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May 1997

Designing an Information Management System for Watersheds

The Watershed Academy

• Information Transfer Series •

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The Watershed Academy
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• Information Transfer Series, No. 5 •

Designing an Information Management System for Watersheds

Assessment and Watershed Protection Divsion,
Office of Wetlands, Oceans nd Watersheds (4503F)

and

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Foreword

The watershed approach has changed the way that the U.S. Environmental Protection Agency (EPA) and other federal, tribal and state agencies formerly managed water resources programs. We now generally recognize that the critical environmental issues facing society are so intertwined that a comprehensive, ecosystem-based and community-based approach is needed. We also recognize that solving environmental problems depends increasingly on local governments and local citizens. Thus, the need to integrate across traditional water program areas (e.g., flood control, wastewater treatment, nonpoint source pollution control) and to cooperate across levels of government (federal, state, tribal, local) and across public and private sectors is leading toward a watershed approach.

Public and private organizations, academic institutions, and citizens and their governments in thousands of communities across the nation are forming partnerships and learning new ways to manage their watersheds together. These groups seek guidance and examples of watershed approach success stories after which to model their own activities. The EPA Office of Water established the Watershed Academy to help address these needs by providing training for watershed managers based on local, state, tribal, and federal experiences in implementing watershed approaches throughout the past decade.

The Watershed Academy provides technical watershed information and outreach through live training courses, the Internet, and published documents. The Academy offers live training courses on the basics of watershed management and maintains a training catalogue concerning where to obtain more advanced training. An Internet distance learning program called Academy 2000 is being developed to help serve the training needs of those who cannot attend the live courses. The Watershed Academy also provides watershed approach reference materials, such as this document, through the Watershed Academy Information Transfer Series.

This document, number 5 in the Series, is an introduction to the information management responsibilities and challenges facing any watershed group. The document reviews the fundamentals of identifying information management needs, integrating different data bases, evaluating hardware and software options, and developing implementation plans.

The Information Transfer Series titles include:

no. 1: **Watershed protection: a project focus** (EPA841-R-95-003)
no. 2: **Watershed protection: a statewide approach** (EPA841-R-95-004)
no. 3: **Monitoring consortiums: A cost-effective means to enhancing watershed data collection and analysis** (EPA841-R-97-006)
no. 4: **Land cover digital data directory for the United States** (EPA841-B-97-005)
no. 5: **Designing an information management system for watersheds** (EPA841-R-97-005)
no. 6: **Information management for the watershed approach in the Pacific Northwest** (EPA841-R-97-004)
no. 7: **Watershed Academy catalogue of watershed training opportunities** (EPA841-D-97-001)

Abstract

To build a foundation for sound decision-making and reduce electronic data transfer time, it is important to build an information management system concurrent with the development of a watershed management framework. Based on watershed management experience in several states, 7 key steps have been identified to design an information management implementation plan.

1) Establish information management design and implementation team
2) survey watershed planning partners
3) identify and prioritize data needs
4) integrate/relate existing databases and develop new databases
5) evaluate hardware and software configurations
6) evaluate organizational , staffing, and support issues
7) develop short- and long-range implementation plans.

Recommended milestones and guiding policies for each of these steps are detailed in the report.

Keywords
data consortium
information management system
GIS packages
information database

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Introduction

Drawing from states' watershed management experiences, this report describes the design and development of an effective watershed management information system in a 7-step process (Exhibit 1). Although the primary audience is states, the process outlined can also help local governments, watershed associations, and others interested in designing an information system to support watershed management. Integrating and assessing information from diverse programs, agencies, and institutions are essential in each stage of watershed management (see Exhibit 2). This management approach begins with public outreach, moves through various stages of data gathering and interpretation, and finally maps management strategies in a watershed action plan.

Time invested building an information management system concurrent with developing the watershed management approach yields long-term returns. It provides a *strong foundation* for management decisions, and reduces time spent collecting data and converting from one computer format or language to another.

One product of this 7-step process for information management system design is an information management implementation plan. When planning, it is important to remember that full implementation is a long-term commitment, and will likely take years. Experience shows that a successful program requires that staff be practical and flexible in meeting short-term needs, and at the same time, be dedicated to its long-term vision.

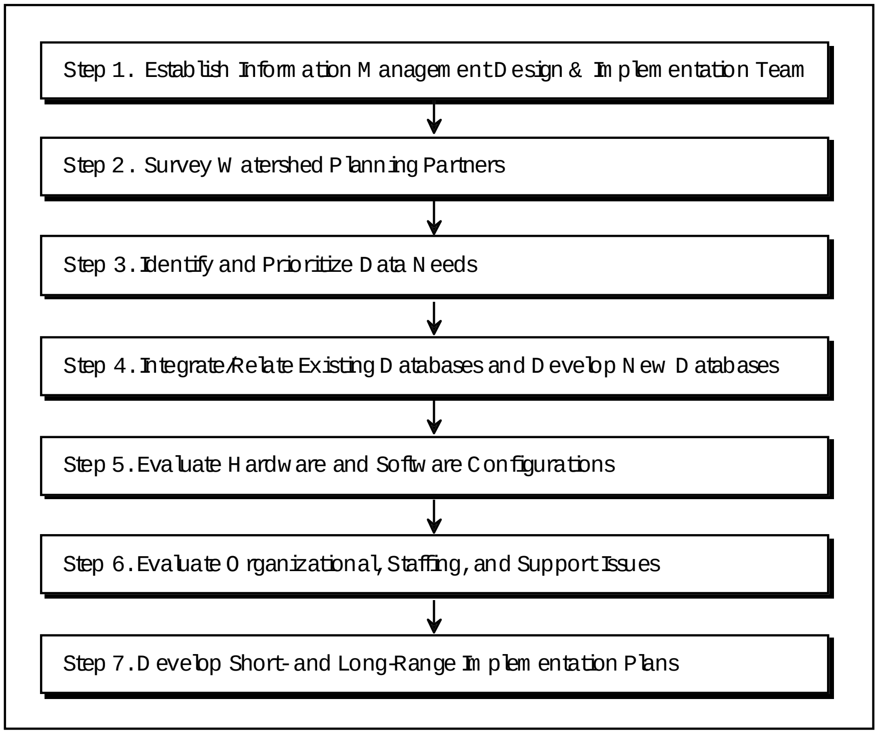
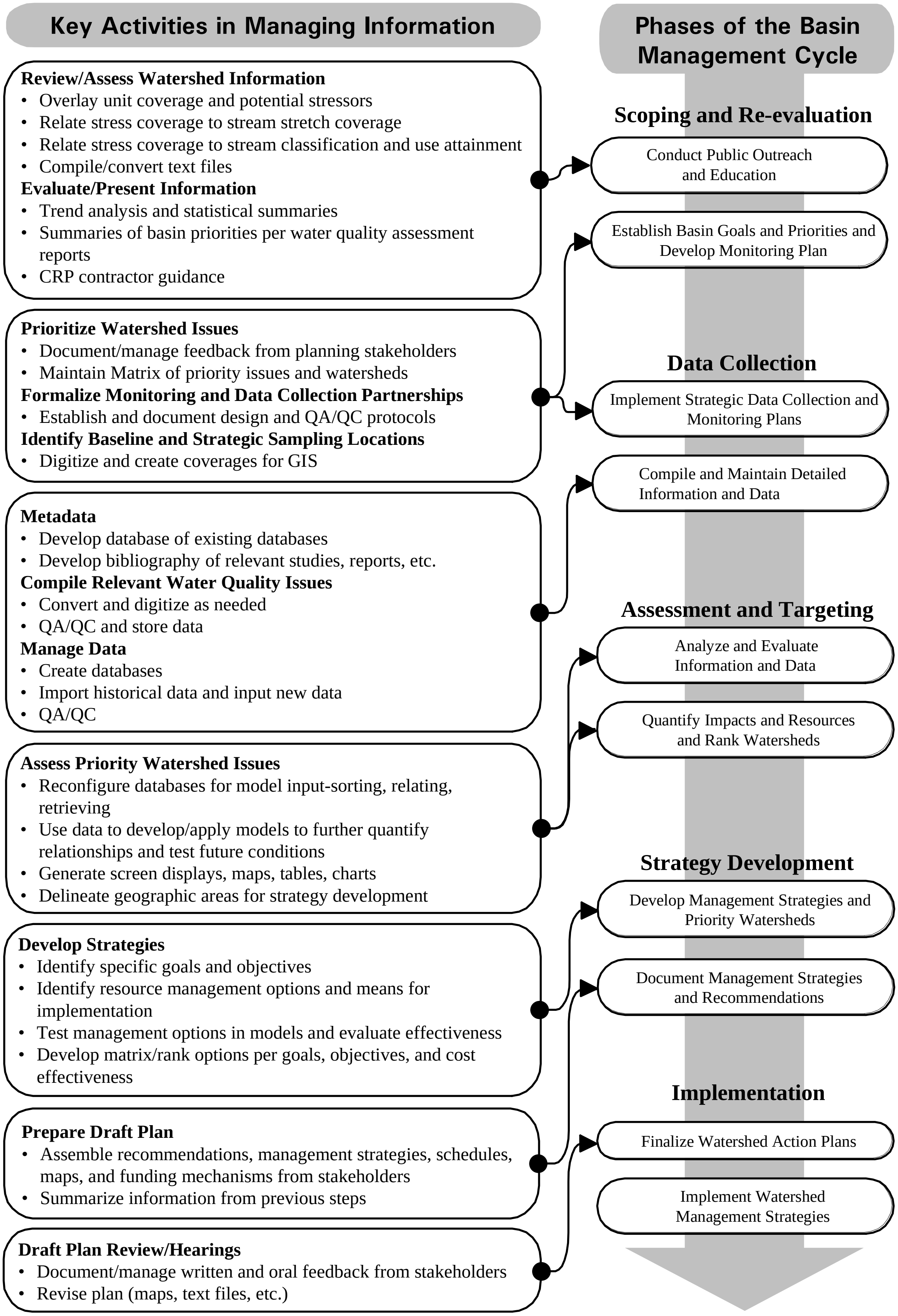


Exhibit 1. Steps for Designing an Information System



Key Activities in Managing Information

Review/Assess Watershed Information
- Overlay unit coverage and potential stressors
- Relate stress coverage to stream stretch coverage
- Relate stress coverage to stream classification and use attainment
- Compile/convert text files

Evaluate/Present Information
- Trend analysis and statistical summaries
- Summaries of basin priorities per water quality assessment reports
- CRP contractor guidance

Prioritize Watershed Issues
- Document/manage feedback from planning stakeholders
- Maintain Matrix of priority issues and watersheds

Formalize Monitoring and Data Collection Partnerships
- Establish and document design and QA/QC protocols

Identify Baseline and Strategic Sampling Locations
- Digitize and create coverages for GIS

Metadata
- Develop database of existing databases
- Develop bibliography of relevant studies, reports, etc.

Compile Relevant Water Quality Issues
- Convert and digitize as needed
- QA/QC and store data

Manage Data
- Create databases
- Import historical data and input new data
- QA/QC

Assess Priority Watershed Issues
- Reconfigure databases for model input-sorting, relating, retrieving
- Use data to develop/apply models to further quantify relationships and test future conditions
- Generate screen displays, maps, tables, charts
- Delineate geographic areas for strategy development

Develop Strategies
- Identify specific goals and objectives
- Identify resource management options and means for implementation
- Test management options in models and evaluate effectiveness
- Develop matrix/rank options per goals, objectives, and cost effectiveness

Prepare Draft Plan
- Assemble recommendations, management strategies, schedules, maps, and funding mechanisms from stakeholders
- Summarize information from previous steps

Draft Plan Review/Hearings
- Document/manage written and oral feedback from stakeholders
- Revise plan (maps, text files, etc.)

Phases of the Basin Management Cycle

Scoping and Re-evaluation
- Conduct Public Outreach and Education
- Establish Basin Goals and Priorities and Develop Monitoring Plan

Data Collection
- Implement Strategic Data Collection and Monitoring Plans
- Compile and Maintain Detailed Information and Data

Assessment and Targeting
- Analyze and Evaluate Information and Data
- Quantify Impacts and Resources and Rank Watersheds

Strategy Development
- Develop Management Strategies and Priority Watersheds
- Document Management Strategies and Recommendations

Implementation
- Finalize Watershed Action Plans
- Implement Watershed Management Strategies

Exhibit 2. How Information Management Relates to a Watershed Management Cycle

A Seven-Step Process for Designing an Information Management System

Step 1. Establish an Information Management Design and Implementation Team

A team involved in all phases of design and implementation should conduct the information management planning process. Generally, a team should include representatives from key stakeholder groups and staff knowledgeable about information systems. The design and implementation team will likely evolve into a data consortium that supports information needs throughout the initial and subsequent watershed management cycles.

Selection of team members should consider where program and agency coordination will be crucial to the success of watershed management and also individual knowledge of database management technology and geographic information system (GIS). The team should have clearly defined goals and tasks and a mechanism for providing feedback to the watershed management group. The management group can provide additional guidance for the team's efforts by developing policies (e.g., level of program interconnection desired, cost constraints, etc.) or general conceptual models of database needs.

Once the team is established, it should conduct a self-assessment to answer questions such as:

- What is each member's skill or expertise?
- Are there gaps? If so, do you need an information management consultant?
- What else is happening that may affect our design efforts?

After this self assessment, the team is ready to take the next steps in designing an information system.

Step 2. Survey Watershed Planning Partners

Your water resources program probably uses information from diverse sources in a myriad of electronic formats. Many state programs have general databases to support their programs in addition to a GIS. Staff use these general databases to analyze trends, assess and summarize current conditions, and generate reports—tasks that require such software functions as storing information, analyzing statistics, sorting and extracting data, converting data, creating summary charts, and word processing. GIS, on the other hand, is designed for those applications with geographical references.

Designing an information system to support watershed management usually requires that managers identify specific requirements through a user survey. The survey can target a wide range of divisions, departments, and agencies, or can target representatives on the information system design team. In any case, the survey should include existing and potential watershed management partners that will use or contribute program data.

Many state and regional agencies have designed user surveys that can be drawn upon.[1] States that conducted user surveys to help develop an implementation plan offer the following advice:

- Get people thinking geographically in day-to-day business before designing specific analytical programs or macros.
- Initially focus on overlay/watershed orientation and mapping functions for the GIS.
- Delay development of expensive, customized GIS/database application and assessment tools.
- Carefully set priorities on data essential for watershed management.

Step 2: Key Survey Questions

What are your group's primary responsibilities related to watershed management?

What databases, maps, and geographic records do you currently use? How do you use or analyze them? Which are important for watershed management? What is their current format?

What map-related problems (e.g., scale and accuracy) does your group have? What priority would you give each problem?

In the watershed management context, what mapping, data management, and analysis would you like to accomplish with a GIS? What functions should the GIS perform? What non-GIS functions need to be performed?

What are the obstacles to developing an information system for the watershed management approach? How could they be overcome?

What potential sources of funding and staff support can your group provide?

What projects might impact implementation of an information system to support watershed management?

Staff will have a better sense of what they really need when they think geographically, know the time involved in using GIS, and understand the constraints of developing or acquiring certain data layers.

Step 3. Identify and Prioritize Data Needs

If you are striving for rapid implementation of watershed management, and cost effectiveness, using survey findings to distinguish essential mapping and assessment

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[1] Example User Surveys: (a) Croswell, Peter. 1993. *GIS Conceptual Design for the North Carolina Water Quality Section*. PlanGraphics, Inc., and (b) Atlanta Regional Commission. 1990. *Implementation Plan for a Regional Geographic Information System.*

data from second-priority and low-priority data is important. Although user surveys often generate lengthy lists of data needs, states have found that some base mapping coverages and analytical data are most frequently needed for watershed management:

- Geographic management units (e.g., river basin, watershed boundaries, and subwatershed boundaries), major hydrology, major roads, and political boundaries (e.g., county and municipal)
- Sub-basin units, ambient monitoring sites, National Pollutant Discharge Elimination System (NPDES) permittee outfalls, US Geological Survey (USGS) flow gauging sites, stream classifications, stream use information, water supply intake locations, regulated flow structures, primary shellfish waters, fish nurseries, closed shellfish waters, superfund sites, landfills, wetlands, land use/land cover, small area population/household estimates and projections[2], slopes, soils, and stormwater management

Data priorities will vary with the scope of watershed management.

After developing data priorities, develop an action plan and timeline for acquiring essential data, starting with the initial target basins. *Make the most of existing data*, even though they may not be perfect or complete, and improve data quality over the duration of the implementation plan. Delaying your watershed management program for 5 or more years while you develop high-quality data for each category is both impractical and unnecessary.

Step 4. Integrate/Relate Existing Databases and Develop New Databases

Formalizing a data consortium is an important first step in integrating and relating existing databases. A consortium maximizes interagency talents, expertise, and resources; reduces data transfer and conversion headaches; and produces higher-quality data that can lead to higher-quality analyses. Documenting roles,

Step 4: Key Questions Related to Existing and New Databases

How often will you create additional GIS coverages upon completion of base watershed management coverages?

How often will you update watershed management data files and existing GIS map coverages?

What map coverages are currently used (such as NPDES sites, landfills, and Superfund sites)? What databases will be related to map coverages (such as effluent water quality information related to an NPDES site file or stream classification related to stream stretch file)?

What databases will not be linked or related to GIS?

How will you relate water quality and supply data to specific streams, stream segments, and aquifers?

What is the smallest management unit you should have, remembering that nesting up is easier and more accurate than nesting down?

How will you relate important off-stream watershed data (such as location of landfills)?

Who will be the custodian of watershed management data?

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[2] Land use, wetlands, and population/household projections for small areas are the most difficult data to acquire at the high spatial resolution and accuracy needed for small areas.

responsibilities, and procedures extends institutional memory, which is especially important during times when staff changes are common. The following milestones are suggested for formalizing the data consortium:

- Develop data transfer and quality assurance/quality control (QA/QC) protocols
- Evaluate data sources, including software and language compatibility
- Choose key relational fields and unique identifiers
- Develop a detailed plan for converting, relating, integrating, and updating databases

The fundamental question to answer in designing your database system is, "How connected and how centralized should it be?" Consider strengths and potential pitfalls of the following two database management models which are at different extremes in terms of connectivity and centralization. Model 1 is decentralized, but connected electronically. Model 2 is a centralized, relational database. For each model, we have assumed that the state has created one or more watershed management coordinator positions and has developed a GIS program that could support multiple agencies.

- **Model 1**: Watershed management coordinators would use the state's GIS program to compile existing GIS databases and develop new ones; they would use EPA's Reach File 3 (RF3), and other database and spreadsheet files provided by other branches, departments, and agencies. These partners would be the responsible custodians of their datasets, making sure that watershed coordinators receive updated files. Additionally, different divisions or departments would write chapters or sections of the watershed management plan and provide the narrative and tables to the basin coordinators in electronic format. Partners exchanging large files are connected via Internet; other file exchanges are made through e-mail or tapes and disks.

  The strengths of Model 1 include the use of wide resources and staff who have incentives and insights into data QA/QC. Potential pitfalls include the risk of numerous, incompatible types of databases; lack of standardized file conversion and file transfer procedures, which creates inefficient and frustrating data exchange; and questionable data due to lack of overall QA/QC procedures. These pitfalls could be addressed through standard operating procedures that outline QA/QC procedures and compatible database structures.

- **Model 2:** Watershed management coordinators use one relational database, develop and update most watershed databases in-house, and create GIS coverages and conduct spatial analyses in-house, and write the watershed management plan in-house. Partners transferring data are required to use uniform software and database structures; databases or files retrieved from partners are linked to the centralized database.

  Strengths of Model 2 include more control over QA/QC, data documentation, and other procedures. Potential pitfalls include large demands on watershed management planning coordinators. Custodians of data and information are not as familiar with specific databases as program staff. Also, on-site data storage requirements are great, and the larger and more complex the relational database, the more likely that it will fail.

After your watershed management team has reviewed and discussed two or three conceptual models, it should develop guidance for the information system design team. Some *decision points* include:

- Develop goals consistent with the long-term vision for the watershed management information system;
- Develop criteria for evaluating model options;
- Develop a consensus conceptual model; and
- Identify key short-term steps to transfer, relate, and convert data for the initial watershed plan.

Step 5. Evaluate Hardware and Software Configurations

In evaluating hardware and software configurations, it is important to understand basic system components and some frequently used terms. These are provided in Appendix A.

Geographic Information Systems: A General Overview

Evaluating existing and future conditions in subwatershed units and targeting high-priority problem areas are central to the watershed management approach. These efforts not only require compiling and storing tremendous volumes of information, but in many cases, involve referencing the data geographically, overlaying georeferenced data for an entire river basin, then overlaying sub-basin boundaries for detailed analysis. Analyses are conducted at the sub-basin level and then aggregated to the basin level to see the overall picture.

Most states use a GIS to “georeference” data types or layers, overlay layers, conduct spatial analysis, and generate report maps and charts. Exhibit 3 compares ArcView2, MapInfo, and Atlas GIS—three popular, user-friendly GIS packages. Technology changes quickly; therefore, you will need to refer to trade magazines and vendors for up-to-date comparisons.

General Comparison of Arc/Info and ArcView2

To a large degree, the decision to use a specific GIS software package should be based on the volume of information and the complexity of the operations that are expected, as well as the skills of the users. Will users require a large, regional-scale database that supports heavy use, or is the need restricted to a single, local-scale watershed? Can the team afford a full-time GIS specialist, or will a small, minimally funded staff need

Exhibit 3. Comparison of Three User-Friendly GIS Packages[a]

Characteristics and Capabilities	ArcView2	MapInfo	Atlas
Vendor		MapInfo Corporation	Strategic Mapping
Platforms		PC, Macintosh, Unix	PC
Version Tested		Windows, version 3.0	Windows, version 3.0
Minimum Hardware		80386 microprocessor, 4 MB RAM, and 11 MB hard disk space	80386 microprocessor, 8 MB RAM, and 12 MB hard disk space
Cost		$1,295	$495
User Interface	Multiple windows	Multiple windows	Single window
Database Management	Relational structure	Relational structure	Flat file structure
Proximity Analysis	Yes	Yes	Yes
Polygon Overlay	No	No	No
Buffering	Cannot create buffer layer; selects objects w/in criteria set by buffer	Excellent buffer creation	Fair buffer creation
Map Creation	Good symbology; exc. layout design	Fair symbology; exc. layout design	Fair symbology; fair layout design
Thematic Mapping	Polygon fill only	Polygon fill, dot density, and others	Polygon fill, dot density, and others
Programming	Avenue, object-oriented language	MapBasic	Atlas ScriptVB, Atlas Script C
Strongest Features	Powerful user interface and programming language; work with ArcInfo coverage; wide set of alliances	Excellent set of GIS tools; powerful user interface; wide set of alliances	Solid product; easy to use; exc. price to performance ratio; wide set of alliances

[a] Adapted from *Planning Magazine*, July 1995.

to develop basic GIS survival skills?

As GIS software has diversified, it has become possible to trade off complexity and power for simplicity and a higher degree of user-friendliness. A good example of the opportunity for this kind of tradeoff is illustrated by the choice between ARC/INFO, which is a powerful but very complex UNIX-based GIS, and ArcView, which is a more easily learned but less powerful, PC-based or UNIX-based package from the same vendor. Exhibit 4 compares these software packages in terms of the information management functions each will support. Again, for up-to-date comparisons, it is recommended that you consult trade articles and vendors.

Evaluating Three General Hardware and Software Configurations

Step 4, Designing a Database Management Model, reviewed conceptual models for consideration. A similar exercise is helpful in evaluating hardware and software configurations. The hardware and software configurations outlined below fall at different points on the continuum, from centralized to decentralized, and electronically connected to disconnected. Of course, options and capabilities will change over time.

Option A

In Option A, watershed management coordinators use PC ArcView2 , numerous databases assembled from basin planning partners, and Internet connections for large file transfers (Exhibit 5). This option is decentralized and adequate if the majority of basin data and GIS functions will be overlaying, selecting and viewing coverages, and designing maps and charts. Option A also requires that coordinators have a good working relationship with outside GIS partners to create and update map coverages, generate color maps, and conduct GIS spatial analysis. It also assumes that there are Internet connections between major data partners.

The limitations of Option A include a five-step conversion process to export ARC/INFO files into PC ArcView2. Also, agencies must store both UNIX and DOS copies of each file (which increases the complexity and cost of file management) and must install additional software to enable ethernet or network communication between DOS and UNIX. Finally, Option A is operationally slower than other options.

Option B

In Option B watershed coordinators use ArcView2 run from a UNIX workstation through PC X-emulation or X-terminals, databases retrieved from basin planning partners, and Internet connections for large file transfers (Exhibit 6). Option B is suitable when the majority of basin data and GIS functions will be overlaying, selecting, and viewing coverages, and designing maps and charts. Option B also requires that the coordinators have a good working relationship with outside GIS partners to create and update map coverages, generate color maps, and conduct GIS spatial analysis.

The main limitation of Option B occurs if you do not already have a workstation, in which case this option will require additional hardware purchase and staff training on the UNIX system.

What Both ARC/INFO & ArcView2 Can Do

- **Identify, List:** Choosing sites, displaying and listing information about them
- **Select, Re-select:** Selecting sites that meet certain criteria in the relational database, displaying and listing information about them
- **Display overlay:** Overlaying map features to show their relationship on screen or print out
- **Buffer Display:** For example, showing the land area, streams, landfills, etc. that fall within a prescribed radius or linear distance
- Import dBASE, Paradox, and other database files related to map coverages
- Update information/tabular databases related to map coverages
- Map design and generation
- Summary charts and tables

Additional ARC/INFO Functions

- Overlay existing coverages (through joining, intersecting, selecting, etc.) to create and display new coverages
- Overlay coverages for calculation, analysis, and display (for example, calculating the total number of housing units and average housing density per Census block group in a given watershed management unit)
- Buffer coverages for calculation, analysis, display (for example, calculating the number of stream miles or land area within a certain linear distance or radius)
- Perform special functions such as networking and address matching
- Digitize new coverages

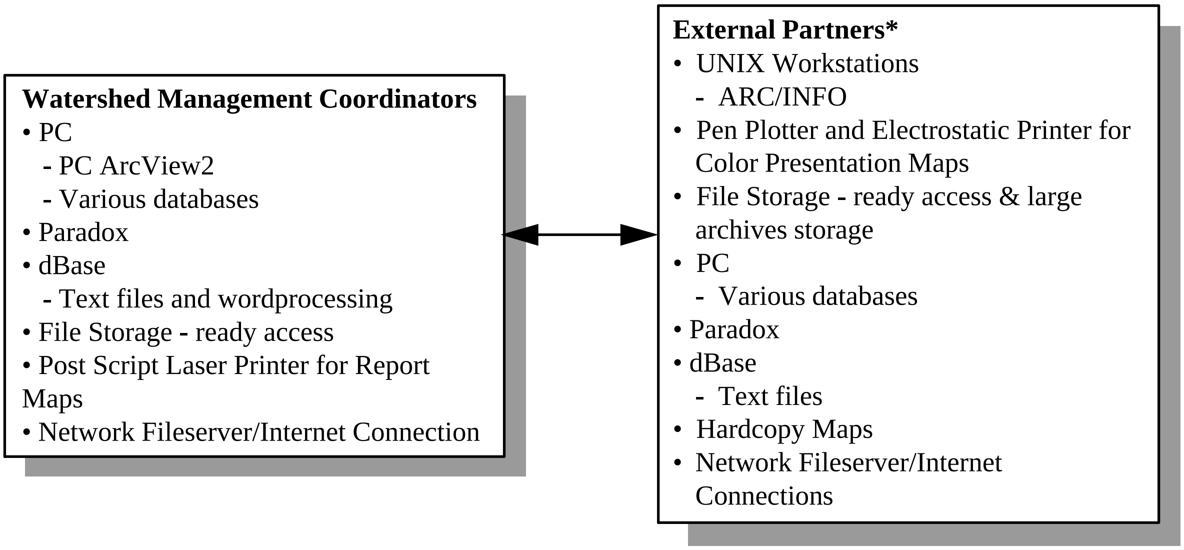
Differences Between ArcView2 & PC ArcView2

- ArcView2 and ARC/INFO are run in a UNIX operating system environment, generally running off a UNIX workstation [Through your network and/or special software (X-emulation), you can link a PC or X Terminal to the UNIX Workstation, essentially running ARC/INFO or ArcView2 off the workstation while entering commands and viewing the results at your PC or X Terminal.]
- PC ArcView2 is generally run in a DOS environment.
- Functionally, there is no difference between PC ArcView2 and ArcView2 run through X-emulation, due to the differences between the UNIX and DOS systems, however, some key network, file management, and processing differences need to be considered.

  For instance, with PC ArcView2 running in a DOS environment on a 486:

  - A five-step, export-import conversion process is necessary to use map coverages or databases created in ARC/INFO (in the UNIX environment) (No translation/conversion is needed for ArcView2 using X-emulation on a PC or using an X-terminal).
  - Must keep two updated copies of every file (one in DOS, one in UNIX-based environment), which makes managing/storing files more complicated and expensive.
  - Running large files off a PC is much slower than off the workstation (directly or through X-emulation).
  - It is necessary to have additional ethernet or network software, such as PCNFS, that allows communication between the UNIX and DOS operating systems.
  - Fewer digits are allowed in PC ArcView2 names than in ARC/INFO and ArcView2, which means database structures and nomenclature would need to be changed in ARC/INFO before converting a file to PC ArcView2—a process that can be very time-consuming.

Exhibit 4: Comparing ARC/INFO and ArcView2 (1996)



Watershed Management Coordinators
- PC
  - PC ArcView2
  - Various databases
- Paradox
- dBase
  - Text files and wordprocessing
- File Storage - ready access
- Post Script Laser Printer for Report Maps
- Network Fileserver/Internet Connection

External Partners*
- UNIX Workstations
  - ARC/INFO
- Pen Plotter and Electrostatic Printer for Color Presentation Maps
- File Storage - ready access & large archives storage
- PC
  - Various databases
- Paradox
- dBase
  - Text files
- Hardcopy Maps
- Network Fileserver/Internet Connections

*Assume GIS partner provide GIS coverages and other data; other partners provide data and text files and maps

Adequate if:
- Majority of watershed planning data/GIS functions are viewing, overlaying, selecting coverages and designing/generating maps and charts.
- Most GIS map coverages are static and you only need to regularly update associated databases.
- Good working relationship with a GIS/Spatial Analysis Center in creating and updating map coverages and conducting special analysis.
- Internet connections between major partners for transferring large files.

Limitations:
- 5-step conversion process to export ARC/INFO into PC ArcView2
- Copy of UNIX and DOS file increases complexity and cost of managing files
- Slower
- Need additional software to allow ethernet to communicate between DOS and UNIX

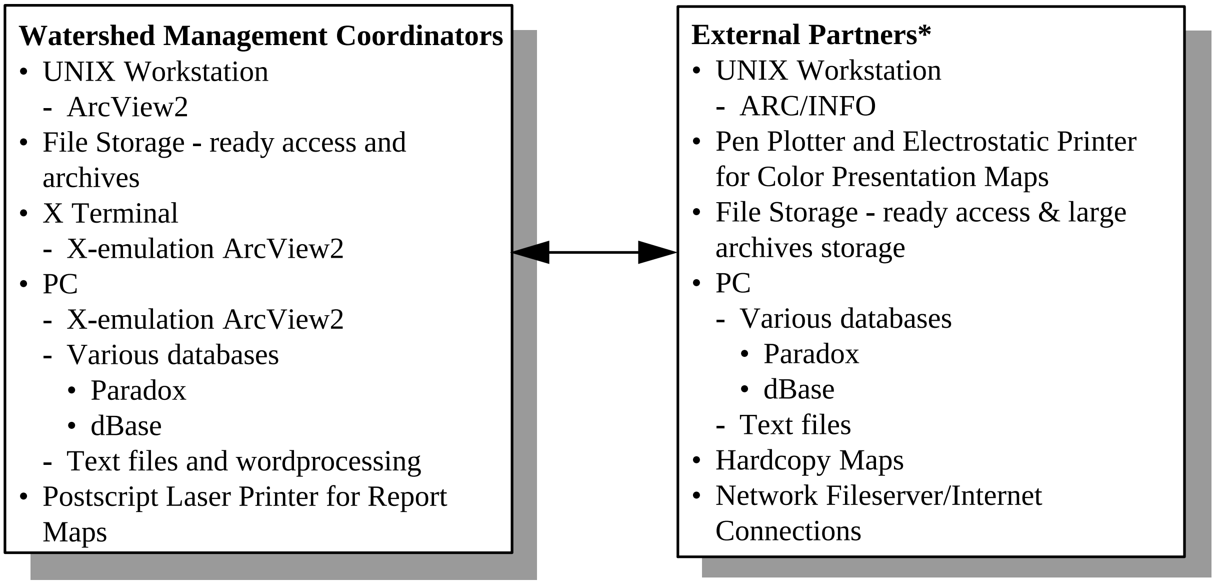
Exhibit 5. Option A - PC ArcView2

Option C

In Option C, watershed management coordinators would run both ARC/INFO and ArcView2 from a UNIX workstation through X-emulation or X-terminals to create, update, and store most basin map coverages and databases *in-house*. Option C is best if the watershed management program needs the full range of GIS functions in-house, including creating GIS coverages, and conducting special analyses, or if uniform procedures and database structures are needed (Exhibit 7).

The limitations of Option C include higher investment in hardware and software, basin planning staff and training, duplication in investment in basin partners' expertise, and GIS technology.

After reviewing and discussing two or three conceptual models, the watershed management team should develop specific guidance for the information system design team. Step 5 decision points include:



Watershed Management Coordinators
- UNIX Workstation
  - ArcView2
- File Storage - ready access and archives
- X Terminal
  - X-emulation ArcView2
- PC
  - X-emulation ArcView2
  - Various databases
    - Paradox
    - dBase
  - Text files and wordprocessing
- Postscript Laser Printer for Report Maps

External Partners*
- UNIX Workstation
  - ARC/INFO
- Pen Plotter and Electrostatic Printer for Color Presentation Maps
- File Storage - ready access & large archives storage
- PC
  - Various databases
    - Paradox
    - dBase
  - Text files
- Hardcopy Maps
- Network Fileserver/Internet Connections

*Assume GIS partner provide GIS coverages and other data; other partners provide data and text files and maps

Very Strong if:
- Majority of basin planning data/GIS functions are viewing, overlaying, selecting coverages and designing/generating maps and charts.
- Most GIS map coverages are static and you only need to regularly update associated databases.
- Good working relationship with a GIS/Spatial Analysis Center in creating and updating map coverages and conducting special analysis.
- Internet connections between major partners for transferring large files.

Limitations:
- Requires additional hardware (workstations) and staff training.

Exhibit 6. Option B - ArcView2 X-Emulation (or X Terminal)

- Develop long-term goals.
- Select criteria for evaluating options.
- Design a consensus conceptual model.
- Identify key short-term steps that support initial basin plans.

Step 6. Evaluate Organizational, Staffing, and Support Issues

Whether you hire new staff, reassign existing staff, or some combination, below are some responsibilities that should be addressed to have a smoothly running system:

- **Watershed Management Coordinator***:* As watershed plans are developed, the Watershed Management Coordinator arranges meetings with partners and stake-

Watershed Management Coordinators
- UNIX Workstation
  - ARC/INFO
  - ArcView2
- File Storage - ready access and archives
- Digitizing Table
- X Terminal
  - X-emulation ARC/INFO and ArcView2
- PC
  - X-emulation ARC/INFO and ArcView2
  - one relational database (Paradox)
  - Text files and wordprocessing

↔

External Partners*
- PC
  - Various databases
    - Paradox
    - dBase
  - Text files and word processing
- Hardcopy maps
- Network Fileserver/Internet Connections

*Assume external partners would provide limited databases and text files.

Very Strong if:	• Watershed management program needs full ranges of GIS functions in house including creating coverages and conducting special analysis.
Limitations:	• Much higher investment in additional hardware/software. • Much higher investment in additional staff and staff training. • Duplicates watershed management partners' expertise and investment in GIS technology.

Exhibit 7. Option C - ArcView2 plus ARC/INFO

holders; communicates data and information needs; tracks progress of data acquisition and tasks related to plan development and updates; encourages and assists with the integration of data and results across branches, divisions, departments, and agencies; communicates and arranges meetings with stakeholders; assembles and assesses comments from stakeholders; and maintains a bibliography of basin-related documents and a library index of related data files. The coordinator also helps summarize and assess data and narrative contributed by watershed management partners.

- **Technical Coordinator:** The Technical Coordinator conveys the overall vision of watershed management technical functions; serves as liaison with outside agencies and partners; administers overall equipment, staffing, training and purchasing.

- **Systems Administrator:** The Systems Administrator configures, optimizes, and main-

Step 6: Key Questions Related to Organizational, Staffing, and Support Issues

- Which responsibilities should be centralized versus decentralized?
- Should we hire new staff or allocate additional information management responsibilities to existing staff?
- Who takes the lead in marshaling resources and managing information?

tains the GIS network, peripherals, software, and databases. Administration includes software installation, operating system upgrades, hardware installation, hardware and software troubleshooting, system back-ups, and security.

- **Database Administrator***:* The Database Administrator manages the creation and maintenance of GIS and other databases, defines and enforces QA/QC procedures, structures data sources, identifies data sources, coordinates data translation and exchange activities, and manages access to GIS watershed management databases.

- **GIS Technician:** The GIS Technician enters data, manages the database, creates maps, generates reports, performs high level GIS functions; hardware and software troubleshooting.

- **GIS Analyst/Programmer:** This GIS specialist performs GIS application analysis, design, coding, training, and technical support as well as customizes software for watershed management applications.

Lessons Learned from Other States

- Top priority: invest in watershed management coordinator(s) and GIS/database technician.

- An agency should not assign watershed management information tasks to existing staff on top of their existing workload and expect to meet schedules; watershed management staffing needs should be included explicitly in the organizational budget and workplans.

- These days, state and other agencies are usually facing no increase in, and often a decrease in resources. Therefore, implementing watershed management means making tough choices about allocating existing staff time to watershed management and decreasing staff time in other activities.

- Across the country, states have successfully convened watershed management partners to negotiate a management framework that enables them to 1) get formal buy-in from partners on when and how they will contribute to watershed management; 2) allocate program resources more flexibly and cost effectively; and 3) leverage outside resources for information management and other activities.

Step 7. Develop A Short- and Long-Range Implementation Plan with Realistic Funding for Staff, Hardware, and Software

Step 7 essentially pulls together the work of Steps 1–6 into a multi-phase, 5-year information management system implementation plan. Key components of the plan include:

Step 1. Set Up an Information Management Design and Implementation Team

- Establish clear goals, tasks, and schedules as well as a mechanism for communicating with the watershed planning workgroup
- Inventory skills and knowledge of the team and bring in other expertise as needed
- Inventory existing information systems to be linked to watershed planning
- Identify potential users of the information system

Step 2. Survey Watershed Planning Partners

- For each group of users, identify primary responsibilities related to watershed planning/ management
- Document relevant existing databases, maps, and geographic records and their formats
- Identify data gaps
- Distinguish GIS and non-GIS mapping, data management, and analytical functions
- Identify current obstacles to developing an information system and potential solutions
- Identify potential sources of funding and staff support
- Identify current or planned projects that could impact implementation of an information system

Step 3. Prioritize Data Needed

- Prioritize data need
- Create a schedule for developing or acquiring data

Step 4. Integrate/Relate Existing Data and Develop New Data

- Develop and formalize data transfer standards and QA/QC protocols
- Develop and formalize a plan for transferring, relating, integrating, and updating data
- Evaluate data sources (including quality and compatibility)
- Choose key database relational fields for geographic analysis
- Determine how database relational fields will be linked to GIS hydrology and land coverages
- Determine how frequently new GIS coverages will be created after core watershed planning coverages are completed
- Determine how frequently watershed planning databases will be updated
- Develop criteria for integrating and relating data (based on the above findings)
- Develop options that meet the criteria (adequate, good, very good) as well as the strengths, weaknesses, and cost of each option
- Get feedback on which option is preferred and fundable

(continued)

Exhibit 8. Recommended Milestones and Guiding Policies

(continued from previous page)

Step 5. Evaluate Hardware and Software Configurations

- Identify existing plans for reconfiguring hardware and software that may impact information system design
- Determine the priority and sequence of basin planning hardware and software applications
- Identify existing hardware and software and how they can best be incorporated into the watershed planning information system
- Evaluate the compatibility of operating systems (for example, transferring data between the PC DOS and workstation UNIX environment)
- Determine need for exchanging and accessing data (including network speed)
- Develop criteria for configuring the hardware/software/network
- Develop options that meet the criteria (adequate, good, very good) as well as the strengths, weaknesses, and cost of each option
- Get appropriate feedback on which option is preferred and fundable

Step 6. Evaluate Organizational Design, Staffing, and Support Issues

- Based on preferred hardware/software and database management models, outline information management responsibilities
- Identify staffing needs (including hiring, reassigning, and training staff)
- Outline staffing options (adequate, good, very good), as well as the strengths, weaknesses, and cost of each option
- Get appropriate feedback on which option is preferred and fundable

Step 7. Develop a Short- and Long-Range Implementation Plan

- Based on Steps 2-6, develop a multi-phased, 5-year plan, including
  - Staffing (including training)
  - Hardware
  - Software
  - Application development
  - Data development, conversion, and integration
  - Network/communication
- Include realistic funding for each component

Exhibit 8. Recommended Milestones and Guiding Policies (continued)

- staffing (including training)
- hardware
- software
- application development
- data conversion
- network/communication

Experience from other states regarding the implementation plan shows that, to be successful, it is important to remember the *dynamic nature* of an implementation plan (i.e. be flexible to take advantage of emerging grant opportunities or new technologies and address short-term needs) at the same time that you work steadily toward the long-term vision. Exhibit 8 suggests milestones and guiding policies for each step in the process.

Appendix A

Definitions for Six Basic Computer System Components

Before comparing GIS systems and hardware/software configurations, it is important to understand some frequently used terms. Definitions are divided into the six basic system components:

- Small Bits and Bytes
- Processing Units
- Input Devices
- Output Devices
- Mass Storage Devices
- Communication Network Lines

Note: Some price ranges listed below may vary by region and will change over time. Prices are listed for conceptual perspective and should not be used for planning purposes.

Small Bits and Bytes

A bit is the smallest unit of data stored in a digital computer and represents the state of a binary switch (e.g. on or off, I or O). A byte is the basic unit of data storage in computers and consists of eight contiguous bits. Other common data units are a kilobyte (KB) which is 1024 bytes, a megabyte (MB) which is 1024 kilobytes, and a gigabyte (GB) which is 1024 megabytes.

Processing Units

- ***Microcomputers:*** commonly referred to as personal computers or PCS, microcomputers normally support one user with a limited number of peripheral devices (e.g., printer, modem, etc.). They can also fill the role of a server (an administrative machine) on a network of microcomputers. A computer's memory (storage space) is divided into two components: random access memory (RAM) and mass storage. Currently, the most popular PC operating systems are Windows, MacOS, and OS/2. Baseline PC systems that are currently available generally contain 16 MB of RAM and approximately 1 GB of mass storage. Such a system typically costs between $1,500 and $3,500.

- ***Workstations:*** usually support one user plus peripheral devices, are more powerful than microcomputers, and support multitasking (ability to perform more than one operation at a time). They are often used as network servers, graphics workstations, or for computational intensive tasks. The most popular operating system for workstations is UNIX, although OS/2 and Windows can also be used. Workstations are available in many system configurations, which can range in price from $10,000 to $25,000.

- ***Minicomputers:*** support multiple users (often up to 100) working on remote terminals and are used primarily as servers in a network of minicomputers, workstations, and microcomputers. UNIX and VMS are the most common minicomputer operating systems. Minicomputer prices vary depending on their configuration and manufacturer.

Input Devices

- ***Digitizing Tablets:*** convert analog data (e.g., maps) into digital information capable of being input into GIS and mapping software packages. Digitizing generates vector (line and point) features by tracing analog features (e.g., roads, land parcels, and watershed boundaries) with a digital cursor and recording the coordinate locations (i.e., digitized X and Y points) in a software package. Digitizing tablets range in size and cost from small, desktop models (12" x 12") of about $200 to large, tabletop models (30" x 40") of over $3,000.

- ***Optical Scanners:*** convert analog data into electronic images for input into mapping or image manipulation. Scanning uses a photoelectric process to record data into a digital image consisting of unrelated pixels (i.e., picture elements). Scanning offers a more rapid means to convert analog data into digital data, however, feature identities are lost. Flatbed scanners, the most common type, scan up to legal size (8.5" x 14") and cost from $400 to $1,000.

Output Devices

Prices for output devices are based on the resolution, color, and size of the output generated, and range from $300 for desktop ink jet printers to $50,000 for E-size (36" x 48") capable, electrostatic plotters.

- ***Ink Jet Printers:*** useful for low-cost, low-resolution color output. Limited to letter and legal size output.

- ***Laser Printers:*** useful for low-cost, high resolution, monochrome output. Color laser printers are available at significantly increased prices. Limited to letter and legal size output.

- ***Pen Plotters:*** useful for generating extremely high resolution, color output of linework and simple features and patterns on paper sizes A (8.5" x 11") to E (36" x 48"). Limitations include a finite palette (limited color set and patterns) and susceptibility to media errors (e.g., pen artifacts in linework and patterns, paper tears, pens running out of ink).

- ***Ink Jet Plotters***: generate high resolution, color output on paper sizes A to E.

- ***Electrostatic Plotters***: generate high resolution, color output on paper sizes A to E (or larger). Limited by high cost of hardware.

Mass Storage Devices

- ***Disk Drives***: peripheral device storage connected to the central processing unit, which stores data and applications (software) for direct access. Disk drives fall into three categories: hard disks (including disk arrays), floppy disks, and removable media (e.g., optical disks, Syquest cartridges, and Iomega Jaz drive cartridges). Removable storage capacity ranges from 1.4 MB to 1 GB and fixed storage capacities range from 400 MB to 12 GB. Disk drives range in cost from approximately $50 for a floppy disk drive, $200 for a 1.2 GB hard disk, to $1,500 for a 2.6 GB removable optical hard drive. Removable media range in cost from about $1 for a floppy disk (1.4 MB), $40 for a Syquest cartridge (230 MB), and $200 for an optical rewritable media cartridge (2.6 GB).

- ***Tape Drives***: high speed data archiving devices which store data in compressed format on magnetic tapes. Common magnetic tape sizes are 3mm, 4mm, 8mm, and 9mm, with capacities ranging from 40 MB to 10 GB. Tape drives range in cost from about $200 for low capacity tape drives to about a $1000 for high capacity tape drives. Tape cost ranges from $5 for low capacity tapes to $20 for high capacity tapes.

- ***CD-ROM Drives***: CD-ROM technology has storage capacities from 660 MB to 2.3 GB. CD-ROM drives cost from less than $100 (for slow speed) to $400 (for high speed). Recordable CD-ROM drives are also available at an increased price (about $1,000) to write to CD-ROMs.

Communication Network Lines:

- ***Ethernet***: communications standard used in many local area networks (LANs). Hundreds of protocols may be used with Ethernet, such as TCP/IP, IPX (Novell), Appletalk, and DECNet. Ethernet has a throughput of approximately 10 megabits per second (Mbps), and may use 10Base-5 (thick coax), 10Base-2 (thin coax), or 10Base-T (twisted pair) cable. Data transfer *between* sites may be accomplished using ISDN, frame relay, or leased lines.

- ***Integrated Services Digital Network (ISDN)***: uses existing copper telephone lines to provide simultaneous voice and/or data communications. The Basic Rate Interface (BRI), the most common configuration capable of supporting up to three simultaneous voice or data "conversations", is usually not cost effective for continuous network communications. Transmission rates on ISDN vary from 64 to 128 Kilobits per second (Kbps). To incorporate ISDN into a LAN, an ISDN router is required at a cost of approximately $1,500 to $2,000. In addition, telephone charges for a BRI configuration range from $25 to $70 per month, plus $.01 to $.04 per minute of use. Flat rates are available in some areas. Finally, Internet access using ISDN generally costs about $200 per month.

- ***Frame Relay:*** a cost-effective alternative to traditional leased-line connections. It uses technology based on the efficient switching of data packets across the network. It is less costly than the equivalent service provided by leased lines. Frame relay is available in capacities ranging from 56 Kbps to 1.5 Mbps. At higher capacities, frame relay will support dozens of simultaneous users. Costs for using frame relay include telephone charges from $175 to $475 per month and an on-site router for about $2,000. Internet access charges for frame relay range from $200 to $800 per month, depending on the transmission rate.

- ***Leased Lines:*** provide continuous point-to-point network access. They consist of dedicated trunk lines between user locations and telephone company central offices. Leased lines are generally available in capacities ranging from 56 Kbps to 10 Mbps. Telephone charges vary according to the distance from the central telephone company office and the capacity of the line. They typically range from $250 to over $1,000 per month. On-site equipment (e.g., a router) ranges from $2,000 to $4,000. Internet access fees range from $500 to $1,200 per month.

In determining the appropriate communications link, the watershed partners need to consider the extent to which real-time data access is needed; the degree of data centralization; existing hardware, software, and network configurations; and available resources. Graphic-intensive applications such as GIS typically require a T1 line for fast, on-line access.