An Overview of the Virginia Remote Sensing Center

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The Virginia Remote Sensing Center (VRSC) is conducting an ongoing high tech study activity initiated in 1988 under the sponsorship of the Secretary of Economic Development. The VRSC is located in the Computer Science Department of the College of William & Mary. The Center is solely supported via independent grants awarded through the Grants Office of the College of William & Mary. The VRSC conducts applications research, acquires and processes data, conducts educational and training workshops, and organizes and conducts pilot projects for users. Satellite data collection, Global Positioning Measurements, GIS, and image processing are used to produce maps and other products needed to address the management of resource conservation and consumption dealing with environmental impacts.

An essential element of developing applications includes the joint participation of users, representing a wide assortment of public agencies and organizations. These participants are linked primarily through common environmental concerns and the shared need for up-to-date natural resource and environmental information and other data required to produce maps for use in their state, city, and local government GIS. Goals include evaluating the feasibility of using remote sensing to meet practical needs and demonstrating the operational utility of remote sensing and image processing products.

Remote sensing provides low-cost, timely, and accurate maps

These goals are achieved by focusing on the following objectives: 1) defining applications for remote sensing; 2) identifying appropriate remote sensing technology; 3) matching applications to technology (application experiments); 4) identifying results and benefits; and 5) drafting recommendations for a long-range remote sensing plan.

Remote sensing and ancillary technologies have evolved over the past few yearsto become more accessible. Remote sensing satellites (EOSAT, SPOT) are in orbit providing data on a continuous basis. Low-cost, high performance computers exist for image processing. A large and growing number of value-added data processing firms are available. Also, significant effort is being committed to the development of Information Systems (IS). Data banks (raster and vector) and operational software are now available and access to data banks is expanding. In addition to satellite data systems, advanced aircraft remote sensing technology (such as high resolution video, synthetic aperture radar, and advanced aerial photo systems) exist and can furnish information to complement large area satellite data. Remote sensing is providing low cost, timely, and accurate maps for many GIS users.

The applications phase of this study involved an iterative process whereby users identified specific practical applications. This process involved drafting a set of requirements and identifying areas of potential interest. Continuous refinements were made until a final list of users and applications was evident. The users identified applications addressing the interface between public policy and environmental resource management. Example statutes are: State—*Chesapeake Bay Preservation Act-Title 15.1, Code of Virginia; 1985 Food and Security Act ("Farm Bill); Virginia Tidal Wetlands Regulatory Program 1972; Land Use Regulations/ Zoning Restrictions; and FederalClean Water Act; Rivers and Harbors Act; Flood Disaster Protection Act.*

User groups formed and isolated such sample applications as land use; changes in land-use; land development (extent and type); type of land cover; Chesapeake Bay monitoring; study of vegetation in the Virginia Beach area; survey of brackish waters; monitoring water density (levels, distribution, and changes); mapping of wetlands and monitoring changes; and inventory of rivers. Evaluation of all applications resulted in isolating the need to detect, classify, and inventory forests, wetlands, streams/ shoreline systems, croplands/ pasture, roads, and land-use/ land cover. In addition to the above classical image processing products, change detection, vector/raster data combining, and mapping were deemed necessary. Data were purchased from EOSAT, SPOT, and USGS. Ground truth and correlative study data relative to the selected site locations were available and used.

Each application was evaluated to isolate technology requirements. Aerial photos, USGS DLG data, SPOT and EOSAT satellite image data, fixed frame video image data, and GPS measurements data were identified as technology products capable of providing the basic needs for most applications being considered. Data from these technologies were selected and processed. Processing can take many forms, but in VRSC's experience, data products are most useful in digital image or photographic-like format. Thus, image processing was included, completing the technological tools used.

Three basic types of digital data (image) processing were performed—correction, enhancement, and information extraction. Geometric, radiometric, and atmospheric corrections were performed. Enhancements were achieved as required using a variety of processing techniques including pseudo-coloring, linear stretch, histogram equalization, RGB-to-HIS and HIS-to-RGB transformations, principal component transformations, application of 3 element kernel spatial filters, and application of image arithmetic operations, and polygon extraction. Information extraction was achieved using a variety of processing techniques including supervised and unsupervised classifications, density slicing, threshold slicing, logical image operations, registration, image/vector warp, band selection, color gun assignment, area calculation, and signal combining and display.

Processing of EOSAT, SPOT, and USGS data is completed as required to suit user needs. More specialized products can also produced and include classification, ratio, vector overlays, acreage measurement, merge, replication, principal component, classification sub-class grouping, change detection, and individual ban images. These specialized image products are custom developed for each user during the experimental hands-on processing.

These technologies are not competitors, but rather tools to be used in concert and orchestrated to suit the application

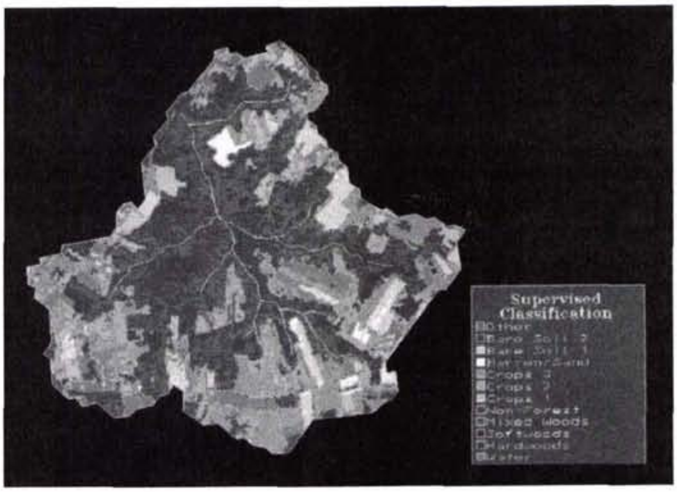
Two computer systems are currently in use by the Virginia Remote Sensing Center. The first system, Intergraph MicroStation with MicroStation Imager, is a fast, high-end product using an Intergraph InterPro 6040 providing GIS and image processing (IP) capabilities. The second system, Resource by Decision Images, Inc., operates on an IBM-AT class of machine providing a basic range of IP operations complemented with optional GIS functions. These systems are located in the VRSC image processing lab.

The Intergraph InterPro 6040 system is Intergraph's Unix™ workstation. The 27" color monitor is controlled by an Emerald I/O board and has a screen resolution of 1248 rows by 1664 pixels. The InterPro has a Menu/Digitizing tablet for graphic input and control. The Decision Images Resource System is a DOS-based system running on a Compaq DeskPRO with a math co-processor. The image is displayed on a 19" Aydin RGB monitor. The primary input device for the system is a Summagraphics tablet and mouse.

Demonstration experiments and projects have been or are being executed for numerous users, including the Virginia Department of Forestry, Chesapeake Bay Local Assistance Department, Northern Neck Planning District Commission, Middle Peninsula Planning District Commission, Watershed Study Groups, Wetlands and Shoreline Scientific Inventory Groups, Mapping Offices, Virginia Department of Transportation, County Planning Offices, James City County, and the City of Virginia Beach. Demonstration experiments and projects are undertaken based on user requirements. The experimentation focus is on processing satellite and other data to extract information relating to user organizational objectives and geographic locations. Examples of the projects follow.

Forestry interest included the inventory and change detection of four primary forest classes: deciduous trees, conifer trees, open land, and cutover. Approximately 13 forest sites in the Northern Neck area were targeted. Image data for these sites were processed and evaluated. Major benefits identified by foresters included: (1) the detection of change in forest cover resulting from timber harvests; (2) the ability to identify the boundaries and acreages of changes; and (3) the ability to distinguish between four basic forest types—pine, hardwood, recent cutover, and nonforested areas.

The Virginia Remote Sensing Center image processing lab.



A land-use map addressing forestry needs.

Water quality and sedimentation were compared with rainfall surface runoff and forestry activity. Classification and acreage maps of water, wetlands, forest (hardwood and softwood), farmland, bare earth, and cutover areas were evaluated. New change detection processing techniques are under development as the forestry use of remote sensing technology expands.

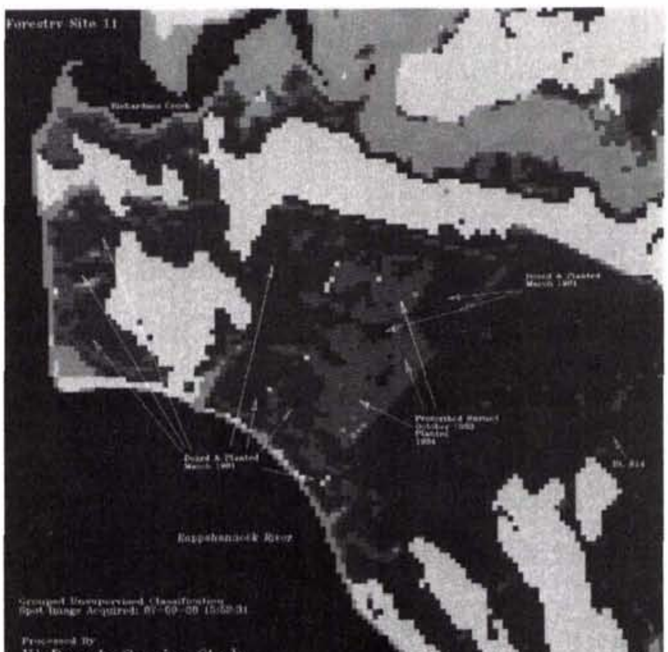
The Nomini Creek Watershed was selected for exploring remote sensing for defining a water quality experiment focused on Forestry Best Management Practice. Significant Nomini Creek Watershed correlative measurement data were available. Images of the Nomini Creek Watershed were processed and measurement techniques were evaluated using the correlative data base. Land-use maps were produced. Techniques included watershed boundary polygon merge with FCIR and classification images to define land-use within the watershed. Signature data were used to classify land classes and thus, land-use. Signature classes were isolated from cluster analysis and the statistical evaluation of training sets gleaned from the supervised evaluation of correlative data. Numerous cluster analyses were performed that produced a 12 class inventory of land-use within the watershed. The 12 classes are: water; hardwoods; softwoods; mixed woods; nonforest; crops 1, 2, and 3; bare soil 1 and 2; barren sand; and other.

Land-use inventory maps were produced for use in Forestry field surveys. Multispectral satellite image data were processed to produce normal color, FCIR, and classified image maps. In selected locations, multiple classes of farm land-use and other pasture and crop and nonwooded classes were grouped into an overall "nonforest" class. A land-use map, addressing Forestry needs, was produced having the classes of cutover, conifers, deciduous, young forest, water, wetlands, young vegetation, and nonforest.

Forest inventories, including land-use and wetland mapping, of areas in Northern Neck (Windmill Point, Smith Point, Farhow Creek, and Richardson Creek) and Virginia Beach (Back Bay, Lynnhaven Inlet, and Rudy Inlet) were conducted. Three types of marsh grass were mapped. Resultant forest wetland maps included fringe wetlands and provided improved information when compared to more conventional wetland inventories.

There are also urban projects with interests including land-use/land cover, wetlands (non-tidal and tidal), shoreline erosion, accretion, shoaling, forest/vegetation cover, transportation network, and land development. The greatest spatial resolution data available was used to allow classification and spatial separation to match the characteristic of high-density, high-growth (change) land-use. The Virginia Beach projects focused on land-use, water quality, environmental awareness, and city mapping and planning. Satellite data covering the city were processed to produce land-use maps for addition to the Virginia Beach GIS. Operational products included wetland inventories, sediment and shoreline details, seasonal impact, water quality influences, fresh water survey, forest land inventory, and agricultural land-use and area measurements. Wetland inventory image maps of areas in Virginia Beach were produced. As in forestry applications, resultant wetland maps included fringe wetlands and provided improved information when compared to more conventional wetland inventories.

The VRSC developed an



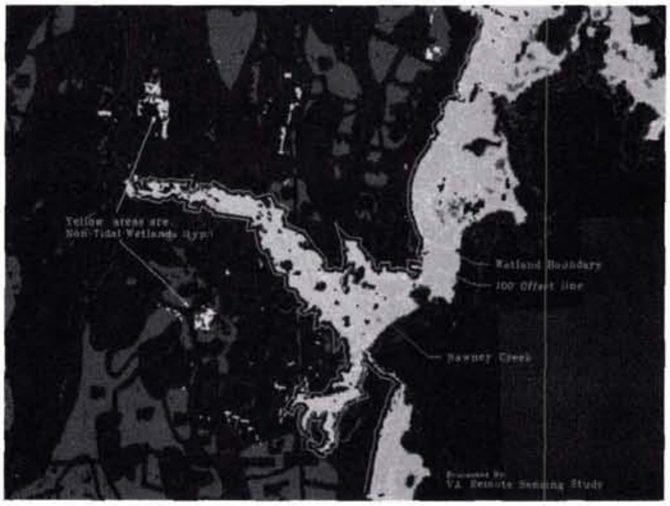
The Nomini Creek watershed classification.

approach to separating tidal and non-tidal wetlands. The method uses oil type and vegetation signature images in a Boolean merge operation. Both remotely sensed image data and soils map data were used. The final product included maps of tidal and non-tidal wetlands with 100' setback lines identified. The technique consisted of the coregistering and Boolean merge of hydrous soil map data with wetlands map data. Methods were developed and a map delineating tidal from non-tidal was produced. SPOT satellite remote sensing data were processed to produce a wetland map of the Nawney Creek area. After coregistration with a Virginia Beach digital soil map, the two digital maps were Boolean merged and the non-tidal/tidal wetlands map was produced. Wetland setbacks were computer generated and demonstrated in the same image. The boundaries were computer generated using a "parallel draw" from the linear feature interface between wetland classes and other classes of land-use. Setback dimensions were prescribed and the entrapped areas within the setbacks were computer measured. This technique provides new methods for defining setback dimension as a function of surface runoff, sedimentation, nearby land-use, and water quality.

Water density images were provided Virginia Beach as input for water quality evaluations. Included were images of the Chesapeake Bay and ocean shoreline areas as well as offshore zones. The Sandbridge shoreline, with offshore currents and erosion pattern, is shown. Monochromatic, FCIR, and classified images were evaluated. Also, specific water body sites were processed. Images produced (including city map GIS design file merges) provided detailed, close-up information for numerous water sites.

A Global Position System (GPS) experiment was conducted to evaluate its utility for locating GIS positions in processed satellite images. This work was conducted in conjunction with the Surveying and Mapping Department of the City of Virginia Beach and was reported in the Proceedings of the ASPRS/ACSM 1992 Annual Convention in Albuquerque, New Mexico. The Virginia Beach Surveying & Mapping Department GIS road and stream digital design files were accurately coregistered with satellite images of the city and GPS measurements made by the VRSC. This merge of data sets (vector with raster) provided a unique match encompassing the entire city. Detailed, merged images were provided the Surveying & Mapping Division. Thus, Virginia Beach can display maps and print out land-use image data as a base information layer for the city-wide GIS. This is an accurate, practical addition for surveying and mapping products needed for a variety of city day-to-day operations.

A Virginia Beach poster concept using a classified image, text and layout was developed. The poster image map is a thematic multispectral classification image. Posters (2' x 3') were printed and delivered to Virginia Beach for distribution by the Environmental Management Division, Natural Resources Department, City of Virginia Beach. The posters initiated a special environmental awareness program for the city. In addition to the Virginia Beach effort, many of the urban application techniques were used to provide James City County with land-use resource inventory base maps that are being used in the development of a James City County GIS. This



Virginia Beach tital/non-tidal wetlands map.

The Sandbridge shoreline with offshore currents and erosion pattern.

Virginia Beach thematic multispectral classification image poster.

work is also initiating discussion for an environmental awareness program for James City County.

For transportation uses, the Virginia Department of transportation received land-use survey and wetland inventory images addressing potential road work plans in a Virginia Beach Mount Trashmore area location. Final products included change detection and inventory of wetlands with setback lines. Working with VDOT (Engineering), VRSC explored the use of remote sensing for assessing road/highway preliminary planning. A planned Virginia Beach road modification in the vicinity of Mount Trashmore was the study area. A manual sketch provided a rough cut of a new road connect between Independence Boulevard and Constitution Drive. The new road traverses Lake Trashmore, Mount Trashmore Park area, Virginia Beach Toll Road (44), and Thalia Creek.

SPOT data were processed to produce land-use classification images. A Virginia Beach road GIS map design file was merged with all SPOT bands. After image processing and merge, a new road segment was added to match the rough sketch. The new road was positioned and the computer generated 500 foot parallel right-of-way zones on each side of the road center line. Lake Trashmore total area was measured. The area percent involved with the road and its right-of-way was determined. Also, wetland areas impacted by the new road were identified and measured, and the new road linear dimension was measured.

The land-use satellite image provided detailed information on water density factors involving water quality. It was quickly noted that Lake Trashmore waters differed from Lake Windsor waters. Further evaluation of the satellite image revealed a tie of Lake Windsor to tidal waters via Thalia Creek, Lynnhaven River, Lynnhaven Inlet, Chesapeake Bay. Lake Trashmore, however, was isolated as a landlocked, man-made lake.

The land-use inventory technique used for the VDOT road change study demonstrated the utility of using multispectral remote sensing images processed to measure land type areas within a specified zone (roadway). This technique is applicable to measurements for new roadway/right-of-way zones, planning and/or surveys/inventories, and transportation environmental impact studies.

Resource management is becoming increasingly dependent on accurate and timely resource information. The importance of information has arisen in parallel with emerging high technology information tools. The high-speed digital processing ability to electronically correct, enhance, and extract information from various remote sensing satellite sources has many attractive benefits. While traditional methods of data acquisition will remain relevant and are mutually complementary with newer technology, the power of one instrument system to acquire, process, and analyze data in a decision-support mode exerts economic advantages of its own, and is providing the means to achieve results previously unattainable.

Remote sensing can be of significant benefit to local governments by concurrently providing information to a variety of users. These benefits fall largely within the context of enabling extraction of new of updated information to analyze and manage critical resources. Users throughout Virginia have expressed a strong, positive response to satellite image quality and accuracy. Sharp-edged, high resolution images, particularly when displayed on the laboratory monitor or as high resolution laser photographic products, enabled information extraction needed to conduct analysis and accurate area measurements. An important acquisition benefit is timeli-

The benefits of remote sensing for Virginia go beyond simple cost and time savings.

ness, both in terms of frequency and responsive data delivery. The ability to satisfy the wide range of user parameters for seasons, tides, terrain, and leaf cover demonstrates this high-frequency, up-to-date coverage.

Another acquisition aspect is the cost advantage of remote sensing data. By comparison, remotely sensed satellite image maps cost as little as 25 percent of aerial photography, and only five percent of ground survey costs. While aerial photography and field survey are still important, satellite imagery can be used as a timely, accurate source to focus attention and better target GIS use, thereby maximizing effectiveness and reducing overall cost.

An additional financial benefit of the satellite technology is economy of scale. The extraction of different environmental elements from the same geographic data set permitted the VRSC to enjoy scale benefits. The same economy of scale is possible for an entire state. As an example, with data cost of less than $20,000, data could be purchased providing complete, saturated coverage of two regions (four counties and one city) for several seasonal periods. When divided among the users, the cost per user is significantly affordable. This point is further reinforced when considering that the data can be reused and extended to additional user groups.

The numerical format of remotely sensed data affords many new opportunities to exploit the advantages common to information systems, including rapid data retrieval, ease of data transfer, multiple display formats, sophisticated calculations and manipulation, rapid data updates, direct cost and time savings, decision support capability, and dynamic analysis capability. The flexible and "living" nature of remote sensing data lends itself specifically to the increasingly useful geographic and resource information systems now being developed. Remote sensing data can be processed to generate specific, tailored products in a format that best suits user needs. The generation of desirable user products is clearly evident among principal VRSC clients. This is attributable largely to the hands-on, dynamic image processing workshops conducted during the Experiment/Project phase. The benefits derived from users personally interacting with the data to solve real world problems cannot be over-estimated. One county planner located new changes in land-use and noted the ability to better plan, monitor, and control development patterns based on imagery output. Many study participants noted that user access and manipulation by personnel within their own facilities would boost productivity and accuracy.

In conclusion, remote sensing offers substantial benefits as a high quality, timely, and cost-effective data acquisition and analysis tool, as an information support system, and as a source of custom tailored products and information maps for GIS. In order to maximize potential benefits, however, a concerted effort must be made to combine selective aerial photography, various GIS-type sources, and remote sensing into a cooperative-use structure that strengthens an economy by accommodating controlled growth through careful planning and management of natural resources. Remote sensing can play a key role in the acquisition and extraction of information needed to manage natural resources.

The Virginia Remote Sensing Center is a unique facility and conducts applications research, acquired and processes data, conducts educational and training workshops, and organizes and conducts pilot projects for users throughout the Commonwealth. The Center is directed by the VRSC's Principal Investigator, W. E. Sivertson, Jr., an is located in the Computer Science Department of the College of William and Mary.Remote sensing provides low-cost, timely, and accurate maps