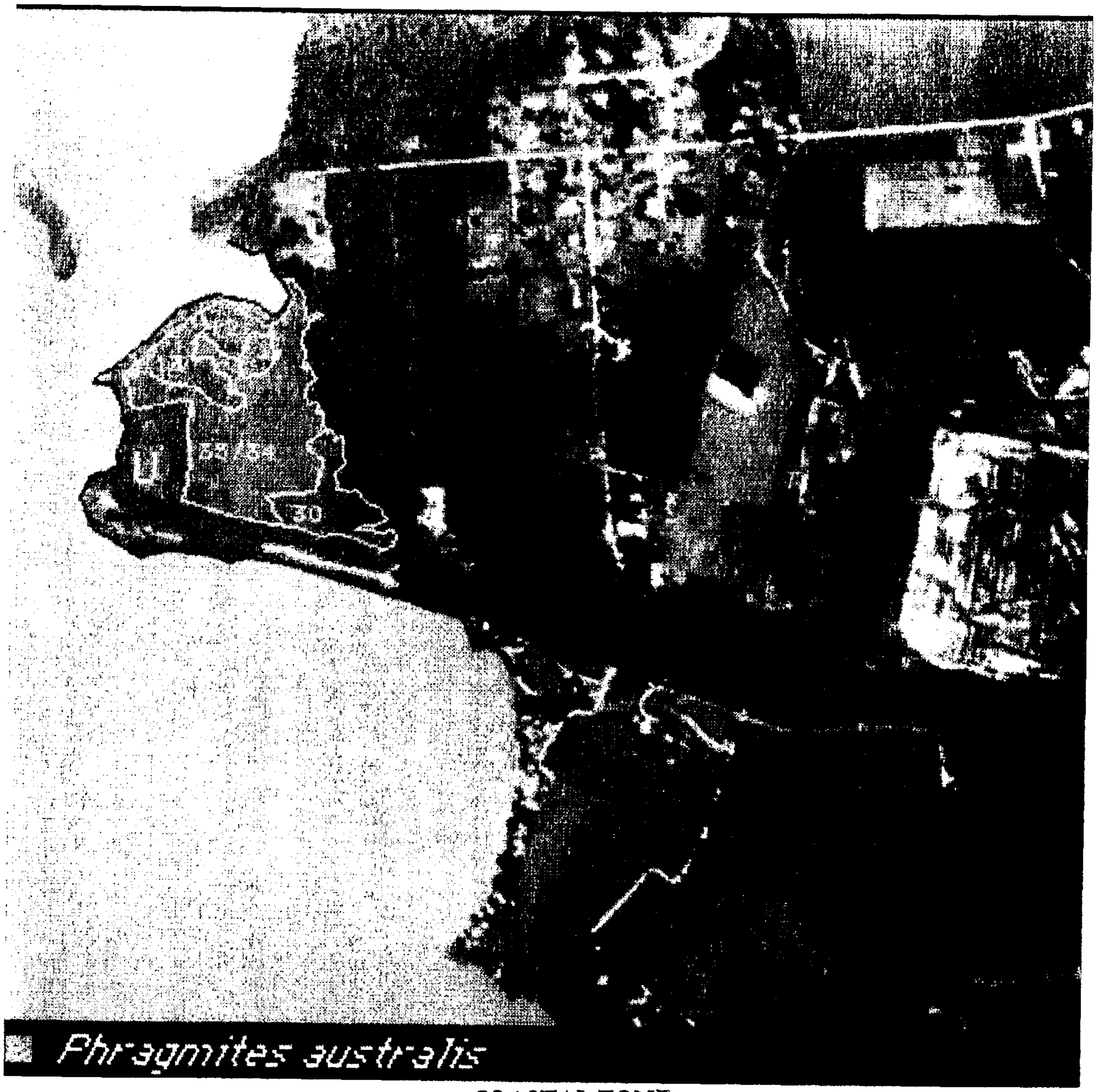
W.P.

Computerized Mapping of Phragmites Australis

[Automated Feature Mapping of 1985 Aerial Photography]



Maryland Department of Natural Resources

March, 1988

Phragmites australis French Town Cecil County Scale 1" = 700' (approx)	Aerial Photo 07/18/85 FL:192 Frame 0051	Interpreted: 01/15/88

Maryland Department of Natural Resources Coastal Resources Division / Salisbury State College

Delineation and Classification of Phragmites communis (common reed) By Interpretation of Aerial Photography and SPOT Satellite Multispectral and Panchromatic Digital Data

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I. INTRODUCTION:

The purpose of this study was to explore the possibility of using satellite digital data (SPOT 10 meter panchromatic) and aerial photography for the purpose of mapping Phragmites australis. Phragmites australis (common reed) is found widely distributed over much of the coastal zone and is particular evident in those areas where the natural terrain has been disturbed through such human activities as road construction and dredging. Although much of the occurrence of Phragmites is in small linear bands, there are some occurences of fair sizes of nearly uniform stands. Large concentrations of Phragmites seem to be more common in the northern part of the state, especially in Kent County on the Eastern Shore.

Phragmites is part of a mixture of wetland vegetations which is generally most often found in either fresh marsh or brakish high marsh environments. An excellent description of Phragmites australis is provided by McCormick (1982) who placed the vegetative species into a more general context. The following excerpts from McCormick's work (The Coastal Wetlands of Maryland) provide an excellent overview of the species:

> The common components of freshwater marshes form stands of medium to tall grasses or grasslike plants (wildrice, big cordgrass, common reed, threesquares, bulrushes, cattails, and sweetflag), masses of broad, erect leaves that extend above the muck surface of the marsh and are nearly inundated daily during periods of high water (spatterdock, arrowarum, burreeds, pickerelweed, arrowheads, and white waterlily), stands of tall, single-stemmed herbaceous plants (burmarigolds, waterhemp, spotted touch-me-not), low to rather tall, erect or matted herbaceous thickets, (smartweeds, burmarigolds), low stands of tangled grasses (rice cutgrass), and shrublike thickets (rosemallow, water willow). Although there is a wide range in stature, the predominant plants of freshwater marshes generally are tallker than those in saline and highly brackish marshes. Measurements of 27 species are presented in Table 6. (p.14)
>
> Ten types of vegetation are recognized for the purposes of mapping in the fresh coastal marshes of Maryland (Table 1). Eight of these types typically are represented by more or less pure stands of the species for which each is named. ... [Cattail, pickerelweed/arrowarum, ... common reed (Type 39; 747 acres)] Common reed is seventh in order. (p.19)
>
> Common reed (Type 39) also forms tall, dense, virtually pure stands (Figure 19). This perennial grass commonly develops on sites that have been disrupted by such actions of man as the placement of fill or dredged material, the excavation of the wetland surface, or the introduction of toxic pollutants or high concentrations of

> nutrients. The rhizomes, or underground stems, of common reed elongate rapidly. An inch-long fragment of rhizome may lodge in a barren area and begin to grow. Within a few months, this minute fragment may produce new rhizomes, culms, and leaves that cover several square meters of the soil surface. (p.21)
>
> Other types of vegetation that compose the high brackish marshes, in the order of their areal abundance, are: cattail (Type 44), switchgrass (Type 46), common reed (Type 49), and rosemallow (Type 45). (p.22)
>
> Many of the extensive brackish marshes on the Eastern Shore are burned intentionally during November and December of each year. The fires are generally set in stands of meadow cordgrass (Type 41), needlerush (Type 43), cattail (Type 44), threesquares (Type 47), big cordgrass (Type 48) and common reed (Type 49), in which flammable dead plant materials persist after the growing season is completed. (p.30)

Aerial photography and ground inspection have been, to date, the principal data source other than field verification. There is little question that good quality aerial photography, taken under the right circumstances, at the right scale, and supplemented by good field testing, can be useful in the mapping of most kinds of vegetation. However, the mapping of Phragmites has been particularly difficult and photointerpretation of aerial photography has not been as successful as one might wish in providing reliable estimates of Phragmites distribution. Ground mapping by field survey remains, to date, the most reliable method for mapping the distribution of Phragmites. The cost of ground mapping, however, is prohibitive and other strategies will need to be employed in order to develop a means by which large-scale mapping may be accomplished.

It is important, then, to consider methods other than ground mapping by which the coastal zone may be monitored and Phragmites distribution determined. Photointerpretation of aerial photography is an often used method for mapping vegetation. This method was used for mapping Phragmites as part of the National Wetlands Inventory. A wide variety of photography is currently available. For example, U-2 photography is periodically flown of much of the state of Maryland. This form of high level aerial photography is most frequently shot in color infrared and has a multiplicity of uses, but is wanting mostly because it has been difficult at best to orchestrate the logistics of having the aircraft fly at the right time of year and under the appropriate sun angle conditions. Where available, U-2 and other high level aerial photography should be used and seen as an important ancillary data source. Other forms of aerial photography, shot in either color infrared, natural color, specially filtered color or panchromatic, can also be extremely useful, especially in those cases where the resolution is sufficient to see fine ground detail.

Satellite data is, perhaps, the next most obvious data source. Synoptic in its coverage, digital in format, satellite data has the potential of not only automating much of the tedious process of matching "photography" to standard orthographic projections, but has the further advantage of being comparatively inexpensive. The disadvantage is mostly one of resolution. LANDSAT carries two sensors. The MSS is far too coarse for meaningful analysis of coastal zone vegetation. Conversely, the Thematic Mapper, at somewhat under 30 meters, has been considered by a number of researchers as a potentially useful tool for a number of different kinds of land cover analysis. However, with the availability of 20 meter multispectral and 10 meter panchromatic data from the SPOT satellite, it is possible for the first time to see satellite data and imagery as a possible alternative to high-level aerial photography.

This project acquired a number of scenes of 20 meter multispectral and 10 meter panchromatic SPOT data of the coastal zone. Scenes were acquired for Spring and Fall dates of 1986 and 1987 under nearly perfect weather and lighting conditions. The digital tapes were processed with particular attention given to the extraction of areas of the coastal zone that were likely to represent areas of significant Phragmites occurence. Although it was not expected that it would be possible to make specific identification of stands of Phragmites except in those instances where those stands were quite large, it was hoped that in conjunction with various kinds of aerial photography and ground testing, the satellite data would represent a "first cut" for identifying and isolating those areas that should be investigated in detail for mapping purposes.

II. WORKSTATION DESIGN: Hardware System Components

Overall Concept and System Design

The system designed for use by Coastal Resources Division is microcomputer based using standard off-the-shelf components. Compatibility with the IBM-PC standard was a primary requirement. The additional graphics capabilities needed to drive a high resolution rgb analog monitor act independently of the function of the microcomputer to the extent that other activities may occur on the microcomputer, including data base management, word-processing, and page composition.

Computing Platform

The core software used to run the graphics capabilities is the Map and Image Processing System (MIPS) to which was added a feature mapping capability custom designed to allow mapping specific vegetative classes such as submerged aquatic vegetation and common wetland species (such as Phragmites) or species clusters. The work station components consisted of the following:

1. IBM PC AT 339 computer
2. 32 megabyte fixed disk
3. 80387 mathematics coprocessor
4. 3 megabytes of random access memory
5. EGA monitor
6. color inkjet printer
7. monochrome laser printer
8. high density & medium density floppy disk drives
9. mouse
10. 20 + 20 megabyte Bernoulli storage

Based on the compatibility tests completed as part of this project it is felt that most IBM compatible microcomputers running INTEL's 8088, 8086, 80286, or 80386 cpu's will adequately host the software.

All microcomputers used in this project require the addition of an arithmetic coprocessor (INTEL's 8087, 80287, 80387); a minimum of 640 kilobytes of ram (random access memory), console display device, one or more floppy disk drives, a mouse, and either the PC-DOS or MS-DOS Operating Systems (version 3.0 or higher). Practical considerations also dictate the availability of one or more mass storage devices (fixed disk, removable cartridge, optical disk). Because of the very heavy storage requirements for image data, large-capacity off-line mass storage is desirable. The system supports large-capacity hard disks (70 megabytes and higher), nine-inch open reel tape drives, and optical disk (200 megabytes and higher).

Although 80386 machines were used in software development, and one such machine is being used by the non-tidal wetlands program to run the software, it should be noted that such machines are more susceptible to bus timing conflicts. If the bus speed exceeds 8 megahertz some hardware may not run properly, and if the CPU speed exceeds 12 megahertz, careful attention must be given to determining that all components, including base memory, are capable of supporting the higher speeds.

Graphics Platform

Graphics functions are provided through peripheral equipment capable of producing analog rgb output. The following hardware was installed as part of the work station supplied under this contract:

1. AT&T Targa-16 Graphics Board with 512 by 480 resolution
   and Frame Grabber
2. Electrohome monitor (Sony Multiscan used for testing)

The software does not require data to be organized to match the resolution of the display device. The graphics displays act as "windows" on any data set, permitting the same data set to be as easily manipulated on a medium resolution system as on a high resolution system.

Data Input Devices

Since data input is a major requirement of any computerized system, considerable attention was paid to the selection of appropriate storage devices. The following devices were tested and are now supported for data input:

1. Standard DOS-supported devices
   - floppy disk drive
   - removable hard disk (e.g. Bernoulli Box)
2. Non-standard devices
   - optical disk drive (may emulate a DOS device)
   - 9 inch open reel drive (tested only)
   - CD ROM (tested only)
   - mini/mainframe communications linkwith file transfer (tested only)

Data Storage Devices

Data storage utilizes the same hardware types as Data Input Devices. See above.

Output Devices

Once data has been input into the system, stored, and manipulated in some fashion, there is usually a requirement to produce some physical representation thereof. Although one might consider data storage to be a form out data output, we will consider only hardcopy devices here.

The following devices have been tested and found satisfactory for the production of tabular and graphic output:

1. Tabular/Text Only
   - all dot-matrix printers
   - laser printers (preferred & supplied)
   - ink jet printers (supplied)
   - thermal transfer printers (tested only)
2. Graphics/Text Output
   - thermal transfer (e.g. Calcomp Plotmaster) (tested only)
   - color ink jet (e.g. Tektronix 4060) (tested only)
   - solid color ink (e.g. Howtek Pixelmaster) (under development)
   - monochrome laser (e.g. HP Laserjet Series II) (supplied)

There are many considerations that must be taken into account regarding the number of colors that can be produced, the resolution capabilities of individual printers, and the ability to emulate pen plotters. As a rule of thumb, resolution should be at least 200 dots/inch in either monochrome or color, color dithering must be possible to produce hundreds of colors, and hardware limitations governing output size must be defeatable if a printer is to be considered satisfactory. In all cases special drivers were written to extend and enhance the capabilities of printers tested for this project.

III. Workstation Design - Software System Components

Overall Concept and System Design

Although estimates of Phragmites quantities in the Coastal Zone are provided in this report, one of the major goals of this project was to construct a system useful to the Department of Natural Resources for reviewing the distribution of Phragmites for all calendar periods of coverage. This review process may involve graphic manipulation of not only the satellite imagery, but also associated maps and previous years' mapping efforts. The current system uses data from the French SPOT satellite and published quad sheets interpreted for Phragmites stored on Bernoulli Cartridge and optical disk.

The feature mapping utility developed as part of this project derives from a commitment to utilize customary photo interpretation techniques to derive estimates of the distribution of Phragmites in the Coastal Zone. The graphics support aims to present maps and images in full color. The three bands of the SPOT multispectal data may be combined to produce vivid false-color infrared composite screen images; and the preservation of subtle shades of hundreds of colors from palettes of millions of colors is a characteristic of high-end analog rgb display systems, which is an important requirement where photogrammetric considerations are involved.

Among the various features of the extended MIPS are an intuitive interface made possible by the almost exclusive use of C-language program modules which directly address the appropriate microcomputer dependent hardware. Software functions are menu-driven (see Supplement: User's Guide), but support of a graphics pointing device (most often the mouse) permits point-and-shoot routines to be supported as well.

Data Import Procedures

Getting data into a computerized system is potentially among the costliest parts of building and maintaining the system. Most GIS's (Geographic Information Systems) depend on layers of digitized data, where each layer is carefully matched to a known base map. Satellite data is generally in binary form, supplied on standard computer reel tape. MIPS was modified to directly read these data from the tapes and supply ancillary information before converting all files to a format MIPS understands. Using MIPS menu selection techniques, it is possible to easily import the SPOT data in such a way that it may be stored together with other data types that can interact with the satellite data, e.g:

1. SSURGO (Soil Conservation Service)
2. MOSS (U.S. Fish & Wildlife)
3. EDIPS/TIPS (Landsat MSS & TM)
4. DFX (Autocad)
5. DLG (USGS)
6. DEM (USGS)
7. SPOT (Spot Image)
8. NASS (National Agricultural Statistical Survey)

Generic import procedures to permit inclusion of byte, ascii, and binary data are also included, as is support for some of the newer file formats, including tiff rio, and targa.

The system user is insulated, for the most part, from the details of data import. The data import menu allows selection by name of a foreign data set (see Supplement: User's Guide). Once selected, the software opens an appropriate new or existing data file, skeletonizes the file if necessary, and writes the converted data to the file. For raster data, such as the SPOT digital data, histograms are automatically produced the first time images are displayed. For vector data, automatic fit-to-screen and coordinate orientation routines are accessed by the software to help the user avoid distraction during data analysis.

The preceding discussion and examples assume that existing data is being imported and that this data resides on a device supported by MIPS. Since all common forms of media can be directly accessed through software, there is considerable power to this system. It does not matter whether the data is on diskette, optical disk, magnetic tape or CD Rom. If the devices are available as part of the microcomputer system, they serve as an active shared resource.Thus SPOT and LANDSAT satellite data; Digital Line Graph (DLG) and Digital Elevation Model (DEM) data are all supplied on 9 inch open reel tape, requiring no special procedures to import, a stumbling block for many other microcomputer based systems.

Data Manipulation Procedures

Since there are a large number of ways in which the SPOT satellite data can be manipulated, Appendix A: System User's Guide, should be consulted for details. The feature mapping algorithm illustrates some of the more mature capabilities of the system. Not only can individual features and clusters of features be interpreted and classified, but the computer will process the data and create a statistics file that can be read directly into a database. The statistics file contains the normal annotation data, and also computes the total acreage for each feature mapped.

Data Export Procedures

The same devices and procedures used to import data may also be used to export data. Since data export may be for the purpose of either transferring existing data to another system or for transferring or storing manipulated data, there are two somewhat different procedures to follow.

Data on the system may be exported in either a generic form or in a systems-specific form to a similar or a different image processing or GIS system. This is done by selecting appropriate export forms from the menu and then writing the data out to disk or tape. MIPS allows extraction of rasters from within rasters if a subset of a larger data set is desired. Vector interchange is often best done through an industry-standard or well understood file format such as DFX, TIFF, or TARGA file formats. Although it is relatively straightforward from a software implementation point of view to transfer generic or specific versions of byte raster data or vector co-ordinate data, the increasing commitment to arc-node data with associated attribute files does pose new challenges. This task will require a significant effort if a smooth integration with the existing system is to be achieved.

Transfer and storage of data following manipulation may require no more than a disk-save of a screen-image that has been operated upon. Although many image processing systems allow effortless saving of screen raster images, few provide a sufficiently generic form of such a screen save to permit display of a saved image on different hardware. MIPS is addressing that problem currently by supporting, through software, screen-restoration techniques that identify the original save format and then convert, if necessary, the save files to allow them to be displayed on incompatible hardware.

Data that might have been altered by filtering or classification can be saved as a new element within the original file, thereby becoming appended to the original data set. Storage is therefore automatic. Export would be similar to import except that some consideration must be given to the way in which computed histograms, color lookup tables, and other computed information is passed to external systems. Currently data export is being tested first for software compatibility within the same computing platform. Export to other software packages running on micro or mini or mainframe systems is also scheduled for testing.

A final note of caution should be inserted at this time. Vector and arc-node data require relatively little storage space. For example, an entire quad of NWI data may take up less than two megabytes of space on a disk. Text data also requires comparatively little space. Large data bases may exceed ten or twenty megabytes, in some cases perhaps more. But typically even fairly complex dBase files are under five megabytes in size. Image data, on the other hand, particularly of high resolution, can occupy such vast amounts of space that until recently very little serious consideration had been given to microcomputers because of their limited storage capabilities.

A single 60 kilometer SPOT scene at 20 meter resolution, for example, can occupy over 10 megabytes of data storage. In composited form with histograms and contrast tables, a single scene may occupy well over 40 megabytes of storage. It is clear that storage capacities far exceeding those of the floppy and fixed disk are mandatory.

The solution has been the optical disk. A new technology, there are still no standards and only recently have some manufacturers been able to make their drives and media be DOS transparent. This means that the user notices no difference between using an optical disk with over a hundred megabytes of storage per side and a Bernoulli cartridge, for example, which is limited to a total of 20 megabytes per cartridge. Although the 250 megabyte optical disk is currently available in sufficient quantity to constitute a viable storage medium, the gigabyte drive and disk are the likely stars of the immediate future.

In this and other projects for the Maryland Department of Natural Resources, Salisbury State College has demonstrated the utility of optical disk cartridge storage as a means of ensuring that vast amounts of data can be accessible to the microcomputer user. The submerged aquatic vegetation mapping project has benefitted from this work by being able to access these large databases directly without the need to support either tape drives, or requiring a link with a mini based system for data storage.

Analysis Procedures

Appendix A details the methods to be used for analyzing data using the Feature Mapping Function in MIPS. This section presents a concept-oriented overview of the analysis procedures currently implemented.

Combining base map and vector data together allows the interpreter to evaluate the vector data against various base maps, chosen to suit the particular purpose of the analysis. The power of the computer is realized when base map and vector data at different scales are combined and matched to a common scale, and when inherently distorted base map data is combined with undistorted vector data.

Since MIPS is capable of extracting vectors from hardcopy maps, it is anticipated that a task in the future will be to convert any existing Phragmites distribution maps into vector form. Some vector data already exists. For example, the NWI maps include a coding for Phragmites. A statistical summary of the NWI Phragmites acreage is given later in this report.

The ability to easily manipulate rasters and vectors is an important capability. But of even greater importance is the ability to perform measurements on these data, to enhance them using CAD primitives, to generate hardcopy products rapidly, and to include tabular data as part of a photogrammetric analysis at a cost and speed that cannot be achieved in any way other than through the use of a computer and the type of software made available through this project.

Analysis goes beyond visual inspection, however, and MIPS provides more powerful tools than have been described thus far. For individuals familiar with traditional image processing techniques, the software offers a suite of tools that may be used to operate on raster data. Included are the ability to compute the correlation between rasters, to compute a convolution on a single raster using filters, a semiautomated interpretation of rasters using preidentified features, and several predefined index calculators. The last of these includes the ability to calculate a normal difference vegetation index, a transformed vegetation index, and a leaf area index. Arithmetic and algebraic manipulations can also be performed on rasters.

In the future the expanded ability to deal with multiple vector files, to edit these files through graphics techniques, and perform computations on combination vector planes will provide the essential GIS tools to permit dynamic modeling.

Output Capabilities

Practical applications of image processing and GIS capabilities require that the results of an analysis can be graphically shared or included in a report. Plotters and laser printers have provided reliable and effective means by which presentation graphics can be created. More complex is the process of creating high quality hardcopy output of analog rgb screen images which are of photographic quality. Two processes currently are used to produce good quality prints of analog color images: color ink jet and color thermal transfer.

Considerable effort has been expended to provide the Coastal Resources Division with the capability to produce good-quality hardcopy output. Software control of color separation output characteristics is fairly sophisticated, giving the user control over almost all variables that would affect the quality of the hardcopy product. Additionally, the user is given the opportunity to accurately scale his hardcopy output so as to provide standard map product capabilities. Where the maximum size of the paper that a hardcopy device can handle is less than the required map or image, the software presents a multi-page graphic on-screen. Using techniques associated with page composition, the software automatically generates multiple page output which can then be panelled, if desired, to produce a map of appropriate size and scale.

More details concerning the specific procedures involved in producing hardcopy output is provided in Appendix A. More than a dozen printers are currently supported and there is a strong interest in supporting new printing technology as it becomes available.

IV. Compatibility with GIS and Other Management Structures

During the course of this project, a significant revision of the file structure used by MIPS was undertaken to allow easier manipulation of raster data and also the inclusion of vector data in a common file format.

Currently the file structure is a superset of the enhanced DLG structure published by USGS. Thus a single file, identified by the system as a raster/vector file (.rvf) may contain groupings and subgroupings of data types that are inherently different in their individual structures. By maintaining a single file for both raster and vector data it is possible to investigate the relationship among different data layers more effectively with the additional benefit that the user is not required to maintain a list of compatible files.

To aid the analyst in deciding on which file groupings to investigate, the system now supports an extended labeling feature that permits descriptive labels to be attached to individual file elements as well as the file itself. This may also serve to identify the file element as an import or export data set. The software maintains its own labels to indicate whether the file element is byte raster, compressed raster, binary, ascii, vector, or arc-node.

Import from other image processing and GIS systems requires only knowledge of the file structure used by that system or of the structure of the file exchange format. MIPS will directly import known structures and provides a generic import utility for previously undefined structures that do not appear on the menu. Export to these external software packages is the inverse of import and requires no special knowledge other than the desired export label or format.

Export routines for attribute files linked to arc-node files have not yet been developed. This is a high priority item since true compatibility with other GIS systems necessitates carrying along the attribute files with the vector or arc-node files.

V. METHODS:

For the purpose of generating new tabular statistics both aerial photography and satellite data were analyzed. Aerial photography from 1984, 1985 and 1986 was scanned and digitized. SPOT panchromatic satellite data from 1986 and 1987 was read from tape and transferred onto optical disk for further processing. Both data types were then displayed in segments on screen for computer aided analysis. In each case it was assumed that a stand density of less than 5 acres would probably not be visible at the 20 meter resolution of the multispectral satellite data while a density of less than 3 acres would not be visible at the 10 meter resolution of the panchromatic satellite data. For the aerial photography stands of less than 1 acre were assumed to be difficult to distinguish from other vegetative types. A screen cursor was used to point at Phragmites stands and the computer was permitted to suggest additional locations of Phragmites within the experimental frame.

The effect of this method was to produce a total estimate of Phragmites in two ways. First, there is a figure generated form the satellite data which was checked against aerial photography and ground truth where possible. The margin of error was significant at this level indicating that nearly pure stands of Phragmites, occuping a minimum of 5-8 acres were required for reliable typing and areal extent measurement. The second estimate was produced by utilizing aerial photography in conjunction with ground truthed known sites of phragmites. This should, theoretically have led to a substantial improvement over the previous method and a more reliable acreage figure. However, since the ground truth and aerial photographs were often from different dates, even different years, it was soon discovered that the margin of error was significant here as well.

There was no attempt in this study to take into account the actual homogeneity of the Phragmites stands. Although it is likely that some success may be achieved by examining color infrared photographs in stereo pairs, the linearity and mixed distribution of much of the Phragmites observed in the field suggest that accurate statistics will probably require a very high order of ground mapping.

VI. TABULAR RESULTS:

Table 1 was generated by filtering the dBase tabular data for the Maryland NWI encoded quads to include only summations for Phragmites. Table 1 gives the wetland type for photointerpreted Phragmites stands by USGS quadrangle identification.

Table 2 was generated by feature mapping the remotely sensed data available against a modest amount of data from field verification. The estimates in Table 2 may be considered to be accurate by no more than +/- 30% of true values. Given that the estimates of Table 1 are probably not much better, this is a clear indication that in future it would be advisable to consider more rigorous data collection followed by site specific mapping using computerized techniques so as to make optimum use of the technique described here.

Table 1

Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Maryland Quad ANNAPOLIS	
E2EM1P	16.232
PEM1C	2.552
PEM1E	10.793
** Subtotal **	
	29.577
** Maryland Quad BALTIMORE EAST	
E2EM1P	0.970
** Subtotal **	
	0.970
** Maryland Quad BENEDICT	
E2EM1P6	7.573
PEM1C	4.182
** Subtotal **	
	11.755
** Maryland Quad BERLIN	
PEM1A	5.771
** Subtotal **	
	5.771
** Maryland Quad BETTERTON	
PEM1/5E	7.364
** Subtotal **	
	7.364
** Maryland Quad BOWIE	
PEM1C	13.459
** Subtotal **	
	13.459
** Maryland Quad BOXIRON	
PEM1CD	7.896
** Subtotal **	
	7.896
** Maryland Quad CAMBRIDGE	
PEM1A	2.392
** Subtotal **	
	2.392
** Maryland Quad CHARLOTTE HALL	
PSS/EM1A	3.189
** Subtotal **	
	3.189

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Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Maryland Quad CHICAMACOMICO RIVER	
PEM1R	11.332
** Subtotal **	
	11.332
** Maryland Quad CHURCH CREEK	
PEM1CX	0.596
PEM1EX	4.994
** Subtotal **	
	5.590
** Maryland Quad CURTIS BAY	
E2EM1P	13.874
E2EM1P6	21.644
PEM1/OWF	0.747
PEM1C	6.002
PEM1CH	1.275
PEM1E	4.519
PEM1F	0.405
PEM1FH	1.081
PEM1KFH	77.034
** Subtotal **	
	126.581
** Maryland Quad DEALE	
E2EM1P	53.281
** Subtotal **	
	53.281
** Maryland Quad DELMAR	
PEM1A	5.906
** Subtotal **	
	5.906
** Maryland Quad EASTON	
PEM1CHS	19.017
** Subtotal **	
	19.017
** Maryland Quad EDEN	
PEM1A	25.303
** Subtotal **	
	25.303
** Maryland Quad EDGEWOOD	
E2EM1/5P6	3.356
PEM1A	2.122
PEM1E	4.645
PEM1EH	4.006

Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
PSS/EM1C	1.432
** Subtotal **	
	15.561
** Maryland Quad GIBSON ISLAND	
E2EM1P	3.129
PEM1A	1.756
PEM1RS	10.441
** Subtotal **	
	15.326
** Maryland Quad GIRDLETREE	
E2EM1P	1.595
E2EM1PH	7.991
** Subtotal **	
	9.586
** Maryland Quad GUNPOWDE	
E2EM1P	23.502
E2EM1PH	17.722
PEM1/5F	7.192
** Subtotal **	
	48.416
** Maryland Quad HANESVILLE	
PEM1CH	10.954
PEM1EH	2.978
** Subtotal **	
	13.932
** Maryland Quad HAVRE DE GRACE	
PEM1/5EH	2.709
** Subtotal **	
	2.709
** Maryland Quad HEBRON	
PEM1E	16.928
** Subtotal **	
	16.928
** Maryland Quad KENT ISLAND	
E2EM1P	13.224
PEM1A	3.198
** Subtotal **	
	16.422
** Maryland Quad KINGSTON	
PEM1A	9.576

Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Subtotal **	
	9.576
** Maryland Quad LAUREL	
PEM1A	13.556
** Subtotal **	
	13.556
** Maryland Quad LOWER MARLBORO	
E2EM1P6	5.130
** Subtotal **	
	5.130
** Maryland Quad MIDDLE RIVER	
E2EM1P	23.382
E2EM1PD	0.673
PEM1/5AH	1.176
PEM1AHS	6.958
PEM1C	0.673
PEM1E	3.733
PEM1KAHS	18.597
PEM1KCHS	39.096
PEM1KEHS	4.579
PSS/EM1E	3.801
** Subtotal **	
	102.668
** Maryland Quad NORTH BEACH	
E2EM1P	16.274
PEM1/5E	9.170
** Subtotal **	
	25.444
** Maryland Quad OCEAN CITY	
PEM1C	0.782
** Subtotal **	
	0.782
** Maryland Quad OXFORD	
E2EM1P	3.666
PEM1A	3.579
** Subtotal **	
	7.245
** Maryland Quad PERRYMAN	
E2EM1P6	0.765
** Subtotal **	
	0.765

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Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Maryland Quad PITTSVILLE	
PEM1C	0.283
** Subtotal **	
	0.283
** Maryland Quad POCOMOKE CITY	
PEM1A	6.813
PEM1C	21.770
PEM1E	7.379
PEM1R	16.462
** Subtotal **	
	52.424
** Maryland Quad PUBLIC LANDING	
PEM1CD	29.471
** Subtotal **	
	29.471
** Maryland Quad QUEENSTOWN	
E2EM1P	23.379
PEM1CH	2.240
** Subtotal **	
	25.619
** Maryland Quad RELAY	
E2EM1P6	91.953
PEM1/5R	52.613
PEM1C	3.222
PEM1R	4.383
** Subtotal **	
	152.171
** Maryland Quad RIDGELY,	
PEM1/5CD	23.202
** Subtotal **	
	23.202
** Maryland Quad SALISBURY	
PEM1E	10.631
** Subtotal **	
	10.631
** Maryland Quad SAVAGE	
PSS/EM1A	3.657
** Subtotal **	
	3.657
** Maryland Quad SENECA	
PEM1AD	11.446

Table 1 (continued)

Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Subtotal **	
	11.446
** Maryland Quad SOUTH RIVER	
PEM1A	4.396
** Subtotal **	
	4.396
** Maryland Quad SPARROWS POINT	
E2EM1/5P	5.958
E2EM1P	14.237
E2EM1P6	23.233
E2EM1PS	30.974
PEM1/6E	12.907
PEM1AX	1.286
PEM1C	6.593
PEM1CH	13.869
PEM1E	10.168
PEM1EH	1.268
PEM1FH	18.762
** Subtotal **	
	139.255
** Maryland Quad SPESUTIE	
E2EM1P6	25.955
PEM1EH	33.662
** Subtotal **	
	59.617
** Maryland Quad TANEYTOWN	
PEM1CH	0.391
** Subtotal **	
	0.391
** Maryland Quad TILGHMAN	
PEM1A	1.828
** Subtotal **	
	1.828
** Maryland Quad UPPER MARLBORO	
PEM1/FLAX	9.099
** Subtotal **	
	9.099
** Maryland Quad WETIPQUIN	
E2EM1PH	49.905
** Subtotal **	
	49.905

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Summary Statistics for Phragmites
[Phragmites australis]
*** EM1 ***

Wetland Type	Acres
** Maryland Quad WHALEYSVILLE	
PFO/EM1AD	5.593
PSS/EM1AD	2.422
PSS4/EM1A	6.837
** Subtotal **	
	14.852
** Maryland Quad WHITE MARSH	
PEM1C	0.758
PEM1E	5.893
** Subtotal **	
	6.651
*** Total ***	
	1228.327

TABLE 2 - COMPUTED ACRES OF PHRAGMITES

QUAD	ACRES
Annapolis	11.0
Baltimore East	3.2
Benedict	15.7
Berlin	21.0
Betterton	2.7
Bowie	21.8
Boxiron	12.6
Cambridge	19.3
Charlotte Hall	10.1
Chicamacomico	31.9
Church Creek	3.0
Curtis Bay	112.9
Deale	49.0
Delmar	2.7
Easton	33.9
Eden	71.9
Edgewood	31.0
Gibson Island	33.9
Girdletree	19.3
Gunpowder	108.7
Hanesville	51.0
Havre de Grace	111.4
Hebron	33.9
Kent Island	87.6
Kingston	12.0

Table 2 (continued)

QUAD	ACRES
Laurel	22.2
Lower Marlboro	19.1
Middle River	300.7
North Beach	67.4
Ocean City	18.1
Oxford	11.9
Perryman	19.2
Pittsville	6.7
Pocomoke City	108.1
Public Landing	90.3
Queenstown	77.5
Relay	451.8
Ridgely	81.4
Salisbury	51.0
Savage	19.1
Seneca	91.5
South River	28.2
Sparrows Point	402.1
Spesutie	185.5
Taneytown	3.0
Tilghman	11.7
Upper Marlboro	31.4
Wetipquin	109.5
Whaleysville	78.3
White Marsh	39.6
TOTAL	3,236.8

VII. CONCLUSIONS:

The use of aerial photography and SPOT satellite data can be potentially quite beneficial in maintaining a capability of mapping the distribution of Phragmites australis. The 10 meter panchromatic data has sufficient resolution to allow interpretation of medium to large density Phragmites stands, while the photography, taken under optimum conditions, may be sufficient to map relatively homogeneous small to medium stands of Phragmites.

The benefits of using scanned photography and satellite data include the digital nature of the data which allows ready quantification and comparison to other data sets from different seasons and years. The overall cost per unit of ground coverage is also significantly less costly than for ground mapping.

On the negative side is the poorer resolution of remotely sensed data: both aerial photography and satellite data. Even using photographic stereo pairs does not produce a high level of accuracy in mapping a species like Phragmites, which has a tendency to be linear and which also tends to be frequently surrounded by or mixed with other wetland species.

In the analysis of the data for this study it has become clear that a multimedia approach ,heavily reliant on carefully conducted ground mapping, is most likely to yield the best results. Satellite mapping may provide an overall picture and the ability to map on a grand scale such features as very large stands of Phragmites. Satellite imagery may also provide an opportunity to examine more general land cover and land use patterns which might bear on the distribution of specific vegetative types such as Phragmites australis. Aerial photography can fine tune the satellite view and be used more appropriately for photointerpretation, especially when viewed as color infrared stereo pairs. However, aerial photography and ground verification, including the sampling of specific test sites, will only provide enough detailed information to yield a somewhat shaky statistical picture of the distribution of such species as Phragmites. It will be necessary to continue to collect large amounts of ground data and to correlate that to the larger, coarser estimates, achieved by remote sensing.

It is suggested that the techniques used in the preparation of this report be extended so that increasing amounts of field data be collected, correlated specifically to satellite imagery and aerial photography. In those cases where a determination needs to be made regarding small and linear stands of Phragmites, this would probably best be achieved by ground mapping. However, all of this information can ultimately prove dramatically more useful if it is digitized and then vectorized for inclusion in a multifaceted geographic information system. Vectorization of the data can be performed using MIPS and this capability will enhance the ability of researchers in the Coastal Zone to map the overall trend of Phragmites. distribution.