The Surveys and Resource Mapping Branch's report, entitled *General Requirements and Preliminary System Design*, 1989, developed an overall concept for such a system and presented an example of a preliminary system design. The Branch's preliminary design identified the need for local area networks and servers, distributed data management, common standards and specifications, and respected the Ministry of Environment technology architecture. A number of technical issues associated with accessing, updating and managing Ministry of Environment corporate land information in a multi-vendor, distributed environment were not resolved by the preliminary design.

A subsequent project was undertaken to extend and refine the preliminary design to address many of these unresolved issues. This project was the initial system design. A detailed system design based on the recommendations of this project, detailed user requirements, data resource management plans, and Ministry communications architecture will follow.

The initial system design project consisted of a conceptual design (paper system) as well as a physical demonstration of the design (prototype system). The project requirements included providing access to multiple DBMS, integrating multiple GIS products, providing a means of managing associated business data in a distributed regional environment, providing off-line execution as well as interactive GIS, and providing a simple user interface to the GIS.

**Conceptual Design**

With the emphasis of the Ministry of Environment GIS initiative on regional operations, the design infrastructure and subsequent prototype reflect regional requirements. The design was partitioned into a regional GIS infrastructure and a regional business infrastructure. Functional analysis of each component produced a model of information flows which was then translated into a technical design. Each of the features of the conceptual design can be mapped back to the original project objectives.

The characteristic features of the initial system design are briefly described below.

**Client-server architecture**

The principal of 'divide and conquer' gave rise to the client-server architecture, in which specialized processors are dedicated to specific functions, in service to client processors which execute applications for the end-user. This architecture is particularly applicable to distributing geoprocessing, given the enormous volumes of data associated with GIS and the computer resources required to support the complex spatial queries. Although the demonstration prototype described later employs only one server, the design supports the notion of multiple special function servers (GIS servers, database servers, file servers, disk servers, a master server running other servers, et cetera).

**Connectivity**

Backbone network connectivity, which connects each processor with all other processors, is applicable to the local area network of the regional infrastructure. This architecture will ultimately be extended to include WANs, potentially extended LANs, relays, bridges, gateways or routers, et cetera, to interconnect all Provincial Ministry of Environment programs. Design and implementation of this communications infrastructure is currently being undertaken by the Ministry of Environment in conjunction with the British Columbia Systems Corporation.

**Server-based GIS**

For the community of users who normally use the standard, or server-based, GIS software available to a broad range of users, generally non-specialist users or non-graphic business applications. Server-based GIS refers to the fact that a 'server', normally a multi-user processor is executing the GIS software. The design does not preclude the use of multiple GIS servers offering a variety of vendor products for server-based applications.

**Client-based GIS**

Client-based GIS provides unique analytical capabilities to GIS specialists. In this instance, 'client-based' refers to the fact that a client, normally a single-user processor, is executing the GIS software.

**Distributed data**

Each region would maintain a repository of geographic data, both baseline and business. The regional repositories would consist of a partition of the provincial master geographic database. Associated business or administrative data will be distributed between headquarters and the regions.

The business data infrastructure deals with the management of non-spatial data with a view towards the sharing of business data among applications, both GIS and business. Two solutions were offered for satisfying the business data infrastructure. A business data gateway which determines the location of requested business data through a 'meta-database', and returns appropriate tables to the requesting GIS. The other approach provides access to data using a business data repository which has been aggregated, in a standardized format, from the various regional line agencies as well as with centrally managed data from headquarters. With both approaches, the underlying assumption is that business databases should not be required to be implemented with an identical DBMS product. The repository approach was ultimately implemented for the demonstration prototype. It offered fewer management problems and the degree of technical sophistication and risk would likely be less than with the gateway approach.

**Translation services**

Planned data redundancy was designed to alleviate performance constraints associated with on-line conversion.
of BC-SAIR formatted data. BC-SAIR represents a comprehensive set of specifications appropriate for spatial data management and data sharing. Translation servers will provide the two-way translation between the non-proprietary format (BC-SAIR), and the proprietary formats required by the server-based and client-based GIS.

**Physical Prototype**

Over the years, many system designs which have appeared infallible at the conceptual and logical design stages, have totally broken down upon implementation. The demonstration of the physical prototype was required to ensure design integrity. As it was neither appropriate nor realistic to prototype all aspects of the design, the following objectives were identified for the functional prototype:

1. Illustrate the role that BC-SAIR could play in a regional GIS infrastructure;
2. Demonstrate the function of an Application Program Interface (API) which will allow a non-graphic business application to initiate a server-based GIS procedure which returns a tabular result;
3. Demonstrate a GIS-based application which has the ability to access and update business data residing in various formats and locations;
4. Demonstrate the function of a Business Data Repository management system; and
5. Demonstrate a GIS user interface which provides simple operation.

The prototype development was considered exploratory in nature. While it was intended to overcome some of the key technical difficulties, it was not intended to be implemented as a pilot or a production system.

The implementation of the prototype was influenced and constrained by the capabilities and current technology architecture of the Ministry of Environment. The prototype was assembled with the following components: a MicroVax 3100 (VMS) as the host for the server-based GIS, PC 80386SX (DOS), Macintosh Ilcx (Mac OS) used in terminal emulation mode, an Intergraph InterPro 3050 (UNIX) and non-graphic, diskless VT terminals; connectivity was provided by thinwire Ethernet and DECnet Local Area Network Protocol.

Simulated business applications which exploit the functionality of GIS and represent typical operations of the line agencies in Ministry of Environment were developed to demonstrate how each of the prototype objectives were addressed. These included a Water License Clearance System, a Waste Loading Analysis System, a Wildlife Management System and a Pesticide Control Application.

The applications attempted to capitalize on existing Ministry of Environment and Ministry of Crown Lands data. TRIM program 1:20 000 data and 1:250 000 data which the Surveys and Resource Mapping Branch is currently enhancing and re-structuring, was used as the standard baseline framework. Additional business-geographic (thematic) data was then referenced to these baseline products.

The required thematic layers were, in many cases, already available in a variety of digital formats, including IGDS, PAMAP, PC Data, and ARC/Info. Conversion routines such as SIF, DXF and other custom written routines, were used to transform the various input formats to the proprietary formats of the server-based (host) GIS and client-based GIS, in this case, Arc/Info and IGDS. Typical conversion problems were encountered, such as different working unit or units of resolution, differences in the definition of global origins or design planes, incompatible conversion of symbols, cells, fonts, and conflicts between export and import formats related to attribute field definitions.

The associated business data was somewhat less complicated. The prototype design, which details a regionally centralized business data repository, utilized DEC's RdB product on the MicroVAX host. Business data was transformed from a variety of relational formats into RdB tables. Existing tables were enhanced by a single field (spatial key) which was required to ensure compatibility between the graphic and non-graphic data. The prototype also demonstrated how business data generated in dBASE III+ could be aggregated into the RdB repository.

**Prototype Findings**

**The role of BC-SAIF**

Although the efforts of BC-SAIF and this prototype GIS were not synergistic, one objective of this project was to discuss the conceptual role of BC-SAIF in a regional GIS infrastructure.

![Physical topology of the prototype](image)

*Figure 1: Physical topology of the prototype.*

379
In order to describe the relationship between geographic information systems and BC-SAIF, the specification of BC-SAIF introduces the Geomatics Information Architecture (GIA). The GIA attempts to decompose GIS into three distinct layers: the geographic information system, the database management system, and the communications network. This allows development to proceed within each layer, but independent of the other layers. Cartographic concerns are independent of data management concerns which are independent of computer networking concerns. BC-SAIF falls primarily in the middle layer of the GIA, the database management system, which is founded on the ANSI Three-Schema Architecture.

The data translator identified in the conceptual design mandates the existence of an appropriate interchange format such as BC-SAIF. Recognition that the adoption of common models for expressing and transferring information to facilitate communication between provincial agencies was paramount in the preparation of the initial system design.

BC-SAIF has a significant role to play in the initial system design through facilitating the development of standards, and the use of spatial data in diverse applications and environments. Should it be accepted by the user community, BC-SAIF will have a major positive impact on the implementation and effectiveness of GIS technology.

The function of a GIS application program interface (API)

Two of the simulated business applications developed for this prototype demonstrate how a non-graphic business application could pass a request for geoprocessing services to the host (server-based) GIS and receive tables of data that have been spatially processed.

These requests, which can be made quite independently from the graphics environment, may be entirely transparent to the user. This is a very powerful concept when considering enhancing existing business applications or developing new applications which benefit from the dynamics of geoprocessing. These requests can be executed by a character-based business form and a user with no knowledge about the operation of GIS software. Applications which lend themselves to this type of execution include simple and complex queries which do not involve modification of spatial objects, do not require a graphic display, and are repetitive in nature.

Although the execution of the GIS application is transparent to the end-user, the prototype applications are not transparent to the data or the network services and resources. There is no single homogeneous API. To write the applications, the developer must have prior knowledge of database location, data structures and definitions, and knowledge of many data manipulation languages and network protocols.

There is a great deal of work being done in this area to assist systems engineers in developing systems in a distributed heterogeneous environment. The center of this thrust towards open systems is the International Standards Organization (ISO). The ISO have endorsed the Open Systems Interconnection (OSI) Reference model (ISO7498) as the guiding principle for the design and analysis of computer networks. The OSI model is a seven-layered model, each layer performing a different function in the network. Like the ANSI three-schema architecture mentioned above, the OSI model allows partitioning of the network architecture into functional layers, effectively reducing the design and analysis of the overall network into more manageable design problems. At each node in the network, layers communicate with other parallel layers by means of predefined protocols. Software on two different nodes can effectively exchange information using the established protocols between the various layers, without any knowledge of the physical transfer mechanism. The effective result is that software responsibilities can be specialized and systems from a variety of suppliers can communicate harmoniously.

Implementations of OSI protocols are emerging and product offerings are becoming available. By the mid 1990s, industry standards will be in place which will provide practical architectures and methodologies for open system development.

GIS applications accessing and updating multiple business databases

This objective was met without reservation. Demonstration applications created, maintained and manipulated local databases of spatial and associated attribute data as well as accessing attribute data in the business data repository. ESRI's development of a relational database interface (RDBI) for the Rdb product was concurrent with this project and provided an access path into the business data repository.

GIS vendors have begun to integrate their proprietary geographic information systems with commercially-available database management Systems. Some of these integration efforts have taken advantage of OSI standards like Structured Query Language (ISO 9075), which facilitates the management and transfer of business data between the GIS and an SQL-compliant DBMS. This was the case with the prototype applications communicating with Rdb and Informix relational DBMS.

The function of a business data repository

Although not the 'ideal' architecture, the prototype repository provided a functional solution to the creation and maintenance of a sharable database of business information. The host procedure aggregates the contents of server-based and client-based business applications, which are distributed in various formats, into a sharable read-only database in a standardized format on the host.

Data management, particularly in a distributed environment, raises issues such as integrity, security, backup, etc., which are not resolved by current GIS technology. These data management concerns are largely an organizational problem which must be addressed by a complete business solution. The coordination of graphic data with non-graphic business data in a corporate infrastructure creates additional data integrity concerns. The two data
types have traditionally been managed somewhat independently of each other, which will inevitably lead to synchronization anomalies. When additions and/or deletions occur in one domain (graphic) and not in the other domain (non-graphic business data) concurrently, these compatibility concerns become apparent and are referred to as 'spatial referential integrity' problems. The integration of GIS must be a part of the business plan and is no longer merely a technological solution.

Again, the initial system design offered a gateway approach as well as the repository approach. Although the repository was prototyped, the ultimate solution would likely be a hybrid approach incorporating aspects of both the gateway and repository methods in a unified architecture.

A simple GIS user interface

When introducing geoprocessing capabilities to all levels of an organization, consideration must be given to the eventual users of these systems and the way in which they interact with them. The user interface component of these systems must be able to be customized to the specific job functions, needs and abilities of these users to allow for a clear concise dialogue to take place, while at the same time, hiding much of the overall complexity of the system. Both of the GIS products used in the prototype, ESRI's ARC/INFO and Intergraph's MGE, have enough maturity and flexibility in their Graphical User Interfaces (GUIs) to address the needs of expert users and beginners alike. They both contain a rich set of commands and functions for interacting with the system or for customizing the system to meet the specific requirements of the organization.

The application developer should have complete control over the appearance of the menus for each application. This means that, at any given time, only the relevant commands for performing particular functions are visible to the user on menus and available to invoke commands. Customized menus might include application-specific menus, or be used to limit or extend the range of GIS functionality based on user expertise or application requirements. The GUI makes extensive use of a pointing device (mouse), thus minimizing the amount of operator keystrokes. A sophisticated procedural command language is also required to allow the application developer to group system commands into macros or programs for execution. As noted above, in the discussion of the application program interface, this facilitates the use of the system by the largest population of corporate users: the casual user.

Conclusions

The implementation of a corporate geographic information system for the Ministry of Environment is technically feasible. The initial system design and subsequent prototype demonstrated the ability to effectively customize the execution of the GIS software, to implement distributed technology, and to adhere to the evolving guidelines for data sharing as set forth by the Land Information Strategic Committee (LISC). LISC is an inter-ministerial executive committee coordinating a government-wide land information management strategy.

A number of data management issues raised, but not resolved in this prototype, include database contention, two-phase commit, query decomposition and optimization, data encryption, and maintenance of the integrity between graphic and non-graphic business data. Data security and integrity issues must not be minimized.

Multiple hardware platforms can be accommodated, from low-end non-graphic terminals to mid-range PCs and workstations as well as high-end servers performing specialized functions. A variety of GIS products were integrated and supported by this design, with centralized GIS services for a broad range of users, as well as a number of specific products and systems necessary for those users with specialized requirements. Effective data sharing can be realized in a number of ways. Repositories of shareable information can be aggregated from multiple distributed DBMSs in various formats, gateways can be used to directly access distributed data in various formats and BC-SAIF and proprietary formats can co-exist.

Although the prototype implemented primitively specified design protocols, the underlying principles which facilitate data integration in a multi-vendor, distributed environment are a common data model, such as BC-SAIF, the recognition by software engineers that designing software using the OSI model will facilitate interchange between system parts, and that the ISO standard SQL be adopted for manipulation of associated business data. The future direction of corporate geographic information systems will be based on designs which are specified in terms of a coherent, layered framework which embrace recognized standards.

In this atmosphere of ever changing technology, adherence to recognized standards such as the OSI model, will ensure compatibility with a large number of organizations including the ability to link together systems which were not originally intended to be linked. This will provide a 'future-proof' design which can accommodate new technology. As changes related to open systems and inter-operability are just beginning to occur, decisions organizations make today may affect their future ability to exploit that potential.

References


Creating a Corporate Graphic Database: A Manager’s Perspective

R. Prokop
Timber Harvesting Branch, Ministry of Forests
1450 Government Street, Victoria, B.C.

Abstract
Various provincial agencies in British Columbia have been producing digital maps for a number of years. The process each agency uses duplicates much digital data, but a recent case study has brought these agencies together. The case study standardizes depiction, captures data using specific rules and moves information between agencies in a standard archival and interchange format. This paper, from a non-technical manager’s perspective, discusses some of the problems and successes associated with multiple agencies contributing to a corporate graphic database. A basic review of the pilot project is presented.

Background
In British Columbia, two ministries, Crown Lands and Forests, are major electronic mappers. Crown Lands is responsible for topography, planimetry, cadastral and Land Act tenures. The Ministry of Forests has the mandate to graphically represent forestry themes. This translates into forest inventory, forest tenures and forest related administration boundaries.

Within the Ministry of Crown Lands, the Surveys and Resource Branch is responsible for producing planimetry and topography. The Surveyor General’s Branch, part of the same Ministry, maps all primary survey parcels, leases, legal rights of way, authorities to occupy, associated administration boundaries and other similar areas of interest. The Timber Harvesting Branch of the Ministry of Forests captures all forest and range tenures, restrictions related to forest activities, and administration boundaries related to forest and range activities. The Inventory Branch of the Ministry of Forests maps timber types and forage classifications.

In the recent past there has been little data sharing. When available, the Inventory Branch would use pre-North American Datum (NAD) 1927 information from Crown Lands. When not available, they would create their own databases. The Timber Harvesting Branch is a more recent entry into the electronic mapping environment and has used Ministry of Crown Lands databases for all their work, which is based on NAD 1927.

All the graphic data captured thus far, in a production environment by all four of these players, has been topologically unstructured, captured using inconsistent capture rules to generally inconsistent standards and to non-compatible specifications using vendor-dependent formats. There is one major exception which will be discussed shortly.

This lack of coordination between ministries and branches, notably the Timber Harvesting and the Inventory Branches has resulted from:

1. electronic mapping activities starting at different times;
2. traditions associated with manual mapping being extended into the electronic environment;
3. different and products requiring decidedly different levels of accuracy; and

4. the normal biases and feelings of ownership associated with agencies competing in the same arena.

**Terrain Resource Information Management (TRIM)**

TRIM is the one exception mentioned above. It is a recent B.C. mapping project that provides digital baseline topographic and planimetry information at a 1:20 000 scale in a non-proprietary format. Data is captured to rigorous specifications. All data passes through a series of quality assurance steps. The Surveys and Resource Mapping Branch oversees this project, which began in 1986. Approximately 1 500 of the 7 000 files (mapsheets) required to cover the Province at 1:20 000 scale are complete. The initial learning curve was steep but the production rate now stands at about 600 files per year.

This graphic data is cartographically clean: all polygons close; all intersections are nodded; and rules defining adjacency and connectivity are followed. All water courses are captured according to the downstream rule and polygons are defined by the right-hand rule. This data, in comparison to the NAD 1927 data previously being captured, is consistent in quality and precision.

The non-vendor dependent data exchange format being used for this project is called MOEP, after the Ministry of Environment and Parks, which at the time was the Ministry responsible for TRIM. This format is limiting in that it can specify graphic information only and has no ability to represent attribute data. Translators exist that convert MOEP files to most vendor formats used for data capture, display, analysis, updating and amendment purposes.

**The Concept of a Corporate Database**

Everyone agrees that graphic data presently being captured by both Ministries is a corporate resource: agencies other than those capturing their specific information have a use for it. This includes users outside as well as inside the government. And it makes good sense that information should be captured only once. If the Ministry of Forests needs legal survey information, it should be supplied by the geographic information experts in that mapping field, which, in this example, is the Surveyor General’s Branch. The Ministry of Environment should be able analyze the affected downstream hydrology of a chemical spill without having to build connectivity and downstream rules into data they receive from the Surveys and Resource Mapping Branch.

In order for information to be compatible across mapping disciplines there are a few basic concepts that everyone can support in theory but often find it difficult to agree to in practice:

1. standard specifications;
2. standard capture rules; and
3. standard transfer format.

**Standard Specifications**

Standard specifications basically say that all 'mappable things' that are alike will be graphically described the same way. As an example, a river is different from a stream and will be depicted differently, but all streams will be depicted the same way, using the same codes and all rivers will be depicted the same way, using their own codes. The only difference between streams will be location, the only similarity between rivers will be depiction. The key point is that a unique identity is tied to each feature.

The second component is the precision and accuracy at which data is captured. Precision refers to the number of decimal places that will be stored for a particular feature. In a practical sense, precision is only applicable to data captured by coordinate geometry (COGO). Accuracy, in the context used here, refers to how precisely an operator can actually represent a feature on a map, by digitizing, with respect to how it really exists on the ground. At best, this becomes an educated guess.

**Standard Capture Rules**

Simply stated, by following some basic data capture rules, you can embed some Neanderthal intelligence into your data that can be built upon in the future. For example:

1. by digitizing water courses 'downstream', you can preserve the ability to ask questions of your data that rely upon water flowing downhill;
2. by associating a point, line or polygon with a particular feature, you can construct the topology of the feature; and
3. by capturing polygon boundaries such that the inside of the polygon is always defined as lying to the right of the boundary, polygons within polygons can be identified.

Without applying consistently data capture rules, you cannot associate or predict meaningful relationships between data.

**Standard Transfer Format**

A standard interchange format is a critical factor in graphic database scenarios where various players are capturing data within their areas of expertise, but sharing the outputs with others. I liken it to a series of different spoken languages. I may be able to express myself best in Polish, you in German, another person in Italian and a fourth person in French. Common to us all is a universal language such as Esperanto. This universal language is not nation-, or in the case of data, vendor-dependent. We should do our work in the format that best suits our needs and traditions, yet exchange our work in a non-vendor dependent format.
By exchanging data in a non-vendor dependent format, all data contributors must meet minimum specifications. The data receiver knows the data will be consistent in quality, precision and accuracy. Thus, it has the added advantage of keeping all players honest with respect to data quality.

**The Queen Charlotte Islands Case Study**

In May of 1990, a number of ministries in B.C. established a small working group to conduct a corporate graphic database pilot project. Once again, the major players were from the ministries of Crown Lands and Forests, though the ministries of Transportation and Highways, Environment, Municipal Affairs, Parks, and Agriculture and Fisheries did participate as well. The Corporate Land Information Strategic Plan (CLISP) is presently being developed for B.C.; its expectation is to provide a blueprint for exchanging land related information. The Queen Charlotte project was a practical hands on project, driven by the working level of the participating ministries and was intended to supplement the CLISP initiative at the working level.

The terms of reference were modest. Its purpose was to establish a suitable environment for the capture and transfer of a variety of resource based data, which can be geo-referenced, primarily between the Ministry of Crown Lands and the Ministry of Forests, in conjunction with other committed ministries.

Administrative and technical aspects of sharing data between participants were identified and addressed by:

1. defining data capture specification and extending the MOEP specifications to include the data from all participants;
2. capturing data using TRIM-like data capture rules; and
3. performing quality assurance checks on the data to a TRIM-like level.

From the very beginning, the intention was that this case study would be a learning exercise. The specific goal of the Timber Harvesting Branch, however, was to use what was learned as the basis for their mapping in areas where NAD 1983 data was available.

The specific deliverables identified in the terms of reference were:

- data specifications for each participant’s data;
- quality assurance procedures;
- data capture procedures;
- actually capturing graphic data using the previous specifications and procedures over a selected area; and
- a report documenting these activities and recommending further action.

Three map sheets on the east shore of Graham Island, in the Queen Charlotte Islands, were chosen. Choosing three map sheets was viewed as a modest undertaking that each participant could manage, yet at the same time, would provide ample scope to experience most problems. Additionally, it provided the opportunity to address edge-matching concerns since the map sheets were adjacent. Other specific reasons for choosing these three map sheets were:

1. TRIM files were already available for this area;
2. The Surveyor General’s, Timber Harvesting and Inventory Branches all have a moderate amount of activity in the area; and
3. other non-mapping ministries have selected information available which could be graphically represented.

The Surveys and Resource Mapping Branch already had their end product in the form of TRIM files for the case study area. The Surveyor General’s Branch, Timber Harvesting Branch, and Inventory Branch had to produce specifications, load data to those specifications, perform quality assurance checks and then put it into MOEP format.

The three remaining branches began setting specifications by first listing all the features that would be captured. This was a simple process, since most features were already being captured in their ongoing mapping initiatives. Then responsibility for capture was negotiated between players. This was more difficult, since many features are already being mapped by more than one of the three. This was followed by setting a capture standards such as accuracy and precision. With this accomplished, each branch proceeded to write their data specifications.

With draft specifications in hand, data loading began. Procedurally, timber tenue information could not be loaded until cadastral was available; the point of commencement for timber tenure is legally described from known survey points. These types of data relationships exist between all of the players, though at varying degrees. In the past, data was shared when and where available; where it was not available, each mapper would capture any information they deemed necessary to do their tasks.

The Surveyor General’s Branch completed their information and ran it through quality control. The Timber Harvesting Branch then referenced both the TRIM and Surveyor General’s Branch files and captured timber and range tenure information. This, too, was quality assured. The Inventory Branch then mapped all timber types to complete the cycle. Each time a file was completed, it was translated into MOEP format and passed along, with all previous files, to the next mapper.

The end product was four separate positional files, all with non-redundant data captured to predetermined specifications at the same positional accuracy and precision.
Further, the data resided in a non-vendor dependent format. Since all data was captured according to specified rules that maintained data structure, it was then possible to build a topology for each feature. This meant that polygons could be geo-referenced. Not just polygons on each file, but polygons could be mixed and matched between files. As an aside, some attribute data was attached to some of the polygons to make the GIS queries more realistic.

**Conclusion**

**What was learned from this exercise?**

First, the foundation for a corporate database is transferring information between users. This implies that numerous players will be capturing information, as well as using other players' information. This case study showed that moving information around in a standard format worked well. Because the format was non-vendor dependent, any system could work with the data, provided that a translator was available and a number of translators do exist.

Second, by adhering to specified data rules, information captured by one participant could be used in the same analytical way as data captured by any other participant. This includes being able to copy, on to your file, lines from a feature that resides on another player's file. Both lines are coincidental and remain positionally correct. For our uses, the rules associated with topological integrity are extremely important. But looking into the future, rules such as connectivity, downstream and others are also very important.

Third, quality assurance is paramount. Data is being captured using various systems and different formats. We found that the standard quality control software supplied by vendors was not always adequate nor was the custom quality assurance software written for the TRIM program. In all likelihood, custom quality assurance software will be required for each contributor to the corporate database, unless there is standardization on data capture software. Even then, there may be sufficient data differences to complicate the quality assurance tasks.

Fourth, the users of the data are faced with graphically representing the positional file in hard copy since no representational files were built. Some features are made up of lines and points that are coincidental with each other, that is, they lie on top of each other. In these instances, one boundary of one feature is very difficult to distinguish from other boundaries. As an example, there are instances in the Timber Harvesting Branch where lines are stacked seven deep. To date, there are two methods to deal with this problem:

1. at the time of data capture, build a representational file with all the coincidental lines offset. The additional staff time, disc space, file management and overhead problems are obvious; or

2. use colour fill. This is not always desirable because colour fill has its own overhead problems associated with creating the colour fill both on screen and on hard copy.

We are presently experimenting with electronically offsetting lines. To date, we are encouraged with our success.

To conclude, the Queen Charlotte Islands case study has encouraged all the participants to continue down the corporate graphic database path. The formal process will continue through the CLISP initiative. At the same time, valuable information has been gained which will assist in future decision making and will give direction to the Timber Harvesting Branch's mapping initiative.
Ten Steps to a Successful GIS

Theodore B. Coffelt
GEONEX Corporation
Denver, Colorado, USA

Abstract
A geographical information system is the embodiment of large-scale organizational practices. Paradoxically, many organizations undertake a GIS implementation without adequate preparation, exposing themselves to unnecessary stresses in both budgets and personnel. Major failures may result. Ten general but battle-proven steps to facilitate the process are presented.

Introduction
A GIS system may be the most complex project ever undertaken by an organization. There are many steps that an organization must take to develop a successful GIS system. Much has been written about these issues over the last several years. There are suggested methods of defining the data layers, determining color and shading methods, selecting a consultant, etc. As an industry, we have no loss for advice on organizing our GIS. The problem that many face is one where the organization must change in order for the project to be successful.

We all know what hardware and software are, but a new term has emerged recently, 'Orgware'. You may want to define Orgware as the instructions available to any organization on how to properly succeed in its task.

There are many steps to be taken toward successful completion of a project. These steps have been used over and over again and are believed to be universal principles. They are not ideas that are made up for a particular project or a particular event. In this paper, these steps have been digested down into 'Ten Steps For A Successful

Project'. They can be used not just for project management but also for managing your personal life. In this paper the emphasis and examples will be for producing a successful GIS project.

Step 1: Review Past Projects
When you're starting off on a major project, one of the first things you have to do is review all the things you've done before: review your past projects, take a look at what you've done before. Make a list of them. Sometimes, organizations really don't understand what they've been doing. Often there is turnover within organizations and some of the newer people don't realize that they are part of a major effort which began in years previous and that they are now seeing the benefits of that effort. What did you learn from these projects? What did you gain from them? When you make a mistake, seize the opportunity to learn from that mistake.

Many people know the frustration of starting on a project and when a problem developed, they stopped that project and then started another one and the next project they did exactly the same way. If you do things the same way, you're going to get the
same results over and over again. Try something different. Learn from the mistakes and apply the improvements on this new attempt.

Many organizations perform what's called a project post-mortem. When a project fails or when a bid is lost, you do a post-mortem on it: What did we do right? What did we do wrong? How would we do this differently if given the opportunity?

GIS is probably one of the most complex projects you'll ever be involved in. It is significantly more complicated than adding a few PCs in the office for word processing. Because of the power of GIS and the many diverse groups that could be involved in its implementation, you have the opportunity of changing the way your entire organization does business. This is very hard to do if you are sitting with an entire office full of other things that you are trying to get accomplished. You cannot do what you are doing now and develop a GIS at the same time. Many professionals have file drawers of old projects. Some of these old projects just need to be completed by writing the final report. Devote the time to clean these out.

Determine what you can't do and make a decision not to do it. There are things that probably can't be or shouldn't be done. Get rid of them. You must free yourself of your old projects; complete them or get rid of them!

**Step 2: Identify and Acknowledge Strengths**

Identify the strengths of the organization and acknowledge these. Most organizations don't spend any time recognizing their strengths. As an example, your organization could state some of the following:

- We are the best community organizers in our state. We've created neighborhood organizations and associations. We are far ahead of all the other communities.
- We train others.
- We bring projects in under budget.
- We bring projects in on time.

Sometimes things work and sometimes they fail. But the important thing is to identify and acknowledge the strength. As with anything, be realistic as well as thorough.

**Step 3: Determine the Mission or Purpose**

Determine and write the purpose or mission, not only of your organization, but also of the project. Once you have the purpose of your organization then you have the purpose of the project. Look carefully to see how these fit together. Do they fit with the purpose and mission of the larger organization? Do these plans work in concert or are they in conflict?

**Step 4: Set Goals and Objectives**

Outlining the goals and objectives of the project is a must. The old saying is "if you don't know where you are going then you can take any path to get there." This is a recipe for GIS disaster.

Establish deadlines. The point of a deadline is to have a consequence at the end. In order to meet your objectives you must have deadlines.

It is important for you to determine what needs to be done to complete the project on time. One way to do that is to display your goals up on the wall of your office.

One of the most important traits for any individual and any organization is the ability to say 'No'. One of the reasons why major GIS projects get delayed, miss scheduled deadlines and come in over budget is because additions are made to the GIS project scope. New projects and new applications are requested and the administrators of the GIS is unable to say no. They say 'sure' and, as a result, not only do they not get the GIS done but when you don't meet your deadline, the credibility of the project people and of the organization is reduced.

**Step 5: Visualize Success**

Show pictures of your successful project. Architects and planners have always done this. It helps people see the successful completion of the project. For a GIS system, put the analysis, mock-ups of the analysis, and maps on the wall of the office for all to see. Show the dates of when you are going to achieve these and how the data will be utilized for the organization.

**Step 6: Take Action**

Visualizing, Organizing, Clearing off your desk. None of these matter unless you take action. The root word of 'satisfaction' is 'action'; Visualizing is not enough. Good ideas are not enough. You and your organization must act on the opportunities that are put in front of you as well as create your own opportunities.

It is usually impossible to complete a major project by yourself. In our environment of declining resources, many are competing with several organizations for just a few dollars. You have to ask others for their support and assistance to get your project done. You can't do it on your own. The more people that help you with the project the greater the likelihood of your success. Ask others to participate. Once you have established the greater goal and once you say, "We're going to get this done by this date", it is amazing how many people will try to help you obtain your goal.
Step 7: Get Feedback

Once you start on a path, you need some feedback about the actions that you have taken. You have to know if you're going in the right direction and doing the right things. You've planned. You've taken action. You start walking down the path. Feedback guides you in the right direction.

Planning is really easy. It's implementing the plan that is tough. Part of the problem of implementing is this problem with feedback. It doesn't always happen automatically. You have to ask for it.

When you are asking for feedback, you not only ask at the top of the organization, you ask at the bottom of the organization. The people who are at the lower end of the organizational ladder are doing the production and the analysis work that you will need to achieve your goal. These people are frequently passed over. These are the ones who frequently have the best ideas.

Part of your review must include checking to see if you had the right ideas in the first place. You must ask "Was it an appropriate goal? Was it a realistic deadline?"

Step 8: Persevere

Calvin Coolidge said "Nothing in the world can take the place of persistence. Talent will not; nothing is more common than unsuccessful men with talent. Genius will not; unrewarded genius is almost a proverb. Education will not; the world is full of educated derelicts. Persistence and determination alone are omnipotent." There is a similar quote attributed to Winston Churchill, which says "Never give up. Never, never give up."

As you persevere, it is important to review the goals and objectives to make sure that they fit and are still appropriate. Review the mission to assure that it fits together with the goals and objectives.

Step 9: Reap the Rewards

After you've done all of the work for the GIS project, reap the rewards of your success. Celebrate the successes. Celebrate realizing the smaller, individual steps that were taken to reach the goal.

Step 10: Share the Success

Once you have it, you've got to share it. In order to have something, you have to give it away. Share your experience with others. Present papers. Give talks. Write articles for magazines. Help others in your neighboring communities to achieve what they are trying to achieve. Thank the people who helped you meet your goal because you couldn't have done it by yourself. Reward the people in the organization who helped you obtain your goals. One of the saddest things in an organization is when the leader takes all the credit.

Conclusion

The material presented in this paper has been written in brief outline form. Along with other GIS specific suggestions, the material outlined in this paper will help you and your organization implement a successful GIS project that will be good for your organization as well as good for your community.
Concurrent Session 17

Techniques - integrated database management
Creating a Digital Natural Resource Database
Technological Advancement in Forest Inventory
Managing the House that GIS Builds
Creating a Digital Natural Resource Database: The Results of the 1:250 000 Baseline Thematic Mapping Prototype

Malcolm Gray and Fern Schultz

Ministry of Crown Lands
Surveys and Resource Mapping Branch
VICTORIA, B.C.

Abstract

A Baseline Thematic Map is a natural resource database derived from processing satellite imagery in conjunction with digital topographic data. The database is comprised of three themes: present land use, ground cover and topographic features. Two scales are proposed corresponding to the two available digital topographic data sets, 1:250 000 and 1:20 000. Both scales utilize Landsat TM satellite image data. The motivation for this work is the development of an efficient, cost effective method of providing GIS compatible natural resource map data in a standardized form across the province.

This paper presents an overview of the methodology and results of the 1:250 000 scale Baseline Thematic Mapping prototype. A GIS compatible database covering 16,000 square kilometres was constructed that included: 8 land use types, 19 ground cover classes and four topographic attributes. Technical requirements of Baseline Thematic Mapping are presented, with the objective of implementing this concept as an operational mapping program.

NTS mapsheet 82 E (Penticton) located in the southern interior was the area chosen for the 1:250 000 prototype work. Input data consisted of a Landsat TM image (digital and hardcopy transparency) acquired August 22, 1987, the digital base map for NTS mapsheet 82 E, ground truth collected by two persons over four weeks in 1988 and 1990 and some existing map information.

Introduction

The Baseline Thematic Mapping (BTM) prototype was initiated to define a methodology for extracting thematic information from satellite image data and digital topographic data. The thematic information is intended to populate a natural resource database comprised of three themes: present land use, ground cover, and topographic features. The complete database would provide consistent, province-wide coverage in a format compatible with commercial geographic information systems (GIS). The primary motivation for this work is to satisfy the increasing demand for natural resource information that is GIS compatible, comprehensive, up-to-date, and cost effective.

The approach taken in establishing the BTM methodology was a comprehensive evaluation of the potential for information extraction from satellite imagery, analyzed in conjunction with digital topographic data. This paper reports on the methodology developed for 1:250 000 scale mapping. The area of interest is National Topographic Series (NTS) mapsheet 82 E covering 16,000 square km in the southern Okanagan Valley. The methods employed in creating each of the three themes comprising the BTM database are summarized below.
The present land use theme was derived from a manual interpretation of a colour transparency of the satellite image. The land use interpretation was accomplished by projecting the satellite image onto a paper plot of the digital 1:250 000 mapsheet. The interpretation was then digitized into this digital file and the attributes loaded into the database.

The ground cover theme was derived from a supervised classification of the digital satellite image data. Other required image processing included 2-D rectification, image mosaicking, data volume reduction, context filtering and error assessment. The image was stratified before classification to strengthen the spectral classification process. Eleven broad strata were defined, based on present land use, topographic or ecologic zone and illumination considerations. Classification accuracy was assessed by using ground truth to construct error matrices for the ground cover classes of interest. The raw classification was context filtered to reduce the complexity in a cartographically acceptable manner. Context filtering amalgamates small areas with neighbouring classes based on user supplied criteria. The ground cover theme was then transferred to the GIS domain for further editing and inclusion in the database.

The digital topographic information is in the form of scanned contour lines. The published paper 1:250 000 NTS mapsheets have been scanned and are available from Energy, Mines and Resources Canada as digital files. A digital elevation model (DEM) was produced from this data as a regular grid (100 m spacing) of elevation, slope and aspect values.

The following is a summary of the schema for the three themes of the prototype Baseline Thematic Map Database for NTS mapsheet 82 E.

**BTM 1:250 000 Prototype Schema**

**Landuse**
- Urban
- Agriculture
- Rangeland
- Logging Clear-cuts
- Forest
- Alpine
- Rock
- Water

**Ground Cover**
- Agriculture
  - Orchard and Vineyards
  - Irrigated Crops
- Forage and/or Grazing and/or Shrub covered
- Rangeland
  - Range (steppe and savannah)
  - Sparsely Forested Range

**Logging Clear-cuts**
- Disturbed Soil, Rock and Slash
- Herb and Grasses
- Shrub and Deciduous
- Regeneration, Shrub and Herb Mixtures
- Immature Coniferous (< 10 m height)
- Coniferous Forest (this class because some areas of many small clear-cuts were mapped as a single land use polygon, thus they included mature coniferous forest)

**Forest**
- Wetlands and Meadows
- Sparse (less than 25% canopy closure)
- Open (26 to 65% canopy closure)
- Dense (more than 66% canopy closure)

**Alpine**
- Rock
- Krummholz
- Alpine Meadow
- Subalpine Forest

**Topographic Features**
- Elevation (average)
- Slope (average)
- Aspect (dominant)
- Watershed

**Present Landuse Methodology**

Landsat thematic mapper (TM) image data were used for both this theme and the ground cover theme. The present land use was derived from a manual interpretation of a colour transparency hardcopy (TM bands 5, 4 and 3 displayed as red, green and blue). The imagery was acquired on August 22, 1987 and included the area covered by the 1:250 000 Penticton NTS mapsheet (82 E). This task was accomplished under contract.

**Classification Scheme**

A modified version of the schema for Land Use Classification in British Columbia (Sawicki and Runka 1986) was used to categorize the present land use activities identifiable in the interpretation of the transparencies. Generally, the highest level of the land activity classification hierarchy was used, with the inclusion of some secondary and tertiary classes where these were clearly differentiable. No fourth level classes were identified although four additional modified classes were added. The level of generalization was appropriate for the 1:250 000 output scale. In some areas, particularly agricultural areas, the level of detail interpretable from the image data would allow for lower level classes to be included. In other areas, the level of detail interpreted was limited to that suitable for inclusion in 1:250 000 scale thematic map output.

**Database Creation and Evaluation**

The present land use was interpreted from the satellite image transparency using a PROCOM projection device. This device projects the transparency onto a paper base
map and the features of interest are simply drawn directly onto the map. In this case, the base map was a plot at 1:100 000 of the 1:250 000 digital file for NTS mapsheet 82 E. The interpreted present land use features were then digitized into the digital map file for 82 E. Attribute data (polygon numbers and classification codes) for each polygon were included in a dBase III PLUS database.

The estimated map accuracy for the eight general classes was approximately 75 per cent before editing and approximately 85 per cent after editing. This estimate was arrived at by inspection of this theme overlaid on enhanced imagery and by reference to topographic maps and local knowledge of the area.

**Ground Cover Methodology**

Ground cover thematic information was derived from digital Landsat TM imagery of the same data as the transparency hardcopy. These data were received as a systematic georeferenced full scene covering an area measuring 184 km by 172 km.

Digital image analysis procedures were applied to the image data including geocoding, mosaicking, and digital classification for ground cover. Although seven bands were available for this digital analysis, only TM bands 2, 3, 4 and 5 were utilized in the classification procedure.

**Georeferencing**

Two-dimensional rectification of Landsat image data involves the identification of ground control points on the image which correspond to features on the associated paper or digital map. Forty-five control points were identified in the image data and on the sixteen 1:50 000 paper map sheets that cover the 1:250 000 sheet. The image was then warped to fit the map, with the RMS positional error estimated to be 75 metres in both the x and y directions.

At this stage, the pixel size was resampled from 30 metres to 25 metres (pixel = picture element; a single grid cell of the scanned image). This was done because 25 m is a standard size for geocoded Landsat TM imagery and for ease of transfer to and from GIS files, since 25m nests evenly within a 100 m interval.

The availability of the digital elevation model allowed for the explicit correction of relief displacement. This correction was not applied to the 1:250 000 prototype image data set because relief displacement was not a significant concern at this small scale, with maximum expected displacements of approximately 1 mm at 1:250 000.

The issue of relief displacement has been investigated utilizing 1:20 000 TRIM (Terrain Resource Information Management) digital elevation models. The software development is complete tests confirm the usefulness of the technique, with accuracies of ±30 m (one pixel). In high relief areas, with relief greater than 1000 m and at large mapping scales, scales larger than 1:100 000, this approach and the associated processing is justified. This is particularly important in British Columbia when producing thematic mapping from Landsat TM data at 1:20 000 scale. At smaller scales, such as 1:250 000 or where there is little relief, the two-dimensional correction is adequate.

**Mosaicking**

Complete coverage of the entire 1:250 000 NTS map sheet (82 E Penticton) used for the prototype required image data from more than one Landsat TM scene. A Landsat scene is equal in area to about two 1:250 000 sheets, but the angular tracking of the satellite as it acquired the image scene resulted in the southeast corner of the map area (82 E) being excluded from the main digital image. When ordering image data the user can specify location along swath in a north-south direction but the east-west location is constrained by the satellite's orbit.

Additional image data, from July and August 1985, for that corner was incorporated into the larger digital image through image-to-image registration and mosaicking. The resulting image covered the entire prototype map area with little noticeable difference in the radiometric balance between the portions of the mosaicked image originating from different scenes. Because of this and because of the small area covered by the additional imagery no radiometric correction was performed. In this case, the area was very small, covering less than 5 per cent of the total mapped area, and the ground cover was primarily forested with a few small logging clearcuts. The additional processing involved in selecting separate training sites for cover classes and resolving any inconsistencies between the statistics generated for the main image and the small corner area was not justified in this case.

**Data Volume Reduction**

A major consideration in dealing with the digital image data was managing the large data volume. At full resolution, using the 25 m by 25 m pixels, each band is a 28 Mbyte file. For each operation performed in the digital analysis domain, one or more files of equal size would be generated, resulting in a tremendous demand on the physical storage capacity of the PC-based image analysis system. In addition, the time involved in processing files of that size would be prohibitive, even for relatively simple operations. Under these circumstances, a test was performed to compare classification results using the full resolution of the image data, using the 25 m by 25 m pixel size, with classification results using imagery resampled to 100 m by 100 m pixel size. The data volume was reduced by a factor of sixteen (28 Mbyte input to 1.8 Mbyte output) through this procedure.

The test was performed on a small data sample for which good ground truth was available to facilitate accuracy assessment. This sample was a composite image of five locations consisting primarily of logging clear cuts. Both the 25m full resolution image and the 100 m resampled version of the same image were classified using the Bayes Maximum Likelihood classification algorithm with bands 5, 4,
and 2 as input. The resulting classified images were compared to the corresponding truth images for the area. Context filtering was applied to each of the classified images to simulate the results which would be required in completing the classification of the image covering the entire area.

The error assessment routine involves a pixel by pixel comparison of a truth image versus a classified image. The resulting matrix contains both the user’s and producer’s accuracies on a class-by-class basis. Comparisons of overall mapping accuracy for pre- and post-context filtered versions actually show a slight improvement in classification accuracy from 79% to 83%. The results of the data reduction tests indicated no meaningful loss of classification accuracy in reducing the data from the 25 metre full resolution pixel size to the 100 metre pixel size. The use of the resampled imagery was justified in this manner and further processing of the 1:250 000 prototype data set proceeded using the reduced data set.

**Digital Image Classification**

Classification of digital satellite imagery requires the delineation of training sites to be used for the generation of classification statistics. The classification may be performed on the full image, or may be restricted to a particular area of interest. The ground cover classification for the BTM 1:250 000 prototype consisted of a number of separate classifications. The classification effort was stratified by land use, ecological zone and illumination conditions. This was done to make the spectral classification process more robust by limiting the number of variables affecting the signatures of the ground cover. Pre-classification stratification also made error assessment simpler because of the limited number of ground cover types.

The detailed land use codes produced in the present landuse interpretation were generalized into eight levels for transfer from the GIS to the image analysis environment. The eight strata covered alpine, forested, logging clear-cuts, rangeland, agriculture, urban or commercial, water and rock. Five of the eight bit-maps were used as masks in the classification procedure, with rock, urban/commercial and water not classified in the ground cover processing. A similar sequence of steps was used to perform the classification for each strata under the appropriate area, with some additional refinements incorporated for the forest strata.

**Training Site Delineation, Signature Generation and Classification**

Training sites were identified for the logging clearcuts from detailed ground truth information collected during September 1988, corresponding to the same time of year that the satellite image data were acquired in late August 1987. Eighteen signatures were generated from TM bands 2, 4 and 5 for classes including bare soil or rock, slash areas, herbs, grass, shrubs, deciduous and coniferous regeneration ground cover types.

Training sites and signature generation for the rangeland and alpine strata were determined by identifying broad cover types of the digital image in the area under the appropriate mask. These classes were based on colour, brightness and, to some degree, by topography. Six rangeland signatures and four alpine signatures were generated from these training sites.

The training sites for agricultural classes were defined using class information from existing 1:20 000 scale present land use mapping digital files for parts of the area, which were derived from photo interpretation and intensive field work, and from ground truth of a more general nature collected through field work for this project. Signatures were produced for four agricultural classes.

For the forest strata, ground truth was determined from Ministry of Forests (MOF) 1:20 000 digital forest cover maps. These digital files contain detailed information such as species, crown closure, age class, height class, etc. One 1:250 000 map includes one hundred 1:20 000 maps. Nine map files were used for ground truth. Treatment of the forest strata is addressed in greater detail under Forest Classification Stratification.

Supervised classification was performed for each of these five strata, with TM bands 2, 4, and 5 input for classification of the alpine, logging clearcuts and rangeland strata, while the agriculture and forest classifications also included TM band 3. The Maximum Likelihood classification algorithm was used for all classifications.

**Forest Classification Stratification**

The forest cover mask overlays a substantial amount of the source imagery, an estimated to be 70 per cent, and contains a wide variety of forest types. In an attempt to produce a more accurate classification of the forest types, the overall forest cover area was stratified based on elevation and illumination as follows:

- below 1250 metres, designated as low;
- above 1250 and below 1870 metres, designated high;
- above 1870 metres, designated as subalpine;
- high illumination, designated as sunny; and
- low illumination, designated as shady.

The lower elevation break corresponds to the interior Douglas fir to montane spruce biogeoclimatic zone change for the western part of the map sheet.

Relative solar illumination was calculated for the sun position at the time of image acquisition. At mid-morning (Landsat imagery is always acquired at the same time for any one spot on the globe, about 10:30 for southern B.C.), the sun is in the southeast, specifically at an elevation of 47 degrees and an azimuth of 147 degrees for August 22, 1987. The sunshaded image, appearing much like a shaded relief map, did not determine cast shadow areas but shadows represented less than 5% of the total area for this
summertime acquisition date. The resultant sunshaded image was displayed along with two other bands of TM imagery. The sunny/shady threshold of the sunshaded image was interactively manipulated to determine what illumination threshold would mimic the obvious illumination differences visible in the imagery. These stratifications resulted in six areas within the forested area:

- Forested - High and Sunny;
- Forested - Low and Sunny;
- Forested - High and Shady;
- Forested - Low and Shady;
- Forested - Subalpine and Sunny; and
- Forested - Subalpine and Shady.

The six strata were each classified into three canopy closure classes and a wetlands/meadows class; wetlands and meadows were only extensive in the subalpine and high elevation strata. The canopy closure classes were: Sparse (less than 25%), Open (greater than 26% and less than 65%), and Dense (greater than 66%).

Context Filtering, Modal Filtering and Class Amalgamation

The requirements of output at 1:250 000 scale are such that the reduction of the complexity of the classified image is necessary. This is both to produce a cartographically acceptable presentation and to accommodate possible limits in the GIS environment in which the thematic database will reside. Simplification of the classification output was achieved through post-classification processing using the context filtering routine developed in-house. Context filtering introduces the concepts of adjacency, similarity between classes, and minimum polygon size. Small areas are merged or not merged with a neighbouring class based on their similarity, length of shared boundary and area. This capability allows a great deal of control over the generalization of the raw classification and produces a cartographically acceptable final map.

Polygons defined in the context filtering process were retained at a minimum size suitable for presentation at the 1:250 000 output product scale. This was set at 200 hectares for the 1:250 000 prototype, which equals 200 pixels for the 100 by 100 metre pixels. For the clearcuts, the minimum size was set to a smaller size with some individual clearcuts being only 30 hectares. It was not considered desirable to merge these areas into the surrounding forest areas because clearcuts are so highly differentiated from the surrounding forest. Subsequent to the post-classification processing in the image analysis domain, the classified image was transferred to the GIS for further processing.

The highly detailed result of the classification and context filtering procedures produces some very convoluted boundaries between class polygons. These were smoothed to reflect the level of detail appropriate to the 1:250 000 scale of interest. This was accomplished by applying a 3 x 3 or 5 x 5 modal filter to the output files.

The complexity of the classification schema was reduced by amalgamating selected classes, through the application of an appropriate look-up table. This process resulted in nineteen final ground cover classes.

Error assessment

After final class amalgamation and field validation of the prototype, error assessment matrices were produced for all classifications. Overall classification accuracy results for the five classified strata are summarized below:

<table>
<thead>
<tr>
<th>LAND USE</th>
<th>Number of Ground Cover Classes</th>
<th>Overall Thematic Mapping Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>3</td>
<td>89 %</td>
</tr>
<tr>
<td>Rangeland</td>
<td>2</td>
<td>84 %</td>
</tr>
<tr>
<td>Forest</td>
<td>4</td>
<td>84 %</td>
</tr>
<tr>
<td>Logging Clear-cuts</td>
<td>6</td>
<td>86 %</td>
</tr>
<tr>
<td>Alpine</td>
<td>4</td>
<td>97 % *(note)</td>
</tr>
</tbody>
</table>

(* Note: Overall thematic mapping accuracy for the Alpine area was assessed for 2 classes only due to accessibility in field validation.)

Topographic Features

The topographic features for BTM are derived from digital topographic data. The National Topographic Series (NTS) 1:250 000 maps have been scanned to generate digital files. Coverage is available for the entire province. The digital file for 82 E, the prototype area, was obtained and used for the base map and also to generate a digital elevation model (DEM) for the area.

Aside from the use of the DEM for pre-classification stratification, average elevation, slope and aspect attributes were allocated to every ground cover polygon. Additional topographic information has been included in the BTM database in the form of major and minor watersheds, digitized from Ministry of Environment, Water Management Branch records.

It was found that scanned contour lines alone do not provide a well-controlled model of the topography because all of the information is, of course, restricted to certain elevations which depend on the contour interval. Data restructuring has been undertaken, including the creation of a DEM based on a subset of the contour line points, interpolated mass points and hydrographic breaklines. This work was performed under contract for a different 1:250 000 mapsheet than that of the prototype. A significant improvement in the resulting digital elevation model is achieved through this process. Specifications have been developed for the application of this data restructuring for all of the 84 1:250 000 map files covering B.C. (Ministry of Crown Lands, 1990).

GIS Integration

The completed ground cover classification was transferred to the GIS. Polygons were defined based on the ground cover classification, and attributes were attached in.
the associated database. Although context filtering results in a single ground cover attribute for each polygon, the proportions of the four main ground cover types making up the polygons could be extracted from the pre-context filtered classified image. This was accomplished by overlay processing within the GIS and the four predominant ground cover classes were included in the database, expressed as percentages.

The composite number of polygons for the various strata covering the entire map area is 2345. This is in keeping with the maximum number of polygons manageable by some GIS, and is also intended to satisfy cartographic standards in presentation of the map information at the 1:250 000 output scale. Additional polygons would introduce a high level of confusion for users.

**1:250 000 Prototype Results**

The 1:250 000 Baseline Thematic Mapping prototype is comprised of three themes, present landuse, ground cover and topographic features. The product consists of two digital files; one graphic and one database. The database attributes include land use, ground cover, proportions of unfiltered ground cover classes, average elevation and slope, dominant aspect and watershed. These attributes are listed in Table 1. The landuse theme included 1368 polygons for the eight general land use classes, the entire 1:250 000 mapsheet area. Ground cover classification produced 2345 polygons the prototype area.

**Table 1. Baseline Thematic Mapping Database Attributes**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polygon #</td>
<td>346</td>
</tr>
<tr>
<td>Present Land Use</td>
<td>Logging Clear-cut</td>
</tr>
<tr>
<td>Ground Cover</td>
<td>Disturbed Soil</td>
</tr>
<tr>
<td>Pre-Context Filter Ground</td>
<td>70% Soil 22% Herbs 6%</td>
</tr>
<tr>
<td>Cover Proportions</td>
<td>Shrubs</td>
</tr>
<tr>
<td>Average Elevation</td>
<td>1150 Metres</td>
</tr>
<tr>
<td>Average Slope</td>
<td>12 %</td>
</tr>
<tr>
<td>Dominate Aspect</td>
<td>South Southwest</td>
</tr>
<tr>
<td>Watershed</td>
<td>Mission Creek</td>
</tr>
</tbody>
</table>

**Conclusions**

The derivation of a 1:250 000 scale digital natural resource thematic database from the analysis of Landsat TM imagery and digital topographic data has been demonstrated. The product is called a Baseline Thematic Map and is comprised of three themes, land use, ground cover and topographic features. This methodology can be an efficient, cost effective approach to providing GIS compatible natural resource map data in a standardized form. Based on this methodology, it is feasible to propose an operational program to produce Baseline Thematic Mapping at 1:250 000 for the entire province.

**References**


Technological Advancements in Forest Inventory

Chris Webber
GIS Project Manager
DataSpan/UGSL
207 - 1682 West 7th Ave.
Vancouver, BC V6J 4S6

Joe Weiss
Head of Photogrammetry

W.T. Dawson
Photogrammetry Supervisor
Fletcher Challenge Canada Ltd.
9th Floor - 700 West Georgia St.
Vancouver, BC V7Y 1J7

Abstract
To efficiently manage its forest resource, both environmentally and economically, Fletcher Challenge Canada Ltd. has been using the latest technological advances to aid in forest inventory. Fletcher Challenge Timberlands Department, in conjunction with DataSpan/UGSL, have developed an automated process to digitize attributed forest polygon classifications from orthophotos derived from high elevation (1:6 000 - 1:70 000) TRIM imagery. The automated digitization process involves scanning of the orthophoto map, editing, and digital mosaicing to provide a topologically clean, highly accurate GIS digital product. The techniques used to derive this product allow Fletcher Challenge Canada Ltd. to appreciate a cost saving at each level of the project. The final digital product is being used to aid in field sampling intensity planning, preliminary inventory analysis, forest classification field work verification, forest classification finalization, annual allowable cut (AAC) calculations, logging development plans, cut block layouts, and road designs. Such flexibility is available only because the digital data is accurate enough to be used at scales suitable for both operational and inventory mapping.

Background
Fletcher Challenge Canada Ltd. wood products is composed of three corporate entities: Coast Wood Products; Northern Interior Wood Products and South Interior Wood Products. To best suit their needs, each of these corporate entities have chosen their own Geographic Information System (GIS). Based at Fletcher Challenge Headquarters, the Timberlands Department presently compiles forest inventory and operational mapping for Fletcher Challenge Canada's holdings within British Columbia.
DataSpan/UGSL is a joint venture between DataSpan Technology Inc. of Alberta and Underhill Geographic Systems Ltd. (UGSL) of British Columbia. For the past six years, DataSpan have owned and operated the highest resolution service bureau scanner in North America. UGSL is a GIS service bureau providing data conversion, custom software, and project management for industry and various levels of the public sector.

Together, Fletcher Challenge Timberlands Department and DataSpan/UGSL have worked on the Ospika River project, a 700,000 hectare digital forest inventory project in the MacKenzie Timber Supply Area (TSA) of North Central British Columbia.

**Introduction**

Accurate, cost effective field inventory and operational mapping must be carried out in many stages. The first step in this mapping process involved the production of 1:20,000 rectified orthophotographs, with a stereome, from high elevation TRIM aerial photography (1:60,000 to 1:70,000). Forest cover polygons and attribute information, drainage, roads, and helipads were typed directly onto the 1:20,000 orthophotos. This information was then scanned directly from each individual orthomap. The digital information from each orthomap was edge tied and any source document discrepancies were highlighted in red on a digital test plot. The Timberlands Department made the necessary modifications to the highlighted areas manually, utilizing the original orthophotos as reference. DataSpan/UGSL incorporated these modifications and produced a GIS-ready digital product. The Timberlands Department field rectified the digital data, and subsequently is able to use this product for many planning functions both in the field and the office.

Drawing on the experience attained during the project, this paper will justify the methodology used to derive the final product, both in financial and mapping terms.

**Forest Inventory Objectives**

Throughout the project Fletcher Challenge Canada Ltd. has maintained the following objectives for their mapping products:

- To provide inventory tree quality information of sufficient detail not only for existing mill supply forecasts, but also for future mill improvement and new facility construction; and,
- To provide a preliminary analysis of other resource values currently existing in the TSA, and to develop a long term resource inventory program for data collection and assimilation.

**Mapping Requirements**

The three year goal of this field inventory is to complete a forest inventory analysis of the MacKenzie region, an area of over six million hectares. To allow the type of forest management analysis required, a GIS approach will be necessary.

Current MOF methodology requires 1:15,000 - 1:20,000 low elevation photos be made available for forest stratification and forest attribute labels. In the MacKenzie TSA, there was little or no current low level photography available and, due to weather conditions, obtaining full low level photo coverage would require up to three years and an estimated $750,000 to $1,000,000.

Traditionally, forest stratifications would be designated from the low level photography using the mechanical Kail plotting process. Current techniques of Kail plotting the low level photography forest classifications would require that the TRIM base map and the low level aerial triangulation, for photogrammetric transfer to TRIM mapping, be completed. The approximate cost of aerial triangulation alone, at $50 per model, is $1.8 million. In addition, based on studies done for the Provincial government, Kail plotting is not capable of meeting TRIM positional standards in BC, and therefore does not provide an acceptable product.

Instead, forest stratification and attribute labels were obtained from 1:20,000 orthophotos and subsequent stereomes utilizing a high quality mirror stereoscope with 3x power binoculars. The resultant base mapping and forest stratifications are in the government standard format and meet the positional accuracy required by the TRIM standards (see TRIM release 3.1). In general, Fletcher Challenge Canada Ltd. must fit into the MOF's long range goal of adopting the MOEP government standard and incorporating their forest cover, range and recreation Inventory Branch information with the Timber Harvesting Branch (ATLAS), Surveyor General Branch (Cadastre) and the Surveys and Resource Mapping Branch (TRIM base map) information.

**Fletcher Challenge's Approach to Data Collection**

Fletcher Challenge has been utilizing high elevation TRIM photographs to produce corporate inventory and operational mapping for the past ten years. Use of high elevation photography, in conjunction with photogrammetric
stereoplotters, produced topographic and forest polygon mapping at a scale of 1:10 000 in the MacKenzie TSA. The resultant map met Fletcher Challenge Canada Ltd.'s standards in regards to polygon size, to the detail of label information, and to operational requirements.

Conclusions Related to the Data Collection Approach

Based on Fletcher Challenge Canada Ltd.'s past experience, several facts relating to the MacKenzie inventory have become evident:

- Low level photographs and the traditional procedures were both impractical in terms of cost and time frame constraints;
- High elevation TRIM photographs, as well as block aerial triangulation, were available over the entire MacKenzie TSA;
- Fletcher Challenge technology had demonstrated that forest stratification standards could be met utilizing 1:70 000 TRIM imagery;
- Limited in-house staffing required that contract photo-interpretation was necessary, which required the production of the 1:20 000 orthophoto and stereomates to utilize conventional photo interpretation;
- Cost for a controlled photogrammetric map-based product, produced from the TRIM imagery with TRIM control points was significantly less and made it possible to commence the project immediately in the summer of 1990; and,
- An orthophoto with a stereomate was required for stereoscopic viewing. This allowed classifiers to use present equipment and produce a base map and forest stratifications.

The greatest advantage of the orthophoto product is that the resulting classified orthophoto is capable of being directly digitized. Low level techniques require an interim step of photogrammetric transfer with its associated cost and editing.

In summary, the 1:70 000 high level aerial photography has the necessary resolution for classifiers to stratify the photos to meet corporate and Ministry of Forests specifications. Forest stratification from high level aerial photography was produced for approximately one third the cost of traditional low level photographic processes.

Methodology

Due to the need to provide a tremendous amount of stratification and preliminary attribute labels in the primary stages, orthophoto coverage would be obtained for approximately fifty percent of the area of priority. This was to assist in obtaining the ground sample plots to adequately sample stratum types within the supply blocks, specifically for those areas with the highest amount of merchantable timber.

The orthophotos with stereomates were then distributed to the contract forest classifiers. The orthophoto product was proven to have the necessary resolution to stratify and attach forest labels to the polygons. The polygons had an average size of 15 to 20 hectares, depending on the forest's productivity.

The classifiers have also interpreted planimetric detail which served as an interim base map until the final TRIM base map was available. This base map information was digitally separated from the forest cover overlay in the automated digitizing process.

Results of Data Collection

The source document for digital data conversion was an orthophoto map based on TRIM imagery, superimposed on a NAD83 UTM grid to facilitate digitizing and subsequent mosaicing of the polygons. The source document is, in essence, a highly accurate orthophoto-based thematic map, which can meet government specifications and address long term strategic operational planning.

Digital Data Conversion

Digital data conversion included scanning typed orthomaps (typing included forest cover polygons and attribute information, drainage, roads, helipads, etc.), separating this information into layers, mosaicing adjacent digital orthophoto files into seamless data sets and cropping these files into British Columbia Geographic System (BCGS) map sheets. To complete the digital conversion of this 700 000 hectare project area in the required two months, DataSpan/UGSL produced an average of 16 000 hectares of final product per working day.

Providing topologically correct data files requires comprehensive data validation and editing functions. The tools used to provide this volume of digital data can be isolated into the categories of project management, data conversion processes, and software. All phases of the project management were vital to provide expedient solutions, which the project team could support, to the technical problems that arose. DataSpan's high resolution scanner provided the required precise geometrical representation of the source data. The data editing process has been aided by the proprietary software developed by DataSpan in cooperation with the National and Alberta Research Councils.

The success of this project has highlighted several advantages of this digital data conversion system when used for forest inventory and operational mapping requirements. These advantages include delivery of topologically correct data files through a comprehensive data validation and editing system, exceptional data handling capabilities, and precise geometrical representation of source data.
Data Validation and Editing Capability

One of the most significant advantages of this data conversion system is the ability to provide topologically correct data files for uploading to a GIS.

To streamline the validation and editing of these large and complex data sets, several automatic software processes have been developed. These processes involve the removal of all spurs (undershoots and overshoots), checks to ensure nodes were mathematically correct, and the detection and flagging of source errors which can include unlabelled forest cover polygons, forest cover polygons with multiple labels, and incomplete line work. Utilizing specially developed software routines, spurs were removed automatically while improperly connected nodes and other similar problems were queued for interactive rectification on the graphics terminal. As required, source-related labelling and line work errors were highlighted on a check plot for review and modification. These unique software abilities ensured significant cost and time savings throughout the GIS loading and processing sequence.

Attribute Data Handling Capabilities

Within this conversion system, all forest polygons were mathematically linked to the appropriate attribute information through the use of an 'intelligent' geographic marker and related intelligent user data file system. The simplicity of this approach offered significant advantages over traditional techniques of linking each polygon to its attribute through a 'unique' polygon number. These advantages became evident when adjacent files needed to be mosaiced or a digital data segment was cropped out of a larger seamless data base. Utilizing the DataSpan/UGSL system, the potential complexities associated with duplicated polygon numbers, non-matching ASCII files, and other source and 'unique' polygon number errors were eliminated. These processes were completed quickly and efficiently by manipulating a series of 'intelligent' markers.

After all mosaicing and cropping operations were completed, the user data file was sequentially numbered and a polygon number associated with each marker in the graphics file. An ASCII file of polygon numbers and corresponding attribute data was also prepared. In this way the host GIS could build topology for future analytical processing.

The final process before delivery of the data was the generation of additional polygon attribute data in the format required. The polygon attribute data included polygon area, UTM position and UTM polygon number, a subset of UTM position. Fletcher Challenge Canada Ltd. can refer to any attribute or combinations thereof, in a digital or hard copy form, for planning and review purposes.

Geometrical Representation

One of the principal advantages of scanning the base information from the source document is the geometrical accuracy with which the line work is replicated. Utilizing these data conversion and editing techniques, the digital line work precisely overlays the original source document or its digital raster representation. This precision results in improved accuracy and validity of results (timber volume, AAC calculations, etc.), ease of uploading, and an overall development of confidence in the data set. In general, this scanning process eliminates the inconsistencies introduced by the human element in providing precise, clean digital data, and provides this superior product at a projected 30% lower cost.

The Final Deliverable

To this stage, the final deliverable was a prelabelled forest inventory BCGS map sheet, which had not yet been ground-truthed. Ground-truthing verified that 85 to 95% of the pre-labelling was valid. Fletcher Challenge Timberlands Department have had to re-address a maximum of 15% of the labels and a maximum 5% of the stratification line work.

Use of the Digital Data

Producing digital data early in the forest inventory allows for many additional updating and data generalization functions once compiled utilizing traditional laborious processes. As an ongoing process, any data additions or deletions to forest cover polygon information are easily made by simply editing the intelligent user data file and the associated graphics file. Fletcher Challenge Canada Ltd. uses the prelabelled BCGS map sheet for:

- field sampling intensity planning;
- preliminary inventory analysis;
- forest classification field work verification; and,
- forest classification finalization.

The geometric accuracy of the data allows it to be used to in the same way that traditional operational mapping is used, namely for:

- annual allowable cut (AAC) calculations;
- logging development plans;
- cut block lay outs; and,
- road design.

Fletcher Challenge Canada Ltd. also uses the data at scales from 1:10 000 to 1:50 000. The forest cover classifications were much too dense to be useful at 1:50 000. To produce a legible product at such small scales required data generalization. Using DataSpan/UGSL software, selected linework is deleted and selective topological building is performed to connect the remaining line work. Generalizing this level of mapping requires generalizing labels as well as line work. Label generalization often involves selecting a separate classification from those previously attributed to individual polygons. Digitally relabelling only requires only simple graphic and ASCII file editing.
Conclusion

This project has proven that the described methodology of forest inventory and operational mapping more accurately and expediently produces easier to manipulate digital data. The cost associated with orthophoto collection is one third the cost of utilizing the traditional methodology to collect the forest stratification data. The cost savings do not end here; in fact, the cost of the automated digital data upload used is projected to be thirty percent less than the cost of manual digitization. This project has successfully demonstrated a more cost effective method of forest inventory.
Managing the House That GIS Builds

Tony Hart
State Land Information Council
Sydney, Australia

Abstract
The ability of modern computers to handle spatial information has stimulated the interests of many who felt themselves in danger of missing the technological information revolution. GIS gives surveyors, geographers, planners and natural resource managers the opportunity to use computers for the collection, management and manipulation of data for spatially-based decision making. But GIS has a power, unlike many other computing applications, which has yet to be properly harnessed, a power which extends beyond its mere technical horizons. GIS breaks down barriers, barriers that in the spatial data arena have created separate disciplines, even professions. No longer can special spatial data management skills remain the specific preserve of particular professions.

To fully benefit from GIS, traditional data management processes must change; yet, historically, these processes have provided the foundation from which some special-purpose agencies have emerged. Proper application of GIS requires as much attention to the management and institutional issues as to the data to be successful.

This paper draws upon the experiences of a State-wide jurisdiction in building a pan-agency GIS; it describes many of the institutional and management issues faced, some of which were solved, and some which were not.
Municipal GIS Applications

Data Standards and Conversions
Digital Information Standards: a Major Step in Developing a GIS
Automated Data Conversion: Technology and Case Studies
Fast Track to Database Completion

Municipal case studies
Current and Future GIS Applications in the City of Halifax
GIS and the Smaller Community
URISA Exemplary Property Management Systems for Richmond

Issues in Municipal GIS
GIS Integration with Business Systems
A Regional Information Centre - a Planning Supermarket
A team approach to distributed GIS management
Digital Information Standards - A Major Step In Developing a Municipal GIS

Rostam Yazdani
and
Peter Friesen
British Columbia Ministry of Crown Lands
Surveys and Resource Mapping Branch
Victoria, B.C., V8V 1X5

Abstract
Development of municipal GIS has progressed enough to benefit from the latest in digital mapping technology. As most of the information required to operate a municipality are referenced to a geographic location, the municipal GIS should provide flexibility and ease in the retrieval and integration of this information. The system should also be able to cope with an increasing demand for the integration of applicable digital data from different sources. So far, the limiting factor for the broader use of GIS in a municipal environment has been the lack of generic digital data standards and specifications. This paper describes issues related to the development of large scale digital specifications as applied to a municipal GIS for data capture, data management and data sharing.

Introduction

More than seventy percent of the information for day to day operations in a municipality are geo-referenced in some way. Examples of this information are parcels, roads, sewers, buildings, sidewalks, parks, schools, environment, drainage and waterworks (Liley, 1987). In addition, some municipalities maintain utility operations such as telephone, electricity and gas distribution networks which also need land-related information.

Although municipalities have been using computers for a long time, the development of Geographic Information System (GIS) applications has been very slow, as municipalities have not fully recognized the benefits of the integration of geo-based digital data in a computer system. Rather, they have been simply overlaying hard copy maps for planning and engineering works.

As GIS technology has matured, municipalities have realized the advantages of an integrated approach to the management of their land-related information. In the past ten years, a large number of municipalities, mostly in the United States (Los Angeles, Minneapolis, Houston and San Diego) and a few in Canada (Calgary, Toronto, Burnaby and Oak Bay) have made substantial investments in GIS (Aronoff, 1989). These systems are being used in municipal operations such as property management (parcel) and appraisal (parcel and building), licenses and permits, planning and design for subdivisions, transportation and route analysis, engineering work, inventories of water, sewer and electrical systems, and general and detailed land use planning.
Manual or digital integration of land-related data was in the past centred mostly on the needs of provincial agencies. This resulted in a lack of understanding of the benefits of data sharing between municipalities, provincial and federal agencies. Although limited studies and pilot projects were carried out within municipalities, there has been little effort in coordinating the needs of land-related information for the municipalities and the provincial government.

Presently, the need to exchange geo-based information between municipalities and provincial and federal agencies has grown rapidly. But data exchange, using a variety of non-standard exchange formats, is a difficult and sometimes an impossible task (Pearson and Gareau, 1986). Examples of this are when municipalities have to use land-related data from the Ministry of Environment, Statistics Canada, or topographic data from National Topographic series maps.

Data sharing will be even more difficult, since municipalities are seeking GIS solutions in an independent manner. Consequently, it is desirable to develop common standards and specifications, before municipalities are too heavily committed to incompatible endeavours.

The Future Trends in Land-Related Data Integration

There are two ways of integrating geo-based data in municipal applications. One is to make available data which are captured in one system to the users of other systems without manipulation or changes. An example of this is the use of soil or environment data for planning. The other is to utilize GIS technology developed for processing land-related information in the very fundamental operations of a municipality in an on-line fashion. Examples of this type of integration are GIS applications in licensing, building permits, route selection and engineering works.

The future of data integration will combine both these approaches. As the benefits of geo-based digital data have been recognized by the municipalities, they will be more in demand. At the same time, more and more distributed graphics and land-related attribute data will be created which will attract municipalities. Eventually, municipalities with advanced GIS technology will have to integrate other land-related data into their fundamental day to day operations such as planning and decision making. This trend will continue until more than ninety percent (90%) of municipal operations will require a GIS with proper data integration capability.

The Important Role of Standards and Specifications

The Ministry of Crown Lands (MoCL) has been given the mandate to develop a strategic plan for the management of land-related information in the province of British Columbia. One of the goals of this initiative is to provide a facility for the exchange and sharing of geo-based information. This mandate will provide the opportunity to look at the entire geographic referencing structure for the province, including local governments. It will also provide an overview of existing and future land-related information systems as an integral part of the B.C. Land Information System. The outcome will be a series of actions which should be taken to create an environment in which independent land-related systems could function as members of a larger team within the province-wide goals and objectives.

The basic principle of data sharing is to capture data within pre-developed standards and specifications. Standards are required for the collection, referencing and storage of land-related data. These standards and specifications should provide consistency in the quality of data collected with regards to accuracy, resolution, geo-referencing systems, and data capture rules. A catalogue of data sources, internally and externally, is also needed to facilitate search on-line data and also to prevent duplication in data collection.

Conclusion

Municipalities are becoming more involved in the application of GIS for their basic operations. Integration of geo-referenced data between municipalities, province and federal agencies is necessary for planning, engineering works and decision making. The cornerstone for a reliable and easy data integration process is the creation of standards and specifications for data capture which are developed and maintained by an inter-agency committee. Fortunately, this task has been completed in the province of British Columbia. The Geomatics series of specifications for 1:250 000, 1:20 000, 1:5 000/1:2 500 and 1:1 000/1:500 map scales comprehensively cover all aspects of land-related digital data collection.

References


Automated GIS Data Conversion Technology with Case Studies

Mickey A. Fain
President and CEO, SMARTSCAN, Inc.
5797 Central Avenue, Boulder, Colorado USA 80301

Abstract
For the last five years the Automated Mapping and GIS market (AM/GIS) has anxiously awaited the arrival of automated data capture or scanning technology to speed the conversion of existing hardcopy maps and facilities drawings into intelligent data. This paper presents several case studies in which automated data capture technology has been successfully employed in the conversion of hardcopy documents into intelligent digital data for use on AM/FM and GIS systems. For each of these cases, a comparison is presented showing the quality improvements, time savings and cost savings resulting from the use of this technology.

Introduction
Modern scanning technology was introduced in the early 1980s. At first, it was hailed as a miracle solution that would magically turn data conversion into a totally automated process. Automatic raster to vector conversion and automatic character and symbol recognition promised to eliminate the expensive, labor-intensive aspects of conversion projects.

Unfortunately, these initial claims seemed inflated and 'scanning' technology began to conjure up images of hours at an edit station correcting 'automatically vectorized' drawings. Then unintelligent raster and incremental conversion systems were developed, but it was found they did not offer the analysis capabilities typically required by a Geographic Information System (GIS). Costs decreased, but at the same time, so did the intelligence, quality and value of the resulting systems.

These disappointments were caused by two understandable errors:

First, scanning technology was incorrectly oversold as a cure-all.
Second, and more importantly, scanning both provides and requires a whole new approach to conversion. Scanning is only one ingredient; many technologies must be effectively integrated to allow the entire operation to be successful. For example:

- Optical disk technology is necessary for storage and access to large amounts of grey scale image data;
- High speed dedicated processors are needed to provide efficient raster-to-vector conversions;
- Artificial intelligence techniques must be integrated to provide sophisticated line and symbol classification;
- High resolution interactive raster and vector graphic workstations must be employed for efficient interactive scrubbing, map registration, vector editing and attribute assignment;
Local area networks (LANs) must connect numerous workstations to allow images and data to be easily accessed and transported between processors; and,

All of these technologies must then be carefully integrated into a finely tuned, automated production management system.

In other words, for scanning to replace manual digitizing as a more effective means of GIS conversion, the development of an integrated Automated Data Conversion (ADC) process was required. By combining these technologies, it has been possible to significantly increase the quality of GIS conversions and, at the same time, reduce the amount of time required to complete a project, particularly a large, complex project.

Definitions

Because integrated ADC technology is so new, much of the terminology associated with it is not yet fully defined or consistently used. Therefore, before describing the various technologies and how they are integrated, it is important to first define some of the basic terms as they are used in this report.

GIS Conversion:

The compilation and digitization of a related and consistent set of data to produce the intelligent graphic and non-graphic information required to support a Geographic Information System.

Automated GIS Conversion:

The integration of a variety of appropriate technologies into the GIS conversion process resulting in improved quality, reduced project completion time and lower cost through the reduction of manual labor.

Scanning:

The process of converting a hardcopy document or map into a digital picture or image. The scanning operation produces unimportant digital information called a raster image, which serves as the basis for an automated conversion process.

Raster Image:

A digital picture resulting from scanning a document. This raster image is composed of an array of dots, or pixels (picture elements). Each dot represents the level of darkness, or grey scale, of the original document at that location. Raster images typically range in resolution from 200 to 500 dots per inch and may represent either black and white (binary) or full grey scale images with up to 256 levels of grey. For instance, a grey scale image of a 24 inch by 24 inch map at 250 dots per inch produces 36 megabytes of data.

Raster to Vector Conversion:

The process of identifying pixels which represent line work or graphics, separating these pixels from the background and converting them to a connected vector representation. This vector representation allows graphic information to be easily manipulated, edited, attributed and stored and is a basic component of a GIS. The raster to vector conversion process may occur either in a batch process, which requires no human interaction, or in an interactive process, in which an operator simply points to lines to be vectorized on a workstation screen and the system automatically follows, or vectorizes, those lines.

Interactive (Vector over Raster) Editing

The use of a high resolution color graphics workstation to allow an operator to easily view vector graphics as an overlay on top of a grey scale image of a source document. This interactive editing station is a key ingredient in the automation of the conversion process, including vectorizing, attributing, land base correction, edge matching and data verification.

Orthophotograph:

An aerial photograph which has been corrected for geometric distortions. The resulting photograph is accurate to scale in both x- and y-directions and can be used as a photographic map of the area.

Artificial Intelligence:

The ability of a computer to make decisions which appear to require human reasoning. These decisions are made by applying probabilistic rules that represent a given knowledge base corresponding to a particular situation. Each of these rules, depending on its degree of correlation to the situation, is given a different weight in the determination of an answer to a problem.

Edge Matching:

The comparison of pairs of common linear features along a specified map boundary to create a single, joined feature.

Layer:

A ‘structure’ within a data base which contains individual features, or a combination of features and networks, which are logically related or associated by information type. A GIS database may contain as many layers as the user requires. Layers may be identified by number, name and description.

Hardware Technologies

Critical to the creation of the automated conversion process has been the development and integration of several key hardware technologies. The most important of these are briefly reviewed below:

High Resolution Grey Scale Scanners:

The first step in the automated conversion process is the scanning of source documents. Since the entire ADC process relies on the manipulation of digital images of maps and other documents, it is extremely important to make sure that an accurate representation of the documents be captured during this initial phase of the project.
Most scanners consist of two basic components: a sensing device which detects the amount of light reflected from a point or group of points on a document, and a transport mechanism which causes the sensing device to move in relationship to the document.

Most scanners today utilize a charge-coupled device (CCD) as the sensing element and one of the following types of transport elements:

- **continuous feed**: the document is moved over the sensing device by pinch rollers;
- **flat bed**: the document is laid flat on a table and held constant as the sensing device is moved over it; or
- **drum**: the document is attached to a drum while the sensing device moves across the drum as the drum is rotated.

Drum scanners are typically both the most accurate and the most expensive, but are limited as to the size document they can handle, which depends on the circumference of the drum. Flatbed scanners are slightly less accurate and a little less expensive, and maximum document size is also limited to the size of the bed. Continuous feed devices are both the least expensive and the least accurate, and have the greatest flexibility in the size document they can handle, particularly in the document feed direction. Most scanners being purchased today are either continuous feed or drum type scanners.

**Optical Disk Drives:**

A 24 in by 24 in document scanned at 200 dots per inch with 256 levels of grey produces 25 megabytes of data. A project consisting of 1,000 such documents therefore requires 25 gigabytes of image storage. Because of this massive storage requirement and the need to have very rapid access to all of the drawings which comprise a project, 'write once-read many' (worm) optical disk technology has been critical to the development of the automated conversion process.

Optical disk drives utilize removable platters which can be taken out and replaced in much the same manner as floppy disks. Optical disk platters are available in two basic diameters: 12 centimeters and 12 inches. Each platter can hold from 300 megabytes up to 2.4 gigabytes, depending on the particular technology used, and these storage capabilities are continually on the increase. Each 2.4 gigabyte optical disk platter can therefore hold approximately 100 high resolution grey scale images. A project which consists of 1,000 drawings can be maintained on only 10 platters and, by utilizing multiple drives, or simply by switching platters as necessary, drawings from multiple projects each consisting of thousands of drawings, can be easily accessed, manipulated, and archived by an operator at a workstation.

**Interactive (Vector Over Raster) Workstations:**

Automated data conversion technology relies on the ability to manipulate very high quality raster images of maps, as opposed to sheets of paper. An operator must also be able to display vector information created from a map, or other sources, as an overlay to a raster image of a document. Thus, the development and integration of very high resolution and high speed graphics workstations has been one of the most critical elements in the ADC development process.

New display systems have very large internal memories, from 5 to 16 megabytes or more, to allow high resolution grey scale images to be quickly displayed, panned to any location and zoomed into to magnify small numbers and symbols. These systems also allow full grey scale images to be displayed, permitting an operator to easily view documents with varying shades of grey, scanned aerial photography and digital satellite imagery, with overlays of vector data. This allows vector data from one source to be easily compared to raster data from another source and for these documents to be viewed simultaneously, one over the other, for very precise manipulation and registration.

**High Speed Dedicated Processors:**

The analysis and processing of images requires very complex operations to be performed on very large data sets, a 24 in by 24 in grey scale image can produce as much as 36 megabytes of data. To reduce the processing times of specialized operations such as feature extraction and raster to vector conversion, high speed arithmetic array processors are employed. These processors allow the complex mathematical transforms required for vectorization and classification to occur between 10 and 100 times faster than possible on conventional, general purpose CPUs. Without this type of processing power, it would be impractical to perform these operations in a high volume production environment in which thousands of documents are routinely converted.

**Local Area Networks:**

One of the key challenges involved in developing the ADC process has been adapting it to large volume production needs. Much of the work done by the major vendors of scanning and drawing conversion systems has been based on the one drawing per operator concept. In other words, they were designed with the idea that one person would perform all of the conversion functions required on a single document before moving on to the next document.

This is not a practical approach for a large volume operation. Multiple operators must be able to work within a smooth production flow on very large, complex projects. This means that documents must be able to move automatically from one operator/workstation to another. And this requires moving tremendous amounts of information at very high speeds. A single drawing, with its associated files, might easily represent 30 to 50 megabytes of data. Thus to move just 20 maps through a process involving five different workstations, or processes, in a day requires the rapid transfer of about five gigabytes of data. On a typical day, a large volume conversion process may move as many as 100 maps, or 25 gigabytes of information.
The advent of local area networking (LAN) and cluster technology has therefore been a critical element in the success of the ADC process. LANs allow data to be moved from one processor to another at speeds of up to 1 mega-byte per second. This means a drawing, as well as all of the information associated with it, can be available at any one of many locations in less than 60 seconds.

This technology has also led to the clustering of data. Centralized magnetic and optical storage systems can now be used without sacrificing rapid access by large numbers of workstations. In an ADC process, the LAN becomes the backbone of the operation by acting as the electronic 'conveyor belt', routing each document to the appropriate process at the appropriate time. As a result, there is no longer a need to manually move sheets of paper through the production process, and the movement of every drawing can be automatically tracked and relayed by the system.

The Process

The traditional conversion process can be broken down into five basic steps:

1. Landbase conversion;
2. Review and compilation of source documents (scrubbing);
3. Registration of source documents to the landbase;
4. Digitization of graphic entities; and
5. Building of attribute database for graphic entities.

Two additional procedures are not steps but, in an automated conversion process, take place continuously throughout the process:

- Quality control of both graphic and non-graphic information; and,
- Project and document management for the entire project.

These steps are described in detail in the following sub-sections, along with information on how they are being automated through the use of new conversion technologies.

### 1: Digital Landbase Conversion

There have traditionally been three ways to create a digital landbase:

1. **Digitize the landbase directly from an existing hardcopy source.**

   Although these maps may be readily available, may be at the proper scale and are only moderately expensive, many existing landbases were created with poor ground control and cartographic standards. Thus, these maps may be very inaccurate and individual sheets may not tie together.

2. **Purchase an existing digital landbase from a source such as the USGS or ETAK.**

   This data is generally readily available and very inexpensive when compared to other alternatives. On the other hand, landbases from these sources are often at a fairly large scale (1:24 000 or 1:100 000), may not contain the information required, or may not be available for the required area.

3. **Create a new digital landbase from recent stereo aerial photography.**

   While this is very current and accurate digital landbase data and can provide significant details, including such things as driveways, sidewalks, utility poles and individual trees, it is also the most expensive of the three alternatives. To create a digital landbase for a single county from stereo photogrammetry could cost several million dollars.

   Now, by integrating scanning, raster to vector conversion and interactive editing workstations, a fourth alternative is being developed. It combines the digitization of existing source maps and the use of aerial photography to provide the accuracy of aerial photography at a significantly lower cost.

   The original hardcopy landbase maps are scanned and converted to raster images. Then these raster images are processed through raster to vector conversion software to separate the linework from the background and to automati-
cally digitize the graphics. The graphics are also divided into individual layers based on line width or line symbology. This information is then reviewed and edited at an interactive editing workstation. This process significantly automates the digitizing of the existing landbase by eliminating the manual digitizing process. The main problem that remains is that, as mentioned above, the original landbase may not accurately represent the real world.

To correct this inaccuracy, orthophotos are produced from aerial photographs of the area to be mapped. These orthophotos are then scanned to produce a grey scale raster image. The vectorized landbase information captured from the original hardcopy landbase is then displayed on top of the orthophoto at a graphics edit station. By indicating common points such as road intersections or property boundaries, the vector landbase can then be automatically warped to fit the orthophoto. In addition, any information which does not appear on the original landbase, such as new roads, may be easily updated.

This new alternative is less expensive because it uses automatic vectorization, and more accurate because it rectifies the landbase to current orthophotography.

2: Review and Compilation of Source Documents (Scrubbing)

This process, which ensures that all information to be converted to the GIS is up to date and accurate, varies significantly from one project to the next. It is also often a much larger task than anticipated because it is frequently discovered that records have not been kept current as had been hoped. Each drawing must be reviewed and compared to other maps, work orders and property and equipment records, meaning thousands of documents must be organized and handled by dozens of people. Then, to complicate matters, construction and growth alter the information recorded even as it is being converted.

One way of dealing with this problem is to 'freeze' the records as of a specific date before conversion, perform the records updating and conversion, and then update the digital database with the modifications that occurred during this process. This makes the time required to complete the conversion critical: the quicker the conversion, the smaller the updating backlog.

Document management technology can significantly improve the management of and facilitate the handling of these thousands of documents. Each map or document is scanned and stored on optical disks before the scrubbing begins. Information about the type of document, the information contained on the document, and the geographic coordinates of the information contained on the document, are entered. The conversion system will then contain both a digital catalogue and a digital image of all documents, which may be on line and easily accessible to operators at interactive editing workstations.

Automated scheduling then routes specific documents to specific interactive editing workstations. This allows the scrubbing process to be managed through automated production control procedures. Changes or revisions are made through raster or vector editing techniques, rather than via laborious manual drafting. The status of the scrubbing process can be determined at any time and bottlenecks are easily identified and acted upon.

This approach is not usually economical when using a manual conversion system, since scanning all drawings before the scrubbing process simply constitutes an additional cost which is not readily recovered. On the other hand, if the entire conversion process is relying on automation through scanning technology, this approach implies no increased cost since all documents must be scanned and indexed as an initial step in the conversion process. By scanning the source documents before the scrubbing operation, the scrubbing has been integrated into the conversion process and automated the management, handling, manipulation and editing of the documents. Quality improves and both time and expense are saved. Moreover, post-conversion updating costs are also reduced, since the 'records freeze' period is far shorter.

3: Register Source Documents to the Landbase

By this point in the conversion process, a digital landbase has been created and the source documents have been reviewed and updated. The next step is to register these source documents to the digital landbase. Traditionally, the information from the source documents is manually warped to fit the digital landbase by redrafting or by cutting and pasting the source information on the landbase while making necessary adjustments to register the two data sets. This may require the source documents to be manually redrawn and is an extremely time consuming and relatively inaccurate operation.

Another approach has been to utilize control points, such as section corners or other benchmarks, to warp the source data to the digital landbase through the use of warping software. This eliminates the need for redrafting, but often provides insufficient registration since the warping required may vary significantly across a document and there is often limited control information available. For example, on one map, the upper left quadrant may need to be stretched in the x-direction, the lower left may need to be shrunk in y, while the upper and lower right quadrants may require independent distortions of x and y. This kind of rectification will require a minimum of nine control points, and optimally 15 to 25. As a result, it is often impossible to completely rectify the source documents to the landbase using this method.

A third approach, using scanning and interactive editing workstations, is now being developed. The corrected digital landbase is displayed as an overlay on top of a grey scale raster image of the source map. The operator can then easily detect any distortions between the digital landbase and the source map. The operator then identifies pairs of
points, one on the vector landbase and one on the raster document, which should be tied together. After choosing several pairs, an interactive non-linear warping operation occurs and the results are viewed by the operator. To 'fine tune' the registration, the operator may continue entering points until a satisfactory registration is achieved. This operation results in a set of control points which are then used to warp the source map to exactly fit the digital landbase.

Through this process, it is possible to easily and precisely register the source map to an accurate landbase, even when the distortions are very random. More importantly, this does not require any redrafting of the source map to fit the digital base. And finally, it requires no known control points to be identified on the source documents.

4: Digitize Graphic Entities From Source Documents

Now the graphic information on the original source maps may be digitized.

Traditionally, this has meant laying each sheet on a large digitizing table, entering control points to register the map to the table, and manually tracing over each line, point, or symbol to be captured. This manual digitizing process is very time consuming, tedious and error prone. The quality of the digitizing is limited by the operator's ability to consistently follow the center of a line. This accuracy problem is further complicated by the fact that the operator has no opportunity to compare the accuracy of the digitizing to the original map until he or she plots a copy and performs an overlay of the document on a light table. At this point errors are identified and the graphics must be redigitized.

Scanning, raster to vector conversion, automatic layering and an interactive editing workstation significantly automate this laborious process. Source documents have already been scanned for scrubbing and land base registration and are now ready to be converted from raster information to vector information, which may occur in either a batch or an interactive mode. The batch process operates in two phases: first, the system automatically identifies graphics on the source map and separates them from the background image; then the centerlines of each graphic element are computed and converted to a set of connected vectors, or arcs. Artificial intelligence techniques are then used to automatically layer information into major categories, such as symbols, text, dashed lines, dotted lines or thick lines. This batch process provides the first level of intelligence to the data with no operator interaction and greatly increases the value of the data.

Raster to vector conversion may also be done at an interactive editing workstation by an operator, who simply points at the lines on the screen to be vectorized. This eliminates the tedious manual tracing operation required by manual digitizing.

The results of the raster to vector operation, either batch or interactive, is a set of graphic elements which are classified into major layers, such as text, symbols, hydrography, transportation or boundaries. This information can then be displayed on an interactive editing workstation on top of the grey scale image of the original source document.

The operator then groups graphic elements (arcs and points) into unique graphic entities, such as parcels, lakes, transmission lines, roads, etc. In this step, arcs which are required to represent more than one entity, such as both county and state boundaries, are not duplicated but simply linked to both entities. This interactive process can occur very rapidly by simply defining an entity and pointing to the graphic elements which are required to represent it.

The tedious manual digitizing operation is eliminated and the operator can easily compare the vector data to the original source document without generating a hardcopy plot. Graphic entities can be easily created and the duplication of graphics for coincident lines is eliminated. Most importantly, however, because automatic line following is utilized and because the operator has the ability to view the vector data on top of the original source map, digitizing errors are virtually eliminated.

5: Build an Attribute Database For Graphic Entities

It is now necessary to add intelligence to the graphic entities. For example, a graphic representation of a road may have been created, but information such as width, material, number of lanes, number of accidents and speed limit is necessary. Assuming this information is not already available in digital form from other existing databases, it must be manually keyed in. Information may first be manually entered on data entry forms or it may be keyed in directly from the original source map. This type of data entry operation is error prone and quality control is very tedious. Data is sometimes actually keyed in twice by independent operators to ensure quality.

Interactive vector over raster editing workstations can help here, too. When the attribute information appears directly on the original source map, this process can be automated as follows: an operator working at the interactive editing station enters an attribute definition loop in which the system displays the first graphic entity for which the attributes are to be entered; the operator is able to view the vectorized data on top of the original raster image, so all attributes which were indicated on the original map are easily visible. The system then prompts the operator for each of the required attributes. As the attributes are entered, they are displayed on the screen next to the original attributes to allow the data to be easily verified. Once the information has been approved, the system pans to the next graphic entity to be attributed.

There is no need to use data entry coding forms or to key in information directly from the original source maps. More importantly, the accuracy of the information is greatly improved, since it can be verified and approved on the screen. The result is significant time savings and improved data accuracy.
Quality Control of Graphic and Non-graphic Entities

After all of the graphic and non-graphic information has been entered, the accuracy and completeness of the data must be verified. This has traditionally involved numerous data validation steps, the plotting and overlaying of graphics information and the comparison of attribute data lists to original source documents. Depending on the complexity of the data and the quality of the scrubbing process, data validation, review and correction may consume as much as 25 to 35 percent of the total conversion time. In some cases, the customer even becomes involved in this process, reviewing data and often finding it necessary to return large portions for corrections.

Automated conversion can shrink the data verification process to less than ten percent of conversion time and eliminate the need for data to be returned for correction. This is due to the nature of the data creation process itself.

At each stage, scrubbing, landbase creation, graphic creation and attribute entry, two types of verification automatically occur as a result of the technology being used. First, an operator views the resulting data on top of the original raster image of the source document and, as each element is entered, it is compared to the original data and approved by the operator. Next, as the process continues, each operator must review the results of the previous operation.

Thus, quality control is no longer merely a final step; it is automatically built into the data throughout the conversion process. Of course, plots, listings and automated data validation checks are still used to double-check data quality, but the percentage of errors discovered during this final stage is drastically reduced, resulting in higher quality data, increased productivity and further time savings.

Project And Documentation Management For the Entire Project

This is the continuous process of managing the entire conversion project, from before the first map is identified, through the final verification and loading of all data. Thousands of documents are handled hundreds of times by dozens of people. Literally millions of operations must occur to create the final data. The complexity of the process is in direct proportion to the complexity of the database being created. Large conversion projects have historically taken several years, and must deal with having to maintain and update drawings during an extended time period. The management of this complex operation is therefore a key requirement to its success.

In a manual process, manual procedures must be utilized to keep track of each drawing and each process. It is difficult to maintain accountability, identify bottlenecks and keep up-to-date information on a project.

Utilizing the automation tools now available can simplify this management problem, although no large conversion project will ever be a trivial task. Since all drawings are handled as digital images through an automated drawing management system, instead of as sheets of paper, the documents do not deteriorate through handling, drawing images are easily accessed and document routing is automatically controlled. This drawing management system automatically provides individual drawings and project status information to an automated project management system, allowing project status reports and productivity reports to be automatically generated. And problems and bottlenecks are quickly identified and corrected.

Results and Applications

This unique, proprietary process can be beneficial for a wide variety of conversion applications, ranging from complex county parcel projects to soils, timber stands or wetlands mapping, to electric, gas, and water and sewer utilities conversion.

There are instances in which automated conversion is not the most appropriate way to proceed, however. Significantly, it is economics, and not technological limitations, which dictate when manual conversion might be more advantageous.

Because of the set-up required for the automated conversion process, it may not be cost effective to use this process to convert very low density maps, for example, a 40 in by 60 in contour map with a circle in each corner to scan. In this case, very little data is being captured, although the entire document would have to be scanned and processed through the entire system. Thus, it may be more economical to simply manually digitize the four contours on a digitizing table.

In general, the larger and more complex the project, and the denser the data, the greater the benefits derived from the use of this automated conversion technology. An example of how this technology is being utilized on a complex project is currently underway for the Southwest Florida Water Management District.

In this project, the information contained on more than 600 flood insurance rate maps (commonly referred to as FIRMs) and 200 floodway maps, which are produced by the Federal Emergency Management Agency (FEMA) must be integrated and converted. Combined, these cover an area equivalent to about 220 USGS quads, approximately 9500 square miles, making this one of the largest and most complex projects of its kind. The FEMA/FIRM panels provide the only District-wide flood plain information available, essential data for the model being implemented, which will ultimately assist in the identification of lands to be purchased by the District for water resource protection.

In addition, District personnel frequently refer to FEMA maps to answer questions from the public regarding the
location of floodplain boundaries. Automating the FEMA panels also will make it easier to update and improve the original maps, as well as permitting the creation of custom flood plain maps, and FEMA is interested in using address-matching strategies to automatically produce lists of homeowners living within flood-prone areas.

But most of these FEMA maps were made in the 1960s and '70s by a variety of contractors using a wide range of methodologies, with no horizontal control. This, plus the fact that they are being used for purposes never dreamed of by those who produced them, (flood insurance rate maps are being used as the basis for plotting wildlife habitat patterns and soil recharge rates) lay the foundation for a host of conversion difficulties:

- The maps are not simply black & white. They are composed of a number of shades of grey, which are used to delineate different flood zone information, such as 100 and 500 year flood zones.

- The data is derived from two separate maps. The FIRM maps contain flood zone information, and the information from the corresponding floodway maps must be precisely tied to these maps to form the resultant polygon data set.

- None of these maps have horizontal control information. This control must be derived from the corresponding 1:24 000 scale USGS quad sheets. Which further complicates matters, since

- The firm and floodway maps range in scale from 1:6 000 to 1:24 000, and the floodway maps do not usually correspond exactly to a portion of a quad sheet. This means that up to four USGS quad maps may be required to develop horizontal control for a single floodway map.

Ultimately, all of these maps must be precisely edge-matched to form continuous information and then cut into quad sheet-equivalent tiles for use on the District's ARC/INFO GIS.

Despite the fact that most of these maps are considered by many to be unscannable, the project is scheduled for completion in February, 1990. That represents a six-month turnaround time, half that specified by the Water District.

Parcel maps may also be successfully converted. Orange County, Florida needs to convert approximately 240 000 land ownership parcels contained on more than 1 750 parcel maps and encompassing about 500 square miles. Within each map, the parcels, lots, blocks, tie bars, hydrography, municipal boundaries, lot numbers and lot dimension features are being captured, layered and attributed. The entire project will be completed in only nine months. This project is the first major parcel mapping project in the nation to utilize this new technology, but certainly not the last.

In fact, another parcel project which fully utilizes the automated conversion process is just getting underway for the Northampton County, Pennsylvania GIS. This project involves the conversion of 673 parcel maps (100 000 panels) and 51 unrectified soils maps, covering approximately a 376 square mile area. Its purpose is to create a database using parcel graphic overlays, annotation sheets, orthophotos and unrectified soils maps, as well as data on the assessor's digital database. All parcel, soil survey, municipal and district boundaries must be scanned, captured, rectified and registered to the County's orthophoto base map and converted into 1:4 800 tiles. Then the data will be output in ARC/INFO Export format.

Other soil map conversion projects have also benefited from this integrated, automated approach. The USDA's Forest Service needed to convert approximately 10 000 soils information polygons comprising the Olympic National Forest, with associated attributes from 91 sheet maps at a scale of 1:288 000. The resulting data files contain the polygon along with the major soil, minor soil and slope associated with it. All data was then converted to Washington State plane coordinates and edge matched. The final product was a continuous, real world soils database for the entire Olympic National Forest of approximately 2 800 square miles. This data was delivered in MOSS format.

Finally, oil and gas, one of the first sectors to take advantage of this new technology, has particularly appropriate conversion needs. More than 1 000 7.5 and 15 minute USGS quadrangles were converted for a major oil company's corporate GIS. Four primary layers of data, hydrography, transportation, boundaries and points, were captured. Nineteen unique features were identified within these layers and the resulting data was fully topologically structured, converted to latitude and longitude coordinates and edge matched, regardless of the scale of the source maps. The result was an absolutely continuous real world database, covering approximately 80 000 square miles. Significantly, the project was completed in just ten months and fewer than two percent of the maps were found to contain even a single error.

Conclusions

On December 17, 1903 at Kitty Hawk, North Carolina, Wilbur and Orville Wright got their flying machine off the ground for the first time. Although Orville was aloft for only 12 seconds, this was the birth of aviation. Flying, however, did not become a more effective means of transportation than the automobile until several decades later, after an entire system of integrated technologies had sprung up around it.

Through the integration of these technologies, data is now of higher quality, people are more productive and projects are completed more quickly than anyone would have thought possible just a few years ago. But then again, in 1903, who would have ever thought Wilbur and Orville
were not only getting us off the ground and across oceans in record time, but ultimately, all the way to the edges of the universe.

And now, through the creation of geographic information systems and automated conversion technology, we can improve the way we manage our small corner of that universe.

Appendix

Case Study #1
Automation of County Parcel Maps for the Orange County GIS

This project involved the conversion of more than 240,000 land ownership parcels contained on more than 1,750 parcel maps. The County encompasses approximately a 500 square mile area. Within each map, features such as parcels, lots, blocks, tie bars, hydrography, municipal boundaries, lot numbers, lot dimensions, etc., were captured, layered and attributed.

This was the first major parcel mapping project to use automated data conversion technology. As a result of this work, Orange County is experiencing better graphic quality and data accuracy than is typically produced by manual digitizing methods.

The Orange County GIS hardware includes DEC VAX computers, terminals, peripherals and GPX/II workstations located at four major locations. The large scale data processor is a VAX 8850 and is connected with five departmental Micro VAX 3500 computers, all interconnected with very high speed fiber optic links in a government-owned network. Many DEC GPX/II and VAXStation 2000 workstations are also connected to the network using the Ethernet and DECNnet protocols. The network represents a distributed computing network with a central map/database on the VAX 8850 with more than 5 gigabytes of on-line disk. Software includes Geovision Corporation's AMS (Advanced Mapping System) and GIS products, McDonnell Douglas's GDS CADD software, ORACLE and related products for relational database management and SPSS for statistics and business graphics.

All data was translated from internal digital files to Intergraph SOF files and delivered on magnetic tape. Data checkplots were also supplied. The entire 500 square mile project was completed in just 10 months, all original costs and schedules were met and not a single data error has been reported.

Over the next few years, Orange County will be mapping additional layers.

Case Study #2
Pilot Project for Parcel Map Conversion Prince William County, Pennsylvania

This project required the conversion of newly recompiled parcel maps and delivery in ARC/INFO Export format. The source re-compiled maps were colored pencil on mylar maps.

The County had been manually converting their re-compiled parcel maps. In an effort to speed up completion of the parcel database, the County requested a pilot study be conducted to determine the best method for automation. This pilot project consisted of four 1:2400 scale parcel maps. Three of the maps required that a polygon coverage be created from all parcel lines. The fourth map was provided with a polygon coverage of all parcels and with all text on the map. The data was converted to the Virginia Coordinate System using 1983 International Feet coordinates.

The coverages were clipped to a box having the four tics as corners. All four maps were edge matched to assure continuous data across map sheet borders. The digital data was supplied to Prince William County in ARC/INFO Export format on nine track magnetic tapes.

Case Study #3
FEMA Mapping Southwest Florida Water Management District

This project is significant because it involves the creation of a database by combining data from several sources, because it is being delivered to the client in ARC/INFO Export format, and because control information for the FEMA maps is being derived from a third source.

A 9,500 square mile, 15 county area in southwest Florida is covered by this project, making it one of the largest and most complex conversion projects of its kind. The maps to convert are 807 FEMA FIRMs and Floodway maps, at scales of 1:12,000, 1:144,000 and 1:288,000.

The flood zones, hazard zones, political areas, river mile markers and reference marks, and hydrography are the layers, or coverages, captured. Thirty-four unique attributes are assigned to the five coverages. The coding scheme for the project includes a polygon, line, link and network coverage. This allows for maximum flexibility for spatial analysis.

Since the FEMA maps do not contain control information, a third source for control is necessary for conversion. Thus, all FEMA maps are reviewed with corresponding USGS quads for location of coincident features. Section corners, street intersections and hydrologic features are being used to determine control. The digitized linework is being transformed into Universal Transverse Mercator meter coordinates using control information derived from USGS quadrangles.

There are four key conversion difficulties associated with this project:

- The maps are not simply black & white. They are composed of a number of shades of grey, which are used to delineate different flood zone information, such as 100 and 500 year flood zones.
• The data is derived from two separate maps. The FIRM maps contain flood zone information, and the information from the corresponding floodway maps must be precisely tied to these maps to form the resultant polygon data set.

• None of these maps have horizontal control information. This control must be derived from the corresponding 1:24 000 scale USGS quad sheets.

• The firm and floodway maps range in scale from 1:6 000 to 1:24 000, and the floodway maps do not usually exactly correspond to a portion of a quad sheet. This means that up to four USGS quad maps may be required to develop horizontal control for a single floodway map.

Ultimately, all of these maps must be precisely edge-matched to form continuous information and then cut into USGS 7.5 minute quad sheet-equivalent tiles for use on the District’s ARC/INFO system. In addition, the data from the FIRM and floodway maps are being combined. All the quadrangle maps are being edge matched to produce a seamless, topologically correct coverage.

The final data files are being converted to ARC/INFO files. The data is then generated to create line and point coordinate files, and built and appended to combine adjacent coverages. Finally, new coverages are formed in increments of USGS quad boundaries using CLIP. All data will be delivered to the District in ARC/INFO Export format by January 1990, which represents a six month completion time.

By February 1990, the Water Management District will have the data required for the FEMA layer of data needed for the GIS, and FEMA will have digitized maps that it can easily update and, in the future, to which it can tie street names and other pertinent information. This means that banks and insurance companies will have better data on which to base mortgage decisions and insurance rates, and city planners will have accurate flood and water management information at hand when issuing building permits and establishing building codes.

Case Study #4
Automated Conversion of Topographic Maps for District GIS Applications

Southwest Florida Water Management District

This project is significant because of the nature of the source documents: aerial photo contour maps. The map sheets contained 2-foot contours and spot elevations displayed on top of full grey scale aerial photography. This type of original is typically considered impossible to convert via automated processes. However, because of the use of unique grey level scanning capabilities, it was possible to apply the benefits of automated data capture to this project.

Contours were digitized from mylar separates of 1:1 000 USGS contours. All 2-foot contours, spot elevations and associated Z values were captured to an accuracy of 0.004". The plots also exhibited the scale of the plot and maximum and minimum real world values computed for the data captured. The data was converted to UTM coordinates and delivered in the USGS DLG3 optional format on 9 track tape at a density of 6250 bpi for use on an ARC/INFO system. In addition, a final check plot on 4 mil double matte finish film was provided for each sheet.

This project covered an area of approximately 600 square miles and was completed without a single digitizing error being reported.

Case Study #5
Production of Digital Cartographic Base Maps from USGS Quadrangles

This project involved the automated conversion of USGS 7.5 minute, 1:24 000 scale quadrangles for use in the ITT Rayonier, Inc. Southeast Forest Resources PC ARC/INFO system. The database covered approximately 100 000 acres of ITT Rayonier property in five Georgia counties.

Five data coverages were created from the quadrangles: transportation, hydrography, political, point, and section coverages. Within these five coverages, forty-three unique features were identified:

Transportation
Four lane or divided highway
Abandoned railroad
Primary highway, hard surface
Tram road
Secondary highway, hard surface
Airport
Light-duty road, hard or improved
Powerline
Unimproved road
Telephone line
Jeep trail
Pipeline
Railroad
Map neatlines

Hydrography
Intermittent drainage
Ponds, lakes, reservoirs
Rivers
Perennial drainage
Bays, oceans

Map neatline

Political
State line

County line

City boundary

Point
Church
Boat ramp
School
Forest Ranger station
Police station  Cemetery
Radio tower  Hospital
Towns, villages  Lookout tower
Benchmark elevations  Fire station
Gates

Section
Township or range line

Section line

The digital database was created via an automated conversion process. All graphics, polygons and attributes were formed there. All data was converted to Universal Mercator coordinates. Each map sheet was coordinate edge matched, within each respective layer, with adjacent map sheets to provide a contiguous database.

This data was then translated into ARC/INFO format. All coverages were cleaned and built. Two copies of the quad sheets were delivered to ITT Rayonier. Each quadrangle was delivered as an individual 7.5 minute map, as well as edgematched and appended to form coverages per ITT Rayonier specifications. The data was delivered in PC ARC/INFO format on high density 5.25" floppy diskettes.

The 21 quads were delivered in 60 days.

Case Study #6
Automated Conversion of Soils Maps For the USDA - Forest Service, Olympic National Forest

This project required the conversion of approximately 10,000 soils information polygons with associated attributes from 91 map sheets at a scale of 1:24,000. The resulting data files contain the soil polygons with the major soil, minor soil and slope associated with them.

To produce 91 digital map files of soils information polygons in MOSS format, six crucial functions took place:

- lines were captured to a specified degree of accuracy;
- the linework was edited;
- polygons were attributed with soils information;
- the attribution was edited; and,
- MOSS files were written to an unlabeled tape.

A very brief process description follows, describing how each of the above functions was addressed.

After project setup, each mylar was scanned at 100 pixels per inch, which provides an accuracy to within 0.01 inches.

An automatic raster to vector process identified virtually all linework and polygon intersections on the maps and, by appropriately setting parameters, was able to ignore the annotation. A file of unattributed line segments was produced.

At the interactive edit workstation, the operator reviewed all linework by viewing the digitized vectors on the screen with the scanned image in the background. Line segments and intersections were easily added or modified. The editor then formed polygons from the line segments by merely selecting the desired segments of the polygon. After all polygons were so determined, the system looped through each polygon, prompting the editor to enter the soils information attribute, which was read by the operator from the background image. The polygon formation was assured by the operator during this process, and the typed attributes, in the proper three component/slash format, appeared on the screen for easy checking.

The registration tics and their values were then entered at the workstation. The polygon endpoints on the edges of adjacent maps were represented on the screen relative to the current map. Each endpoint was matched with an endpoint from the current map based on location and matching attributes, and this was indicated visually on the screen. Any unmatched endpoints were easily identified and resolved. At the end of interactive editing, the digitized data for the map consisted of clean, accurate linework in a polygonal structure, attributed, and with pre-reviewed edge matches to adjacent maps. All data had been edited and coordinates were in an internal system.

A batch process then converted the internal coordinates to Washington Zone 4601 state plane coordinates. Another batch process performed the actual edge matching of the endpoints on adjacent maps. Plots and listings were produced for the second stage of quality assurance. This second stage re-verified that the plotted data overlaid the original maps, that polygons were properly formed with correctly entered soils information, and that the data on adjacent maps all merged correctly. Any errors were rectified at the interactive edit workstation.

After each map was verified as correct, all data was converted to MOSS EXPORT format files. The MOSS files were written to an unlabeled tape, at 1600 BPI, in ASCII with a blocking factor of 8192. The final product was a continuous real world soils database for the entire Olympic National Forest, approximately 2,800 square miles.

Case Study #7
Automated Conversion of 1 100 USGS Quads for use on a Corporate GIS

This project, completed for a major U.S. oil corporation, required the conversion of approximately 1,100 7.5 minute and 15 minute USGS quadrangles. Four major layers of information were captured from the quadrangles: hydrography, transportation, boundaries and points. Nineteen unique
features were identified within these layers. The resulting data was fully topologically structured, converted to latitude and longitude coordinates and edgematched, regardless of the scale of the source maps. The result was an absolutely continuous real world database covering approximately 80,000 square miles.

The data was structured per USGS DLG standard and delivered in a client-specific format.

Approximately 1 100 digital files on 9-track tape, as well as final checkplots, were delivered in approximately ten months, and fewer than 0.5% of the maps were found to contain even a single error. The original schedule called for the completion of 1020 maps in nine months. This goal was met. An additional 50 quadrangles were added during the final months of the project, and an additional month was added to the delivery date. The cost of the project remained as budgeted.
Fast Track to Database Completion

Dan Bowditch

Project Manager, BC Hydro
Vancouver, British Columbia

Abstract
BC Hydro started its AM/FM system in 1983. Conversion began in-house with land data translated from two existing AM systems. In 1987, the system was extended to all four operating divisions and April 1989 saw establishment of a major project to contract conversion of the remaining distribution system by March 1992. Approximately 10% of this work will remain in-house.

Conversion contractors have established permanent operations in two interior BC cities and will complete the conversion of land and electric facilities data for an electric utility with more than 1.2 million customers and a total service area of 72,800 square kilometres. In-house personnel had converted 18% of the land base, plus 10% of the electric facilities and are continuing to convert about 10% of the remaining area.

In addition to the fast track conversion schedule, more than $6 million will be spent on applications development by March 1992. This presentation will review this ambitious project and the efforts to establish a lasting data conversion industry in British Columbia.
Current and Future GIS Applications in the City of Halifax

J. Gannon
Geographic Information System Co-ordinator
City of Halifax, Nova Scotia

Abstract
Geographic information system implementation within a municipal environment varies from one city to the next. History, politics, and staff all play a major aspect in its successful implementation. This paper will highlight the events that has brought Halifax into the world of Geographic Information Systems.

Introduction
The City of Halifax became a full fledged user of geographic information systems in 1986 by engaging a service bureau to digitize our sewer and water utility information. During the fifteen years before the signing of this contract, the City of Halifax went through many changes in its actual size and shape and in its outlook on information management. These changes were to be the building blocks upon which our GIS would be structured.

Until 1970, the City of Halifax comprised only the peninsula and did not include several small "mainland" communities. With the annexation however, the City nearly doubled its size and was faced with combining two sets of base maps: 1:480 for the peninsula and 1:1200 for the mainland.

To co-ordinate activities, members of the Nova Scotia Power Corporation, Maritime Telephone and Telegraph Company, the Halifax Water Commission and the Engineering Department of the City of Halifax formed the Halifax Utility Co-Ordinating Committee (HUCC) in the mid 70's. After the Committee's investigation of the feasibility of integrated utility mapping, they were unanimous in the need for the creation of new topographic base maps as the first step.

At that time, Land Registration and Information Services (LRIS), a provincial agency responsible for mapping, had as its priority resource mapping and not urban mapping. As a result, the HUC Committee explored avenues for creating its own urban mapping. In 1980, their report, 'Feasibility of an Improved Mapping System', revealed that at 2.5 million (1980) dollars, they could develop a new digital topographical database and necessary utility programs.

The venture was felt to be too costly to receive a firm commitment from the senior management of the Committee members and the efforts came to a standstill.

However, in 1981, LRIS decided to switch its emphasis back to urban mapping. They did the aerial photography for both Halifax and Dartmouth, and began a digitizing program for the topographic base which was completed in 1985. The City, anticipating its future need for digital mapping, approached LRIS to digitize sidewalk information and, although it is not standard for 1:1000 mapping, they complied.
While every city has some form of base maps, it is important to explain the extent of detail that makes up our topographic base. This detail includes pavement edge, buildings, 5 meter contours/spot heights, landcover (shrubs, trees, etc.), structures such as guard rails, billboards, fences, etc., designated areas (parking lots, playgrounds, parks, etc.), hydrographic features, driveways, lanes, walkways and sidewalks.

In 1986, with the new digital topographic base maps available, the City signed its first geographic information systems contract with the Eastcan Group to convert our hard copy sewer and water records. This contract included the:

- development of symbology;
- feature coding;
- data capture;
- topology;
- hardware and software;
- online access; and,
- human resources.

This project included many man-hours on the part of City employees to prepare the necessary data through its various phases. The team of City employees 'scrubbed' the source maps and collected attribute data. The process evolved into these main steps:

- all features were plotted on original maps using existing in-house information;
- clear acetate overlays were used to label each feature;
- for each feature, a data attribute record was prepared;
- attribute data was keyed into an in-house database and transferred electronically;
- graphic source documents were sent for digitizing; and,
- after digitizing, check plots were produced for verification.

This process revealed that the quality of the City's data was not quite up to the level we had always believed. As with any project, many aspects would be done differently if it was to be done over, and the lessons learned will be used in the next conversion projects.

The next significant event that proved the City of Halifax was moving into an enterprise-wide geographic information system was that the City's Planning Department entered into an agreement in early 1987 with LRIS to develop a digital parcel database. At this point, we now were positioning the City of Halifax to have the three fundamental databases needed by any municipal government: the topographic, sewer and water utility, and parcel databases.

On the heels of this contract signing, the City did a complete assessment of its computing requirements to take us into the 1990's, with the assistance of Robert Liley and Associates Consulting. In late 1987, City Council adopted the Systems Implementation Strategy. The strategy included the following recommendations:

- the acquisition of new computer facilities capable of expanding as needs increase, and a communications network;
- new software development tools;
- protection of the current investment in micro computers;
- single workstation access to information; and,
- implementation of in-house geographic information systems

It is very important to understand that this strategy was driven by enterprise-wide effort, as all major departments participated in its development.

It is also important to note that each of these recommendations were to be implemented by various task forces also made up of major user department representatives. As a result, in 1988, the Geographic Information Systems Task Force was created with representatives from Engineering, Finance, Development and Planning, Works, Public Safety and Management Information Services.

Number one on the GIS Task Force agenda was to define the functional requirements needed by the City in choosing its GIS software. In the examination of these functional requirements, the task force put forward the following recommendations:

- utilize a service bureau as necessary;
- initiate on-going GIS database maintenance;
- acquire the appropriate GIS system software;
- acquire specific hardware subsequent to software selection;
- acquire/develop GIS related applications;
- integrate business systems with GIS;
- develop and implement policies and procedures; and
- update human resources requirements.

Throughout this phase, we enlisted the services of Karel Fila, GIS Consultant, to assist City staff in learning and understanding the issues associated with the implementation of GIS.

The next phase of actual GIS system software selection required the City to create a benchtest of all the functional
requirements we felt necessary for our operations. Again, we enlisted the services of Karel Fila to help create, execute, and evaluate the benchtest results and subsequent contract negotiations.

In August of 1989, City Council approved the contract with ESRI Canada which included GIS system software (ARC/INFO), hardware (SUN), data conversion (NTX to ARC), installation acceptance and a performance guarantee.

The other recommendations were also worked on concurrently. The first GIS staff position was filled, the updating of 15 topographic map sheets commenced, draft policies were developed and a sewer database maintenance report was created. Also, the task of data conversion began. A small section of the databases was extracted to be used as a pilot area for the conversion process. After several detailed verifications and modification to the conversion test, the City was ready to design the database layout for our system. The ARC/INFO system uses a file organization called ‘TILES’. It was mandatory that the City first weigh how many TILES were necessary to create the optimum response time against the effort required to update these TILES.

We determined that four (4) tile schemes, municipal parcel utility, and NS 1:1000 would be appropriate for our needs.

The municipal tile (1) contains street centre lines, control monuments, municipal boundaries, water details and administrative coverage, e.g., zoning, wards, polling districts and police zoning.

The parcel tile (12) contains parcels, buildings, civic numbers, trees and miscellaneous features. The utility tile (25) contains curbs, sewer, water and utility coverage. The NG 1:1000 tiles (193) contains contours, spot heights, land cover, sidewalks, driveways and hydrography.

With the database (tile) design complete, ESRI commenced the full conversion process. At the same time, the GIS system software and hardware (SUN) were installed at our offices and City staff began training in ARC/INFO.

The converted data was loaded on this new system and we then started the installation acceptance process. Problems that surfaced along the way were quickly rectified by ESRI and we were able to begin the performance test. This exercise was to test the new GIS system software running on our hardware within our full database, simulating an expected normal day of operation for 20 users.

This proved to be a stimulating experience for both City staff and ESRI, and after certain hardware and software adjustments, the City accepted the system.

Other activities that have been going on include the hiring of a GIS Co-Ordinator and a GIS programmer, policy statement review, the development of standards, and investigation of potential applications. These activities have all been directed by the GIS Task Force.

For a department that so recently came into existence, our services are increasingly in demand.

The City has been working on CORE database (parcel and sewer) maintenance procedures which are planned to be implemented by late spring 1991. We will continue to enhance the general query system as there are currently 17 query users covering all major departments using the GIS data on a daily basis, with 15 more to be installed by the end of February 1991.

The City has also been working with the Halifax Harbour Cleanup Corporation (HHCC) and its consultants to provide an effective information exchange. We became part of their digitizing pilot test. Once provided with their files, we loaded them on our system and combined them with our sewer and water data.

The City is also starting the development of a track of land known as the Mainland Commons. The Mainland Commons Committee have made it mandatory that the consultant firm provide conceptual and detailed plans in an electronic form compatible with our GIS system software.

We are currently determining the electronic specifications required for all information being supplied. Record drawings and development proposals will be presented in digital form and will have a determined level of accuracy associated with them.

1991 promises to be another interesting and busy year. Several new projects are in the immediate horizon, as well as the ongoing and indeed never-ending one. Halifax, with the capabilities of our GIS system, will be striving to increase the quality of its service to the taxpayers.
GIS and the Smaller Community

Robert W. Liley

Robert Liley and Associates
Suite 209 7230 Adera Street, Vancouver, B.C. V6P 5C4

Abstract

Robert Liley and Associates has worked with local governments across Canada and internationally in planning and implementing geographic information system concepts to support government operations and decision making. While the basic elements of planning for GIS remain the same regardless of the size of the community, the issues surrounding and arising from the implementation of GIS in smaller centres have much different implications. In smaller centres, it is usually much easier to form a cross-functional task force which can see the GIS opportunities for the community as a whole, ‘turf wars’ are much less of a problem. But, while the costs of GIS hardware and software have dropped dramatically, making GIS ‘affordable’, the overall costs of GIS implementation remains formidable; and these costs represent a major portion of planned expenditures. Moreover, much of the outlay is required years before any major benefits can be derived. This necessitates an investment decision on the part of council, something with which councils don’t often deal. And simply extending the implementation period to defer the costs unfortunately defers the benefits as well.

Because of the visibility of GIS projects and the associated uncertainties, the risks of failure are high. No solution is available off the shelf. Scarce resources must be committed to the undertaking for substantial periods of time. Lastly, council and management expectations may not always coincide with the practical realities of implementation. This paper discusses some of our experiences in assisting smaller communities to implement GIS capabilities.
The Corporation of the Township of Richmond: URISA Exemplary System in Government Awards

Brian Sameshima
Information Services, The Corporation of the Township of Richmond
6911 No. 3 Road, Richmond, B.C. V6Y 2C1

Abstract
Richmond's Property Management System consists of two distinct components. One is the digitally stored map data overlays and the other is the traditional business systems. The Geographic data management system (GDMS) is an application 'bridge' between the two components. Richmond has created multiple map overlays and business systems to create a complete system. Richmond staff can easily retrieve information from either component. A property-tax assessment inquiry can link into the zoning, agricultural land reserve or drainage levy area map overlays and display the information. This allows computerized map inquiries without physically perusing multiple maps. Some data such as zones or permit areas should be updated graphically on the map data. Zoning changes can affect multiple properties. Therefore, digital changes rather than business system updates will save time and effort. With the mixing of graphic and business data, Richmond can answer public and internal questions very simply with its Property Management System.
GIS Integration With Business Systems

Rip Peterman
Senior Associate
Shortreed Terrain Data
Vancouver, BC

Abstract
Pre-implementation of a GIS all too often concentrates solely on the mapping characteristics with little thought being given to the maintenance of the data behind these map elements. The concentration is directed at defining the GIS data base and the representation of the data on the maps to be produced. The cost of a GIS will not be recovered by just producing maps. The real power of a GIS, and the large payback, will come from the new capabilities to analyze business operations spatially and then representing them in all three modes, spatially, textually and graphically. Therefore, the success of any GIS will rely heavily upon the ability of the business systems to integrate with the GIS such that the business data can be used in the analyses. Further to that, much of the attribute data related to the data elements within the GIS really needs to be maintained by the regular course of business versus the time consuming manual updating on a workstation of every data element which has undergone change. We do not have the personnel to keep a GIS current under these manual methods. Our thoughts must turn to the automatic maintenance of the data, in a timely manner, in order to secure a GIS which represents the current status of the municipal operations. Integration of the business programs with the GIS DBMS is the only practical and economical solution.

Introduction

The fever attributed to the implementation of a GIS is spreading through municipal management at all levels. The interest usually appears first in the Engineering department of the municipality, as that group has wrestled with the production and maintenance of maps for numerous years now. Over the last decade, GIS has grown from AM/FM programs so a major focus of the vendors has been on the mapping abilities of the products. The headaches attributed to the lack of adequate maps reached a point where map automation supplied the justification to acquire the software by the larger municipalities. Time and advancing technology has made this route more palatable to many more municipalities. In fact, any municipality having a population of 35 000 is quite able to afford some degree of automated mapping. Note that I have not said a GIS. However, once the second topic of facilities management is raised, the cost of the system increases dramatically. Even getting map conversion at the scale needed to manage the municipality's infrastructure can be too costly for any but the most financially well off municipalities.

Realizing that mapping alone is not a sufficient justification to warrant the expense in equipment and personnel for automating the reproduction of maps, a broader utilization is required. Granted the computerization of maps will allow many permutations of the
layers of data elements to generate selected maps at will. But, even so, the savings attributed to draftspersons is not sufficient to establish a marketing case to management. Any mapping savings or enhancements compared to the full tally of costs does not impress management nor the public officials who are concerned about large allocations out of the public purse.

Broader utilization can often extend only to that of facilities management before justification of the expense is warranted. Often, the municipality realises that such an investment can benefit more, if not all, departments or agencies at much less incremental effort. Now, a GIS can become a reality within the organization if more departments perceive benefit and thereby join the Engineering department in its campaign for a GIS, and the allocation of funds to implement it. However, the real interests of these other departments deviates significantly from the accuracy and depiction of Engineering-related elements to that of polygonal and socio-economic analyses. The dichotomy is now strung: how to please everyone under the guise of a single system implementation?

What is a GIS?

In some ways it can be easier to describe what a GIS is not. It is not:

- a packaged system implementable upon purchase;
- solely a mapping, an analytical or a graphics program;
- a finite system which can be considered implemented at a point in time; nor
- a panacea system addressing the remaining problems of municipal management.

A GIS must be considered as another 'onion skin' system in much the same way as an MIS (Management Information System) has been described, and often redefined over the last decade, for the unification of business systems in order to obtain inter-related management insights and the exploration of possible actions. So too, the GIS is an 'outer layer' concept that shares the same 'skin' level as the MIS and should be thought of as merging with the MIS concept in its implementation. Any attempt at implementing a GIS without serious consideration regarding integration with the business systems will be a tragic failure for the organization, which will severely restrict the opportunity and limit the financial benefits by at least an order of magnitude.

Just as many people have had trouble in defining exactly what an MIS is, so too, the universal definition of a GIS meets with equivalent numbers of voices of support and disagreement. The truth is that a GIS will assume the character of the organization installing and developing it to suit its own management style. The essence of the GIS will be founded upon the business operations of the municipality and the management methods employed. Knowing that business systems in a municipality undergo constant additions and changes over the long term, it can be assumed, just as easily, that the GIS will be equally dynamic as operating criteria dictate. It must be realised by all participants that "...the implementation of a GIS is a Journey ... not a Destination".

Oversights When Selling the GIS to the Organization

In the attempts to appeal to the greatest number of department heads in the municipality, and sometimes to similarly interested agencies working with the municipality, the establishing of a pilot project to demonstrate the viability of a GIS usually materializes. This is 'sold' with the notion of identifying sources and uses of the data and also to expose the numerous methods of managing the data through the display of information in both graphical and spatial formats in a cost limited basis through selection of a 'representative' area of the municipality. This pilot also has the deliverable of identifying costs of implementation. Unfortunately, there is seldom an all-encompassing region of representation for all parties interested, so some latitude in the development of the pilot is introduced. But the greatest oversight now occurs, that of cost containment and a disposable mind set to the project which precludes the costly and time consuming effort of converting business systems to interact with the GIS pilot program. If the business systems were to be acquired or rewritten to link to the GIS, then the work would have been done and a pilot project is moot. The effort and time to do this are recognized to be excessive and so for the pilot project, data is manually loaded. Because of the lack of automated business updating, the only maintenance of the data is through manual interaction. The realization and comprehension of integrating business systems with the GIS is lost. Observers are lead to believe that the GIS is a stand-alone system which can exist outside of the automated business functions.

The zoom out of, and telescoping into, the pilot project map area to display overviews and details of the loaded data causes much excitement in the eyes of the on-lookers. Unfortunately, like seeing a fantastic new tool displayed at the county fair, the crowd is mesmerized by the slick operation without comprehending the requirements behind the scene. In the case of the GIS pilot, the data is usually several months out of date, but, the question is seldom ever asked as to how it will be kept current upon implementation. If it is asked, the specifics are usually glossed over by a statement to the effect that "The staff will maintain it in their normal course of work". The inquirer is satisfied and moves on to other points of interest. If you reflect upon the overload of work before municipal staff right now, where is all that time going to come from to maintain the integrity of the GIS data base? A simple calculation performed by multiplying the time it took to load the pilot project's data base by the total area of the municipality, of which it represented a small fraction, will open many eyes to the real magnitude of the effort. Add to that another twenty percent, due to the fact that the pilot
project area is usually far less complicated than a good part of the remaining municipality. Municipalities have identified some 2,300 to 3,000 data elements to be used to depict features on the maps of which approximately one-half are identified at pilot operation. Compound that with the realization that a considerable percentage of the municipality's data is changing, in some way, on a daily basis and must be updated in a timely manner after implementation. You just do not have the personnel to keep up with it, and most Councils are not going to approve the huge hiring of additional personnel required to accomplish it. So, what is the solution?

**Integration of MIS and GIS**

Integration of the MIS and the GIS accomplishes two major aims: it supports multiple database integrity and it is the practical method of keeping data current. The only way to attain integrity of the data stored by the municipality in both the MIS and the GIS is not to have redundancy in separate databases. Without this singularity of storage, it is too easy for editing of one form or another to cause data items to become out of synchronisation. This implies a requirement to 'view' the data in each DBMS through either system. This is the first level of integration, data sharing.

The ability to inquire through either a spatial selection, such as an encirclement of elements on a map display or through a selective command using delimiting criteria, such as SQL statements, should be readily available to users of the Municipal Information System. We now have the next level of integration, data linking. There must be an inter-database capability for the linking of elements such that selection and display can be done through either approach. The data value or placement of discrete elements cannot be lost through traditional database parent-child structures and summaries, otherwise, the ability to delineate and display data inquiries and analyses will be severely restricted.

Daily business operations throughout the organization cause significant changes to the data relevant to the management of the municipality. Progress into a GIS for operations-support and decision-support capabilities which is thwarted by waiting for some designated updating session or job stream is a regression to 'batch mode' operation and re-introduces all the problems of non-source data capture and delayed time to actual reflection. We have come a long way towards achieving on-line and real-time data capture and representation in our business systems, so why forsake these principles when implementing a GIS?

Let the business systems maintain the dynamics of the data, to the extent possible. Of course, there will still be the necessity of graphics input regarding the map elements of symbols, points, lines, polygons and attribute data associated with each. However, that attribute data should be very limited, as much of what is called attribute data today in GISs, and especially pilot projects, can be obtained from the business records if integration is performed. By so restricting the attribute data, the manual maintenance of the geographical data elements is kept to a minimum, is more timely through routine automation, and is less likely to be falsified by casual editing.

If we are able to initiate an updating process in either the MIS or the GIS such that the ensuing operation is comprehensive, that is, data is changed where possible or permissible and related elements are flagged as requiring modification by stand-alone actions or a security requirement, then the integration of the GIS with the MIS has attained the highest level, that of operational sharing.

**Where Do We Start Integration?**

The implementation of any GIS is founded upon the base map. Usually this comprises the topographical map and the cadastre for municipalities. That implies that a Property Database is needed to record the cadastre details other than the geographic boundaries. For most municipalities, property records is a business function currently existing as the primary storage behind their taxation program. For others, where taxation is performed by another government body, there is usually just a Property Records System of not much more than a Property Roll Book list. Unfortunately, with the relational database developed software just now appearing in municipalities, it is likely that these programs are file-oriented which will require conversion into a relational database for integration. In most cases, program changes will have to be made, or a new system acquired, in order to make appropriate use of the relational data storage architecture.

The chain of events is now set: determine the foundation data sets, obtain an entry and update program, and develop and acquire operational programs linking to it. This sequence will apply to all operations throughout the municipality. In some cases, the foundation data set overlaps which has already been identified and so becomes a subset on the differences only. The edit and updating should, for the most part, be controlled through the applications developed. Here is a point of contention: who has the right to modify the data? These rights must be determined, collectively, identifying exclusivity for some items and a hierarchical protocol for less sensitive data items. The operational programs may have to be a collective development due to this editing permission on the data. It is unlikely that off-the-shelf programs are available which will address precisely your municipality’s requirements for data sensitivity, security, validity and historical logging. Be prepared to do a considerable amount of in-house development in order to achieve the integration necessary for a truly beneficial MIS-GIS operations-support and decision-support system.

An analysis of needs and costs will be necessary to set priorities on applications implementation. In many cases, it will appear that movement must occur on a broad front. This will only be possible by adopting a strategy within the constraints of your resources and budget. In the early stages, the establishment of the foundation data sets
requires a rather broad implementation plan. Following these primary databases, of which there are six major classifications for municipalities, applications can be implemented as per justification. Often, decisions will have to be made to sequence the implementation of new business systems in accordance with the implementation of the related or prerequisite GIS software and equipment.

**Integration: Is It Really Worth the Effort?**

The way we utilize data, in order to provide us with information such that we can perform our jobs better, is going to change dramatically. If we do not adhere to this direction, then we are conscripted to struggling with text and numeric reports to represent the eccentricities happening in our municipalities. Yes, we can depict the numbers using business graphics packages and even employ draftspersons to map our analysis, but this is the confining environment in which we now operate and we are saying that it is not effective. What other options are there within our cost constraints that are timely enough to make a difference?

To implement a GIS without the integration into the business applications can achieve much more than what we currently do, but is done so at that outmoded level of batch updating and with severely restricted information for analytical purposes. A fully encompassing GIS cannot be maintained in light of the workload added to the personnel. Therefore, anything within personnel capacities will be considerably less in terms of data available. The choice is to determine, in advance, what data will be insignificant in the management of the municipality over time; a very tough choice to make.

I maintain that the really significant uses of a GIS are yet to be discovered. The provision of the tools to the operating and management personnel will enable them to reveal unforeseen applications by their ingenuity. These applications of the GIS are unapparent to the systems builders as they deal with the product from a different perspective and usually without the on the job exposure to operational and management problems. As most great discoveries in science occurred through serendipity, I believe that the great advances in municipal management will only occur through the MIS-GIS integration which creates the environment for progressive investigation and serendipitous revelation in this arena.
A Regional Information Centre - A Planning Supermarket

B. Robbins

Research Officer, Greater Vancouver Regional District
4330 Kingsway, Burnaby, B.C. V5H 4G8

Abstract

This paper discusses the electronic information library maintained by the Development Services Department of the Greater Vancouver Regional District. Their experience may be a useful model for other groups considering offering a similar service. The paper outlines the range of information services available, identifies client groups and examines some benefits and costs of the service. The data centre service has been available internally for ten years and to external clients for more than five years. The services include access to transportation modelling, a geographic information system, and a cohort survival population forecasting model. The information service is provided to internal clients, member municipalities of the District and other public agencies free of direct charges. The service provides access to information that is particularly relevant for the work of economic development officers, planners and transportation specialists. Private sector clients, such as commercial real estate developers, find the concept of one stop information shopping particularly attractive. In addition to the data resources, the knowledge and expertise of the staff members is a particularly valuable component of the service.

Introduction

A Regional Information Centre - A Planning Information Supermarket

The Greater Vancouver Regional District is an agency whose function is to provide services to member communities of the region. These services include water system supply and management, sewage and drainage collection and treatment facilities and administration of provincial pollution control regulations. The development of a regional information centre was an almost natural extension to the District’s range of services to the municipalities of Greater Vancouver.

In the late 1970’s, the Planning Department of the Greater Vancouver Regional District was empowered by provincial legislation to provide planning and development policies to achieve orderly and sustainable patterns of growth throughout the region. These policies and guidelines formed the basis for an Official Regional Plan. To develop the plan, monitor the effect of the existing policies and to explore impacts associated with policy changes in the Official Regional Plan, there was a need for information gathering, maintenance and analysis tools. Much of the information relevant to these issues was geographically based. As a result, a Land Use Information System (LUIS) was developed. The primary information resource for this system was patterns of land use throughout the region. Over time the base system evolved to encompass socioeconomic information derived from the Census of Canada as well as
information related to Commercial and Industrial developments. As the information base grew, the use of the system expanded from the original core in the planning department, to other departments of the Greater Vancouver Regional District and to planners in municipalities throughout the region.

As a result of legislative changes in 1983, the regulatory planning function was removed from the mandate of the regional district and the Planning Department was disbanded. However, the information needs of municipal planners for a regional repository of planning related information remained. The planning department data resources and information systems were transferred to the Development Services department. This department was structured to provide municipal planning and engineering departments with access to a variety of information related to regional and local social, economic, demographic and transportation issues.

Shortly after the formation of the Development Services department, transportation modelling software (EMME/2) was acquired as an additional information processing and analysis tool of the department. Since late 1984, access to the regional transportation model has been available to all municipalities free of charge. The transportation model and related information is maintained and supported by Development Services, with the assistance of a steering committee comprised of representatives from municipal planning and engineering departments, British Columbia Ministry of Transportation and Highways, and BC Transit.

The same intermunicipal and interagency cooperative structure has developed for geographically based social, economic and demographic information. The information maintained for this portion of the departments work program consists of Cohort Survival Population Forecasting Model, General Monitoring Information and Spatial or Geographic Information Systems.

The four systems support a wide variety of internal and external users of the information resources. In subsequent sections, this paper will discuss each of these systems, including the general information components and the associated client communities.

**Technology Environment**

Before discussing the information resources, a brief overview of the computing and communications resources of the Greater Vancouver Regional District is necessary. To support internal applications and information service clients, the regional district operates five Digital Equipment VAX computers running the VMS operating system. Three of the computers are clustered with the other two machines connected via Digital's network communications software DECNET. The external clients of the system establish sessions, under their own usernames and passwords, on the computer network through dedicated lines or dialup 1200/2400 baud modems. All of the permitted information resources and services of the regional district are available to our clients through a single session established on the computer network. To reduce requests for technical assistance the District requires that potential clients use one of three approved terminal emulation software packages.

Although access to the data resources is free to member municipalities of the district, private sector firms and other agencies are charged for use of the systems on the basis of connect and processing time as well as disk storage.

1. Transportation

The EMME/2 model is used by regional or municipal traffic planners and engineers for the analysis of transportation infrastructure changes as well as for estimating the impact of local commercial development and the effects of general population growth within municipalities or throughout the region. Since the model is regional in scope, the impact of local transportation network changes or improvements may be analyzed both within the responsible municipality and in adjoining communities.

The transportation information resources available to clients include:

- A regional transportation network for Greater Vancouver and the Lower Fraser Valley based on a 380 zone system, comprising approximately 7,000 links, 2,300 nodes and 160 bus routes. The network includes all major streets, bus and transit routes, and intersections with turn restrictions.
- Census of Canada data for 1971, 1976, 1981 and 1986 such as employment by industrial and occupational groups by place of residence, employment by place of work, labour force activity by age and sex, level of educational attainment, school attendance and income level by age and sex.
- GVRD proprietary information derived from an origin-destination travel survey conducted in 1985.
- Traffic zone forecasts of population, labour force and employment and trip assignment tables for the period 1991 to 2011.
- Traffic volume counts for major streets and intersections within the Greater Vancouver area and the Lower Fraser Valley. This information is derived from a number of sources including British Columbia Ministry of Transportation and Highways, municipal traffic count programs and from GVRD commissioned traffic count studies. All traffic count data has been standardized in format and adjusted to compensate for seasonal variations. Additional information is available to classify the traffic counts by vehicle type and occupancy levels.

All of this information is available in its original form as well as in the form of origin-destination matrices or trip tables within the EMME/2 system.
The regional transportation modelling system (EMME/2) has been available to clients since 1984. Currently, five high volume clients are using dedicated connections, an additional 12 to 15 clients establish sessions over dialup lines. Transportation modelling is not an activity that is undertaken without considerable training and experience, as a result, the District has expended significant efforts in developing and delivering training courses and demonstration materials to this group of users.

2. Spatial Information

The spatial information maintained by the District falls into three major categories: Census of Canada, Land Use and Commercial / Industrial Floor space. Most census data is available in an aggregated form at the level of census tract or enumeration area polygons, but some information such as raw block face counts of population and households is maintained as point data with specific geographic locations. The Census data is available for 1971, 1976, 1981 and 1986. The Census data includes several hundred variables, with the majority relating to the 1986 Census. Land use data is available for the years 1976 to 1983. The land use information is only available as polygon aggregates. Some internally generated information such as population, household, labour force and employment forecasts are available at the level of traffic zones.

The Commercial / Industrial Floor space information is maintained on the basis of individual properties throughout the region. Commercial / industrial floor space information is available on a parcel basis for 1987 and 1989 with data for other periods maintained in summaries by municipality. There are two information types within the commercial / industrial floor space application: completed buildings and buildings under construction or proposed. All records in this application are geocoded using the exact address with coordinates assigned using the Statistics Canada Area Master File.

To facilitate retrieval of this geographically based information, digitized polygons are maintained for 1971, 1976, 1981 and 1986 enumeration areas and 1981 and 1986 census tracts. Additional map layers for traffic zones, municipal boundaries, regional town centres and other commonly requested geographic aggregations are available.

Spatial information retrieval and analysis is managed with the LandTrak Geographic Information System. Commonly requested information such as commercial / industrial floor space, population counts and household characteristics or age specific profiles are maintained as prebuilt applications. All other polygon based information is stored as normal files on the computer system with automated routines available to generate custom applications and data sets. In some cases, users of the spatial information services may import their own information to the geographic information system for display, reports or thematic maps. After defining a data set appropriate to their requirements, users of the system are able generate any customized map layers or data aggregations for their analysis. Reports can be generated in tabular format or as export files for transfer to spreadsheets or graphics packages. In addition, thematic maps can be created and printed on an inkjet printer or 8 pen plotter up to D size.

This application serves the most varied group of clients. They include internal users such as water and sewer system planners, air quality monitoring staff, hospital planners and housing analysts. The municipal client base includes planners, transportation engineers, social services, parks and recreation, and school board staff. External clients include real estate developers, students, businesses, churches, crown corporations, charitable agencies and members of the public.

3. General Monitoring Information

The General Monitoring Information System is used primarily to maintain non-spatial time series data. The information resources consist mainly of indicators of the regions economic activity. The data sets available are quite extensive and include:

- monthly housing starts by type and municipality;
- value of building permits issued by municipality;
- labour force information including employment, employable population, unemployment rates and labour force participation rates;
- family allowance and old age security transfers;
- annual births and deaths by single years of age;
- consumer price indices;
- average weekly earnings; and,
- retail sales by type of store.

The data management system used to maintain this information consists of routines to create, update and report as well as to graphically display user specified data sets or tables. Most of the information is manually entered as it is released by the collecting agency. The system provides facilities for importing information from data files or exporting complete tables to spreadsheets for further analysis.

The information is most widely used within the Greater Vancouver Regional District for regular publications such as Economic Monitoring Bulletins, reports to internal committees and other agencies. However, since much of the information contained in this component of the data service does not exist in a similar form anywhere else, there is a substantial external demand for the publications based on the information and for the original data.

4. Forecasting

The Cohort Survival Forecasting Model (COHORT) is used to produce regional and subregional forecasts of population, housing demand and labour force by single years of age and sex. Several alternative demographic forecast series are maintained, these usually involve differing assumptions for the level of net migration to the region.
The information base for forecasting consists of population by single years of age 1971, 1976, 1981 and 1986, age and sex specific mortality rates, age specific fertility rates, and net migration propensities by age and sex. For housing demand forecasts, historical data on dwelling type household formation rates by age and sex are maintained. Labour force forecasts are derived from the population forecasts by applying age and sex specific labour force participation rates. The regional forecasts of population, housing demand and labour force are disaggregated to municipalities as well as census tracts or traffic zones for detailed analysis within the transportation model or geographic information system. As is the case with the other systems previously described, all of the forecasting information generated or maintained may be made available to any of the member municipalities or clients of the Greater Vancouver Regional District information systems.

Production of the forecasts involves considerable interaction between the District, member municipalities and professional forecasters. The regional base population forecast is developed in consultation with planners and forecasters working for other government agencies, to identify and assess trends for the base assumptions. When the municipal forecasts are prepared, extensive reviews are conducted with planners to determine the growth potential and capabilities of areas within each municipality to allocate the regional growth shares appropriately. As a result of the close working relationship of all the participants in vetting the forecasts, there is wide acceptance of the final results.

The forecasts of population, households, labour force and employment are widely used by Regional District departments for long range water and sewer system planning as well as by municipalities and private or public sector firms. The centralized approach to demographic forecasting has proven to be very effective in merging the diverse development aspirations of the region's communities.

Conclusions

After almost ten years experience in operating a centralized information service, the benefits and costs of the service are readily apparent. The most significant benefit derived from the service is the degree of cooperation and interdependence that has developed between the Regional District and the member municipalities of the region.

Some of the most obvious benefits accrue from the standardization of information. The existence of a local data library offering consistent information can reduce the extensive analysis efforts that are sometimes required to determine if differences in conclusions are a result of erroneous or inconsistent information rather than errors in method. Along with the benefits derived from high quality information, clients are able to retrieve timely information without the need to devote themselves to extensive information gathering and validation activities. In addition to the information consistency benefits, considerable savings can accrue to clients of the services as a result of the access to knowledgeable individuals whose primary business function is information management, maintenance and validation.

Other monetary benefits can accrue from bundling individual data acquisitions into larger bulk purchases. The bulk purchase benefits can also have a positive effect on the strength and depth of the relationship between the purchaser and supplier of information. For example, the Greater Vancouver Regional District has purchased the Area Master File and Postal Code Conversion File from Statistics Canada with the explicit contract recognition of the right to distribute portions of these products to member communities of the region without additional cost. Additionally, if one community has a requirement for a particular set of information, it is likely that several other communities throughout the region will be able to use the same information immediately or at some time in the future.

There are some costs associated with a service of this type. Many of the costs are attributable to increased network administration and communications services. The increased level of remote access to the systems imposes a requirement for increased awareness of system security issues. While it may appear that there could be higher costs due to increased data storage requirements, this is not actually the case, since most of the information available to the service clients is provided on top of an already substantial internal use of the information.

The primary conclusion to be drawn from the experience of the Greater Vancouver Regional District is that the Information Supermarket provides a consistent and cost effective regional perspective on planning and transportation related information to the communities of Greater Vancouver.
A Team Approach to Distributed GIS Management

Kirsty Burt
City of Bellevue
Bellevue, Washington

Abstract

The City of Bellevue is developing a distributed GIS that encompasses all City departments. This presentation will cover the philosophy that led to a distributed GIS, from the organizational perspective of a team approach to GIS development. Bellevue's GIS design, management approach, teambuilding, user application development and data standards will be addressed.

The Bellevue GIS database has been in development for ten years. In the last year, with the advent of high-speed, low-cost workstations, it has become possible to distribute GIS applications, while maintaining a centralized base layer. Access among workstations is also possible, with security that provides read-only access for any layer. The philosophy behind this approach is designed to allow departmental control over specific layers of the database, with user expertise in each department trained in the use of the GIS software. In this way, the departments which already have a stake in the reliability and contents of the data are responsible for the maintenance.

The organizational issues in distributed GIS development are more important and far more challenging than the technical issues. A distributed GIS becomes a true corporate resource that requires a strong team approach to management and development. The system cannot function technically without the organizational design firmly in place. The system is maintained and managed through the processes by which the GIS is managed and new applications are designed. Needs statements for new applications are defined by user departments and then reviewed by a City-wide GIS management team. The GIS division works with the departments to set out the functional specifications, design the application and provide the training. Maintenance of the new data is the responsibility of the user department. Because all projects are created with the guidance and support of the GIS division, standards are maintained across the GIS and compatibility with existing data is ensured. GIS development is recognized as a team responsibility to provide products and services to the entire City. The partnership in the system extends to the budget process, where team support for the system has provided the constant financial support for healthy growth.