to study the distribution, transport, and disposition of suspended sediment in the Bay of Fundy, the site for a proposed tidal barrage designed to generate electric power. The distribution of suspended sediment mapped by Landsat was used to calibrate and initialize a numerical model of post-barrage siltation. Also, the transport paths of suspended sediment and the general hydrodynamic character of the flow were determined by visual interpretation of mapped suspended sediment patterns.

A report of recent results was presented at the Fifth Annual William T. Pecora Symposium on Satellite Hydrology, June 11-14, 1979, at Sioux Falls, South Dakota (Munday, Alföldi, and Amos, 1979).

THEORETICAL DEVELOPMENT

Remote sensing satellite data must be calibrated by means of surface information, but it is impractical to provide calibration for each scene. Therefore, calibration must be extrapolated from scene to scene. The extrapolation procedure must adjust for date-to-date variations (the temporal dimension), and region-to-region variations (the spatial dimension). Variations occur in solar elevation angle, atmospheric attenuation and path radiance, and extraneous factors in surface reflectance (an example for water quality is whitecaps).

The spatial noise may be termed patchiness. Patchiness cannot be corrected by spatial extrapolation from one part of a scene to another (dark pixel subtraction, for example); instead, a pixel-by-pixel correction utilizing information specific to each pixel is required. Of the temporal variations, solar angle variations are regular and correction methods for their effects are under study.

Our solution for noise treats spatial and temporal noise simultaneously. It involves a preprocessing transformation: total radiance normalization. The procedures outlined below and discussed in previous publications are analogous to some features of chromaticity analysis of human color vision; hence, we term our procedures "chromaticity analysis" (Munday, 1974a, b).

Total radiance normalization involves the ratio transformations $x_i = N_i/\Sigma N_i$, where x_i are "chromaticity coefficients" and N_i are Landsat multispectral scanner (MSS) band radiances. This transformation suppresses noise when all bands suffer radiance changes in the same proportion, while leaving spectral properties of the data unaffected (Munday and Alföldi, 1975). For water quality analysis, we select i = 4, 5, and 6, excluding MSS 7 because strong infrared absorption by water in this band precludes its utility for volume information except at very high constituent concentrations. The result is two independent coefficients, x_4 and x_5, which are henceforth called chromaticity x and chromaticity y. The x-y plane is referred to as a chromaticity diagram with equal radiance point E at (x, y) = (0.333, 0.333). The azimuthal or angular dimension contains "hue" (dominant wavelength) information while the radial dimension from E contains "saturation" (spectral purity) information.

The radial dimension is used to remove "desaturating" effects of environmental noise not suppressed by the chromaticity transformation itself. Atmospheric variations, thin clouds, air pollution, white caps, and thin snow and ice cover, all cause a radial shift of Landsat chromaticities toward E (Alföldi and Munday, 1977, 1978). This desaturating effect of the atmosphere is confirmed by study of atmospheric model data reported in the literature (see Alföldi and Munday, 1978). Hence, a correction procedure for all the above variables involves, simply, a radial shift of chromaticities on the chromaticity diagram.

An attractive property of this noise correction technique is that the correction can be applied to new data lacking surface calibration, to standardize them to other data already calibrated. Consequently, a set of calibration data can be accumulated over any number of Landsat passes. In tidal estuaries, this feature is welcome because of the expense of obtaining surface data from dispersed locations within minutes of an overpass. Also, a unique correction is applied to each pixel rather than a scene-wide correction. Both patchiness and temporal variations are thus corrected coincidentally. The result is that surface calibration of Landsat data can be extrapolated both spatially and temporally.

The chromaticity transformation and the subsequent radial shift of chromaticities remove two degrees of freedom from a multispectral data set. For the three band set of MSS 4, 5, and 6, one degree of freedom remains for correlation with water quality parameters. The bulk of our work has been with suspended sediment measurement (Amos, 1976; Amos and Alföldi, 1979; Munday and Alföldi, 1979); equally satisfactory results are expected

for measurement of secchi disk depth or turbidity. Preliminary results give high correlation coefficients between chromaticity coefficients and the latter variables as well as chlorophyll.

SYSTEM IMPLEMENTATION

A suite of computer programs has been developed for the quantitative mapping of suspended sediment S from Landsat CCTs using chromaticity analysis. The suite of programs is highly user-interactive, involving cued sequences and user queries, graphical and color displays and hard copy output. The suite is implemented at the Canada Centre for Remote Sensing (CCRS) on the CCRS Image Analysis System (CIAS). The programs have recently been transferred under a Canada - U.S.A. software exchange agreement to the Eastern Region Remote Sensing Applications Center (ERRSAC) at NASA Goddard Space Flight Center.

CIAS performs digital image analysis based on a modified General Electric Company Image-100. The chromaticity suite does not use much of the specialized Image-100 signature analysis hardware, but exploits mainly the capability of the PDP-11 control computer. Interactive graphics and output employ the Image-100 color television monitor, a Tektronix 4012 control terminal, a line printer, dot-matrix printers, a thermal printer, and tape-film transfer for photographic print output.

The programs are arranged for construction and subsequent manipulation of two types of files: i) a chromaticity file containing both uncorrected and atmosphere-adjusted chromaticities, and ii) a calibration file containing corrected chromaticities and S values. The programs are written in Fortran. A complete user's manual is in preparation.

The program automatically computes error statistics as described in the next section. For the point mode, in which the user selects points for S measurement using a joystick cursor, the S value and standard error of prediction are automatically displayed on the color television monitor adjacent to the cursor location. For the area mode, the scene is displayed with a color code for S ranges, and a legend shows for each color the mean S, S-range, number of pixels, and area in square kilometres. For a preselected segment of the scene, a histogram may also be displayed showing number of pixels versus S for the entire range of S.

A user familiar with the programs can map S distributions over a complete Landsat scene lacking surface data in under three hours. This time could be reduced significantly by batch processing, but at the expense of the interactive features which permit resource managers to exercise considerable control during data reduction.

SYSTEM VERIFICATION

Regression and Correlation Analysis

Model I linear regression between x' and $\log_e S$ for 108 data points from nine dates produces the equation

$$x' = 0.552 - 0.026 \log_e S.$$

The Pearson produce-moment correlation coefficient r for this regression is 0.965. Removing data at $S > 1{,}000$ mg/l, where N versus $\log_e S$ becomes non-linear, gives r of 0.967. Removing one data set at a time and averaging the resulting r values yields r = .959 with a standard deviation of .01348. The results indicate that data at $S > 1{,}000$ mg/l have little effect, and no one

data set has an unduly large influence on the results.

Results with MSS 5 radiance values instead of chromaticity values give an r of .818. For one set removal, the average r is .821, with a standard deviation of .0241. Comparison of all the above r values shows that the chromaticity transformation with atmospheric adjustment produces substantial correction for environmental noise between dates.

Absolute Error

The absolute error of the regression was determined by using, in turn, each set of data as a test against the other eight sets as training data. The data for $S > 1{,}000$ mg/l were removed before these computations. The errors so determined are true absolute errors. The mean error is 44%. Note that when an r equal to 0.96 is found for a logarithmic relationship, errors of 35% are expected; thus the chromaticity system is achieving very good results for its intended multitemporal application.

The accuracy required by the U.S.A. Environmental Protection Agency for monitoring suspended sediment is defined as a variance not to exceed 0.05 (Holyer, 1979). The corresponding percent error in S is 23%. Results here are outside the EPA standard.

Effects of Sediment Size and Composition

Results from the Bay of Fundy data indicate that the regression is not affected by variations in sediment size and composition encountered in the Bay of Fundy. Additional study has been proposed for a different site, the Chesapeake Bay, in order to confirm the lack of sediment-type effect.

SYSTEM APPLICATION IN THE BAY OF FUNDY TIDAL POWER PROJECT

The Nature of the Application

The Bay of Fundy, because of its large tidal range, is being considered for Tidal Power Development (Atlantic Tidal Power Programming Board, 1969; Bay of Fundy Tidal Power Review Board, 1977). This involves constructing a barrage across the tidal flow, thus creating a headpond, then generating energy by feeding water from the headpond to the sea during periods of low tide. The headpond is subsequently filled on the following high tide. Though simple in principle, the project is an enormous undertaking, estimated to cost $4 billion.

It appears reasonable to assume that siltation will result from Fundy Tidal Power development. The question is where and how much siltation will occur, and also, what will its impact be on the efficiency and lifetime of the power generation. Answers have been provided by a predictive numerical model of the Fundy system (Greenberg and Amos, in prep.; Greenberg, 1977) which has been initialized and calibrated from maps of suspended sediment concentration derived from chromaticity analysis of Landsat data. The maps and their analyses have been the work of Dr. Amos and his staff.

The maps show that the highest S values occur during the spring. The average S in the central part of the basin in this season is approximately 60 mg/l. Lowest values occur during the summer (1-5 mg/l), and intermediate concentrations occur during the winter and autumn (40 mg/l). It is significant that the ice-free pattern of contours (at any particular stage of the tide) does not change. This indicates that the various sediment transport processes change only in magnitude and not in their spatial distribution.

The significance of these calculations is in the prediction of siltation associated with the Fundy Tidal Power Project. The masses of material determined from the maps of S clearly show the need for an analysis of post-barrage sedimentation patterns. Therefore, spring maps were used to initiate a numerical simulation model (Greenberg, 1977) and simulate the most intense conditions of sedimentation which could result. The model was then adjusted (Greenberg and Amos, in preparation) until, after a series of tidal cycles, it approached summer conditions of sediment transport, distribution and deposition. The ebb transport was used as a criterion for evaluating the model simulation. The pattern of S contours agreed markedly with those generated by the satellite data.

Basco et al (1974), in summarizing the field of sedimentation theory, stated that predictive numerical models of sedimentation are only as valid as the boundary conditions and calibration of the model. The application of S maps to the calibration and running of the model unquestionably improved its validity.

The results from the Bay of Fundy model, run with a barrage term, show that only minor amounts of sedimentation within the headpond region will result; the lifetime expentancy (based purely on sediment deposition) will not be affected. This is a rather significant conclusion for the operation of the Tidal Power scheme, and is based in part on the information derived from the Landsat MSS.

SUMMARY

In summary, Landsat data analyzed by the chromaticity technique have been used to show that sedimentation will not impair the Bay of Fundy Tidal Power Project.

The Landsat chromaticity technique is fully operational at the Canada Centre for Remote Sensing, and is being implemented at NASA Goddard Space Flight Center in the Eastern Region Remote Sensing Applications Center.

ESTUARINE CIRCULATION ATLAS

FROM DYE-BUOY PHOTOGRAMMETRY

In earlier years of this grant, a technique was developed to produce circulation data from photogrammetry of dye-emitting buoys (Munday, Welch, and Gordon, 1978). The technique was used to determine the best sites for two sewage outfalls in Hampton Roads, Virginia. Later, circulation data for the Elizabeth River (which empties into Hampton Roads) were collected and arranged for easy reference in an Elizabeth River Circulation Atlas. This Atlas was distributed to the U.S. Coast Guard, the U.S. Army Corps of Engineers, and other parties interested in water quality problems associated with oil pollution in the Elizabeth River (especially oil pollution expected from the proposed Portsmouth oil refinery).

During this year the dye-buoy technique has been used (with Dr. C.S. Welch as Principal Investigator) to collect additional circulation data from the Elizabeth River, and also from the lower York River. In both cases, the dye-emitting window shade drogues developed earlier (see Annual Report Number 3, 1975, p. 120) were used to remotely gather circulation data from different depths in the water column. This is a unique application of remote sensing, to study currents at depth. It will be reported at a Speciality Conference on Energy, Ports, and Perspective, in Norfolk, Virginia, May 19-21, 1980 (Sponsor: American Society of Civil Engineers Ports and Harbors Committee). The abstract for this presentation is found in the appendix.

This year's new study on the Elizabeth River involved the routine deployment of window-shade drogues with accompanying sequences of 9-inch format aerial photography. The study was funded mainly by the U.S. Army Corps of Engineers and partly by this grant. The purpose of the study was to examine the effects of hydraulic and bucket dredging techniques on resuspension of sediments from dredge plumes.

Current meter data were collected to enable intercomparisons between photogrammetrically determined currents and true currents. Sediment concentrations were measured in the field using nephelometers.

A model of dredge plumes based on the data is being formulated by Dr. A. Kuo. This model will be used by the Army Corps to choose appropriate dredging techniques for different circulation conditions.

In the York River study, the window-shade drogue and photogrammetric technique was used by Dr. Welch to study river circulation during the transition between stratified and mixed estuary conditions. The larger context was a York River study of the effect of monthly cycles of hydrodynamic processes on biological processes, particularly on primary productivity and phytoplankton populations.

Both of these applications of window-shade-drogue photogrammetry are evidences of the operational status of the technique. For large area studies, the technique is alone in enabling the collection of circulation data at depth. In the future, the technique will be of singular importance in various applications to facility siting in estuaries and harbors.

WETLAND PERMIT SITE EVALUATION

The Remote Sensing Center is engaged in a joint project with the VIMS Department of Wetlands under contract to the Army Corps of Engineers to provide data, technical assistance, and evaluation of wetland permit applications. The data provided include color aerial photographs of designated sites taken at specified altitudes and angles (oblique and vertical). Photography ranges from individual frames to photo-sequences made into color mosaics. Some of the permit sites require ground control to permit accurate mapping. Environmental evaluations are made of proposed alterations using the photographs as a principal source of data. The funding to VIMS is $10,000 over a three-month period.

A second-year contract will begin in the last quarter of 1979 to continue and expand the same service. Coordinated by the Army Corps of Engineers, the new contract involves several federal agencies sharing in the costs, including the Region V of the U.S. Fish and Wildlife Service, the Northeast Region of the National Marine Fisheries Service, the Region III of the Environmental Protection Agency, and the Norfolk District of the Army Corps of Engineers. The duration of the new contract will be one year with a cost of $40,000. Up to 80 sites will be evaluated in the new contract.

Under the present contract 20 sites have been evaluated. The mosacis and spatial data obtained from the mosaics are frequently entered as

evidence in court and in Wetlands Boards hearings. Illegal activities not allowed by permit are prosecuted by the Corps. VIMS scientists appear as witnesses and testify on the basis of the photographic data.

MAPPING OF SUBMERGED AQUATIC VEGETATION

The Remote Sensing Center, in conjunction with the VIMS Department of Invertebrate Ecology, recently finished a first-year contract with the Environmental Protection Agency to map submerged aquatic vegetation. The distribution and abundance of submerged aquatic vegetation (SAV) in the lower Chesapeake Bay and its tributaries were determined with aerial photography and surface field data. SAV was mapped from aerial imagery onto topographic quadrangle sheets (1:24,000) with a zoom transfer scope, and the area of SAV beds was computed with an electronic planimeter. SAV beds were classified into four density categories based on a comparison with a crown density scale: <10% cover, 10-40% cover, 40-70% cover, and 70-100% cover. Significant beds of SAV were identified on 31 quadrangle sheets, with 27 occurring in the mesohaline and polyhaline areas where Zostera marina and Ruppia maritima predominate. The remaining four were in freshwater and oligohaline areas where most SAV beds are small and are difficult to image using aerial photography.

A second study has been funded to image the SAV beds during calender year 1979, and a follow-on effort for 1980 is anticipated. The first year contract was awarded for $73,000 and the 1979 contract is for $20,000.

AERIAL PHOTOGRAPHIC MONITORING OF BEACH EROSION

During the past year the Remote Sensing Center has provided services on several beach erosion projects on request of the U.S. Army Corps of Engineers.

The main project comprised two flights during a 6-month period over several beach sites in the southern Chesapeake Bay. The unique services provided by VIMS included flights at low altitude (400 m), coincident with low tide at each site, and synchronization with surface beach monitoring by the Corps. Nadir color photography using 2448 reversal film was taken with the Fairchild 9-inch mapping camera, and color oblique photographs were taken using color negative VPS with the Hasselblad 70-mm cameras. The obliques were made into 8 x 8-inch color prints. The total dollar amount of the contract was $2,600.

The Army Corps of Engineers also requested color infrared photography of a drainage channel, and a natural drainage stream. The photography was used to map the adjacent vegetation. One set of 70-mm transparencies was made in the early Spring before deciduous leaf cover had emerged, and one in the later Spring when leaves had emerged. The two flights were made for $760.

REFERENCES

Alföldi, T.T. and J.C. Munday, Jr. 1977. Progress toward a Landsat water quality monitoring system. Proceedings of the Fourth Canadian Symposium on Remote Sensing, Quebec City, Quebec, p. 325-340.

Alföldi, T.T. and J.C. Munday, Jr. 1978. Water quality analysis by digital chromaticity mapping of Landsat data. Canadian Journal of Remote Sensing, Vol. 4(2), p. 108-126.

Amos, C.L. 1976. Suspended sediment analysis of sea water using Landsat imagery, Minas Basin, Nova Scotia, in report of activities, part C. Geological Survey of Canada, Paper 76-1C, p. 55-60.

Amos, C.L. and T.T. Alföldi. 1979. The determination of suspended sediment concentration in a macrotidal system using Landsat data. Journal of Sedimentary Petrology, Vol. 49(1), p. 159-174.

Atlantic Tidal Power Programming Board. 1969. Report of Atlantic tidal power programming board on feasibility of tidal power development in the Bay of Fundy, Halifax, Nova Scotia, August 12, 1977. Unpublished Report.

Basco, D.R., A.H. Bouma, and W.A. Dunlap. 1974. Assessment of the factors controlling the long-term fate of dredging material deposited in unconfined subaqueous disposal areas. Dredged Material Research Program Report D-74-8, 238 p.

Bay of Fundy Tidal Power Review Board. 1977. Reassessment of Fundy Tidal Power. Publ. Thorn Press Ltd., 516 p.

Greenberg, D. 1977. Effects of tidal power development on the physical oceanography of the Bay of Fundy and Gulf of Main. In Fundy Tidal Power and the Environment, Daborn (ed.), Publ. Acadia Inst., p. 200-232.

Holyer, R.J. 1978. Toward universal multispectral suspended sediment algorithms. Remote Sensing of Environment, 7: 323-338.

Munday, J.C., Jr. 1974a. Lake Ontario water mass delineation from ERTS-1. 9th International Symposium, Remote Sensing of Environment, University of Michigan, Ann Arbor, p. 1355-1368.

Munday, J.C., Jr. 1974b. Water quality of lakes of southern Ontario from ERTS-1. 2nd Canadian Symposium on Remote Sensing, Guelph, Ontario, p. 77-86.

Munday, J.C., Jr. and T.T. Alföldi. 1975. Chromaticity changes from isoluminous techniques used to enhance multispectral remote sensing data. Remote Sensing of Environment, Vol. 4(3), p. 221-236.

Munday, J.C. and T.T. Alföldi. 1979. Landsat test of diffuse reflectance models for aquatic suspended solids measurement. Remote Sensing of Environment, Vol. 8, p. 169-183.

Munday, J.C., Jr., T.T. Alföldi, and C.L. Amos. 1979. Verification and application of a system for automated multidate Landsat measurement of suspended sediment. In Satellite Hydrology, Proc. Fifth Annual William T. Pecora Symposium, June 11-14, 1979, Sioux Falls, SD, 27 p. + fig., in press.

Munday, J.C., Jr., R.J. Byrne, C.S. Welch, D. Stauble, E.P. Ruzecki, D. Baker, and H.H. Gordon. 1975. Applications of remote sensing to estuarine problems. NASA Annual Report No. 3, Contract NGL 47-022-005. Virginia Inst. Marine Science, Gloucester Point, VA, 100 p.

Munday, J.C., Jr., C.S. Welch, and H.H. Gordon. 1978. Outfall siting with dye-buoy remote sensing of coastal circulation. Protogramm. Eng. and Remote Sensing 44(1):87-96.

A P P E N D I X

ACCEPTED FOR PRESENTATION AT THE

SPECIALTY CONFERENCE PORTS '80:

ENERGY, PORTS, PERSPECTIVE, NORFOLK, VIRGINIA, MAY 19-21, 1980

Atlas of Estuarine Circulation (3-Dimensional) from Dye-Buoy Photogrammetry for Use in Facility Siting and Port Management

J.C. Munday, C.S. Welch, H.H. Gordon, and F.J. Holden
Virginia Institute of Marine Science and
School of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062
804/642-2111, ext. 254

An atlas of circulation has been produced for the Elizabeth River tidal estuary, Hampton Roads, Virginia showing empirical flow patterns in different wind conditions and tidal phases. Data were obtained synoptically using aerial photogrammetry of fluorescein dye-releasing drogues and buoys as Lagrangian and Euleran tracers. Three-dimensional flow was determined directly from the photogrammetry of window-shade drogues which followed currents at depth but which were marked by dye released at the surface from surface floats. Convergent and submergent streamflow at frontal boundaries was directly revealed on the photographic images by dye streams from dye-releasing anchored buoys. Current vectors computed from the data were verified using current meter records. Sequential photography from a small aircraft was reduced via digitizer, photogrammetric resection program, computation of currents, and automatic plotting. Data are retained in a computerized data base. The technique was advantageous compared to use of current meters for the following reasons: the drogues and buoys were inexpensive; they were easier and safer to deploy and replace in zones of high density shipping traffic; and data reduction was rapid. The format of the atlas is user-oriented and permits analysis of circulation in facility siting and in response to releases of oil and other port pollutants.