Software and Hardware Considerations for a Graphics Workstation

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The Microcomputer Alternatives

To accomplish its research objectives the Office of Land and Water Resources plans to implement high tech computer alternatives in order to solve the water resource management problems of the State. At present, the Office is using microcomputers to accomplish these goals. In the near future, the Office intends to establish a workstation environment to fully accommodate the State's needs.

In all cases, the software drives the solution, and with this maxim in mind, the software necessary to develop these applications will be discussed first. The backbone of this Office's groundwater modeling efforts uses a program called MODFLOW. This powerful analytical tool is a finite difference numerical groundwater modeling program requiring 594K of memory (RAM) to run the model. The operating system chosen for the hardware configuration uses DOS Version 3.3. This version of DOS was chosen because it leaves 605K of low memory free out of the possible 640K. This is in contrast to DOS Version 4.1 which lowers the available free memory down to 560K (which will not accommodate MODFLOW). After running MODFLOW, the user executes SURFER on the data in order to regenerate the numerical output into 2D and 3D graphics. Next, the user loads the graphic output from SURFER into AutoCAD to edit and manipulate the file. Tralaine (geocoordinate converter) is then used to assign LAT/LONG coordinates to any xy/xyz data set. Finally, the user runs TGRAF to upload/download data into ARC/INFO employing modems at the Mississippi Automated Resource Information System (MARIS). There are numerous other programs that are also used to assist in manipulating data, but these packages are ancillary to the software described above. A cost breakdown of the primary software used for this methodology is provided in Table 1.

Table 1: Software Costs

MS DOS Version 3.3	$175
MODFLOW 386	$450
AutoCad 386	$2,750
SURFER Version 3.0	$495
Tralaine Version 2.6	$250
TGRAF	$995

Current PC Configuration

The hardware that the Office of Land and Water is currently using on its most sophisticated PC graphics computer consists of an Everex 386/25 MhZ PC, with 4 MB of RAM, a 1.2 MB and a 1.44 MB floppy drives. In addition, the system utilizes a Dual 44 MB Bernoulli for data storage and backup. The selected monitor is an Everex Evervision VGA monitor. Input devices chosen are a Kurta IS/ONE (12" X 12") tabletop digitizer and an Evercom 24E+ external 2400 baud modem. Output devices are a Panasonic KXP 1624 dot matrix printer and a Hewlett Packard 7475A six pen plotter. Additionally, a Polaroid Palletete film copier is on loan. Other essential items are the Curtis Command Center (surge protector) and a switchbox (ABCDE) from Curtis. This particular hardware configuration is a beginning system (Figure 1) and could be improved by an additional 4 MB of memory. A cost breakdown of this system is found in Table 2.

Table 2: Hardware Cost Breakdown

Everex 386/25 MhZ, 80387/25 math coprocessor 70 mb hard disk 4 MB memory 1 5 1/4" floppy drive 1 3 1/2" floppy drive	
Evervision VGA Monitor and adapter	$6,658
Dual 44MB Bernoulli Box	2,799
ABCDE Switchbox	125
Curtis Command Center Plus (surge protector)	139
Kurta IS/ONE Digitizer	495
Evercom 24E+ External 2400 baud Modem	249
Hewlett Packard 6 pen plotter (7475A)	1,895
Panasonic Dot Matrix Printer (KX-P1624)	525
Polaroid Turbo Palette (software included)	3,495
Total	$16,380

Advanced PC Configuration

Due to the dynamic nature of the computer industry, it is essential to constantly reevaluate the computers and peripherals that are current. This so called "state of the art" equipment is not an easy field to keep pace with. The recommendations for a high tech system may well be completely out of date within several years; however, if this information is used promptly, a new user can be assured of a relatively up-to-date system.

Personal Computers

The cost of PCs has gone down dramatically in the past year, and it is possible to buy a 486 computer for less than the cost of a 386 PC as of this time last year. A 486/25 MhZ computer with 8MB of memory ($6,099) is recommended because of the cost and power of the platform. If money is no object, then a 33 MhZ computer ($7,899) or a 40 MhZ platform is the best choice for speed in developing specific applications. In any case, 8 MB of memory is absolutely necessary to keep from wasting time while processing data. A math coprocessor is another necessity to any graphics system and it is built into some of the 80486 computers. If a decision is made to select one of the 80386 models, then a math coprocessor (80387/25) must be purchased separately ($725).

Hard Disk

Any graphic system is going to require more hard disk space than a system used for word processing or office automation tasks. To adequately plan ahead for most applications, it is recommended a system have a 150 MB minimum ($1,475) and preferably a 300 MB disk ($3,299). The faster the access speeds of your hard disk, the greater the productivity can be expected from personnel. Access speeds for hard disks vary considerably, but a minimum access speed of 20-25 milliseconds is recommended. The price of the hard disk will be determined primarily by the capacity and the access speed.

Bernoulli Box

The Bernoulli Box is one of the most significant component buys for a system. Every user who has invested in purchasing a PC has grappled with the problem of how large a hard disk is right for their applications. Past experience has proven that this need can never be fully anticipated. In order to remedy this dichotomy, a Bernoulli Box is ideal. It will store up to 44 MB on one cartridge, and the system can both store data and run software. The cost for a single Bernoulli drive is about $1400, and $2300 for a dual system. The only additional expense to this scenario is the cost of a 44 MB cartridge for about $100. Still, this is an excellent price for unlimited storage space. A negative factor to consider are the slower access speeds when running large programs from a cartridge.

Color Monitor

The graphics monitor are the eyes of the system. The older systems with CGA and EGA cards should either be turned into word processors or upgraded, if possible, to a VGA capability (640 X 480) or higher (Super VGA 800 X 600). Without becoming too technical, the parameter with which the user should be most concerned in a graphics system is resolution: visual resolution for the monitor (pixels) and output resolution (dpi) for peripherals. The cost of the VGA monitors (Evervision 14", $599) has been reduced along with the cost of the PCs; moreover, the Super VGA is now on the market and is about the same price (Evervision Eversync, $799) as the older VGAs. The VARs (value added reseller's) suggest that the VGA is now the industry standard monitor and that the Super VGAs are the device to choose for a graphics workstation. Be certain to buy an adapter card with as much memory on board as possible. A card will usually come with 256k installed but, depending on the board, this can be upgraded to 512k, 1MB, or higher. Don't try to save money on this option because it will create a bottleneck on the system.

Digitizer

A digitizer for any system will be one of the primary input devices and therefore should be given careful consideration. The first considerations are the size of the largest maps to digitize and how often it will need to be done. If digitizing will be performed often, then buy equipment to accommodate the large sizes fully. If large media is seldom used, then it is possible to electronically splice together maps that are digitized in portions. Therefore, it may be possible to get by on a smaller, less expensive digitizer. For most small operations a 12" X 18" tabletop Digitizer will suffice. Summagraphics markets the MM1812 tablet for about $1000; Kurta and Calcomp also make similar size/cost tablets that are also of high quality.

Modem

An additional, important input/output device is a modem. The industry standard modem is the 2400 baud Hayes compatible. The cost of any such peripheral should be about $200. The important feature to evaluate is the baud rate. The higher the baud rate, the faster communications are possible; speed will cost more. This may not be important in most operations, but a slower baud rate will tie up a system longer. It may be more desirable to select a slower or less powerful PC in the office to perform the communications for the graphics system. Many faster modems (9600+ baud) will require special data transmission lines that will make the cost go up. Also, there are not that many local computers to communicate with that will be able to send or receive signals faster than 2400 baud.

Plotter

A pen plotter can easily be the most single, important peripheral of an entire system. It is nice to have good graphics on a monitor, but there is no substitute for high quality hard copy. People utilizing the graphics output from the system will expect high quality visuals. When dealing with lay people or others without the scientific background to understand the technical attributes of your application, graphics will form a bridge between the science and the real world situation for interpreting information. The cost of a plotter may therefore yield returns that would otherwise be overlooked. Hewlett Packard, Calcomp, and Houston Instruments all make fine plotters. The cost increases dramatically as they go up in size. For example, an A size (8 1/2" X 11") six pen plotter will cost about $1750, and an E size (36" X 48") plotter will cost about $6000-$7000. A very important parameter to consider is how many device drivers are available in the software selected for any application. Check with the software vendors and make sure that there is a device driver for the plotter selected. No one will be happy if a bargain plotter is acquired that does not have the appropriate software drivers.

Printers

A dot matrix printer is essential for any system because it saves wear and tear on the plotter. Many plots require extensive revisions before a final version is ready. If a plotter is used for all of the draft plots, it will use up expensive paper, blunt the nibs of the pens, and take much longer than a simple print. It isn't necessary to spend a lot of money on a printer. A Panasonic printer (KX-P1180) can be purchased for under $300. This printer can also be used for word processing or other tasks.

Another low cost alternative is a laserjet printer or the newer bubblejet printers. These are high quality output devices with letter quality print and can be purchased for around $750 to $1000. The only drawback is the slower speed and the cost of the supplies. If letter quality text is considered as an integral part of a system, then a bubblejet will be a significant addition and should be chosen over the dot matrix printer.

Color printers are also available in many sizes and have a wide range of price variations. An A size color ink jet or dot matrix of surprisingly high quality can be found for under $500 (Quadjet, Epson JX80). For larger printers, the price goes up accordingly. A JDL Autoplotter XP (A-C size) with 16 colors can be purchased for under $5000 or an AMT color printer of the same size for under $3000. Make sure, as in the case of the plotter, that the software will support the printer. In some cases, there are emulation modes that can be set on the printer in manual mode that will make it respond to other device drivers. The most important items to consider with any color printer is the size over the output and the resolution (dpi). Be careful and check all of the possibilities.

Another reason to consider a dot matrix or laser printer is because they can output raster images. A plotter outputs a drawing in a vector format (each point has a defined XY coordinate), and many software packages simply will not work with a plotter. A raster image is usually something like a video still, an aerial photograph, or satellite image. The colors are blended together in varying shades instead of the pen colors found with plotters. An application that works with raster images should have a color printer for output.

Film Copier

In order to maximize the system purchase, creation of the highest quality visuals is critical. Film copiers make overheads, 35mm slides, and polaroids. If a lot of presentations are anticipated, this peripheral will pay for itself. If slides need to be of the highest quality, then costs can range from $10,000 to $15,000. If this exceeds your budget, there are still high quality peripherals available for under $5000. A good buy on the low end is the analog Polaroid Palette for about $3495 and the 35MM Express software package for $395. A software limitation to be aware of with this device is the limitation to only one font. A more expensive, but more versitile device, is the Polaroid CI 3000 digital film copier for $4495. This film copier makes use of the Presentation Express software for $695. This peripheral has much better resolution because it is digital and the software has available 16 fonts.

Accessories

The one item needed regardless of any other piece of hardware is a surge protector. Electrical surges can blow a system and no one will ever know why. The only way to protect the system is with a surge protector. The Curtis Command Center is an ergonomic power strip and surge protector all in one for about $125. It is some of the most important insurance any system can have.

A very useful piece of equipment to include in any system is a switchbox. There are a wide variety of AB and ABCDE switchboxes that will suit any configuration an office is likely to develop. These switchboxes are easy to install and use. They will save time and effort. Curtis and Black Box are both producers of high quality equipment. The cost of these boxes range from $50 to $500 depending on the application. Call the manufacturer to assist in selecting the right product.

Summary of PC Systems

In most circumstances a graphics workstation driven with a PC host will suffice almost all users' needs. Only if the volume exceeds the capacity of the host would an office need to consider a minicomputer or a network. Another situation that might influence a decision to upgrade a system would be that the Complex Instruction Set Computing (CISC) capabilities of a personal computer are too slow for numerically intensive operations. Minicomputers are using the faster Reduced Instruction Set Computing (RISC) architecture that makes normal throughput about 5 times faster than a PC. After much investigation into both alternatives, this Office has decided to implement the fastest possible system (SUN workstation) in conjunction with the current 80386/PC because of the size of our models and the number of models with which this office has to constantly work and update.

Workstation System Alternative

This office has come a long way in the past two years with the development of its PC computer graphics capabilities. However, due to the complexity of the environmental problems encountered on the current system, investigation into a more powerful solution was indicated.

Proposed Configuration

After more than six months of careful examination of technical literature, extensive discussions with MARIS and acquiring price quotes from numerous vendors, the Office of Land and Water Resources decided to purchase a Geographic Information System complete with all of the hardware and software necessary to fully implement a system for Mississippi's water management needs (Figure 2). A computer graphics system equipped with the necessary software (MODFLOW et. al.) was required in order to develop three-dimensional groundwater models as a water management tool using GIS technology. Software to manipulate climatic data, as well as surface water data, and models (HEC 3 et. al.) will also be an integral part of the entire system. The overall objective that evolved is to develop a more complete understanding of the synergistic interrelationships of the entire hydrologic cycle. The GIS technology will further facilitate utilization of the data gathered during field studies that shall become a permanent part of the State Water Data Base for dissemination throughout the State.

Software Strategy

When the new system is delivered, the Office of Land and Water Resources intends to operate as a satellite system to MARIS for access to spatial data, additional processing capabilities, standard base maps, and statewide data sets. This Office sees the MARIS computer eventually evolving as a "file server" of spatial data for the various satellite systems or as a host system for provision of GIS capabilities to agencies with limited resources. Distributed processing will encourage GIS compatibility, data sharing, and independent control and growth for agencies as GIS expertise widens in the State computer community.

Because of the size of the Office of Land and Water Resources' operating environment and the vast, diverse amounts of information used in its mapping system, a software package was needed with very specific capabilities (Table 3).

Table 3: Workstation Software Requirements

* unrestricted by fixed capacity (both hardware and software)
* able to operate more than 100 layers
* work with large areas of coverage at one time
* display and edit huge graphic databases at one time
* standardize existing map entities
* associate these entities with textual information
* attach this information to a computerized database as necessary

The Office of Land and Water Resources has a graphic requirement for both GIS capabilities and automation of the geohydrological mapping process due to the following reasons:

* creation of seamless composite maps at any scale
* reduce manpower and redundancy when updating maps
* be able to record, but not necessarily display, historical data
* tie all maps to a computer database

These capabilities will allow the Office of Land and Water Resources to upgrade the quality of presentations in meetings with other agencies (Federal, State, County, and Local) and to the public. In addition, the data and graphics will be uploaded to MARIS as required for dissemination to other State Agencies and/or the Public. These efforts will be accomplished with modems and tape backups.

Other alternatives include manual processes and requesting time at MARIS to try to accomplish our objectives or a lease or purchase of a larger mini or mainframe system. However, the Office of Land and Water Resources feel these alternatives are not feasible due to the following reasons: time constraints, high costs, long turnaround times, loss of quality control, and the lost qualitative analysis/synergistic effect of the Environmental Scientist working on their applications.

After careful consideration of the application requirements for this Office, the following software packages were decided as the most necessary to satisfy current and future needs (Table 4).

Table 4: Workstation Hardware Requirements

Primary Graphics Desktop Workstation (Sun Sparc II)	$32,609
Secondary Graphics Workstation (Sun IPC GX)	7,466
Multiport Board Serial Multiplexer with 8 ports	1,495
Calcomp Model #95480 "E" (36x48") Digitizer w/16 ButtonCursor and Power Lift Base	5,484
Calcomp Model 1025 "E Size" Plotter w/8 pens and continuous roll capability	5,706
JDL Autoplotter XP, 2.5 MB "A-C" size color printer	3,599
American Power Converter uninterrupted power source	1,170
Delivery, configuration and installation	1,442
Total	$58,971

Workstation Software Requirements

* Sun Unix operating system (Version 4.1.1) software and documentation
* Sun Vision graphics system software and documentation
* Sun Open Windows interface and documentation
* DOS Windows interface and documentation
* Sun FORTRAN Compiler and documentation
* ARC/INFO GIS software and documentation
* ELAS satellite image analysis software and documentation

Hardware Strategy

Currently, small maps (8.5x11) are being created on a PC/386 and printed on a small HP pen plotter. In addition, many maps (both large and small) are being generated by hand or contracted out to MARIS. This increases time delays and overall Office costs.

Presently, there are no existing large digital storage capabilities and the current systems will not allow us to manipulate large file sizes. For example, the completed model of the Miocene aquifer system along the Mississippi Gulf Coast is too large to run on existing equipment. Use of this model must be performed on the USGS Prime computer. The USGS has expressed concern that since DEQ is utilizing the model for mandated regulatory functions, it would be in everyone's best interest to do such on a DEQ system. In addition, existing storage capacity is already being fully utilized. There are no large scale plotters or digitizers for efficient input/output of large maps, nor does the Office have a high-speed/large capacity tape drive available for backup purposes. Current data transfer between MARIS and Land and Water are taking hours due to 2400 baud modems. The high speed/capacity tape drives on the new system will help to alleviate this problem. The existing equipment cannot be used in lieu of the new equipment. Alternatives such as PC ARC/INFO, while being able to run on a PC, cannot handle large data bases or graphics files that will be generated by the models. Current equipment does not give DEQ the graphics resolution for accurate mapping. The hardware solution for our current and future applications are listed in Table 4.

SparcStation 2 Application Discussion:

A fully configured SparcStation 2 will be utilized by the Division of Hydrologic Investigative and Reporting (Ground Water Section) utilizing GIS software and technology to graphically illustrate three dimensional ground-water models. Primarily, this system will compile, edit, and display ground water models, well locations, and other geological/hydrogeological features utilizing ARC/INFO software. In addition, the Office will use MODFLOW to digitally represent the potentiometric surface of the numerous State aquifers which can then be regenerated graphically and uploaded into ARC/INFO.

Primary Workstation Specifications for the Division of Hydrologic Investigation and Reporting

SUN SparcStation 2

* 32 bit address bus, data bus
* 28.5 mips
* RISC 40-Mhz CPU processor
* Minimum of 3 slots
* 32MB RAM, expandable to 64MB on motherboard
* 207MB internal hard disk with 16MS seek time
* 1.44MB 3 1/2" floppy disk drive
* 1.2MB 5 1/4" floppy disk drive
* 669MB external hard disk drive
* 150MB 1/4" tape backup unit, 22MS access time,

* 1.2MB/Sec data rate
* 2.3GB 8mm tape drive
* 644MB CD ROM
* SCSI-2 port, Audio I/O port, keyboard
* 2 RS423 Serial (RS232C compatible standard)
* (1) Ethernet 10 MB/SEC 64K Cache built-in card/port
* (1) 19" color monitor with minimum 1152x900 pixel, 84 DPI, 66Hz non-interlaced, 93MHZ Bandwidth, 256 colors, 16.7M color palette
* 1 Mouse

A high speed processor (32 bits, 28.5 mips) is absolutely necessary to handle the large models for which this system is specifically designed. Requirements for RAM (32 MB) were determined by the amounts needed to run ARC/INFO and AutoCAD along with MODFLOW. Long range planning will provide up to 96 MB of RAM for running all of the models concurrently.

The 2.3 GB and 150MB tape drive will be utilized by the Office of Land and Water Resources and USGS to transfer processed files between the two agencies and the public. The 207MB internal hard disk has been recommended by MARIS to accommodate the Operating System software and ARC/INFO at the same time. The 669MB external hard disk will be utilized for storage of current and on-going processed data sets. The CD ROM will be utilized to download software and digital data from a variety of sources. The tape drives will be utilized to backup on-site and off-site data sets; and, in addition, will be imperative in transferring large data sets between the various agencies. An ethernet card comes with the system and discussions on possible networking with other agency workstations are currently underway. The high resolution monitor is necessary to provide the highest mapping resolution, accuracy, and graphics possible to the Office of Land and Water Resources.

SUN IPC-GX Application Discussion:

This workstation will be utilized by the Division of Hydrologic Investigative and Reporting (Surface Water Section) utilizing GIS technology and software to graphically model, edit, and display surface water models, stream courses, stream profiles and structures. The surface water models produced will be utilized in watershed basin management studies, FEMA floodplain studies, climatic investigations, and interpolation of synergistic computer models for the entire hydrologic cycle.

Secondary Graphics Workstation Specifications for the Surface Water Division

SUN IPC-GX

* 32 bit address bus, data bus
* 15.8 mips
* 64K Cache RISC 25-Mhz CPU processor
* Minimum of 2 slots
* 24MB RAM, expandable to 48MB on motherboard
* 207MB internal hard disk with 16MS seek time
* 1.44MB 3 1/2" floppy disk drive
* SCSI-2 port, Audio I/O port, keyboard
* 2 RS423 Serial (RS232C compatible standard)
* 1 Ethernet 10 MB/SEC 64K Cache built-in card/port
* 1 19" color monitor with 1152x900 pixel, 84 DPI, 66Hz non-interlaced 93MHZ Bandwidth, 256 colors, 16.7M color palette.
* 1 Mouse

Serial Multiplexer Application Discussion

When fully configured to the primary workstation, three slots will be open to accommodate future growth of the system. An 8 port serial multiplexer card will be used in one slot to link the I/O devices (plotter, digitizer, modems, etc.), to the workstation. This will use 3-4 of the available ports, and the remaining ports could be used as direct links to PCs.

Digitizer Application Discussion

Current digitizing is done through a Kurta 12X12 digitizer and cannot easily accommodate larger hardcopy media. On our new system we will use a Calcomp Model #95480 for the primary input device and it must be as large as possible (E-Size) to accommodate the largest maps the agency constructs. This size digitizer will either eliminate or reduce the need for match line or rubber sheeting techniques caused by scaling differences and map size and will greatly facilitate electronic edge matching from digitizing multiple quad sheets. Potential applications will include inputting and manipulating well locations, contouring maps, slope analysis, USGS digital line graphs, Census Tiger files, or political boundaries. The power lift base is necessary for ergonomic (personnel) reasons during long digitizing sessions.

Pen Plotter Application Discussion

Current plotting is done through a HP 7475A (8.5x11/11x14") plotter and cannot accommodate larger hardcopy media. The new plotter (Calcomp 1025) will be the primary hardcopy output device and must be as large as possible (E-Size) to accommodate the largest maps the Office will produce. This size plotter will allow large scale maps to be produced for presentations. Potential applications will include plotting well locations, contour and slope maps of the numerically generated groundwater/surface water models, digital line graphs, or political boundaries.

Color Printer Application Discussion:

The new color printer (JDL Autoplotter XP) with 2.5 MB of memory will allow the Office to make high resolution (A-C size) maps to scale and reports of presentation quality. Presentation or draft maps can be quickly and cheaply generated through this device in lieu of using the pen plotter. This printer will save the pens, nibs, and paper on the plotter for large scale plots. In addition, this system can output raster images (pictures) which the plotter cannot.

Power Supply/Surge Protector Application Discussion:

An uninterruptable power source (American Power Converter) was selected to protect the system and its data in case of power failure or electrical surges. Inputting data via digitizing is a long and laborious process. In the event that a power shut down should occur, this equipment will give our staff time to save their work. In addition, this device will also serve as a surge protector.

Summary of the Proposed Hydrologic Information System

The Office of Land and Water Resources proposes the development of a Hydrologic Information System (H.I.S.) in order to develop water-management models as part of the State Water Management Plan (Mississippi Water Laws, Section 51-3-21). Data gathered during these work efforts will become a permanent part of the State Water Data Base (Section 51-3-16). This system will enable the Office to develop water-management models and also provide complete GIS capability. The long-term benefits of such an in-house system are numerous. Properly constructed models are useful water-management tools in the following applications:

1) Assist in problem evaluation,
2) Design remedial strategy,
3) Conceptualize and study flow processes,
4) Provide additional information for decision making, and
5) Recognize limitations in data and guide collection of new data.

The Office of Land and Water Resources is currently limited in its efforts to develop water-management models because of inadequate equipment. The Office is currently utilizing one Everex 386 personal computer in its efforts to develop these models. With the number of models under development and those being proposed, the capabilities of the one personal computer are far exceeded. In addition, the current system requires that the Office be dependent upon other agencies to meet its computer and mapping needs. After much deliberation, the development of H.I.S. was found to be the most cost-effective alternative to the meet the current and future needs in this water-management area.

One of the goals of the Office of Land and Water Resources is to provide the local water manager with an effective water- management tool to aid in decision making. With the development and implementation of H.I.S., this office will be self-sufficient in providing this much needed information to the local water manager.

Water management is vital to Mississippi in order to provide a long-term reliable source of water for future municipal and industrial development. In order for this Office to accomplish its goal of providing technical information to local water managers, we must have a system in place to disseminate the available data. The proposed Hydrologic Information System will meet this need by providing the platform to enable the development of water-management tools for use throughout the State of Mississippi.

The following is a list and brief description of application examples for the proposed Hydrologic Information System. This list is not intended to be exhaustive but general water-management applications of such a system. This management tool will greatly aid in analyzing hydrologic problems in Mississippi and assist in formulating appropriate management practices.

Application Examples

Ground-water Modeling: Numerical models used in ground-water studies are computer programs that can be applied to a variety of hydrogeological conditions. Through the use of numerical models, staff hydrogeologists can approximate "real world" conditions by calibration techniques and then utilize the model for future forecasting. These management models fall into four basic categories: 1) Well field models; 2) Conjunctive use models; 3) Solute transport models; and 4) Statistical models (Darr 1979).

The purpose of the wellfield model can range from determining the drawdown at a given point due to a defined pumping scenario to maximizing the efficiency of a pumping scheme for the well field. Conjunctive use modeling is a necessity in many regions of the country. For example, in Colorado ground-water users near a stream must determine the stream depletion due to well pumping. Solute transport models can be used to establish the rate of movement of the salt-water interface in coastal areas. Statistical models can be used to determine the values of transmissivity and storage coefficient more accurately.

Surface Water Modeling: Programs to model surface water flow can be used to compute and plot the water surface profile for river channels of any cross- section for either subcritical or supercritical flow conditions. The effects of in-place or proposed hydraulic structures such as ridges, culverts, weirs, and dams may be considered in the computation. Computer programs are now available which will determine river profiles for various frequency runoffs under both natural and modified conditions. These analyses can be used by water planners to develop management schemes for controlling runoff and storage, thereby maintaining a balanced hydrologic system.

Variable Density Modeling: Numerical models to simulate the transient movement of a discrete interface between salt water and fresh water have been developed. These models are designed to allow the analysis of regional two- dimensional ground-water flow in coastal aquifers. Given the increasingly rapid development of coastal areas of Mississippi, coastal aquifers constitute a very important source of fresh water for domestic, industry, or agricultural use. However, the quantitative evaluation of a coastal aquifer is very complex; the proximity of the sea and the contact between fresh water and salt water require special attention and special modeling techniques. The development and implementation of H.I.S. will provide a platform to evaluate these complex conditions.

Geographic Information System: One of the most important features of a data base is the spatial discretization of available data. These data may be well locations, surface water withdrawal points, river courses, land use, and many other attributes. This process of overlaying or layering will allow mapping of pertinent data and storage of such in discrete data layers for future mergers for a final map product. Each of a series of maps to be overlaid is represented at the same scale and registered to a set of common benchmarks and combined through algorithms. The result is a new map with regions corresponding to the combination of the source maps. By digitizing this information and storing to a file, the particular consideration can be recalled for map generation on its own merit or in combination with other attributes.

A Geographic Information System (GIS) combines two computer software technologies: data-base management and digital mapping. The key feature of a GIS is that the digital map elements are linked with the tabular information in such a manner that when either the map or the tabular data are manipulated, both sets of data are updated and adjusted to maintain the relationship between them. For example, a GIS can be used to identify wells having increasing rates of water-level declines and then search land-use maps for potential heavy water users located near these wells. It is this ability to select, manipulate, and analyze data in both a spatial and a tabular sense that make a GIS so powerful.

Modelers of ground-water and surface-water hydrologic systems have found GIS ideal for preparing their data and displaying their results. New techniques for representing terrain features, such as streams and drainage basins, are producing surface-water models with spatial resolutions unimaginable a few years ago. Visual, interactive displays make finding and retrieving water- resource data easier than ever.

The initial elements foreseen as data for our GIS are well locations, surface water withdrawal points, geologic unit contacts, hydrologic characteristics, sand and clay thicknesses, volume of water withdrawn, and land use. This information combined with predictive modeling results will form a technical basis for water-resource management in Mississippi.

Remote Sensing: Remote sensing techniques can be used in determining land use and associated water demand as well as plume movement along the coastal area or along a particular river reach. By utilizing remote sensing techniques, the rate of movement can be determined and dispersal probabilities analyzed. Base line data supplied by NASA can be compared to present conditions through image processing and used in management decisions. This information is critical in properly managing the surface water resource.

Estimating Seepage Rates: Ground-water flow models have been found to be very useful tools in estimating seepage rates between surficial hydrologic systems and underlying aquifer systems. For example, spatial variability in the rate of ground-water flow to and from lakes is a result of complex shoreline morphology, variable lake depth, variable lake sediment thickness and hydraulic conductivity, and aquifer heterogeneity and anisotropy. The presence of these conditions at most lakes insures that manual flow-net calculations based on Darcy's law will be cumbersome and inaccurate. However, two- and three-dimensional ground-water flow models provide flexible and effective means of calculating flow rates in well defined but complex natural flow systems around lakes (Munter and Anderson 1981).

Water Supply Planning: The primary issue faced by water planners today is the need to reliably forecast future water demands. However, in order to provide accurate forecasts the water planner must have access to reliable data to support past and present use. A major function of H.I.S. will be to provide a state-wide water management data base that is continually updated as additional information becomes available. The data base file for water-consumption data will be designed according to beneficial use, place of use, and volume of use. Developing such a comprehensive data base will be very useful in making accurate short- and long-term projections of water-supply requirements. The more accurate and complete the data utilized are, the more reliable and useful the forecast will be -- and the more efficient and productive the plans and projects based on the forecast will prove to be.

The use of ground-water flow models in simulating the effects of ground-water withdrawals will be invaluable in water supply planning. Future water demands can be simulated at existing well fields or may be simulated at other proposed locations. Access to this type of information provides the water planner with an eye into the future upon which to base his decisions. If water planners are to have some role in managing the future rather than just witnessing its arrival, they must have the technical tools available to them to properly manage the resource. The implementation of H.I.S. will provide water planners in Mississippi with the necessary technical tools upon which to base their decisions. Therefore, the availability of H.I.S. will be instrumental in the permitting process involving ground-water and surface water withdrawals throughout Mississippi.

Ground-Water Protection: The growth in the use of management models in the United States stems from a series of ever more stringent and comprehensive environmental statutes developed since the early 1970's (National Research Council 1990). Because the subsurface environment is not easily observed or accessible, models have become the tools employed to better understand ground-water systems by simulating and predicting their behavior. By doing so, the amount of stress the system can safely withstand can be quantified. For example, the volume of water withdrawn along coastal Mississippi can be analyzed as to the effect on the pumped aquifer as well as the effect on underlying and overlying aquifers. In addition, the hydraulic gradient simulated can be analyzed as to the effect on the rate of movement of the salt water - fresh water interface.

Ground-water quality is most vulnerable in areas of recharge to the system, especially where the aquifer outcrops at the surface. The use of GIS technology in defining these areas and the utilization of models to define direction and rate of ground- water movement is necessary to protect the ground-water resource. With the implementation of H.I.S., this information will be readily available to the water planner and those involved in urban planning so that these individuals can work together to protect the recharge areas.

Technology Transfer: One of the most advantageous applications of H.I.S. to water planners in Mississippi is the advent of data dissemination throughout the state. The available technology will enable the mutual transfer of data to all agencies involved in water resource management. This process will not only aid the agencies involved but will also assist in avoiding duplication of effort.

The long-range goal of H.I.S. is to assist other agencies, especially the existing Water Management Districts, in their local water management areas. This can be accomplished through technology transfer including data transfer, hardware and software selection for compatibility, inter-agency expertise, and analytical training. With an active H.I.S. in operation at the State level, this assistance will prove to be the most effective means of water management in Mississippi.

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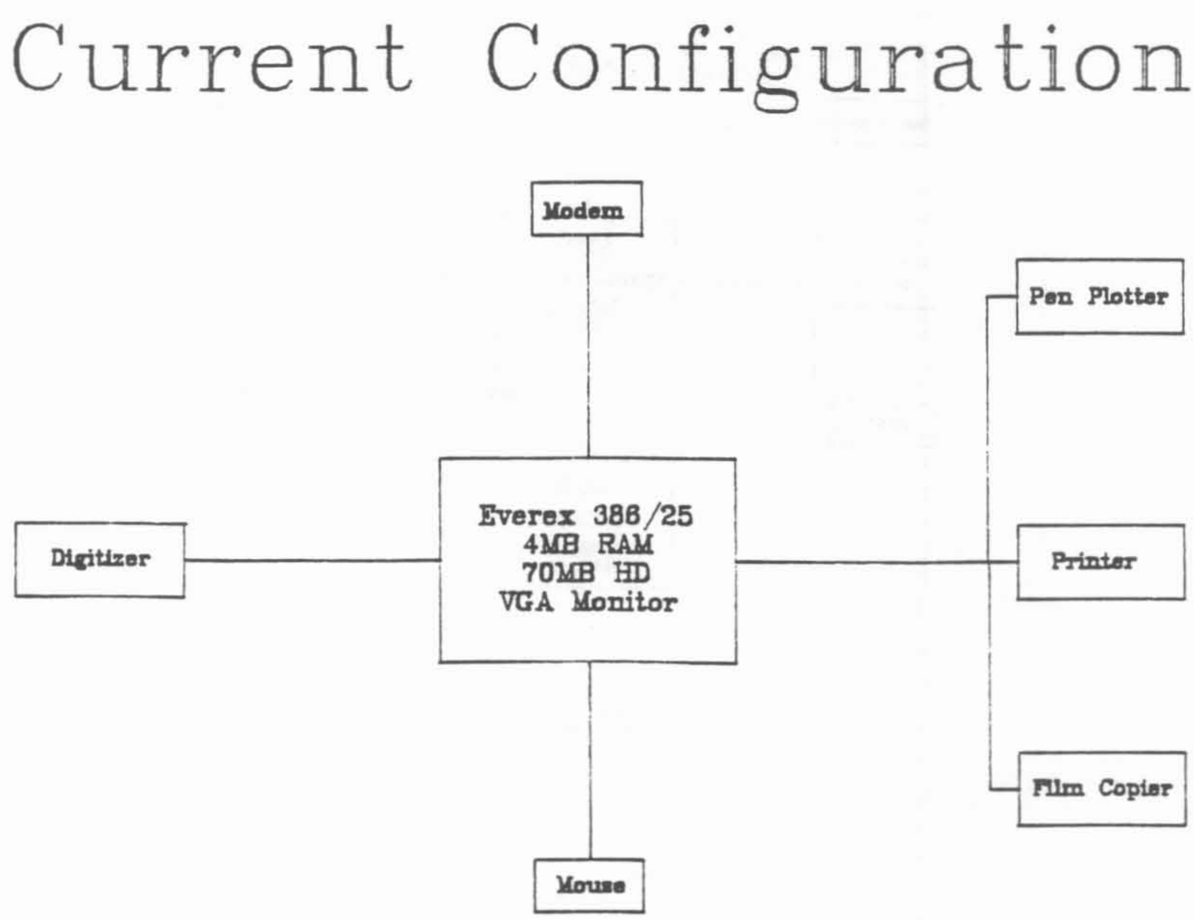

Figure 1

Proposed Configuration

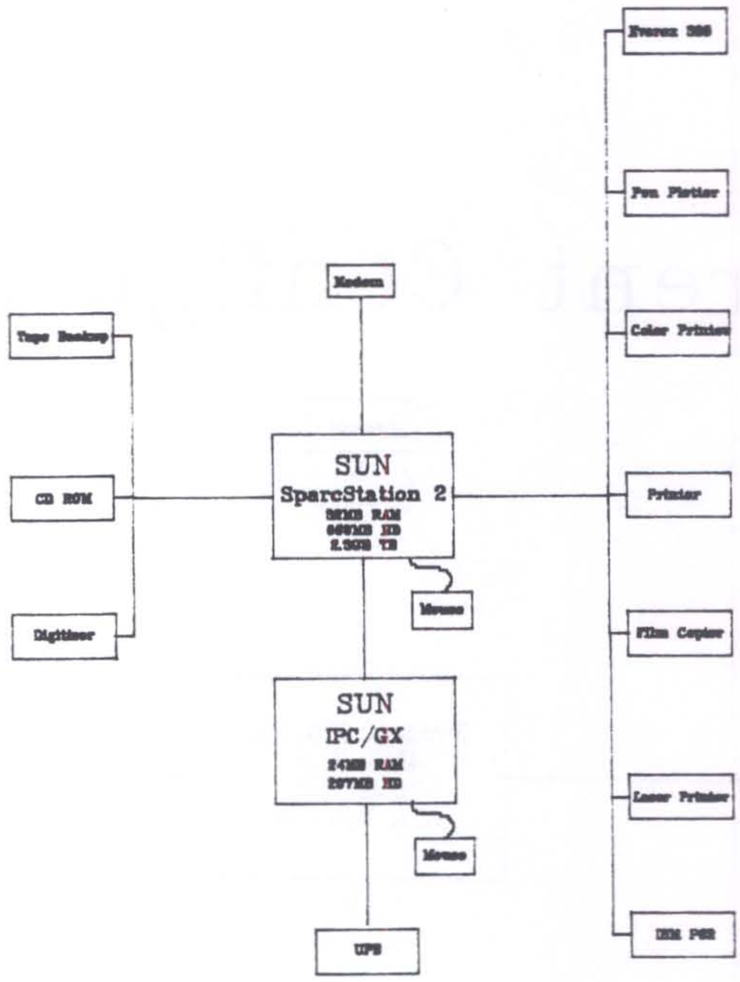

Figure 2